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How the initial retentive force of implant-supported overdentures can be affected with splinted and unsplinted attachments systems

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ABSTRACT

Background: The aim of this study was to evaluate the retention of implant-supported overdentures with different attachment systems.

Materials and Methods: In this *in vitro* study edentulous model with 2 Straumann implant in symphyseal region was used to make an overdenture with different attachment systems. (Dolder bar with 1 and 3 metal clips, Hader bar with 1 and 3 plastic clips, ball on bar with 2 and 4 plastic caps, Locator, Rhein plastic caps and Eleptical matrix). Retention values were recorded by universal testing machine with a cross speed of 50.8 mm/min in vertical, posteroanterior, and lateral direction. Repeated measure ANOVA and Duncan tests were used for the data analysis (α =0.05).

Results: There was a statistically significant difference between the retention values of studied attachments in different dislodgment directions ($P < 0.05$). The highest and lowest retention were recorded for 4 balls on bar (56.71 N) and Rhein pink caps (27.89 N) in the vertical direction. Three metal clips (61.43 N) and Rhein pink cap (24.77 had the highest and lowest retention force in the posteroanterior direction. In the lateral direction, 4 balls on bar (62.68 N) and 1 plastic clip (32.27 N) showed the highest and lowest retention, respectively.

Conclusion: If the higher retention force has been considered for implant-supported overdenture attachment selection, the clinician can use splinted bar or ball on bar superstructure.

Key Words: Dental implants, dental prosthesis-implant-supported, denture design, denture retention/instrumentation

INTRODUCTION

Over the past decade, edentulism has become a serious health problem due to the increase in number of aging edentulous patients.[1] Since these patients need greater retention for chewing and psychological reasons,[2,3] conventional dentures as a common treatment, usually fail to fulfill patient satisfaction.[4] Problems such as residual ridge resorption, excess salivary flow and muscle tone reduction that affect the retention, make the treatment of fully edentulous patients more complicated. Nowadays, the treatment of choice to restore complete edentulism is implant-supported overdentures. Dental implants

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are used to improve support, retention, stability, and function of complete dentures. Location and number of implants for implant-supported overdenture as well as type of attachment systems depends on clinician preference and expert opinion.[5]

The attachment systems are classified into bar (splinted) or stud types (unsplinted).[6] Degree of retentive force, available space, maintenance requirements, and load distribution to the mucosa and implants should be considered in selection of the attachments.[7] Unsplinted attachment systems are recommended when there are limited inter-arch distances. Other advantages of stud attachments include the ease of fabrication, less initial treatment cost, and improved oral hygiene maintenance. If implants are improperly positioned or their angulations has some discrepancies, it is recommended to use bar attachments.[8,9] Advanced atrophy of the alveolar crest is another indication for bar attachments because of providing stabilization against horizontal force.[10]

A retentive force that can prevent displacement of overdenture during function is essential for success of an attachment system. It is suggested that a minimum of 4 N retentive force is needed for a single individual unsplinted attachment.[11] On the other hand, a retentive force of 20 N has been proposed for mandibular overdenture supported with two implants.[12] The retentive force is the result of mechanical, frictional magnetic forces between the patrix and matrix of attachment systems.[13] Different values of retention forces from 1N to 85 N have been reported for splinted and unsplinted attachment systems.[2,14-29] With introduction of new attachment systems, it is important to investigate and compare the retentive force of different attachment systems. The aim of this study was to evaluate the retention of implant-supported overdentures with different attachment systems. The null hypothesis was that there was no difference between initial retention force of different splinted and unsplinted implant-supported overdenture attachments.

MATERIALS AND METHODS

This study this *in vitro* study was approved by the Ethics Committee of Isfahan University of Medical Sciences (IR.MUI.REC: 1395.2.096.). An edentulous mandibular model (140-032 Straumann AG, Basel, Switzerland) with no undercut and two implants (4.1 mm × 10 mm, 043.032, Straumann AG) in the symphyseal region was used. Six splinted bar and seven single stud attachment designs with corresponding abutments and superstructures were evaluated (n = 5 in each group). No power analysis was performed, and sample size was determined according previous work.[2] The splinted superstructures were: Dolder bar with one and three metal clips (048.414, regular Dolder bar matrix, Straumann AG), Hader bar with one and three plastic clips (Preci-Horix, Alphadent NV, Waregem, Belgium), ball on bar with two and four pink plastic caps (Rhein 83Srl, Bologna, Italy) [Figure 1a-c]. Single unsplinted abutments were: Locator abutment with attachments (white, pink, and blue) (Locator; Zest anchors, Escondido, CA), Sphero block abutment with Rhein plastic caps (green, white and pink) (Rhein 83Srl) and retentive anchor with Elliptical matrix (048.456, Straumann AG) [Figure 2a-c].

