

Retention Characteristics of Attachment Systems for Implant Overdentures

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Purpose: The aim of this study was to compare the retention characteristics of various overdenture attachment systems commonly used to retain overdentures to dental implants.

Materials and Methods: An edentulous mandibular model was constructed incorporating 2 parallel 4.0 mm × 13 mm Branemark implants placed in the canine regions. Attachments were embedded in a metal-reinforced experimental overdenture designed to be dislodged from the model by a universal testing machine. Tensile dislodging force was applied to the overdenture at a cross-head speed of 50 mm/min. Five overdentures were constructed for each of the attachment systems. The attachments evaluated were the Hader bar & metal clip, Locator LR pink, Locator LR white, Spheroflex ball, Shiner magnet, Maxi magnet, Magnedisc magnet, ERA white, and ERA gray. Each apparatus was tested with 5 specimens per attachment system. Peak load-to-dislodgement was measured. Analysis of variance and Scheffé multiple comparison tests were applied to the data with $\alpha \leq 0.05$ level of significance.

Results: Peak load-to-dislodgement for all attachment systems ranged from 3.68 ± 1.32 N to 35.24 ± 1.99 N. Strain-at-dislodgement, calculated from stress-strain curves, ranged from 0.78 ± 0.20% to 2.78 ± 0.5%. The ERA gray attachment demonstrated the greatest retention, with a peak load-to-dislodgement of 35.24 ± 1.99 N, and a relatively low strain-at-dislodgement of 1.64 ± 0.09%. Less retention was recorded for the Locator LR white, Spheroflex ball, Hader bar & metal clip, and ERA white systems. The Locator LR pink attachment demonstrated still less retention with a load-to-dislodgement of 12.33 ± 1.28 N. Significantly high strain-at-dislodgement was recorded for the Hader bar & metal clip and Locator nylon attachment systems. The lowest dislodging loads and strains were recorded for the Shiner magnet, Maxi magnet, and Magnedisc magnet attachments.

Conclusions: Results suggest that the attachment systems evaluated may be grouped into high (ERA gray), medium (Locator LR white, Spheroflex ball, Hader bar & metal clip, ERA white), low (Locator LR pink), and very low (Shiner magnet, Maxi magnet, Magnedisc magnet) retention characteristics.

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IN HIGHLY industrialized countries, the percentage of edentulous people over 65 years

of age is projected to decrease considerably; however, the absolute number of people over 65 years is expected to double by the year 2030, and the actual number of those needing complete denture therapy will remain almost constant.¹⁻³ The removable prosthodontic needs of this elderly population are not only significant, but they pose unique challenges not commonly seen in younger individuals. These challenges may reflect a progressively decreasing neurophysiologic adaptive capacity to wearing complete dentures with increasing age.^{4,5} Deteriorating muscle strength and coordination in elderly patients may lead to problems fabricating complete dentures, as well as difficulty achieving and maintaining acceptable denture stability and retention.⁵⁻⁷ Moreover, elderly patients often have difficulty adapting to new complete dentures and have problems attaining comfortable and efficient denture function.^{4,8,9}

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One therapeutic approach directed at improving oral function in elderly edentulous patients is the use of overdentures. Rather than extracting all remaining teeth and placing conventional complete dentures, treating and maintaining several strategic teeth can lend critical support to the prosthesis. Endodontic therapy, followed by reduction of the crown height, permits improved support for the removable prosthesis, particularly in the mandible.¹⁰⁻¹² More recently, osseointegrated implants have been used to improve denture support, stability, and retention.¹³⁻¹⁵ According to the McGill consensus statement on overdentures, evidence exists suggesting that a 2-implant overdenture should become the standard of care for treatment of the edentulous mandible.¹⁶

Use of a wide variety of attachment systems, including stud, magnet, and bar attachments, has proven both clinically predictable and effective.¹⁷ Previous investigations have studied the absolute retentive capacity of overdenture attachments.^{18,19} Stud attachments provide varying degrees of resiliency in both vertical and horizontal directions. Magnetic attachments provide no vertical resiliency, while quite effectively decreasing horizontal stress transmission to abutments.²⁰ Few investigations, however, have attempted to characterize the retention of attachments used for implant overdentures.

With regard to implant overdenture attachments, the "release period" may be defined as the time required for the attachment system to lose retention or disengage from the abutment during forced separation.²¹ This parameter has obvious clinical significance in retention and stability of the prosthesis during function; however, an appropriate attachment release period may also serve as a mechanical safety mechanism unique to that attachment system. An attachment system that readily disengages when excessive loads are experienced may shield the transmission of potentially harmful forces to the implants and critical bone-implant interface. Although speculative, the faster an attachment releases from the abutment, the greater the stress shielding function. Therefore, fast releasing attachments may decrease transmission of potentially harmful forces to the mechanical and biologic supporting structures.

