Comparison of the Retention of Conventional and Polyvinyl Siloxane Matrix Materials with Different Patrices for Implant-Retained Overdentures: An In Vitro Study

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Abstract

Purpose: To compare the retention forces of implant overdenture patrices (ball, bar, and TiSi.snap) to conventional (O-ring, metal housing, and clip) and polyvinyl siloxane (PVS)—based silicone (retention.sil 200, 400, and 600; Mucopren Soft; and GC Reline Soft) matrix materials.

Materials and Methods: Two implant analogs, in which the patrices were to be placed, were embedded parallel to each other in polyethylene blocks, and the matrices were placed in heat-polymerized acrylic blocks that were fabricated as overdentures. Ten samples were prepared for each attachment type, and 180 samples were obtained from 18 groups. All samples were placed in a chewing simulator for occlusal force application and for insertion and removal of the pieces. Retention measurements were performed with a universal testing device at the initial (10 cycles), simulated first-year (1,825 cycles), and simulated second-year (3,650 cycles) periods, assuming that the patients would insert and remove their overdenture five times daily. Results: Loss of retention occurred in all the attachment systems at the end of 3,650 cycles ($P < .05$). The PVS matrix materials showed less retention than the O-ring and metal matrices when a ball patrix was used, while they had higher retention than bar clips when the Hader bar patrix was used ($P < .05$). Among the PVS matrix materials, retention.sil 200 produced the lowest retention values, whereas retention.sil 600 generated the highest. Conclusion: PVS matrix materials show higher retention than that achieved by yellow plastic bar matrices. However, these materials exhibit lower retention than with plastic and metal matrices of ball abutments. Int J Prosthodont 2021. doi: 10.11607/ijp.6882
Introduction

Implant-retained mandibular overdentures with two implants are regarded as the first treatment of choice for edentulous mandibles. Implants are connected to the overdentures with various attachments consisting of matrices and patrices. Among these, bar and ball attachments are the most commonly used ones. In bar attachments, retention is ensured through a clip or rider, whereas in ball attachments, such retention is guaranteed with the use of metal, resilient nylon, or O-ring plastic ring matrices.

In addition to conventional matrices, different types of resilient liner materials and, more recently, polyvinyl siloxane (PVS)-based matrices, which are fabricated specifically for use as a retention material, have been used. All these materials have been tested in various clinical and laboratory studies.

It has been reported that resilient denture liner matrix materials increase patient satisfaction and comfort, provide increased retention, ensure the health of peri-implant soft-tissues, reduce costs, and result in few denture-related complications compared with bar clips. These materials also absorb the occlusal forces and distribute them equally to the implants and the residual crests, and their easier application and reparability than those of conventional matrices translate to applicability to geriatric patients who cannot leave their homes.

In a clinical study, plaque, bleeding, and probing index scores of clips have been found to be higher than silicone-resilient soft liners when two separate bars were used as patrices. In their long-term prospective clinical trials, Elsyad et al. examined patients wearing mandibular two-implant-retained overdentures and maxillary complete dentures, with the subjects assigned to two attachment groups, namely the bar/clip and bar/resilient liner groups. The first-year results
showed that compared with the clip matrix, the resilient liner matrix material significantly decreased peri-implant plaque and gingival scores as well as probing depth and marginal bone loss.\textsuperscript{5} The third-year results indicated that the bar/clip attachments caused mucositis, hyperplasia, and maxillary flabby ridge formation under the bars, that the bar/clip group more frequently needed prosthetic adjustment and repair.\textsuperscript{6} Five years after implantation, less resorption and flabbiness occurred in maxillary anterior residual crests, and fewer relining requirements arose in the maxillary complete dentures of the bar/resilient liner group.\textsuperscript{7} At the end of seven years, the resilient liner matrix materials were superior to the clip matrix in terms of peri-implant tissue health and prosthetic complications \textsuperscript{8}, but they caused more posterior mandibular crest resorption.\textsuperscript{9}

In an \textit{in vitro} study, auto-polymerized/heat-cured silicone and plasticized acrylic soft-liner materials were used as retaining matrix materials of bar overdentures. The study discovered that silicone-based resilient liners are more retentive and suffer from less deterioration.\textsuperscript{12} Abdel-Khalek et al. found that a heat-cured silicone matrix material provided greater retention than clips with Hader bars and acceptable retention values for all bar types (circular, oval, and Hader).\textsuperscript{16} The results of a similar \textit{in vitro} study also revealed that the retention values of heat-cured resilient liners are superior to those of Hader bars with clips.\textsuperscript{11}

