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Comparison of retention in polyvinyl siloxane matrix systems versus conventional metal housing with nylon inserts in ball-retained mandibular implant overdentures

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Abstract

Objective: This study compared the retentive performance of two polyvinyl siloxane (PVS) matrix systems (retention.sil 400 and 600) versus conventional metal housing with nylon inserts in ball-retained mandibular overdentures.

Methods: Thirty ball-retained overdenture models were allocated into three groups based on the attachment system material (n=10): Group 1, conventional metal housing with nylon inserts; Group 2, retention.sil 400; and Group 3, retention.sil 600. A total of 1440 insertion-removal cycles, simulating one year of clinical use, were conducted at 50 mm/sec using a universal testing machine. Retention forces were measured at baseline (0 cycles) and after 360, 720, 1080, and 1440 cycles. Statistical analyses were performed using one-way ANOVA, followed by post hoc Tukey's test at a significance level of $P<0.05$.

Results: The conventional group showed the highest retention at all cycles. There were statistically significant differences in retention between the conventional group and both PVS groups at all cycles ($P<0.001$), but no significant differences were found between the two PVS groups ($P>0.05$). Absolute retention loss was significantly greater in the conventional metal housing with nylon inserts than in the two PVS groups ($P<0.001$). No significant difference was found in relative retention loss among the groups ($P=0.108$).

Conclusions: Conventional metal housing with nylon inserts provided superior mean retention compared to the retention.sil 400 and retention.sil 600 matrix systems at all cycles, with no significant difference between the two PVS materials. The relative retention loss, however, did not significantly differ between the conventional group and PVS groups.

Keywords: Dental abutments, Dental implants, Dental prosthesis retention, Denture precision attachment, Edentulous jaw, Overlay denture

Introduction

Managing severely resorbed residual alveolar ridges in the lower jaw of edentulous patients presents a considerable retentive challenge due to reduced adaptive capabilities, particularly in older adults (1). Literature highlights that the mandibular ridge undergoes up to 4–5 mm of bone reduction over time, whereas the maxillary ridge experiences around 2–3 mm of resorption (2). These compromised conditions lead to poor retention and stability of complete dentures, reduced masticatory efficiency, and potential psychosocial problems (2).

Implant-supported overdentures (ISODs) have become the gold standard for treating edentulous mandibles, offering a more cost-effective solution compared to fixed implant-supported prostheses and delivering superior comfort, chewing capacity, quality of life, and patient satisfaction, compared to conventional complete dentures. The use of two to four interforaminal implants has been suggested for implant-supported overdentures (3, 4). While two implants provide adequate retention and are the minimal standard of care (5, 6), additional implants allow for a staggered arrangement, reducing fulcrum movement and retention loss in overdentures (7-9).

Precision attachments are small interlocking devices that connect prostheses to abutments, improving retention, support, stability, and longevity of implant

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restorations while allowing for easy maintenance (10, 11). These attachments can be used in splinted designs with bars or unsplinted configurations, using stud attachments (male components) such as ball, locator, equator, magnetic, or telescopic mechanisms (4, 12). Ball attachments are widely used due to their simplicity, ease of cleaning, cost-effectiveness, and ability to distribute and absorb occlusal loads through slight multidirectional movement (13-16).

Overdenture attachment components usually feature a metal/plastic interface, which undergoes wear over time due to repeated insertion and removal cycles. This wear often requires frequent replacement of attachment components to maintain optimal function (17-19). Nylon inserts in stud attachments gradually degrade due to wear, surface alterations, and plastic deformation caused by functional and parafunctional loads. This deterioration leads to a progressive loss of retention over time (20-23).