Questions regarding the most effective mode of attachment between the overdenture and sup-

porting implants remain unanswered. In elderly patients, attachment systems that permit ease of prosthesis placement and removal, and those that are readily hygienic, may be preferable.² Ultimately, the most suitable attachment for implant overdentures should permit the atraumatic and even distribution of stress to both the mechanical and biologic supporting structures.

This study was designed to investigate the magnitude of retentive force in implant overdentures retained using a variety of attachment systems. The hypothesis tested was that different attachment systems would result in different peak load-to-dislodgements. A grouping system based on the identified retention characteristics of these attachment systems will be suggested.

Materials and Methods

Attachment Systems

Nine commercially available attachment systems were evaluated:

1. ERA white (APM-Sterngold, Attleboro, MA)
2. ERA gray (APM-Sterngold)
3. Locator LR white (Zest Anchors, Inc., Escondido, CA)
4. Locator LR pink (Zest Anchors, Inc.)
5. Spheroflex ball (Preat Corp., San Mateo, CA)
6. Hader bar & metal clip (APM-Sterngold)
7. Shiner SR magnet (Preat Corp.)
8. Magnedisc 800 magnet (Aichi Steel Corp., Aichi-ken, Japan)
9. Maxi 2 magnet (Golden Dental Products, Inc., Savannah, GA)

The Test Model

A model was constructed in dental stone (ResinRock, WhipMix Co., Louisville, KY) to simulate an edentulous mandible. All edentulous ridge undercuts were eliminated. Two parallel 4.0 mm × 13 mm implants (Branemark System, Noble Biocare USA, Inc., Westmont, IL) were placed in the canine regions. Rigid fixation of the implants in the dental stone model simulated the condition of osseointegration. A single cast metal, chrome-cobalt framework (Wironium[®], BEGO Herbst GmbH & Co., Bremen, Germany) was fabricated to serve as a reinforcement for the experimental overdentures (Fig 1).²² An overdenture housing constructed with light-cured resin (Trial, Dentsply International, Inc., York, PA) was positioned over the attachment sites. The attachment systems evaluated were individually



Figure 1. Mandibular experimental cast with implants and impression posts in the interforaminal region, and the cast chrome-cobalt framework.

fixed in the overdenture housing using light-cured material (Triad Gel, Dentsply International, Inc., York, PA) following the manufacturers' instructions for direct attachment pick-up procedures. The cast metal Hader bar (Jelenko#7, Heraeus Kulzer/Jelenko, Inc., Armonk, NY), the metal clip attachment system, and the associated overdenture housing are illustrated in Figures 2-4. Machine screws were incorporated into the cast metal framework so overdenture housings containing different attachments could easily be secured and removed during testing. The cast metal framework also possessed 4 withdrawal loops that were engaged during direct pull-off testing (Fig 5). In total, 45 overdenture housings were fabricated, including 5 specimens of each attachment system tested.

Materials Testing

A universal testing machine (Model 5T, China Material Technological Co., Taipei, Taiwan) was applied to



Figure 2. A Hader bar & metal clip attachment system.



Figure 3. A Hader bar & metal clip attachment system with overdenture housing.

test retentive force for each experimental overdenture at a cross-head speed of 50 mm/min. This crosshead speed has been reported to approximate clinically relevant movement of the denture away from the edentulous ridge.²² A metallic chain connected the universal testing machine to the overdenture framework at the withdrawal loops. Vertical testing forces simulated anticipated overdenture removal forces.²¹ Peak load-to-dislodgement and strain-at-dislodgement were recorded and calculated from stress-strain curves in order to determine the retention force and the change of distance between the patrix and the matrix of each attachment system respectively.

Data Analysis

An analysis of variance and Scheffé multiple comparison tests were performed to statistically compare performance measurements at the $p < 0.05$ level.



Figure 4. Internal view of overdenture housing with a metal clip.



Figure 5. Experimental overdenture assembly connected to the universal testing machine.

