In Vitro Evaluation of Resilient Liner and Hard Denture Liner on the Retentive Force

Shunsuke Nagata,¹ Hiroyuki Saeki,² Aya Kitamura,² Asako Suzuki,² Masayuki Kamada,² Yasuhiro Tanimoto,³ and Yasuhiko Kawai²

¹Nihon University Graduate School of Dentistry at Matsudo, Removable Prosthodontics, Matsudo, Chiba 271–8587, Japan
Departments of ²Removable Prosthodontics, and ³Dental Biomaterials, Nihon University School of Dentistry at Matsudo, Matsudo, Chiba 271–8587, Japan

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Abstract
Purpose: To clarify the relationship between the retention force and saliva viscosity for resilient denture liners.

Methods: Tensile tests were performed using a simple model to compare the retention force of two commercially available resilient denture liners (SOFRELINER TOUGH MEDIUM and SOFRELINER TOUGH SUPER SOFT) and a hard denture relining material (TOKUYAMA REBASE III NORMAL). Retention force measurements were conducted with three intervening liquids of different viscosities and repeated 10 times. The measured retention force and viscosity of the intervening liquid were compared with two-way ANOVA. The statistical significance was P < 0.05. Post-hoc Bonferroni multiple comparison tests were used to analyze significant results.

Results: The saliva viscosity and relining material significantly influence denture retention. When purified water was used as an intervening liquid, significant differences were observed between all groups, and the SOFRELINER TOUGH SUPER SOFT material showed the highest retention force.

Conclusions: Relining a denture with a silicone-based resilient denture liner increases the retention force of the denture, and is particularly effective when the fluid viscosity is high.

Keywords: complete denture, retention, in vitro, resilient denture liner, saliva viscosity

Introduction
Japan is known as a “super-aging society” (1). The average age of the Japanese population is increasing rapidly, with the proportion of over 65 year-olds reaching 26.6% in 2015 (2). Although this is the highest proportion in Japanese history, the number of elderly people is increasing annually, with the proportion over 65 year-olds expected to rise to 38.5% by 2065 (3). The prolonged lifespan has given rise to an increase in the proportion of the Japanese population that wear dentures (4).

Complete denture wearers experience problems such as loosening of the denture during speech or mastication (5–8). The problems encountered with complete dentures are exacerbated by the poor retention of the dentures (9). Several studies have revealed that dental problems such as the poor retention of mandibular dentures decreases patient satisfaction (10–15) and oral health-related quality of life.

The application of a resilient denture liner to mandibular complete dentures has been investigated to improve the quality of life of patients wearing complete dentures. Several clinical research studies have reported that resilient denture liners can significantly increase the satisfaction and chewing ability of patients, while also reducing sore spots on the alveolar ridge mucosa (13, 16, 17). This is because resilient denture liners absorb and distribute...
occlusal forces (18) and enhance the fit to the alveolar ridge (19), thus protecting soft tissues. These effects lead to enhanced denture retention. Although clinicians have reported that silicone-relined mandibular complete dentures show better retention than those with a hard denture liner (20), no research-based evidence is available regarding the retention to the alveolar ridge by using resilient denture liners.

Furthermore, denture retention depends on several factors, including denture coverage area, the characteristics and volume of saliva, and the thickness of the oral mucosa (21). In particular, the properties of saliva significantly affect denture retention. Bláhová and Neuman reported that high-viscosity saliva increases denture retention (22). Thus, saliva viscosity is an important factor in denture retention. Adhesion and cohesion also play an important role in denture retention (23, 24). Adhesion induced by saliva, the denture mucosa surface, and cohesion of saliva molecules can be enhanced by improving the intimate contact of the final impression with the surface mucosa to achieve the greatest feasible coverage area (25).

Therefore, the objective of this fundamental in vitro study was to evaluate the difference between the retention force of resilient denture liners and hard denture liners with intervening liquids of different viscosities. The interaction between the denture liners and the intervening liquid was examined with respect to its effect on the retention force. The null hypotheses of this study are that there is no difference in retention force between materials with the same intervening liquid, and that the interaction with different materials and intervening liquids has no effect on the retention force.