Recently, polyvinyl siloxane (PVS) matrix systems have emerged as an alternative to conventional metal housing with nylon inserts to serve as female components in overdentures (24). These cost-effective chairside materials create mechanical interlocking through frictional contact, ensuring secure retention. Their resilient properties also provide chewing comfort for patients. Klampfer et al. (25) reported that PVS matrix materials improve patient comfort while chewing, exhibit low plaque adherence, and reduce stress on supporting tissues. Burns et al. (26) found that retention.sil, a PVS matrix material, provides sustained retention, ease of removal, and greater freedom of movement. Retention.sil is available with different shore hardness and pull-off forces, ranging from the softest to the hardest: retention.sil 200, 400, and 600 (27). Retention.sil 400 and 600 have demonstrated superior retention in mandibular overdentures with various stud attachments (28).

The present study aimed to compare the retentive force of conventional metal housing with nylon inserts and retention.sil matrix systems with various hardness grades in ball-retained mandibular overdentures. The null hypothesis was that there is no significant difference in retention force between the two hardness grades of retention.sil and conventional metal housing with nylon inserts in mandibular overdentures.

Materials and methods

The protocol of the present in vitro study was approved by the Research Degree Committee of the institute with letter no. D-HSJ/22/1183 dated 30.5.2022. The study was conducted at Panjab University in collaboration with Punjab Engineering College, Chandigarh, India. The sample size was calculated based on a study by Khan et al. (27), with an alpha level of 0.05 and a power of 80%. Subsequently, 30 samples were calculated, with each study group consisting of ten overdentures.

A completely edentulous mandibular model was fabricated using heat-cured polymethylmethacrylate resin (DPI, Mumbai, India). Three implants (Pivot Implant; Pivot Fabrique Inc., Mohali, India) measuring 3.7 × 10 mm were used. Implant positions were marked using a Straumann® planning guide (Institute Straumann AG, Basel, Switzerland) to ensure parallel placement (Figure 1A). Two implants were placed in the premolar region and one at the midline using a physiodispenser (ST-923; W&H Implantmed, Burmoos, Austria) (Figure 1B). Afterwards, the ridge was covered with a 2 mm layer of auto-polymerized silicone resilient liner (Esthetic Mask Automix; Detax GmbH & Co. KG, Ettlingen, Germany) to simulate attached mucosa. Ball

Figure 1. (A) Angulation assessment of implant sites using a planning guide; (B) Three parallel implants placed in the mandibular model; (C) Auto-polymerized silicone resilient liner simulating mucosa, with ball abutments (male parts) exposed

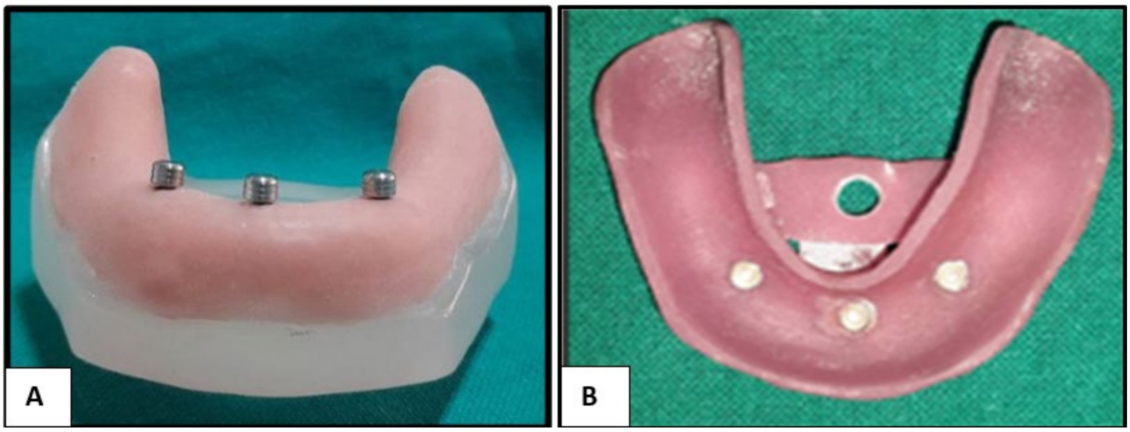

Figure 2. (A) Metal housings (female components) with nylon inserts positioned over the ball abutments (male components); (B) Pick-up of the housings within the overdenture base. Note the punctured T-bar for secure attachment to the universal testing machine

attachments were tightened using a hex driver by torque wrench at 25 Ncm as recommended by the manufacturer (Figure 1C). The same model was used for all the study groups.

