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RESEARCH ARTICLE

Effect of Cyclic Dislodging on the Retention of Two Attachment Systems for Implant-supported Overdentures: An *In Vitro* Study

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ABSTRACT

Purpose: The aim of this study was to compare and evaluate the retention of two new attachment systems used for implant-supported overdentures subjected to insertion-removal cycles.

Materials and methods: Twenty custom-manufactured polyvinyl chloride models mimicking implant-retained overdentureresin blocks were fabricated and divided into two groups (n = 10): group 1 ('Kerator' attachment) and group 2 ('Emi' attachment). Each model received two parallel implants (JD evolution®) 20 mm apart and was subjected to cyclic retention forces of 10, 100, 1000, 5000, 10000 and 14600 cycles using a universal testing machine in a 0.9% sodium chloride water solution at 22° C.

Data were analyzed using one-way analysis of variance; the level of significance was set at $\alpha \leq 0.05$.

Results: The 'Kerator' and 'Emi' attachment systems reported a significant decrease in retention (64 and 56.6% respectively) after 14600 insertion-removal cycles ($p < 0.001$). The 'Emi' attachment showed significant higher loss of retention than the 'Kerator' attachment all along the 14600 cycles ($p < 0.05$) except for cycles 100 and 5000 ($p > 0.05$).

Conclusion: Within the limitations of this *in vitro* study, both attachments reported satisfactory retentive values during the 14600 cycles, the 'Kerator' attachment showed better retention than the new 'Emi' attachment. The initial retentive force of both attachments has gradually decreased.

Clinical significance: Both attachment systems evaluated in this study can be used in clinical practice for implant-supported overdentures.

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INTRODUCTION

The introduction of implant-supported overdentures (IOD) enhanced the retention of conventional removable prostheses and improved patients' satisfaction.[1] These overdentures are supported by dental implants and intraoral tissues.[2] The consensus statement from McGill University and the British Society for the Study of Prosthetic Dentistry determined that two-implant overdenture is the treatment of choice for edentulous patients.[3,4]

The link between implants and prostheses is provided by an attachment in which the female part is invested into the denture base and a male part screwed into the implant a system composed of an abutment including the attachment and a denture base, which accommodates the counterpart. An ideal attachment should be resilient allowing a free movement between the prosthesis and the abutments which will lead to a uniform stress distribution on the residual ridges and less concentration on the implants.[5] The ideal chosen attachment should also fit into the appropriate prosthetic height and must provide easy prosthetic maintenance over time.[6]

The attachment systems used in IOD have different retentive capacities and can be either a splinted attachment system (bar) or unsplinted type (ball type, magnets, telescopic, Locators and stud).[6,7]

The advantages of bar-clip attachment are its high retention and stability and its low rate of prosthetic complications in comparison to unsplinted stud attachments, on the other side, its major disadvantage is a difficult oral hygiene control.[8,9] This type of attachments is recommended in cases of implant angulation discrepancies.[10]

Unsplintedstud attachments are recommended because of simple hygiene control, cost-effectiveness and their indication in limited interarch distances.[9-11]

The Locator attachment was introduced in 2001 by 'Zest Anchors' (Escondido, CA, USA), this self-aligning attachment is resilient, durable, needs low prosthetic height and has dual retention.[12-15] The 'Kerator' system (Daekwang Co., Seoul, Korea) is a newer version of the 'Zest Anchors' Locator. This type of attachment is characterized by its lowest vertical dimension among all other attachments.[16]

The retentive force of various attachment systems has been widely investigated in the literature over their loss of retention due to wear, deformation and fracture of different components of the attachment used.[16-22]

The type of connector used is directly responsible for the overdenture's retention.[14] Some studies showed that the retention of the Locator (Zest Anchors) was higher than the ball attachments,[19-23] while others have stressed on the better retention of splinted and spherical attachments.[24-29]