Results

Results with statistical summaries are presented in Tables 1 and 2. Peak load-to-dislodgement for all attachment systems ranged from 3.68 ± 1.32 N to 35.24 ± 1.99 N. Strain-at-dislodgement, calculated from stress-strain curves, ranged from $0.78 \pm 0.20\%$ to $2.78 \pm 0.15\%$. The ERA gray attachment demonstrated the greatest retention, with peak load-to-dislodgement of 35.24 ± 1.99 N, and relatively low strain-at-dislodgement of $1.64 \pm 0.09\%$. Less retention was recorded for the Locator LR white, Spheroflex ball, Hader bar & metal clip, and ERA white attachment systems (Subsets III and IV [Table 1]; Note: Spheroflex ball statistically falls within both subsets). The Locator pink attachment system demonstrated still less retention with a load-to-dislodgement of $12.33 \pm$

1.28 N. Significantly high strain-at-dislodgement was recorded for the group of the Hader bar & metal clip and Locator LR white attachment systems ($p < 0.05$). The lowest dislodging loads and strains were recorded for the Shiner magnet, Maxi magnet, and Magnedisc magnet attachment systems. Statistically, the load-to-dislodgement of the magnet attachment group is significantly lower than other tested attachment systems ($p < 0.05$).

Discussion

The results of the ranking according to the means of peak load-to-dislodgement in this study are similar to the data reported by Petropoulos and her colleagues.²¹ Because of the flat and simple geometric configuration, magnet attachments showed less retention and low strain values. Gilling and Samant mentioned that most of the magnetic systems have a self-limiting capacity, releasing from the abutment when subjected to excessive lateral forces.²³ This reduced retention characteristic may be desirable for patients with poor manual dexterity, who may have difficulty inserting and removing the overdenture. Therefore, under specific circumstances, matching the retentive characteristics of the attachment system to the physical conditions and needs of the patient may be an important treatment planning consideration and critical to restorative success. In addition, the grouping of attachment systems in Table 2 according to the significant differences of the mean values of strain-to-dislodgement in this study revealed that many attachment systems with

Table 1. Summary of Arithmetic Means of Peak Load to Dislodgement of Attachment Comparisons After ANOVA and Scheffé Tests, ($n = 5$) with Standard Deviations in Parentheses

Attachment Systems	Subset for $\alpha = 0.05^*$				
	I	II	III	IV	V
Maxi 2 magnet	3.68 (1.32) N				
Magnedisc magnet	3.69 (0.88) N				
Shiner SR magnet	3.88 (0.95) N				
Locator LR pink		12.33 (1.28) N			
ERA white			23.76 (1.02) N		
Hader bar & metal clip			24.15 (3.40) N		
Spheroflex ball			27.34 (2.00) N	27.34 (2.00) N	
Locator LR white				28.95 (0.78) N	
ERA gray					35.24 (1.99) N
Significances	1.00	1.00	0.240	0.97	1.00

*Mean values within the same column represent no statistically significant differences at $p > 0.05$; significant differences are determined between columns at $p < 0.05$.

Table 2. Summary of Arithmetic Means of Strain at Dislodgement of Attachment Comparisons During Loading Test and After ANOVA, as well as Scheffé Tests, (n = 5) with Standard Deviations in Parentheses

Attachment Systems	Subset for $\alpha = 0.05^*$		
	A	B	C
Magnedisc magnet	0.78 (0.20)%		
Shiner SR magnet	1.00 (0.29)%		
Maxi 2 magnet	1.02 (0.08)%		
Locator LR pink		1.46 (0.17)%	
ERA gray		1.64 (0.09)%	
Spheroflex ball		1.84 (0.06)%	
ERA white		1.86 (0.11)%	
Locator LR white			2.42 (0.13)%
Hader bar & metal clip			2.78 (0.15)%
Significances	0.673	0.075	0.154

*Mean values within the same column represent no statistically significant differences at $p > 0.05$; significant differences are determined between columns at $p < 0.05$.

patrix and matrix configuration have a relatively low strain-at-dislodgement value. Physically, it may relate to a snap action during insertion and removal of the overdenture. For the relatively high strain-at-dislodgement group, including Locator LR White and Hader bar & metal clip, this indicates that high distortion of the retentive elements would happen during dislodgement. Clinically, this group of attachment systems may need adjustment after short service period.

The testing here was directed at limited, specific, and expected mechanical conditions, and this in vitro protocol undoubtedly falls short of clinical reality. The dynamic nature of overdenture function in the complex and variable biomechanical environment of the oral cavity has proven challenging to replicate in a laboratory setting. Additional in vitro experimentation addressing the retentive characteristics of implant overdenture attachments should involve thermal cycling, variable fluid environments, multidirectional force application, load-unload conditions, and the effects of fatigue on material properties. Ultimately, short-term and long-term clinical trials should be accomplished to critically assess the attachment systems evaluated in this laboratory investigation.

Conclusions

Results of this study suggest that the attachment systems evaluated may be divided into 4 groups based on retention characteristics and statistically significant differences: high retention (ERA gray), medium retention (Locator LR white, Spheroflex ball, Hader bar & metal clip, ERA white), low

retention (Locator LR pink), and very low retention (Shiner magnet, Maxi magnet, Magnedisc magnet).

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