Thirty ball-retained overdenture models were allocated into three groups based on matrix types:

Group 1 (n=10): Overdenture retained using conventional nylon inserts within the metal housing.

Group 2 (n=10): Overdenture retained using retention.sil 400 matrix system.

Group 3 (n=10): Overdenture retained using retention.sil 600 matrix system.

In group 1, nylon inserts were placed into metal housings (female parts) and aligned with each ball abutment (male part). A light-cured polymethylmethacrylate (PMMA) sheet was adapted over the attachment system to simulate the overdenture, extending 2 mm short of the vestibular depth at the midline and molar regions (Figure 2A). A T-shaped bar was attached to the overdenture, and the assembly was then polymerized for 10 minutes using a light-cure device. The housings were picked up within the overdenture base. A hole was drilled in the center of the T-bar to enable secure attachment to the universal testing machine (UTM) (Figure 2B).

For groups 2 and 3, a light-cured PMMA custom tray with a T-bar structure was adapted to the mandibular model with ball abutments in place. The ball abutment positions were marked on the overdenture using a thin-flowing impression material. The fitting surface of the

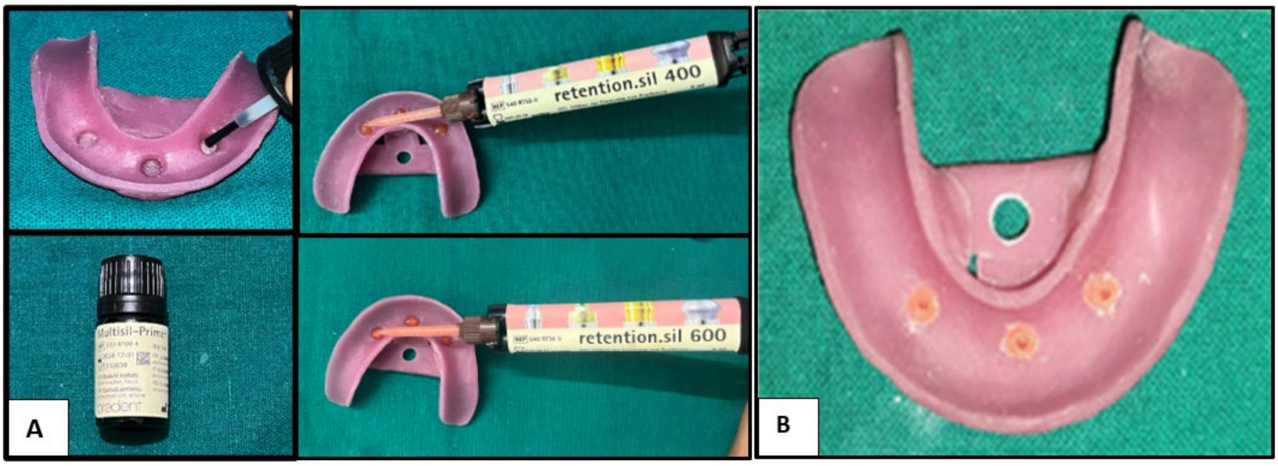

Figure 3. (A) Application of Multisil primer, followed by the placement of retention.sil 400 and 600 into the marked holes of the overdenture for the matrix system (female components); (B) Final overdenture with the PVS matrix material fully set and excess retention.sil material removed

Figure 4. The universal testing machine (UTM) setup for evaluating the retentive force of attachment systems

overdenture at these marked points was hollowed out and treated with Multisil Primer to facilitate bonding between PMMA and the retention.sil material. The prepared cavities were then filled with retention.sil 400 and retention.sil 600 for groups 2 and 3, respectively (Figure 3A). The overdenture was inserted while the retention.sil matrix material (female part) was still soft, ensuring engagement with the ball attachments (male parts). After three minutes, the overdenture was removed, and excess material was trimmed using silicone cutters (Figure 3B).