Superstructures preparation

For making the bars, castable rotating abutments (108 BFT, Rhein Srl 83) were screwed into the implants. Regular plastic bar (048.460, Straumann AG) for metal clips, plastic bar pattern (Preci-Horix, Alphadent NV) for plastic clips, and castable presectioned bar containing balls (150BPN, Rhein 83Srl) for ball on bar were fitted between the two abutments and 1 cm length at the distal of the abutments as the cantilever (for balls on bar groups) with Pattern resin (GC America, Alsip, IL). Superstructures were invested and casted (Degobond 4, DeguDent, Hanau, Germany). The castings were divested, finished, and transferred to the model. Locators, retentive anchors, Sphero block abutments, and/or bars systems were screwed into the implants and their counterparts attachments were positioned on them with the

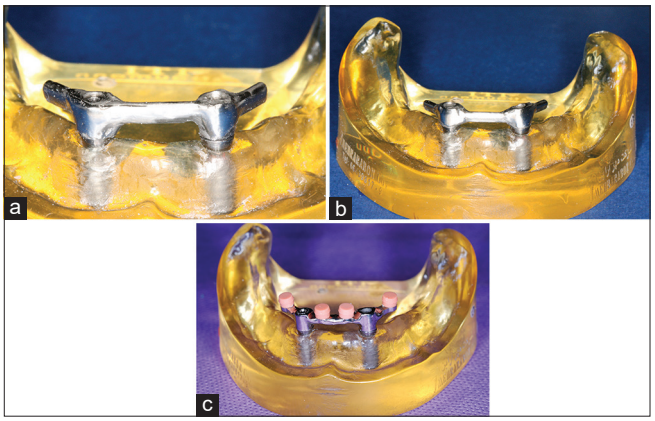

Figure 1: Studied splinted attachments. (a) Dolder bar (b) Hader bar (c) Ball on bar.

spacers. The method for making overdenture base and special acrylic housing for incorporating each attachments have been previously described and validated in our pervious article.[2] Three withdrawal hooks were attached to the overdenture base (one in the anterior and two in the first molar areas) with autopolymerizing acrylic resin (Meliodent, Heraeus Kulzer, Hanau, Germany) [Figure 3].

Retention test

The model and overdenture with each of the studied attachments were secured in a universal testing machine (Instron Corp, Canton, Mass). The hooks were connected by three 10 cm metal chains to the movable head of the universal testing machine. The chains were adjusted to reduce slack to a minimum. The universal testing machine was set at a constant cross head speed of 50.8 mm/min, which has been reported to approximate the speed of the movement of the denture away from the ridge during mastication.[22] Dislodging forces were applied in vertical, posteroanterior (by disconnection of anterior chain), and lateral (by disconnection of right chain) directions to simulate function. After 12 pulls, the plastic clips and caps were renewed and the metal clips and Elliptical matrix were reactivated.

The vertical, posteroanterior, and lateral peak loads were analyzed. Mean retention values (N) were subjected to repeated measure analysis of variance and Duncan tests to determine differences (α =0.05).

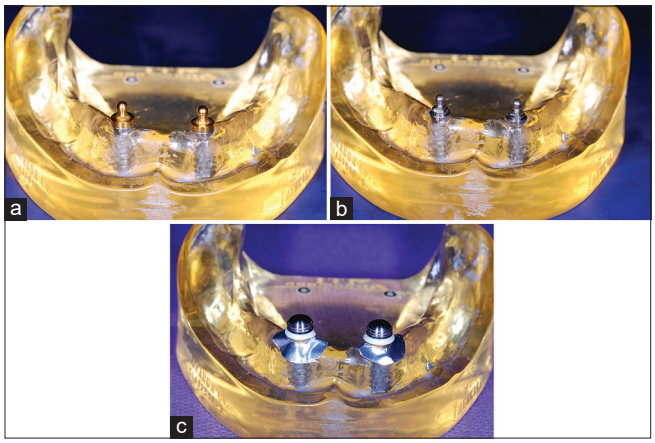

Figure 2: Studied unsplinted attachments. (a) Rhine sphere block (b) Retentive anchor (c) Locator.