Schweyen et al. compared three PVS materials with different shore hardness values and used locator attachments as controls in an \textit{in vitro} study.\textsuperscript{14} Locator attachments showed a retention loss of 58\%, whereas the special attachment comprising a matrix of a solely-PVS material (TiSi.snap patrix) exhibited no change in retention values.\textsuperscript{14}
Most of the above mentioned in vitro and clinical studies have focused on the bar patrix,\textsuperscript{5-12,16} and only a few have examined a combination of ball patrix and resilient matrix materials.\textsuperscript{13,15,17} Koike et al. emphasized that achieving clinically adequate retention with a soft-liner matrix material for overdentures is possible only when the diameter of the ball patrix used exceeds 2.5 mm.\textsuperscript{13} Kubo et al. demonstrated that the hardness of the silicone resilient liner was the main factor affecting the initial retention force and that the physical properties of silicone resilient liners were more stable than acrylic-based materials.\textsuperscript{17} Similarly, in a three-dimensional finite element study, it was demonstrated that both thermoplastic resin and silicone-based liners reduce the micro-movements of the implants and the stresses at the bone/implant interface.\textsuperscript{15}

There is still a lack of detailed information about the retention values of different attachment types. Therefore, this study was conducted to compare the retention forces of the commonly used balls and bars and the more recently introduced TiSi.snap patrices used in implant-retained overdentures with their conventional matrix components and PVS-based matrix materials. The null hypothesis was that PVS matrix materials would show the same retention values when compared with the conventional matrices.

**Materials and Methods**

Rectangular polyethylene blocks with the size of $15 \times 20 \times 45$ mm were designed and produced. To accommodate implant analogs and patrices, two holes were prepared parallel to each other with a distance of 22 mm with a computer numerically controlled (CNC) machine (Super KiaTurn 21, KIA, USA).\textsuperscript{16,19-22} Two implant analogs (Bredent Medical, Senden, Germany) were mounted into the prepared holes of each block.
Eighteen test groups were created as follows: 5 PVS resilient matrices were used for all the patrices (ball, Hader bar, and TiSi.snap) used in the study. Additionally, the conventional matrices of O-ring and precious metal matrices (SKYGM225, Bredent Medical, Senden, Germany Au 68.6%, Ag 11.85%, Cu 10.6%, Pd 3.95%, Pt 2.45%, Zn 2.5%, Ir 0.05%) for ball patrices and yellow plastic matrices made of polyoxymethylene for Hader bar patrices were used. Since the TiSi.snap attachments (Bredent Medical, Senden, Germany) only have resilient matrices, only PVS was utilized for these patrices.

Hader bars (Bredent Medical, Senden, Germany) were fabricated by wax modeling and Cr-Co casting (Bego Wironit Extrahart, BEGO GmbH, Bremen, Germany) procedures. Ball and TiSi.snap patrices were prefabricated by the manufacturer. The properties of the PVS matrix materials and all the tested attachment combinations are shown in Table 1. All the patrices were fastened to the implant analogs with 25 N using the torque wrench of the manufacturer (Figure 1). 180 identical upper blocks were also fabricated with heat-polymerized polymethylmethacrylate (Promolux, Merz Dental, Lütjenburg, Germany) (10 for each group) to mimic the overdentures with the use of the CNC machine. Holes with distances of 2 mm from the accommodating patrices were prepared on each of the acrylic blocks.