From an aesthetic, function and hygiene points of view, patients are satisfied with implant-supported overdentures. However, it was reported that this satisfaction level decreased with time,[13,30-32] this may be due to the loss in retention, caused by mechanical properties of the materials used, especially the hardness and elastic modulus that could affect the wear pattern.[33,34]

Only one study in the literature evaluated the 'Kerator' attachment that reported a higher initial retentive force in comparison to both spherical attachments 'O-ring' and 'EZ lock'; initially, there was no significant difference among the different attachments this trend changed after 2500 insertion-removal cycles where the 'O-ring' attachment had the highest retention.[16]

The new stud-type attachment 'Emi'introduced by J Dental care (J Dental Care, Modena, Italy) that is composed of an abutment with a titanium ring and transmucosal sleeve coated with a layer of titanium nitride. These abutments come in different heights, while the denture attachment housing has 4 different retention nylon inserts.

Till present, no study has evaluated the retention of the new stud-type attachment 'Emi' in comparison with the 'Kerator' attachment.

The aim of this *'in vitro'* study was to compare the retention between the 'Kerator' and 'Emi' attachments subjected to insertion-removal cycles. The null hypothesis tested was that there is no difference in retentive forces between both attachments.

MATERIALS AND METHODS

Testing Model Fabrication

An experimental set-up was used to simulate a clinical situation with a mandibular overdentures supported by two implants as described by Kobayashi et al.[25] Twenty custom-designed polyvinyl chlorides (PVC) models were fabricated. Samples (n = 20) were equally divided into two groups according to the attachment system used: group 1: 'Kerator' attachment (Daekwang Co., Seoul, Korea) and group 2: 'Emi' attachment (J Dental Care, Modena, Italy).

Both attachments are composed of abutment coated with nitride titanium and a retentive femalepart made from nylon seated in a stainless steel housing fixed to the overdenture. The supra-gingival part of the 'Kerator' implant attachment is characterized by the lowest vertical dimension of 1.48 mm among all stud-type attachments.

The retentive parts of the 'Kerator' and 'Emi' attachments are composed of 7 and 4 different colors of nylon inserts respectively corresponding to different retentive forces (Table 1). The pink nylon inserts were selected for this study (retentive force of 1.1 kg for the 'Kerator' and 1.2 kg for the 'EMI' attachments).

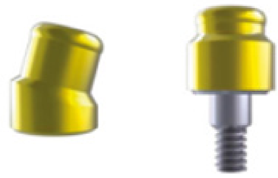
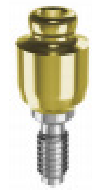
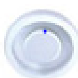
Each model was composed of two blocks: a lower part called 'matrix'(65 × 12 × 20 mm) receiving 2 parallel implants (JD evolution, Italy) of ø = 4.3 mm and 10mm length and an upper part called 'patrix' receiving the metallic housings (60 x 12 x 40 mm) (Fig. 1). Implants were stabilized in their milled spots and the female parts were fixed into the upper block using auto-polymerizing polymethylmethacrylate (PMMA) resin. Particular attention was carried out to avoid any leakage of resin into the male and female parts of the attachments.

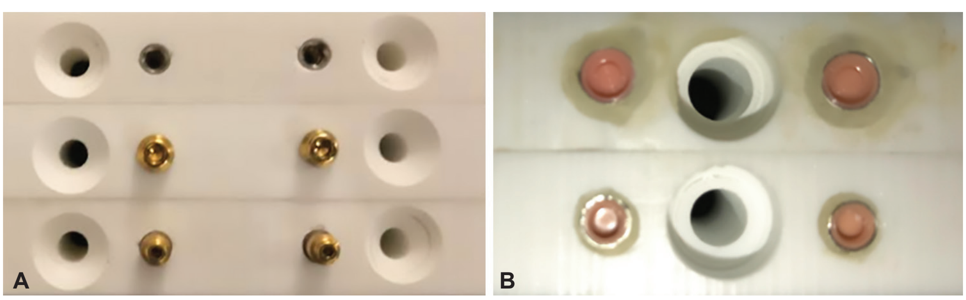
Implants were positioned parallel to each other with an inter-implant distance of 20 mm. The 'Kerator' Magic tool® and tip housing' instrument and the 'JD evolution' ratchet were used to place the 'Kerator' and 'Emi' implant abutments respectively with the torque of 35 N/cm following the manufacturer recommendations.