Figure 3: The overdenture with 3 hooks.

RESULTS

The mean retention values of the studied attachments in different removal directions are presented in Tables 1-3. In the vertical direction, the highest and lowest retention was recorded for 4 balls on bar (56.71 N) and Rhein pink caps (27.89 N), respectively. Results showed that there were significant differences between the retentive values of the studied groups [$P < 0.001$; Table 4]. However, no significant difference between retention of attachments and number of vertical pulls ($P = 0.27$) as well as interaction between type of attachments and number of vertical pulls was observed ($P = 0.77$).

In posteroanterior direction, Dolder bar with 3 metal clips (61.43 N) and Rhein pink cap (24.77 N) showed the highest and lowest retentive values, respectively [Table 3]. Results showed a significant difference between the retention values of the studied attachments ($P < 0.001$). There was a significant difference between retention of attachments and number of postroanterior pulls ($P = 0.04$) with no difference in interaction between type of attachments and number of vertical pulls ($P = 0.42$).

Four balls on bar attachment (62.68 N) showed the highest retention when lateral dislodging force applied to the studied attachments. Hader bar with 1 plastic clip showed the least retention value in lateral dislodging force (32.27 N). There was significant difference between only the studied attachments in the lateral direction dislodging force ($P < 0.001$) while the number of pulls had no significant difference ($P = 0.43$).

DISCUSSION

In this study, the retention of the studied attachments was significantly different in vertical, posteroanterior and lateral directions. Thus, the null hypothesis

Table 1: The mean (Se) retention (N) of the studied attachments and Duncan's groups in vertical direction

Attachments systems	Subset for α=0.05						
	I	II	III	IV	V	VI	VII
Rhien pink	27.89 (1.15)						
Locator blue	29.11 (1.82)	29.11 (1.82)					
Rhien white	31.20 (1.38)	31.20 (1.38)	31.20 (1.38)				
Locator pink	32.02 (3.63)	32.02 (3.63)	32.02 (3.63)				
1 plastic clip		32.47 (3.07)	32.47 (3.07)				
3 plastic clips			34.65 (2.73)	34.65 (2.73)			
Locator white				37.64 (2.61)	37.64 (2.61)		
Rhien green				38.54 (1.46)	38.54 (1.46)		
1 gold clip					39.17 (2.73)		
2 balls bar					41.89 (2.46)		
Elliptical matrix						47.93 (3.65)	
3 gold clips							54.41 (4.21)
4 balls bar							56.71 (2.46)
Significances	0.07	0.14	0.14	0.08	0.06	1.00	0.27

Table 2: The mean (Se) retention (N) of the studied attachments and Duncan's group in posteroanterior direction

Attachments systems	Subset for α=0.05					
	I	II	III	IV	V	VI
Rhien pink	24.77 (0.67)					
Locator blue	28.48 (3.32)	28.48 (3.32)				
Locator pink	29.06 (3.28)	29.06 (3.28)				
Rhien white		30.13 (0.96)				
1 plastic clip		32.30 (2.76)				
3 plastic clip		32.35 (2.62)				
Rhien green		32.93 (2.97)				
Locator white			38.98 (3.54)			
1 gold clip			39.51 (3.96)			
2 ball bar			42.12 (3.40)	42.12 (3.40)		
Elliptical matrix				44.44 (3.50)		
4 ball bar					50.79 (3.50)	
3 gold clip						61.43 (4.41)
Significances	0.08	0.09	0.20	0.31	1.00	1.00

was rejected. The retentive force of overdenture attachments is provided by friction or magnetic forces between the patrices and matrices of various attachment systems. An ideal overdenture contains an attachment system that provides sufficient retentive forces to oppose dislodging forces.[12,13] However, to the best of our knowledge, there is no any published research introducing a retentive force value as a commonly accepted worldwide. There is several *in vitro*[2,16-21] and *in vivo*[14] studies on mandibular overdentures which have used two or more implants with a wide range of retentive forces for various attachment systems, including bars, balls, studs, and magnetic attachment systems (from 1N to 85N). Some decided that a retentive force of 20 N is sufficient.[12] Thus, mean retentive forces of attachments (24.77–62.68 N) found in this study appear sufficient to ensure patient acceptance. On the other hand, easy placement and removal of prosthesis may be preferred for hygienic purpose in elderly patients.[20]