The O-ring, metal, and bar clip matrices were placed on the patrices and attached to the acrylic blocks with auto-polymerizing acrylic resin (Meliodent, Heraeus Kulzer, Hanau, Germany). The PVS materials were prepared in accordance with the manufacturers’ instructions and placed in the prepared holes of the acrylic blocks. During the polymerization of the resin and the PVS, polyethylene blocks carrying the patrices were connected to the acrylic blocks carrying the matrices with the help of a specially created holding device in order to ensure that the attachments were connected to each other in a standard way.
All of the samples were immersed in artificial saliva (modified Fusayama’s artificial saliva: NaCl 0.4 g/L, KCl 0.4 g/L, CaCl$_2$.2H$_2$O 0.795 g/L, NaH$_2$PO$_4$.H$_2$O 0.690 g/L, Na$_2$S.9H$_2$O 0.005 g/L, urea 1.0 g/L, KSCN 0.3 g/L; pH 7.0) and mounted to a chewing simulator (CS-4 / SD Mechatronik GMBH, Westerham, Germany) afterwards. The vertical component of a chewing simulator was used for the application of cycling loading function along the implants’ long axis by insertion and dislodgement of the blocks (f=0.8 Hz). Retention forces were measured with a universal testing machine (MTS 322 Test Frame, MTS Systems, USA) with a load cell of 1 kN and a crosshead speed of 50 mm/min$^{23}$ at the end of 10 insertion/removal cycles for determining the initial retention, at the end of 1825 cycles for determining the retention after simulated 1 year of clinical use assuming overdenture removal five times a day,$^{12,16,24,25}$ and finally at the end of 3650 cycles for the simulated second-year retention values.

**Statistical analysis**

IBM SPSS Statistics 22 (IBM SPSS, Istanbul, Turkey) was used for statistical analyses. The Shapiro-Wilk test showed normal distribution of the parameters. In the comparison of quantitative data, two-way ANOVA test was used to evaluate the joint effect of patrix and matrix on retention force. For ongoing tests, one-way ANOVA and Tukey HSD tests and/or Tamhane’s T2 test were used for post hoc evaluations. Repeated measures of variance analysis and Bonferroni tests were used for the evaluation of initial (10 cycles), 1825 and 3650 cycles in vitro retention forces for the groups. Significance was evaluated at P < 0.05. Sample size was determined by using power analysis. Ten samples for each group were required to detect the differences depending on the calculation with 5% alpha errors and 80% power of the test (d: 0.488, SD: 6.4).
**Results**

According to the two-way ANOVA test, the interaction between the patrix and matrix materials was significantly effective on retention force (p<0.01).

The initial, 1825 and 3650 cycles *in vitro* retention values of ball attachment, TiSi.snap, and Hader bar patrices with both conventional and silicon-based matrix materials are presented in Tables 2, 3, and 4, respectively. Both at the end of 1825 and 3650 cycles, the lowest retention values were observed in Retention. Sil 200 matrices when ball and TiSi snap patrices were used, whereas in yellow clips when hader bar patrix was used. Highest retention values were observed in Retention. Sil 600 matrices when TiSi snap and hader bar patrices were used, whereas in metal matrices when ball patrix was used at the same cycle points.

At the end of 1825 cycles, ball/Retention.sil 400-Mucopren Soft and Hader bar/Retention.sil 600-Mucopren soft-GS Reline Soft attachment system groups showed statistically significant loss of retention. However, at the end of 3650 cycles, there was a statistically significant loss of retention in all groups except the ball/O-ring, TiSi.snap/Mucopren Soft, and TiSi.snap/GS Reline Soft attachment system groups (P < 0.05).

When comparing the conventional systems with all silicone systems, two ball patrix groups showed significantly higher values, whereas the group with bar patrices showed lower retention values (P < 0.05). The comparison of the retention values of PVS matrix materials with different patrices is presented in Figure 2. Ball patrices with all the PVS matrix materials showed the lowest retention values for all parameters compared with TiSi.snap and Hader bar patrices (P < 0.05). Among the PVS matrix materials, Retention.sil 200 showed the lowest retention values while Retention.sil 600 showed the highest retention values (P < 0.05; Figure 2).
Discussion

The null hypothesis was rejected. PVS matrix materials showed higher retention values as compared to plastic matrices when a bar matrix was used, whereas they had lower retention compared to conventional metal and plastic matrices when a ball matrix was used.

Since the two-implant overdentures option was accepted as the first treatment option for mandibular edentulous jaws,¹ our study was performed with two implants, similar to many in vivo and in vitro studies in the literature.⁵⁻⁹,¹⁵,¹⁹⁻²¹

In the present study, implant analogs were used instead of real implants. Although there are studies using real or dummy implants in the literature,²⁰,²¹ there are also in vitro studies using implant analogs similar to the present study.¹²,¹⁴,¹⁸ In the present study we were not comparing the surface or the design of the implants; rather, the abutments and the attachment systems were compared. Therefore, cost-effective implant analogs were preferred instead of real implants.