Cyclic Testing

Samples were tested using a universal testing machine (YL01- Cyclic Dental Tester, YLE GmbH, Germany). Each model was submitted to an amount of 14600 insertion-removal cycles corresponding to a mean of 4 insertion-removals of the overdenture per day during a period of 10 years. The testing was performed in a medium

Table 1: Specifications and different components of tested attachment systems. F: Retentive force

	'Kerator'	*'Emi'*		
Implant abutments	 Straight and 15° angulated abutments Correction of up to 40° interimplant angles		 Correction of up to 30° interimplant angles	
Male and female parts	 Height = 2.2 mm		 Height = 2.1 mm	
Nylon inserts	*Color*	*F (Kg)*	*Color*	*F (Kg)*
	 Blue	0.55	 Black	Used for laboratory work
	 Pink	1.1	 Yellow	0.6
	 White	1.8	 Pink	1.2
	 Yellow	Interimplant angles 0°	 White	1.8
	 Red	Very lightly angulated	 Purple	2.5
	 Orange	Lightly angulated		
	 Green	Angulated		



Figs 1A and B: (A) Top view of the matrices showing the 2 implants, Kerator and Emi implant abutments respectively with the location of the screws connecting the matrice to the machine; (B) Top view of the patrices showing the nylon inserts of the Kerator and Emi attachments respectively and the location of the screw connecting the patrix to the load cell of an isotonic 0.9% sodium chloride water solution at 22°C simulating the oral environment. At 7300th cycle, each test was interrupted to check the presence of any macroscopic cracks.

The matrix is connected to a Plexiglas container filled with isotonic solution and to the lower border of the machine with two long screws from either side of implants allowing for all the lower part to stay fixed and motionless during tests. The upper part of the system is composed of the patrix, which is connected to the 500 N load cell and the upper part of the cyclic tester with one screw (Fig. 2).

During the 14600 cycles, the retention forces corresponding to the removal of nylon inserts were measured at the following cycles: 10, 100, 1000, 5000, 10000 and 14600. The first three cycles were not taken into consideration to ensure a complete wettability of the system. A speed of 50 mm/min was adopted during the 14600 cycles but it was decreased to 1 mm/minute at the cycles 9, 99, 999, 4999, 9999 and 14599 to be able to read and save the desired retention forces.

Statistical Analysis

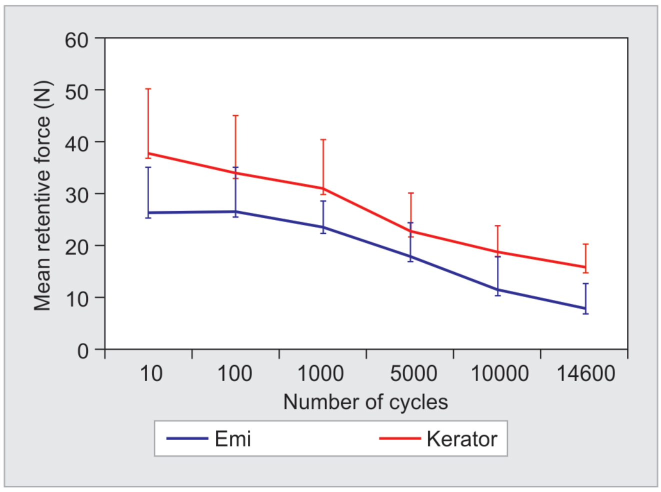
The Statistical Package Software for Social Sciences (SPSS, version 19.0, Chicago, IL, USA) was used for statistical analysis. The significance was set at 0.05 (≤ 0.05). Kolmogorov–Smirnov test was performed to assess the normality distribution of the continuous variable in each group. Repeated-measure analysis of variance with one within-subject factor (number of cycles) and one between-subjects factor (attachment type) was used for statistical comparisons; it was followed by univariate analysis and SIDAK multiple comparisons tests.