The overdenture assembly was then mounted on the universal testing machine (UTM) (Figure 4). The mandibular model, containing the abutments (male parts), was secured to the lower member, while the overdenture (female part) was attached to the upper member using the T-bar. Each overdenture underwent 1440 insertion-removal cycles, simulating one year of overdenture use. Data were collected at five cycles: 0 cycles (baseline), 360 cycles (3 months), 720 cycles (6 months), 1080 cycles (9 months), and 1440 cycles (12 months). Each cycle involved a 4 mm upward movement at a crosshead speed of 50 mm/min, followed by a downward movement at the same speed, at a frequency of 12 cycles per minute.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 21.0; IBM Corp., Armonk, NY, USA). The normal distribution of the data was confirmed using the Shapiro-Wilk test (P>0.05). One-way ANOVA was used to compare mean retention at different cycles as well as the absolute and relative retention loss between 0

Table 1. Intergroup comparison of retention (Newtons) between the study groups at different cycles (simulated periods)

No. of cycles (simulated period)	Group	Retention Mean±SD	Pairwise P-value		
			Group 1	Group 2	Group 3
0 (0 month)	Group 1	158 ± 12.44		< 0.001*	< 0.001*
	Group 2	22.1 ± 2.92			0.891
	Group 3	23.7 ± 2.40			
	P-value	< 0.001*			
360 (3 months)	Group 1	147.7 ± 10.81		< 0.001*	< 0.001*
	Group 2	20.3 ± 2.31			0.848
	Group 3	21.9 ± 2.33			
	P-value	< 0.001*			
720 (6 months)	Group 1	137.9 ± 9.01		< 0.001*	< 0.001*
	Group 2	19.1 ± 2.84			0.867
	Group 3	20.4 ± 2.87			
	P-value	< 0.001*			
1080 (9 months)	Group 1	129 ± 10.19		< 0.001*	< 0.001*
	Group 2	17.2 ± 2.74			0.798
	Group 3	19 ± 2.49			
	P-value	< 0.001*			
1440 (12 months)	Group 1	119.6 ± 9.11		< 0.001*	< 0.001*
	Group 2	15.3 ± 2.26			0.773
	Group 3	17 ± 1.94			
	P-value	< 0.001*			

Group 1: Conventional metal housing with nylon inserts; Group 2: Retention.sil 400; Group 3: Retention.sil 600.
* indicates a significant difference between groups at P<0.05.

cycles (baseline) and 1440 cycles (12 months) among the study groups. Post hoc Tukey's multiple comparison test was applied for pairwise analysis between the study groups.

Results

As shown in Table 1, the conventional group exhibited the highest mean retention at baseline (158 ± 12.44 N) and maintained the highest retention at the end of the simulated 12-month period (119.6 ± 9.11 N). On the other hand, the retention.sil 400 group showed the least mean retention at baseline (22.1±2.92 N) and at the simulated 12-month interval (15.3±2.26 N).

One-way ANOVA revealed a statistically significant difference in mean retention among the groups at all cycles (P<0.001 for all). Pairwise comparisons using Post hoc Tukey's test demonstrated a significant difference between the conventional group and PVS groups at all cycles (P<0.001 for all). However, no significant difference was observed between the two PVS groups at any cycle (P>0.05).