**Materials and Methods**

The materials used in the experiment are shown in Table 1. A heat curing acrylic resin denture base (URBAN, Shofu, Kyoto, Japan) was used as the denture base resin. Two commercially available resilient denture lining materials (SOFRELINER TOUGH MEDIUM, Tokuyama, Tokyo, Japan (RT-M) and SOFRELINER TOUGH SUPER SOFT, Tokuyama, Tokyo, Japan (RT-S), with low and high viscoelasticity, respectively) and a hard denture relining material (TOKUYAMA REBASE III NORMAL, Tokuyama, Tokyo, Japan (HR)) were used in the experiments.

**Table 1. Materials used in this study (RT-M: SOFRELINER TOUGH MEDIUM; RT-S: SOFRELINER TOUGH SUPER SOFT; HR: TOKUYAMA REBASE III NORMAL).**

| Materials                          | Code       | Materials type                  | Curing type          | Lot no. (powder/liquid) |
|-----------------------------------|------------|---------------------------------|----------------------|-------------------------|
| URBAN                             |            | Denture base material           | Heating polymerization| 021961/021729           |
| TOKUYAMA REBASE III NORMAL        | HR         | Hard denture lining material    | Autopolymerization    | 028097                  |
| SOFRELINER TOUGH MEDIUM           | RT-M       | Resilient denture lining material | Autopolymerization    | 088037P                 |
| SOFRELINER TOUGH SUPER SOFT       | RT-S       | Resilient denture lining material | Autopolymerization    | 1290Y8P                 |

**Materials**

**Fabrication of simulated denture specimens**

The specimens were fabricated as disks with an acrylic resin base. One side of the specimen was relined with a denture lining material, and the other side was fitted with a hook to measure the retention force. The area of the relined surface was set close to the area of the support of the lower denture (14 cm² on average) (26). The diameter of the relined surface was 50 mm and the thickness of the relined material was 2 mm as per the manufacturer’s instructions. The fabrication process is illustrated in Figure 1. First, we made resin blocks for lathe processing. Columnar paraffin wax with a diameter of 75 mm and height of 60 mm was fabricated and invested in a metal flask (Flask Upper, Whip Mix Co., Kentucky, USA) with gypsum (Dental Plaster, Mutsumi, Mie, Japan). The invested paraffin wax was removed by running hot water. A heat-curable acrylic resin was injected into the mold and then slowly heat-polymerized (Aqua Marathon, Dentronics, Tokyo, Japan).

The base resin was carved out from the resin block (Fig. 2 A). Numerical control machine tools (SP-CHP, Shizuoka Iron Works, Shizuoka, Japan) and lathes (SL-25, DMG Mori Co., Ltd., Nagoya, Japan) were used for lathe machining. The denture base resin was machined in the form of a cylinder with a diameter of 50 mm and height of 8 mm, and the opposite side of the relined surface was fitted with a cylindrical box with a diameter of 65 mm.
A stainless-steel eyebolt (IB-4M, Mizumoto Machine Mfg. Co., Ltd., Hyogo, Japan) was attached to the center of the box tray with an M4 screw hole (Fig. 2 B). Part of the stainless-steel eyebolt was processed into a form for attaching the traction line. The denture base resin was divided into three groups with each material constituting a group, and eight pieces were fabricated for each group.

The spacing box was obtained by lathe fabricating from a polytetrafluoroethylene (PTFE) block (Teflon, DuPont, Delaware, USA), and had a pipe shape with an outer diameter of 70 mm, inner diameter of 50 mm, and height of 10 mm (Fig. 2 C). The base resin side of the box contained a groove with a height of 3 mm for opening the box. By fitting the base resin and the spacing box, a space was provided on the reline surface for relining with a thickness of 2 mm (Fig. 1 vii).

Next, the denture lining materials were injected. The surface treatment associated with the denture lining material injecting operation, the application of adhesive, and the adjustment of the denture lining material were in accordance with the manufacturer’s instructions. After treating the surface of the base resin with a primer (Sofreliner Tough Primer, Tokuyama, Tokyo, Japan), the base resin and spacing box were fitted together and the
resilient denture lining material was injected (Fig. 1 viii, Fig. 2 D). Similarly, for the injection of the hard denture lining material, the surface treatment was performed using the primer specified by the manufacturer (TOKUYAMA REBASE ADHESIVES, Tokuyama, Tokyo, Japan). After injection, it was gently pressed against a glass plate and fixed under a pressure of 1 MPa using a hydraulic flask press (FP7, Morita, Tokyo, Japan). After waiting for 30 min at room temperature to confirm polymerization, the completed specimens were carefully removed from the spacing box (Fig. 1 ix, Figs. 2 E,F). The specimens were fabricated at room temperature (23±2 °C) and a relative humidity of 50±10%.