The effective use of resilient denture liners with implant-retained overdentures as permanent attachments for providing retention has been reported previously.¹²⁻¹⁴ Therefore, besides three PVS materials manufactured only for attachment fixation, two commercially available PVS denture liners with comparable shore hardness were also tested in the present study. According to the present results, these materials are more retentive than Retention.sil 200, about equally retentive with Retention.sil 400, and less retentive than Retention.sil 600 in all the matrix types. When the TiSi.snap system is considered, which can only be fixed to overdentures with PVS materials, the GC Reline Soft group showed even better retention than Retention.sil 400 at the end of 3650 cycles, demonstrating that conventional denture liners can be used for attachment fixation and confirming the results of previous reports.¹²⁻¹⁴
A crosshead speed of 50 mm/min, which has been verified as the speed for overdenture removal,\textsuperscript{23} was used for the retention force measurements in the present study as it is the value used in the majority of similar \textit{in vitro} investigations.\textsuperscript{14,18,20-24} Additionally, since it was reported that the use of artificial saliva affects the retention forces of attachment types,\textsuperscript{18} artificial saliva was used in the present study to simulate the oral environment.

In an \textit{in vitro} study with bar patrices on four implants, it was reported that all silicone-based resilient liners exhibited 3 to 5 times greater retention compared to plasticized acrylic resin matrices and the plasticized acrylic resin was chafed and crumbled in stress areas at the end of 2740 cycles.\textsuperscript{12} Therefore, only silicon-based matrix materials were used in our study in order not to cause similar deficiencies.

Another factor that varies in \textit{in vitro} studies is the reference cycle value, which represents the number of daily insertions/removals of the overdentures. There are studies assuming that insertion/removal occurs three times daily,\textsuperscript{14,17,19} others assuming four times,\textsuperscript{26} and also some assuming five times, like in the present study.\textsuperscript{12,16,24,25} Since a certain value for this does not exist in the literature, this choice is left to the discretion of the authors, and in the present study five daily insertion/removal cycles were chosen according to our clinical observations.

It has been recommended to replace O-rings annually or biannually,\textsuperscript{2} and therefore 2 years of use were simulated in the present study. However, the other retention mechanisms tested in the present study do not have this type of recommendations. It would have been interesting to test these systems in further experimental studies with similar designs in more cycles simulating 4 or 5 years.
Although silicone-based matrix material test samples showed retention loss after simulated 2 years, macroscopic deterioration of their surfaces was not detected. This result is in accordance with the results of Kubo et al., who reported no separation of silicon matrix material from acrylic after 3348 cycles. However, it should be kept in mind that these materials are not only subjected to forces simulated in the testing machines but they are also subjected to chemical degradation, which cannot be seen in an *in vitro* study. The retention behavior of attachment systems differs even in *in vitro* environments with different lubricant solutions. Additionally, only vertical loads were applied to the samples, but as stated previously, retention forces and deterioration might develop differently if eccentric forces are applied or the overdentures could be removed by the patients, which can only be examined clinically. Therefore, the microscopic examination of surface properties and clinical investigations, which may be the subjects of forthcoming studies, can give detailed results about this subject.

Retention force of 5-7 N is reported to be sufficient to stabilize overdentures intraorally. In all of the ball matrix and PVS matrix material groups in the present study except Retention.sil 600, second-year retention results were below this value. Furthermore, even the initial retention values could not reach 5-7 N in the ball matrix/Retention.sil 200 group. Therefore, if a ball matrix with a 2.25 mm diameter is used, only Retention.sil 600 could be recommended as the PVS matrix material based on the present results.

In the other tested groups, only the retention forces of the TiSi.snap matrix/Retention.sil 200 matrix remained below these values, while other groups showed retention above these values in all measurement parameters after 2 years.

