Retention force dynamics of two different soft liners over ball abutments for mandibular implant overdentures

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Purpose: This study was conducted to comparatively evaluate the initial and reduced retention force of two different soft liners over ball abutments for mandibular implant overdentures.

Materials and Methods: Two implants corresponding to 33 and 43 (mandibular left and right canine, FDI notation) were placed in a mandibular edentulous heat cure master model with ball abutments of 3 mm diameter and 0.5 mm collar height. Overdentures were processed in heat-activated denture base resin and divided into three groups, group A (n = 15), group B (n = 15), and group C (n = 15). Group A was lined with Ufi-gel P, group B with Molloplast B, and group C was polymerized with plastic caps. Each of the 45 denture bases was subjected to an initial retention force and reduced retention force testing after 3,348 cycles using a servohydraulic testing machine. The dual recess areas and the soft liner bonded to the denture base were observed with a stereomicroscope both before and after the 3,348 cycles. Statistical analysis was performed using the ANOVA Kruskal Wallis test and Wilcoxon signed-rank test.

Results: There were insignificant differences ($P > 0.05$) in the mean rank values of all the three groups for reduced retention force after 3,348 cycles and percentage reduction in force. There were significant differences in all the three groups between initial retention force and reduced retention force after 3,348 cycles ($P < 0.05$).

Conclusions: Both the liners could be used as attachments for mandibular implant overdentures over the three-year simulation period. (JOURNAL OF DENTAL IMPLANT RESEARCH 2021;40(1):23-34)

Key Words: Dental abutments, Denture bases, Denture, Denture retention, Denture liners, Mandibular prosthesis, Silicone elastomer, Dental implant

INTRODUCTION

Soft lining materials are a well-established entity in prosthetic dentistry. These materials are polymers undergoing elastic deformation when subjected to an applied force¹⁾. Dentists currently are faced with the selection of many soft liners with a wide variety of uses. With the increased number of products available, the dentist must understand the differences in the materials to prescribe select and use the product best suited to meet the challenges a patient may present clinically²⁾. Silicone elas-

tomers most widely used as soft lining materials due to their excellent elastic properties³⁾.

The term soft liners refer to the class of resilient materials used to relined denture base surfaces in contact with the occlusal stress-bearing oral mucosa⁴⁾. Failure in adhesion, rough surfaces and changes in hardness are favourable factors for microbial accumulation and compromise the durability of the liner. A study done on mycotic flora on Molloplast B (heat curing silicone soft liner, Detax GmbH, & Co, Ettlingen, Germany) lined dentures and the associated denture bearing mucosa indicated that in the

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presence of inflamed mucosa, fungus growth was detected in all the mandibular soft-lined dentures and on the associated mucosa in 93% of the patients⁵. Liners also used for prosthesis fractures, remodelling of the bone crest, cleft palate, and tissue conditioning during implant healing^{3,6}. Apart from this, they are used under complete and partial removable dentures to distribute functional loads homogeneously on the denture bearing tissues. They are useful in patients with irregular bone resorption, bony undercuts, thin atrophic mucosa, immediate prosthesis, for aiding in healing after implant placement, and for patients with bruxism and xerostomia⁷.

Edentulism is considered a poor health outcome and may compromise the quality of life. The prosthetic management of edentulous patients has long been a significant challenge for dentistry. The ideal treatment plan for the edentulous patient is a conventional complete denture. However, due to clinical situations like poor muscular co-ordination, low tolerance of mucosal tissues, the presence of parafunctional habits results in chronic soreness, and instability of the prosthesis⁸.

Although most patients adapt to complete dentures, about one-third of them are dissatisfied, particularly about their mandibular prosthesis. Among their chief complaints are insufficient stability and inadequate retention as well as discomfort during mastication. One of the rehabilitation options for patients with such kind of persistent problems in the fabrication of overdentures⁶⁻⁸. By using a cross over experiment Burns et al. found a strong patient preference for the attachment with superior retention. Therefore retentive forces and loss of retention are essential data in the selection of an appropriate attachment when treating a patient's edentulous mandible with implant stabilized overdenture⁹.