Table 2 presents the absolute and relative retention loss from baseline to the simulated 12-month period. One-way ANOVA revealed a significant difference in absolute retention loss among the study groups (P<0.001). Post hoc Tukey's test revealed a significant difference between the conventional group and both PVS groups (P<0.001 for both), but no significant difference was observed between the two PVS groups (P=0.847). Regarding the relative retention loss, the percentage decrease did not significantly differ among the study groups over the 12-month simulated period (P=0.108).

Discussion

This in vitro study evaluated the retention of retention.sil 600 and retention.sil 400 matrix systems compared to conventional metal housing with nylon inserts in ball-retained mandibular overdentures at baseline and after 3-, 6-, 9-, and 12-month simulated intervals. The study incorporated 1440 insertion-removal cycles to simulate one year of denture use based on Kobayashi's protocol for long-term wear simulation (1). The retention assessment was performed under standardized conditions, with vertical dislodgement cycles using a 2-mm upward displacement at 50 mm/min, followed by a downward movement of equal specifications.

The findings of the present study revealed that the mean retention was consistently higher for the conventional group compared to both retention.sil 400 and retention.sil 600 groups. No significant difference was observed between the two PVS matrix systems at any insertion-removal cycle.

The literature lacks a consensus on the minimum retentive force necessary for implant-retained overdentures. Scherer et al. (29) defined 8-10 N as a clinically acceptable retention level for Implant-supported overdentures. Lehmann and Amim (30) suggested that a single unsplinted attachment should provide at least 4 N of retention, whereas Burns et al. (31) proposed a wider range of 7-31 N. Petropoulos and Smith (32) recommended 20 N as sufficient retention, while Pigozzo et al. (33) stated that 5-7 N was adequate for prosthesis function. Despite these differences, all three groups in the present study demonstrated retentive values above the clinically accepted range mentioned in the literature.

Ball attachments used in this study allow multidirectional movement and facilitate sufficient stress distribution in implant-retained overdentures (29). Conventional metal housing with nylon inserts is well-known for its high initial retention, though frequent maintenance is required due to nylon wear and associated retention loss. Passia et al. (34), Ludwig et al. (35), and Choi et al. (17) have all confirmed that nylon

Table 2. Intergroup comparison of absolute retention loss (Newtons) and relative retention loss (%) between 0 cycles (simulating 0 months) and 1440 cycles (simulating 12 months)

Group	Absolute retention loss Mean±SD	Pairwise P-value			Relative retention loss Mean±SD
		Group 1	Group 2	Group 3	
Group 1	38.40 ± 3.33		< 0.001*	< 0.001*	24.3 ± 2.6
Group 2	6.8 ± 0.66			0.847	30.7 ± 2.2
Group 3vl	6.7 ± 0.46				28.2 ± 1.9
P-value	< 0.001*				0.108

Group 1: Conventional (metal housing with nylon inserts); Group 2: Retention.sil 400; Group 3: Retention.sil 600; SD: Standard deviation.
* Indicates a significant difference at P<0.05.

inserts experience degradation over time due to friction between components.

This study evaluated a three-implant design for overdenture retention. The use of three implants to support a ball-retained mandibular overdenture has been found to improve retention compared to two implant configurations. Oda et al. (36) found that three implants reduce denture base rotation. Similarly, Scherer et al. (29) and Uludag and Polat (7) reported that three implants provide significantly greater resistance to vertical dislodging forces. The three implants in this study were placed in the first premolar regions and midline, as wider implant spacing has been associated with greater retention.

Retention.sil PVS-based matrix systems are customizable and resilient alternatives to traditional metal housings for stud attachments (e.g., ball attachments). These systems are designed to simplify clinical procedures by reducing the number of patient visits and follow-ups required. They facilitate easy denture insertion and removal, providing a practical option for immediate loading cases to minimize implant stress. Unlike conventional systems, retention.sil does not require a metal housing; instead, the PVS material is directly bonded into the fitting surface of the denture (27). Available in three retention grades (200, 400, and 600), retention.sil systems enhance denture retention and can be tailored to patient needs. Retention.sil 200 has the lowest hardness (200 g / 2 N pull-off force) and is recommended for immediate restorations, with a maximum recommended use of six months to avoid uncontrolled stress. Retention.sil 400 (400 g / 4 N pull-off force) with medium hardness, and retention.sil 600 (600 g / 6 N pull-off force) with the highest hardness offers greater durability, suitable for up to two years. For a two-implant prosthesis, retention.sil 600 is recommended by the manufacturer for better stability, while for cases with four or more implants, retention.sil 400 provides optimal balance (37).