In the present study, there was a loss of retention at the end of 3650 cycles for all attachment types (Table 2-4 and Figure 2). This result is in accordance with the results of studies showing
loss of retention in ball patrix/O-ring matrix, ball patrix/metal matrix, and Hader bar patrix/yellow clip (polyoxymethylene) matrix attachments.\textsuperscript{17,20,22,25,26}

Our results showed that, except for the TiSi.snap patrix/Mucopren Soft and GS Reline Soft groups, there was a decrease in retention after 2 years in all silicon-based matrix material groups (Table 2-4 and Figure 2). These results are consistent with the results of studies presenting a loss of retention with resilient liner matrix materials with ball and bar patrices.\textsuperscript{11,16,17} This retention loss may be the reason for the permanent strain accumulated in the material during repeated insertions/removals and consequently the deformation of the material, as was underlined previously by Kubo et al.\textsuperscript{17} However, in an \textit{in vitro} study, no difference in the retention values of PVS materials produced only as the matrix material for TiSi.snap patrices was found after 5000 dislodging cycles.\textsuperscript{14} This contradictory result may be due to the use of TiSi.snap patrices with different diameters in the two studies. In our study, TiSi.snap patrices were used with smaller diameters and lengths and bigger undercuts. However, we obtained results similar to those of Schweyen et al.\textsuperscript{14} in our Mucopren Soft and GC Reline Soft groups even with these patrices. This result may indicate that GS Reline Soft and Mucopren Soft are more elastic and can retain their retention without deformation in patrices having large undercuts.

An important finding of the present study was that silicon-based matrix materials with bar patrices showed better retention than the clip matrices. This result is in accordance with the results of other investigations.\textsuperscript{11,16} When bars are used for overdentures, PVS matrix materials can be recommended instead of plastic clip matrices based on the findings of the present work and the above-mentioned studies.
Studies have shown that the hardness of resilient matrix materials is effective in terms of retention forces and that they are more retentive as their hardness increases.\textsuperscript{14,17} Similarly, the results of our study revealed that Retention.sil matrix materials showed greater retention forces as their hardness increased. However, Mucopren Soft and GS Reline Soft showed greater retention values with all matrix types as compared to Retention.sil materials having approximately the same hardness values (Table 1). This may indicate that not only does the hardness of the PVS matrix materials affect their retention capabilities, but the extra substances added to their contents in different brands may also influence the retention. This subject requires further investigation. Additionally, only the retentive properties of PVS matrix materials when the implants were parallel to each other were investigated in the present study in order to not generate an important sample size. The effect of implant angulation on the retention behavior of these materials may be of interest in future studies. Although both metallic and non-metallic matrix control groups were made for the ball matrix, since metallic bar clips are not available in the system used, a bar system where the clips were only non-metallic was used, which may be regarded as a limitation of the present study.

**Conclusions**

Within the limitations of the present study, it may be concluded that:

1. Retention forces decrease in all attachment types at the end of simulated 2 years of use.

2. When ball matrix is used, conventional matrices show more retention force than PVS matrix materials.

3. When bar matrix is used, PVS matrix materials show higher retention as compared to plastic bar clip matrices.

4. PVS matrix materials show greater retention forces as their hardness increases.
5. When Tisi.snap patrix is used, although Retention.sil 600 which is its specific matrix, reveals the highest retention value, conventional soft-liner materials show promising results as an option for attachment fixation with this patrix.

References


Acknowledgments

The authors would like to thank the Bredent Medical GmbH for their financial support for providing the matrices and patrices used in the present study.
Table 1. All the evaluated attachment combinations and the hardness values of the PVS materials used in the study

<table>
<thead>
<tr>
<th>Products used as matrices</th>
<th>Manufacturer</th>
<th>Shore Hardness (SH) value *</th>
<th>Patrice types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention.sil 200</td>
<td>Bredent Medical</td>
<td>25 SH</td>
<td></td>
</tr>
<tr>
<td>Retention.sil 400</td>
<td>Bredent Medical</td>
<td>50 SH</td>
<td>Tisi.snap</td>
</tr>
<tr>
<td>Retention.sil 600</td>
<td>Bredent Medical</td>
<td>65 SH</td>
<td>Hader Bar</td>
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<tr>
<td>GC Reline Soft</td>
<td>GC Corporation</td>
<td>48 SH</td>
<td>Ball Attachment</td>
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<tr>
<td>Mucopren Soft</td>
<td>Kettenbach GmbH</td>
<td>28 SH</td>
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</tr>
<tr>
<td>O-ring</td>
<td>Bredent Medical</td>
<td></td>
<td>Ball Abutment</td>
</tr>
<tr>
<td>Metal Matrix</td>
<td>Bredent Medical</td>
<td></td>
<td>Ball Abutment</td>
</tr>
<tr>
<td>Yellow Bar Clip</td>
<td>Bredent Medical</td>
<td></td>
<td>Hader Bar</td>
</tr>
</tbody>
</table>