RESULTS

The 'Kerator' attachment reported a significant higher retention compared to the Emi attachments for the cycles 10 ($p = 0.028$), 1000 ($p = 0.046$), 10,000 ($p = 0.012$) and 14600 ($p = 0.012$). Although the retentive force was greater with 'Kerator' group compared to 'Emi' for the cycles 100 and 5000, however, the difference was not significant ($p > 0.05$) (Graph 1).

The mean retentive force observed with'Emi' attachment did not significantly change between cycles 10 and 100 (p = 1,000), 100 and 1000 (p = 1,000) and 1000 and 5000 ($p = 0.110$). However, it has significantly decreased between the cycles 5000 and 10000 ($p < 0.001$) and 10000 and 14600 ($p < 0.001$). The mean retentive force for the 'Kerator' attachment did not significantly change between cycles 10 and 100 ($p = 0.078$) and 100 and 1000 (p = 1,000). However, it has significantly decreased between cycles 1000 and 5000 ($p = 0.004$), 5000 and 10000 ($p = 0.001$) and 10000 and 14600 ($p < 0.001$) (Table 2).

At the cycle 10000, the mean retentive force decreased (49.6% ± 36.6%) with the 'Emi' attachment and by (47.9% ±



Graph 1: Mean retentive force (N) in tested groups

Table 2: Mean retentive force (N) of the tested groups at different cycles

Groups	Number of cycles	N	Mean (N)	Standard-Deviation (N)	Minimum (N)	Maximum (N)
Emi	10	10	26.40	8.799	12	37
	100	10	26.65	8.489	11	35
	1000	10	23.54	5.147	16	30
	5000	10	18.17	6.480	10	27
	10000	10	11.55	6.552	3	19
	14600	10	8.08	4.883	2	15
Kerator	10	10	37.90	12.442	23	58
	100	10	34.14	11.096	22	50
	1000	10	30.93	9.614	20	50
	5000	10	22.92	7.433	15	39
	10000	10	18.88	5.036	13	29
	14600	10	15.86	4.566	11	24

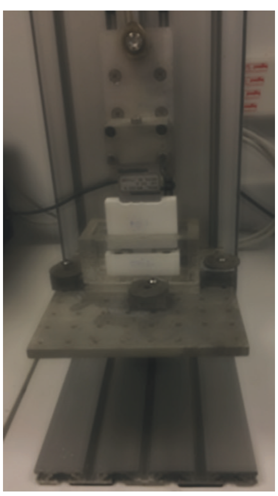


Fig. 2: The experimental set-up

12.2%) with the 'Kerator' attachment, with no significant difference between both attachments (p = 0.889).

At the cycle 14600, the mean force decreased by (64.6% ± 26.5%) with 'Emi' and by (56.6% ± 9.4%) with 'Kerator', with no significant difference between both attachments (p = 0.387).

DISCUSSION

The results of this study led to the rejection of the null hypothesis that there is no significant difference between tested groups.

The retention of both tested attachments has gradually decreased during the 14600 cycles. Most attachment systems are submitted to a reduction of retention over time.[35] This retention's behavior can be compared with that of the 'Zest Anchors' Locator attachment since no study has followed the progression of the retention of the 'Emi' attachment in the literature and only one recent study has compared the blue 'Kerator' attachment retention to that of the 'EZ lock' and 'O-ring' spherical attachments.[16] Most studies have effectively noticed a reduction of the 'Zest Anchors' attachment retention over time.[18,21,29,35]

The mean retention results of the present study (26.4 N for the 'Emi' attachment; 37.9 N for the 'Kerator' attachment) are in disagreement with previous reports that showed lower values;[16,18-20] This difference may be due to a fewer experimental samples used in previous studies, or variation in the medium used such as artificial saliva and some cleansing solutions, which may have tendency to cause more, wear to the nylon inserts than the isotonic solution used in this study.