In this study, the conventional metal housing group with nylon inserts demonstrated significantly higher retention than the two retention.sil groups. Previous in vitro studies by Khan et al. (27), Osman and Aal (38), and Yılmaz et al. (28) also found that conventional metal housing with nylon inserts provided higher retention than retention.sil 600 in two-implant overdenture designs.

Scherer et al. (29) reported a mean retentive value of 51.79N for ball attachments with conventional metal housing and nylon inserts in three-implant mandibular overdentures. The present study recorded a much higher baseline mean retention in the conventional nylon inserts group (158 ± 12.44 N). This discrepancy may be attributed to the use of low-retention pink nylon inserts (1200 g) in the study by Scherer et al. (29), whereas the current study utilized high-retention white nylon inserts. Additionally, the present study employed a full-arch acrylic mandibular model with three implants, whereas Scherer et al. used polyethylene block models with one or two implants.

All attachment systems showed a decline in retention over time. Although the absolute retention loss was highest in the conventional group, the relative retention loss did not differ significantly between groups. This reduction is likely due to material wear and deformation from repeated insertion-removal cycles.

The findings of the present study suggest that conventional metal housings with nylon inserts provide greater retention at baseline and after exposure to various insertion-removal cycles. However, retention.sil matrix systems offer clinically acceptable retention while offering ease of use and convenient application. The customizable nature of retention.sil may allow for better patient-specific adjustments, which is particularly advantageous for elderly patients with compromised motor control. The PVS's resilience may also help distribute occlusal forces more evenly, potentially reducing the risk of implant overload and failure. When selecting an attachment system for implant-supported overdentures, clinicians should consider initial retention, long-term maintenance, and cost-effectiveness. Although conventional metal housings offer superior retention, they require frequent maintenance due to nylon wear. Retention.sil 400 and 600 provide an alternative with adequate retention, easier customization, and reduced maintenance demands. Future research should focus on the long-term clinical performance of these systems to validate their efficacy and durability in the oral environment.

One limitation of this study is that the overdenture dislodgement patterns may not fully replicate those encountered in clinical function. The applied forces were unidirectional, whereas real-life masticatory movements involve multidirectional forces that can accelerate the wear of precision attachments. Additionally, all insertion-removal cycles were performed under dry conditions without considering the effects of saliva, temperature variations, or denture cleansers. Further research should investigate retention and wear of precision attachments under in-vivo conditions.

Conclusions

Under the conditions used in this study:

1- The conventional metal housing with nylon inserts showed significantly higher mean retention than retention.sil 400 and retention.sil 600 across all insertion-removal cycles. No significant difference in retention was observed between the two PVS matrix systems, either at baseline or over a simulated one-year period.

2- There was no significant difference in relative retention loss among the groups.

3- Despite the higher retention of the conventional system, all groups maintained clinically acceptable retention levels, allowing for clinical preference in selecting the attachment system.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

S.B. contributed to the research implementation and writing of the original draft. L.K. contributed to the research design and experimentation. S.S. contributed to the research supervision and editing of the manuscript. C.S. contributed to data collection and analysis. All listed authors have contributed significantly to the manuscript's preparation and content, and read and approved the final manuscript.

Ethical approval

The protocol of the present in vitro study was approved by the Research Degree Committee of the institute with letter no. D-HSJ/22/1183 dated 30.5.2022.

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