Currently, numerous attachment systems are available for utilization with implant-supported overdentures. Attachments can be classified based on their variability in flexibility, geometrical shape, and cross-section, casting precision, and process of manufacture¹⁰. However, no attachment system considered as a gold standard. Although excellent attachment systems are available, each attachment system has its problems¹¹.

During one's lifetime, good daily oral hygiene is indispensable for maintaining good oral health and quality of

life. It is even more critical for people of advanced age. Most denture wearing patients, especially those who live in nursing homes, do not keep their prosthesis clean¹². Mouth cleaning is difficult for many older patients to perform by themselves, especially those who require long term care and a large amount of plaque often adheres to the mouth and dentures. Insertion and repair of soft-lined overdentures for homebound patients can be performed more efficiently and safely than insertion and repair of existing attachment systems. In this view silicone, flexible liners with overdenture attachments may be considered for homebound dental patients because they can be provided efficiently and safely at home. The present study uses resilient silicone liners as straightforward and safe overdenture attachment system where liners applied as the matrix of an attachment system with ball anchor as the patrix, and this system can be provided efficiently and safely at homes¹³.

Retention by a hole in a soft liner which is undersized to the diameter of the abutment allows us to form insertion which generates an implant silicone rubber frictional connection¹⁴. Within the various commercially available implant systems, ball attachments frequently used due to their simplicity. Specifically, ball attachments considered as one of the simplest attachment for clinical usage^{10,13,14}.

From a clinical point of view, a resilient retention mechanism for overdenture fixation should allow equal tissue and implant support. The resilient retention plastic caps protect against implant overloading as most of the masticators' stresses transmitted to the posterior edentulous ridge. Hence plastic cap was used in this study as a control¹⁵.

The null hypothesis adopted for this study was that there would be no significant differences between the retention forces (initial and reduction) of the two soft liners over ball abutments of mandibular implant overdentures.

MATERIALS AND METHODS

An acrylic resin model of an edentulous mandible fabricated (Fig. 1). Two implants (ADIN Dental implants, Israel) inserted in the canine areas 33 and 43 (mandibular left and right canine, FDI notation). Stainless steel ball

Fig. 1. Mandibular edentulous master model.

Fig. 2. Grouping of samples.

abutments (ADIN Dental implants, Israel) screwed over the two implants. Space under the ball abutments blocked out with wax (DPI, India).

Experimental overdentures without teeth fabricated using heat-activated acrylic resin (DPI, India). Two long term silicone soft denture liners namely Ufi gel P (soft cold curing silicone soft liner, VOCO GmbH, Germany) and Molloplast B (heat curing silicone soft liner, Detax GmbH, &Co, Ettlingen, Germany) polymerized against each overdentures according to manufacturer's in-

Fig. 3. Master model assembled in servohydraulic testing machine.

structions over dental stone casts. As the control, plastic cap (Nylon, ADIN Dental implants, Israel) used. The plastic caps fixed onto the overdentures with auto polymerizing acrylic resin. A total of 45 specimens were fabricated and divided into three groups to test 2 kinds of liners and a plastic cap (15 specimens for each group) (Fig. 2).

A Special fixture to ensure the perfect alignment and desired depth of insertion and removal developed for manually operating the liner and master model 10 times before determining the retention force. Subsequently, a specified volume (10 μ l) sprayed on the samples, and ten manual operations performed.

Servohydraulic testing machine (ITW Biss make, S-721 nano model, USA), with 0.1N load measuring sensitivity was used for determining the retention force (Fig. 3). A unique fixture replicating the application condition had been designed, developed, and fabricated to hold the liners and master model on the machine during testing. The samples fixed on the fixture. Up and down movement of the sample along with the fixture on the crosshead on the testing machine is precisely controlled to ensure that (a) the abutment in the master model travels only to the desired depth in the recess of the samples and (b) prevents ant damage of the samples or application of excessive force onto the samples.