Three direction of dislodgment was used in this study. The vertical direction simulated retentive force of overdenture.[2,29] Posteroanterior tests simulated a posterior dislodging force which lift off the denture from tissue such as biting hard foods.[29] Lateral and horizontal stability of mandibular overdenture can be tested by lateral direction dislodgment.[29] According to the result of current study, Ball on bar with 4 Rhine pink caps, Dolder bar with 3 metal clips showed the highest retention in vertical (56.71, 54.41 N, respectively); however, in posteroanterior direction,

Table 3: The mean (Se) retention (N) of the studied attachments and Duncan's group in lateral direction

Attachments systems	Subset for α=0.05					
	I	II	III	IV	V	VI
1 plastic clip	32.27 (2.85)					
3 plastic clip	33.41 (2.68)					
Locator blue	34.36 (1.68)	34.36 (1.68)				
2 ball bar	35.30 (2.21)	35.30 (2.21)				
Rhien pink	36.55 (2.60)	36.55 (2.60)				
Locator pink		40.04 (4.07)	40.04 (4.07)			
Locator white			44.07 (3.80)	44.07 (3.80)		
Rhien white				46.98 (3.98)	46.98 (3.98)	
1 gold clip				48.22 (4.27)	48.22 (4.27)	
3 gold clip					52.07 (4.30)	
Rhien green						58.06 (4.09)
Elliptical matrix						59.95 (3.98)
4 ball bar						62.68 (5.66)
Significances	0.19	0.07	0.16	0.17	0.10	0.13

Table 4: Two-way repeated measure ANOVA of vertical, posteroanterior, and lateral retention values for the experimental groups

Direction	Type III sum of squares	df	Mean square	*F*	Significance
Vertical					
Groups	32,600.087	12	2716.674	8.602	0.000
Consecutive pulls	4632.853	12	386.071	1.222	0.267
Groups × pulls	33,077.405	118	280.317	0.888	0.770
Corrected total	159,935.372	421			
Postroanterior					
Groups	40,157.870	12	3346.489	9.795	0.000
Consecutive pulls	6593.401	10	659.340	1.930	0.041
Groups × pulls	41,395.900	118	350.813	1.027	0.425
Corrected total	180,474.529	409			
Lateral					
Groups	45,330.658	12	3777.555	8.215	0.000
Consecutive pulls	5122.305	11	465.664	1.013	0.435
Groups × pulls	53,976.076	121	446.083	0.970	0.570
Corrected total	234,798.911	424			

4 balls on bar had the highest retention (61.43 N). Rhine pink caps had the lowest retention in vertical and posteroanterior directions (27.89 and 24.77 N, respectively). In lateral direction, 4 balls on bar and bar with one plastic clip showed the highest and least retention, respectively (62.68 and 32.27 N). The retention of bar with 4 Rhein caps was significantly higher than bar with 2 Rhien caps in vertical and lateral directions ($P < 0.05$). Thus, a greater number of these attachments resulted in increase the retention. The bar with two Rhein pink caps showed significant more retention in the vertical and posteroanterior directions ($P = 0.05$) than two unsplinted Rhein pink caps. It seems that bar was effective in retention of the implant-supported overdentures, although it was not involved in the intaglio of the denture. Bar with four Rhein pink caps showed the highest retention value, but there were not significant differences between these attachments and three metal clips with Dolder bar in the vertical and lateral directions. Thus, the use of ball on bar should be justified especially when the space for attachments are limited.

The results of this study were similar with our previous study that three metal clips and Elliptical matrix showed the highest retention in the vertical direction.[2] The higher retention of these attachments in the current study compare to previous study may relevant to adjustment ability of these attachment by the clinician.[2] In contrast, the nonmetallic attachments cannot be adjusted. The prefabricated nonmetallic matrices exhibit different shape even before usage which shows that the manufacturers cannot maintain the same retentive forces during their production [Figure 4].