*SH values were obtained from technical product documents of the products
Table 2. *In vitro* retention values of different matrices with ball matrix

<table>
<thead>
<tr>
<th>Retention Value(N)</th>
<th>Matrix name</th>
<th>Retention.sil 200 Mean±SD</th>
<th>Retention.sil 400 Mean±SD</th>
<th>Retention.sil 600 Mean±SD</th>
<th>Mucopren Soft Mean±SD</th>
<th>GC Reline Soft Mean±SD</th>
<th>O-ring Mean±SD</th>
<th>Metal matrix Mean±SD</th>
<th>1P</th>
<th>Post-Hoc</th>
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</thead>
<tbody>
<tr>
<td>Initial (10 cycles)</td>
<td>3.9±0.48</td>
<td>5.46±0.61</td>
<td>9.44±0.69</td>
<td>5.62±0.83</td>
<td>6.87±0.51</td>
<td>14.61±2.93</td>
<td>33.43±6.37</td>
<td>0.001**</td>
<td></td>
<td>a&lt;b.c.d.e.f.g** b.c.d.e&lt;f&lt;g** b.c.d.e&lt;f&lt;e** b&lt;d**</td>
</tr>
<tr>
<td>1825 cycles</td>
<td>3.79±0.52</td>
<td>4.44±0.71</td>
<td>9.3±0.51</td>
<td>5.44±0.45</td>
<td>6.79±0.81</td>
<td>13.82±3.15</td>
<td>28.3±8.54</td>
<td>0.001**</td>
<td></td>
<td>a&lt;c.d.e.f.g** b.c.d.e&lt;f&lt;r** b&lt;d.e&lt;f&lt;r** c&lt;r** c&lt;b&lt;d.e&lt;e** b&lt;d**</td>
</tr>
<tr>
<td>3650 cycles</td>
<td>2.91±0.67</td>
<td>4.14±0.46</td>
<td>6.93±1.05</td>
<td>3.55±0.69</td>
<td>4.39±1.25</td>
<td>12.04±3.68</td>
<td>24.8±7.11</td>
<td>0.001**</td>
<td></td>
<td>a.b.c.d.e&lt;f&lt;r** a&lt;b.c.d.e&lt;g** b.d.e&lt;f&lt;r** c&lt;r** b&lt;d.e&lt;e**</td>
</tr>
<tr>
<td><strong>2P</strong></td>
<td>0.003**</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.002**</td>
<td>0.200</td>
<td>0.001**</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Post-Hoc</td>
<td>T0&gt;T2**</td>
<td>T0&gt;T1.T2**</td>
<td>T0&gt;T1.T2**</td>
<td>T0&gt;T1.T2**</td>
<td>T0&gt;T2**</td>
<td>T1&gt;T2*</td>
<td>T0&gt;T2**</td>
<td></td>
<td></td>
<td>T0&gt;T2**</td>
</tr>
</tbody>
</table>

1 One-way ANOVA Test 2 Repeated measures of variance analysis. *P < 0.05  **P < 0.01

a: Retention.sil 200, b: Retention.sil 400, c: Retention.sil 600, d: Mucopren Soft, e: GC Reline Soft, f: O-ring, g: Metal matrix; T0: Initial (10 cycles) , T1: 1825 cycles, T2: 3650 cycles, N:Newton
Table 3. *In vitro* retention values of different matrices with TiSi.snap patrix