The testing machine calibrated, and the load scale set to zero. Next, the crosshead moved downwards to make the abutments on the master model just enter the recess in the sample to the desired level. Subsequently, a small quantity of artificial saliva sprayed on the samples. Next,

Fig. 4. Insertion and removal simulation test.

Fig. 5. Stereomicroscope.

Table 1. Percentage reduction in retention force (N) group – A (Ufi-gel P)

Sample no.	Initial retention force (N)	Retention force after 3,348 cycles (N)	%Reduction In retention force (%)
1.	7.94	6.00	24.47
2.	9.61	4.73	50.78
3.	15.89	5.30	66.67
4.	19.91	8.90	55.29
5.	22.46	7.70	65.71
6.	00.00	0.00	00.00
7.	15.49	5.10	67.09
8.	10.30	5.21	49.40
9.	25.30	13.00	48.62
10.	12.26	4.97	59.46
11.	20.01	7.35	63.26
12.	18.54	9.17	50.52
13.	15.99	0.00	00.00
14.	21.38	8.35	60.94
15.	13.73	6.67	51.42
Mean	15.25	6.16	47.57
S.D	±6.54	±3.32	±22.03

The mean percentage reduction in retention force of group A samples was found to be 47.57 ± 22.03 .

the crosshead set at 0.1 mm/second and slowly moved upwards to take the abutments from the recess in the sample (Fig. 4). The tensile force needed for removing the samples from the master model was measured using a load cell with 0.1 N measurement capability. Retention force determination performed on all 45 samples.

The samples were examined under the stereomicroscope at 7× magnification for the appearance, condition, and damage if any (Fig. 5).

RESULTS

The retention force of the denture was measured using a servohydraulic testing machine, and the maximum force of traction regarded as the initial retention force. The intaglio of the matrix observed with a stereomicroscope before and after 3,348 cycles.

The initial retention forces and the reduction in retention forces of 3 different groups presented in Tables 1~3. Kruskal-Wallis ANOVA and Wilcoxon signed-rank test (SPSS 20.0, Statistical package for Social Sciences for windows; SPSS Inc, Chicago, USA).the former test is used for comparison of retention force between groups and the latter test is used to identify significance in before and

Table 2. Percentage reduction in retention force (N) group B (mollioplast B)

Sample no.	Initial retention force (N)	Retention force after 3,348 cycles (N)	%Reduction in retention force
1.	14.78	5.12	65.35
2.	12.30	5.05	58.93
3.	10.69	5.45	49.01
4.	27.27	9.35	65.70
5.	10.20	4.91	51.85
6.	14.51	4.40	69.68
7.	14.32	8.93	37.62
8.	5.00	4.10	18.02
9.	8.53	5.94	30.37
10.	10.29	6.12	40.50
11.	8.55	7.13	16.59
12.	7.55	3.99	47.16
13.	12.75	6.67	47.68
14.	11.47	5.96	48.05
15.	10.79	4.42	59.02
Mean	11.92	5.83	47.03
S.D	±5.04	±1.62	±16.23

The mean percentage reduction in retention force of group B samples was found to be 47.03±16.23.

Table 3. Percentage reduction in retention force (N) group C (control)

Sample no.	Initial retention force (N)	Retention force after 3,348 cycles (N)	%Reduction in retention force (N)
1.	10.57	4.39	58.47
2.	9.02	4.66	48.34
3.	13.63	0.00	00.00
4.	15.40	7.12	53.75
5.	14.22	7.17	49.57
6.	14.32	8.03	43.95
7.	15.59	5.97	61.71
8.	14.42	6.56	54.49
9.	18.05	7.75	57.05
10.	15.10	6.89	54.37
11.	7.94	6.62	16.66
12.	13.14	5.60	57.38
13.	8.73	6.07	30.45
14.	7.98	0.00	00.00
15.	10.30	7.09	31.14
Mean	12.56	5.59	41.85
S.D	±3.19	±2.48	±20.84

The mean percentage reduction in retention force of group C samples was found to be 41.85±20.84.

after comparison values The results presented in tables four and five. Representative images were showing the absence of deformations obtained from stereo microscopic images of all the 3 test groups presented in Fig. 6~8.