Difference in material and design of metal clips may be the reason for more retention of these attachments than plastic clips in the different directions. Particularly, the modulus of elasticity of attachments alloys can influence the retention force and also the wear characteristics of these attachments. On the contrary, polymeric (plastic, nylon, and rubber) components can be more susceptible to wear.[23]

Some of the studies also exhibited that bar and clip design provide the most retention values for the

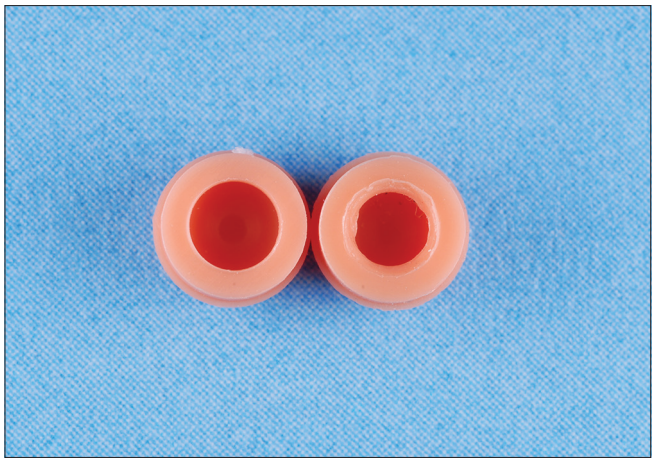

Figure 4: Two prefabricated same pink color plastic caps exhibit different shape before usage.

overdentures.[2,14,17] The retention values of three metal clips were significantly higher than 1 metal clip in both vertical and posteroanterior directions ($P < 0.05$). It means that increasing the number of metal clips affected the retention values of these attachments. This finding does not apply to the number of plastic clips, because the retention values of 3 and 1 plastic clips were not significantly different in all directions of dislodgment. These findings agreed with previous studies[2,15] and may be related to the position of the retentive clips on the bar.[23] However, Breeding *et al*.[25] reported significantly more retention with increasing of plastic clips.

The retention of the studied attachments significantly decreased only in the posteroanterior direction over consecutive pulls [Table 4]. The reason for this finding can be explained by the difference between inserted attachment and the posteroanterior force applied to remove the dentures. In a study by Gamborena *et al*.[23] reported that even after 1500 pulling cycles, the retention of ERA attachments was not significantly reduced. In addition, in a clinical study on IMZ system bar attachments was shown that loss of retention was not significant in the range of 12.8 months.[26] It was suggested that retention of the ball and socket attachments decrease after approximately 500 cycles of repeated insertion-removal and even 80% from the initial retention values after 2000 cycles depend on their morphological characteristics.[23] Loss of retention in bar attachments did not occur even after more than 5500 cycles according to Pigozzo *et al*.[27]

Locator attachments have dual retention with retentive areas on both external and internal surfaces. This provides more contact surface for increasing retention in short vertical space. Kleis *et al*.[28] found that some patients with overdentures retained by two locator attachments had complaints of excessive retention force at post insertion appointments. However, most of their patients needed to replace nylon components after 1 year.

Size of ball attachments can affect the retention force. Larger patrices provide more surface area and higher retentive forces compared to attachments with smaller dimensions.[6,19,20] The diameter of Rhein abutment (Rhein 83Srl) is 2.5 mm compare to 2.25 mm of Retentive anchor (Straumann AG). Despite the slightly smaller size of Retentive anchor, this attachment provides more or equal retention compare with Sphere block abutment [Tables 1-3]. The metal matrix of Retentive anchor may be the reason for this result.

The ball attachments are recommended for mandible overdentures because of more movement freedom in function and less complicated clinical and laboratory procedures compare to bar attachments. On the other hand, bars can simplify the attachment placement in the favorable position and splinting can increase the stability of implants and provide more vertical support.[2,15]

Several factors should be considered for implant-supported overdenture attachment systems selection such as interocclusal space, load distribution between mucosa and implants, the amount of retention force, jaw shape, prosthetic maintenance possibilities, and patient compliance.[29]

The findings of this study should be interpreted carefully. During mastication, the overdentures are submitted to three-dimensional movements which are more complex than three tested directions in this study. In addition, the properties of attachments may alter in the presence of saliva and other substances in the oral cavity.[19] Thermal cycling, using variable fluid environments and multidirectional force application can provide more realistic results.[30]

CONCLUSION

Within the limitation of this study following can be drawn:

1. Four balls on bar showed the highest retention in both vertical and lateral directions
2. In posteroanterior direction 3 metal clips had the highest retention

3. Rhein pink caps provide the lowest retention in vertical and posteroanterior direction and 1 plastic clip was the lowest in lateral direction.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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