<table>
<thead>
<tr>
<th>Retention Value(N)</th>
<th>Matrix name</th>
<th>Retention.sil 200</th>
<th>Retention.sil 400</th>
<th>Retention.sil 600</th>
<th>Mucopren Soft</th>
<th>GC Reline Soft</th>
<th>¹P</th>
<th>Post-Hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>0.001**</td>
<td></td>
</tr>
<tr>
<td>Initial (10 cycles)</td>
<td>9.95±1.43</td>
<td>18.72±1.04</td>
<td>29.8±1.26</td>
<td>17.78±3.93</td>
<td>21.62±1.14</td>
<td>a&lt;b.c.d.e**</td>
<td>b.d.e&lt;c** b&lt;e&lt;<strong>, d&lt;e</strong></td>
<td></td>
</tr>
<tr>
<td>1825 cycles</td>
<td>9.14±1.07</td>
<td>18.61±1.64</td>
<td>29.45±2.1</td>
<td>17.74±3.74</td>
<td>21.16±1.22</td>
<td>a&lt;b.c.d.e**</td>
<td>b.d.e&lt;c** d&lt;e**</td>
<td></td>
</tr>
<tr>
<td>3650 cycles</td>
<td>4.85±2</td>
<td>11.78±1.17</td>
<td>25.52±3.22</td>
<td>16.53±1.45</td>
<td>20.47±2.88</td>
<td>a&lt;b.c.d.e**</td>
<td>b.d.e&lt;c** b&lt;d&lt;e**</td>
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<tr>
<td>²P</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.012*</td>
<td>0.457</td>
<td>0.315</td>
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<tr>
<td>Post-Hoc</td>
<td>T0&gt;T1&gt;T2**</td>
<td>T0&gt;T1&gt;T2**</td>
<td>T0&gt;T2*</td>
<td>T1&gt;T2**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ One-way ANOVA Test  ² Repeated measures of variance analysis  *P < 0.05  **P < 0.01

a: Retention.sil 200, b: Retention.sil 400, c: Retention.sil 600, d: Mucopren Soft, e: GC Reline Soft;

T0: Initial (10 cycles) , T1: 1825 cycles, T2: 3650 cycles, N:Newton
Table 4. *In vitro* retention values of different matrices with Hader bar patrix

<table>
<thead>
<tr>
<th>Retention Value(N)</th>
<th>Matrix name</th>
<th>Retention.sil 200</th>
<th>Retention.sil 400</th>
<th>Retention.sil 600</th>
<th>Mucopren Soft</th>
<th>GC Reline Soft</th>
<th>Bar Clip</th>
<th>¹P</th>
<th>Post-Hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>0.001**</td>
<td></td>
</tr>
<tr>
<td>Initial (10 cycles)</td>
<td></td>
<td>11.4±2.54</td>
<td>18.58±1.52</td>
<td>28.94±3.65</td>
<td>17.92±2.36</td>
<td>19.31±1.84</td>
<td>8.48±1.95</td>
<td></td>
<td>a.b.c.e.f&lt;e** b.d.e&gt;f** a&lt;.b.d.e**</td>
</tr>
<tr>
<td>1825 cycles</td>
<td></td>
<td>9.22±1.33</td>
<td>17.34±2.27</td>
<td>23.14±1.41</td>
<td>13.42±0.72</td>
<td>16.38±0.78</td>
<td>6.6±1.23</td>
<td>0.001**</td>
<td>a.b.c.e.f&lt;e** a.b.d.e&gt;f** a.d&lt;b** a.d&lt;e** a&lt;d**</td>
</tr>
<tr>
<td>3650 cycles</td>
<td></td>
<td>8.03±1.02</td>
<td>15.5±1.24</td>
<td>21.5±1.98</td>
<td>13.03±1.24</td>
<td>14.15±3.05</td>
<td>6.36±0.9</td>
<td>0.001**</td>
<td>a.b.c.e.f&lt;e** a&gt;f* b.d.e&gt;f** a.d&lt;b** d.e&gt;a**</td>
</tr>
<tr>
<td>²P</td>
<td></td>
<td>0.033*</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.049*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Hoc</td>
<td>T0&gt;T2*</td>
<td>T0&gt;T1.T2**</td>
<td>T0&gt;T1.T2**</td>
<td>T0&gt;T1.T2**</td>
<td>T0&gt;T1.T2**</td>
<td>T0&gt;T2*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ One-way ANOVA test ² Repeated measures of variance analysis *P < 0.05 **P < 0.01

a: Retention.sil 200, b: Retention.sil 400, c: Retention.sil 600, d: Mucopren Soft, e: GC Reline Soft, f: Bar clip;
T0: Initial (10 cycles), T1: 1825 cycles, T2: 3650 cycles, N:Newton
Figure Legend:

Figure 1. All the patrices in polyethylene blocks

Figure 2. The columns show the mean and the standard deviations of initial (10 cycles), 1825 cycles, and 3650 cycles in vitro retention values of PVS matrix materials with all patrix types. Statistically significant differences between the time intervals are shown in uppermost post-hoc comparisons and between the attachment combinations below them with by asterisk. One-way ANOVA test and Repeated measures of variance analysis were used (*P < 0.05, **P < 0.01).
Fig 1a
Fig 1b