DISCUSSION

Eric. D. Adrian had suggested the use of resilient denture liner as an attachment for implant-retained overdentures. The flexible liners provide several advantages including minimal wear, patient comfort, absorption of occlusal force, and load distribution to the implants¹⁸⁾. Also, soft liners obturate the spaces in the denture base around the abutment, improve peri-implant tissue health, increase patient satisfaction, reduce costs, and minimize soft tissue complications compared to clip attachments¹⁹⁾. Elsyad noted that patient satisfaction regarding comfort, stability with an upper denture, and ease of hygiene procedures was significantly higher with flexible liner compared to attachments. In another in vivo study patients with clip attachments demonstrated a significant increase in modified plaque index (MPI), Modified bleeding index (MBI) scores, and probing

depths (PD) compared to patients with soft, resilient liner^{20,21)}. This statement is in agreement with previous study⁹⁾ which reported a significant increase in PD with time when the overdenture retained with clips over the bar. This could be attributed to space around the abutments that remain unobturated, thus plaque accumulation with pathogenic bacteria producing peri-implant bleeding and gingival inflammation²²⁾. Another study had pointed out difficulty in performing sufficient oral hygiene measures by wearers of clip-retained overdentures, especially in the abutment region²³⁾. The advantages of soft liners include a greater range of overdenture movement energy absorption and equal force distribution to the implants and the edentulous ridges²³⁾. Shaygan et al.²⁴⁾ found greater retention with soft liners than clip attachments of implant-retained overdentures. Therefore, these liners used also to compensate for clip wear.

Three different types of liners used namely silicone, acrylic, and polyphosphazene. These materials offer the benefits of impact absorption on the residual ridge and prevention of pressure ulceration because of their viscoelasticity and elasticity. However, ethyl alcohol, which is a plasticizer, is eluted from acrylic resilient denture liners and makes the surface rough¹³⁾. Kiat-Amnuay et al.¹⁶⁾ re-

Fig. 6. Stereomicroscopic images of group A dentures.

ported that when applied to overdentures with a bar attachment, silicone flexible denture liners exhibited similar retention to acrylic resilient denture liners. Therefore, this

study used silicone flexible denture liners as the matrix of the attachment because the physical properties of these materials are more stable than those of acrylic materials.

Fig. 7. Stereomicroscopic images of group B dentures.

For the standardization of the study, a single mandibular acrylic master model constructed with a 22 mm interimplant distance²⁵⁾.

The stud attachment systems like plastic caps used for overdentures provides clinically favourable results. Furthermore, used for the system of implant over-

Fig. 8. Stereomicroscopic images of group C dentures.

dentures, and there have been reports presenting favourable results. Therefore if a present attachment system developed in this study, can achieve a retention force equal

to or higher than that of the stud attachment system, then it is considered that the present system will become clinically applicable. In order to achieve a sufficient retention

force using a soft lining material, ball anchors with diameters of 2.5, 2.7, and 3.0 mm were produced and experimentally investigated by Koike et al.¹³⁾, therefore ball abutments of 3 mm diameter used in the present study.

Previous studies^{5,26,27)}, have shown that the dynamic viscoelastic properties of the silicone-based relining material, Molloplast – B liner were not affected by aging. Reduction of the retention force caused by wear of the resilient denture liner after long term use is also of concern for this type of attachment system by soft liners. Therefore it is necessary to select a material with stable physical properties and not one with decreasing retention force, to ensure that the material will last for a long time.