A consensus on the minimum retention value for a lower implant supported overdenture is still not well defined in the literature.[35] Different results on the required satisfactory retention of mandibular overdenture were published equals to 4N according to Lehmann[36] and 5 to 7 N according to Pigozzo and Besimo.[37,38] However, a minimum of 20 N is required according to Setz and Engel.[39]

The practitioner should choose an attachment with a higher initial retention value than to compensate its reduction over time.[40] This loss of retention can be explained by the surface alteration of the locator attachments. In fact, scanning electron microscopic (SEM)analysis showed some abrasion of the inner retentive surface of the locators' abutments as well as wear and plastic deformation of nylon inserts.[16,22,26,29] Therefore, nylon inserts require a follow-up by the practitioner with the possibility of replacing them each year. [26] Patients should be instructed to respect follow-up visits especially when "locator'" attachment is used in restricted prosthetic space.[23]

The accurate simulation of the intraoral environment in an 'in vitro' study is difficult since this environment is constantly subjected to continuous fluids and thermal changes, that represent the weak point in the majority of these studies.[41] The forces direction applied on the attachments by the universal testing machine were purely vertical that is contrary of the clinical reality where masticatory forces applied to the molars lead to rotational forces at the anterior attachments causing more wear and loss of retention.[42] A solution of 0.9% sodium chloride solution at 22° C was used in order to mimic the presence of saliva. In this study, an SEM analysis would have been beneficial to evaluate the deformation occurring on the nylon inserts as performed in other studies.[22]

Two implants were used in the models following the Mc Gill consensus confirming that mandibular two-implant overdentures are the first choice standard of care for edentulous patients.[3] Implants were positioned parallel one to another in all tests. The interim plant divergence was not considered in this study because of the controversy in the literature regarding its effect on the retentive force of different attachment systems.[25,30,40,43]

The pink 'Kerator' and 'Emi' attachments were compared in this study since they have similar retention forces proposed by their manufacturers (1.1 and 1.2 Kg respectively). Also, the 14600 cycles chosen simulated a mean of 4 insertions and removals of the overdenture per day for 10 years.[25] Studies considered a mean of 3 insertions and removals per day during different durations,[32,37,38] while others reported a mean of 5 insertions and removals per day.[44] The cycling testing speed was set to 50 mm/min because it is correlated to the clinical speed of insertions and removals of overdentures as described by previously published papers.[25,32]

The complexity of simulating the clinical conditions, the three-dimensional movement of the implant-supported overdenture, the effects of saliva, food, aging of plastic parts and implant angulation are the main factors of the limitations of this "*in vitro*" study. Further prospective "*in vivo*" studies should be conducted to validate our results and determine the prosthodontics outcome of these attachments.

CONCLUSION

Within the limitations of this "*in vitro*" study, the following conclusions can be drawn:

The retention of the 'EMI' attachment has decreased significantly from the 1000th cycle until the end of the 14600 cycles while losing 49% and 64% of its initial retentive force at cycles 10000 and 14600 respectively.

The retention of the 'Kerator' attachment has decreased significantly from the 5000th cycle until the end of the 14600 cycles while losing 47.9 and 56.6% of its initial retentive force at cycles 10000 and 14600 respectively.

During the 14600 cycles, the retention force of the 'Kerator' attachment has significantly exceeded that of the 'Emi' attachment except for the 100th and 5000th cycles.

Both attachments provided an acceptable retention for mandibular implant supported overdentures.

The loss of retention in both attachments is mainly due to the nylon inserts wear, that needs a periodic follow-up.

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