All the procedures were performed by a single operator to avoid errors by multiple operators. Various authors have used test blocks of varying dimensions for testing the retention force values^{8,13)}. In the present study, the mandibular acrylic master model was used as mentioned in previous studies^{16,17,19)}. Doublident was used as indexing material since the material can record the ball abutment undercuts without undergoing distortion and tearing.

Adin implant analogues, ball abutments, plastic caps inserts, and two different silicone soft liners were selected. These implant analogues placed using the surveyor to ensure the parallelism between the implants as mentioned in previous studies. The parallel placement of implants enables complete insertion of the prosthesis by engaging the ball attachments to prevent the wear of the attachments. According to several authors, inter-implant distance is a factor influencing the retentive strength of attachments. In the present study, the two-implant analogues were placed at a distance of 22 mm apart from each other since it has been reported that the same distance separates the natural canines.

The retentive force was measured previously by various methods like dental mastication simulator, micro material testing machine, cyclic fatigue machine (load cell), and universal testing machine (UTM)^{28,29)}. The retention mechanism of the test samples was measured in the present study using a servohydraulic testing machine (ITW-Biss Make, S- 721 Nano model, USA) to replicate the vertical separation of the denture from the mouth.

A different number of cycles used in different stud-

ies³⁰⁻³²⁾, like 10,000 cycles equivalent to a corresponding time of use of 9 years, 5,500 cycles (3 years), 14,600 cycles (which represents ten years of clinical use). In the present study, the test samples subjected to 3,348 insertion and removal cycles which corresponds to three years of clinical simulation assuming that the patient inserts and removes the denture three times per day.

Previous studies^{33,34)} had employed demineralized water, saline solution, and 0.9% isotonic sodium chloride solution maintaining 22 degrees Celsius to simulate in vivo conditions during their testing procedures. In the present study, artificial saliva (0.2% glycerine solution) sprinkled on all the test samples throughout the testing procedure.

Many studies³⁵⁻³⁷⁾ evaluated the retention force of overdenture attachments in different dislodgement speeds. Kiatamnuay et al.¹⁶⁾ in their in vitro study had used a crosshead speed of 0.2 mm/min; therefore, in the present study, 0.1 mm/min of crosshead speed was used.

In the present study, the test samples have been divided into three groups, group A, group B, group C. Group A comprised of heat-activated denture bases lined with Ufi gel P whereas group B comprised of heat-activated denture bases lined with Molloplast B, and Group C comprised of heat-activated denture bases polymerized with nylon caps. The retention force obtained for all the test samples for both group A and group B and C tabulated and statistically analyzed.

In addition to the analysis of retentive forces, deformations and alterations in the matrix area were also analyzed in the previous studies^{38,39)} by various methods like scanning electron microscopy, co-ordinate measuring machine, and digital light microscopy. In the present study, the qualitative analysis of the deformations of the dual recess' of all the 45 test samples of all three groups done using a stereomicroscope. The recess' were nearly 3 mm in diameter. It was too large for capturing SEM images of the recess. The recess was much larger than the field of view of the SEM. Therefore, it was not possible to examine the condition of the recess under SEM. Therefore the samples were examined under a stereomicroscope at 7× magnification for the appearance, condition, and the damage if any.

The retention force of Ufi-gel P and Molloplast B liners

Table 4. Intra group comparison of initial retention force (IRF) and reduced retention force

Group	Event	Mean	Std. Deviation	Mean rank	P-value
Liner A	IRF	15.25	6.54	7.50	.001
	After 3,348 cycles	6.16	3.32		
Liner B	IRF	11.92	5.04	8.00	.001
	After 3,348 cycles	5.83	1.62		
Control	IRF	12.56	3.19	8.00	.001
	After 3,348 cycles	5.59	2.48		

The mean rank value for liner A between initial retention force and after 3,348 cycles was 7.50 and was found to be statistically significant ($P < 0.05$). The mean rank value for liner B between initial retention force and after 3,348 cycle was 8.00 and was found to be statistically significant ($P < 0.05$). The mean rank value for liner C between initial retention force and after 3,348 cycles was 8.00 and was found to be statistically significant ($P < 0.05$).

over ball abutment found to be ranging between 11.9 To 15.25 N (Table 1~3). These values were comparable with previous studies conducted^{16,17} although those studies were on bar overdentures. This study confirmed that the resilient silicone liners retained the overdentures well as found in the previous studies. In the previous study¹⁷ after 540 cycles, the maximum percentage reduction was found to be 64.3%. Also, in another study conducted by KiatAmnuay¹⁰, after 2,740 cycles, the maximum percentage reduction was found to be 60.2%.

Previous studies¹⁰ showed 18.7% loss of retention of o-rings after simulated 30 months of clinical use and in another study⁸ it was 16.6% retention loss after simulated six months of clinical use and 57.1% loss after 24 months. In a study by Arora and Mittal¹⁰ the retention force values of different attachments like locator, ball/o-ring, and ball/nylon cap simulating one year of clinical usage were evaluated, and retention loss was maximum for ball/o-ring (76.6%) and minimum for ball/nylon cap (18.4%) and locator (20.2%). In the present study, the overall percentage loss of retention force after 3,348 cycles for plastic caps was found to be 41.85% (Table 1~3). Which is comparable to the previous studies^{8,10}. The use of full-length denture bases in the current study could be attributed as a reason for the higher percentage of loss of retention when compared with Arora and Mittal et al.¹⁰ study.

Many previous studies^{28,29,40} have reported that the retention force of about 5 to 7 N was enough to stabilize

Table 5. Comparison of retention forces between the three groups

Groups	Group	Mean rank	P-value
IRF	Liner A	28.80	.086
	Liner B	18.37	
	Control	21.83	
Retention after 3,348 cycles	Liner A	24.97	.636
	Liner B	20.50	
	Control	23.53	
%Reduction	Liner A	26.40	.429
	Liner B	22.33	
	Control	20.27	

The mean ranks for initial retention force for all the three groups was found to be statistically insignificant ($P > 0.05$). The mean ranks for retention after 3,348 cycles for all the three groups was found to be statistically insignificant ($P > 0.05$). The mean ranks for % reduction force for all the three groups was found to be statistically insignificant ($P > 0.05$).

the overdentures during the function. All the test samples of the three groups have retention force values more than the range mentioned above of retention force.

In the study conducted by Kubo et al.¹³. SEM analysis showed deformations and wear on the soft liners after completion of 3,348 cycles. In other previous studies^{13,28,29} wear and deformation were found to be present in the various attachment systems used after a simulated period of cycles. Surprisingly, in the present study, there were no deformations and alterations to be seen under 7× magnification in the dual recess' area of the soft liners after 3,348 cycles.

The present study showed that both the soft liners Ufi gel P, Molloplast B could be an attachment of choice for ball abutments over mandibular implant overdentures since there were statistically significant differences in both the groups (A & B) between their initial retention and reduced retention values. Hence the null hypothesis was rejected. However, in terms of percentage reduction in force, the mean rank value was found to be statistically insignificant for all three groups, which also explains the fact that both liners should be considered for clinical usage ($P > 0.05$) (Table 4, 5).

Limitations of the current study include the use of two different soft liners only, the use of three year simulation period for the reduction in force determination, absence of thermocycling. A similar kind of study should also be extended to locator attachments. Physical properties of

the soft liners and their role in retention management should also be explored.

CONCLUSION

Both the soft liners are recommended for use as attachments over ball abutments for mandibular implant overdentures.

CLINICAL SIGNIFICANCE

Patient comfort and ease of use should always be considered in implant overdentures fabrication. The use of soft liners as an attachment is one step taken in that direction.

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