Fabrication of simulated mucosal specimens

To form the simulated mucosa, a PTFE plate with a diameter of 70 mm and thickness of 10 mm was fabricated by lathing (Fig. 3 A). The surface of the PTFE plate was mechanically polished, and then polished with grade #2000 water-resistant paper (EA366C-200, ESCO, Osaka, Japan). Protrusions (50 mm × 20 mm × 10 mm) for fixing were attached to the opposite side of the PTFE plate and fixed with screws (Fig. 3 B).

Preparation of intervening liquids

Three types of intervening liquids were prepared. Glycerin aqueous solution (Kenei Pharmaceutical, Osaka, Japan) was diluted using purified water to 40% and 80% to provide medium- and high-viscosity simulated saliva, respectively (27). In addition, purified water (Kenei Pharmaceutical Co., Ltd., Osaka, Japan) without glycerin was used as control. Tensile tests were performed with each intervening liquid.

Experiments

Measurement of retention force

A universal testing machine (UTM; Techno Graph TG-5kN, MinebeaMitsumi, Nagano, Japan) was used for the tensile tests. It has been reported that the cohesive force of the intervening liquid is maximized when the distance between the denture base and oral mucosa is minimized, resulting in the highest retention force of the denture base (22). Therefore, the experimental system was set up so as to minimize the distance between the two horizontal plates. The plates were fixed in the UTM so that the PTFE plate was horizontal. The intervening liquid (1.0 mL) was gently dropped into the center of the PTFE plate using a micropipette, and the relined surface of the specimens was then gently placed on the PTFE plate.

The average occlusal force of complete denture wearers is 3.4 kgf (28). To simplify the operation and prevent non-vertical forces from being applied when removing the load, the load was set to 2 kgf in preliminary experiments with a holding time of 10 s. In the subsequent experiments. Once the load was applied, a traction line was quickly connected to the specimens. A stainless-steel chain with a gauge length of 200 mm was used for the traction line (Fig. 4).

The crosshead speed of the UTM was set to 10 mm/min, and the retention force required to vertically separate the specimens was measured. The obtained values were divided by the area of the bottom surface of the
Retention force measurements were conducted with the three types of denture relining materials and three intervening liquids. The measurement was repeated 10 times for each intervening liquid and denture relining material (a total of 90 measurements) at room temperature of (23±2 °C) and a relative humidity of 50±10%.

Measurement of intervening liquid viscosity

The viscosity of the as-fabricated intervening liquids was measured using a vibrating viscometer (Viscomate VM-10A, SEKONIC, Tokyo, Japan). The viscosity was measured at room temperature (23±2 °C) and a relative humidity of 50±10%.

Statistical analyses

We used two-way analysis of variance (ANOVA) to determine the effect of denture lining materials and viscosity of the intervening liquid on the retention force. When interactions were observed, post-hoc Bonferroni tests were used to compare the retention force among denture lining materials and among intervening liquids, and the main effects were compared. All statistical analyses were performed using the IBM SPSS Statistics Package v21 (IBM, Armonk, New York, USA). The statistical significance was $P < 0.05$.

Results

We evaluated the difference in retention force between the high and low viscoelasticity resilient denture liners (denoted as RT-M and RT-S, respectively) and hard denture liner (denoted as HR), and whether the interaction between the type of denture liner and the viscosity of the intervening liquid affected the retention force. The intervening liquids had viscosities of 22.4 mPa·s (80% glycerin aqueous solution), 14.1 mPa·s (40% glycerin aqueous solution), and 1 mPa·s (purified water). The denture lining material and intervening liquid viscosity both had a significant effect on the retention force ($P < 0.001$). Furthermore, there was a significant interaction between the denture lining material and the viscosity of the intervening liquid on the retention force ($P < 0.001$) (Figure 5). The retention force of RT-M and RT-S were significantly higher when 80% and 40% glycerin aqueous solution were used as the intervening liquid, compared to when purified water was intervened ($P < 0.001$). On the other hand, HR showed a significantly higher retention force when 80% glycerin aqueous solution was intervened, compared to when 40% glycerin aqueous solution and purified water were intervened ($P = 0.041, 0.01$). When comparing the denture lining materials, there was a significant difference between all groups when purified water was intervened, and RT-S showed the highest retention
force ($P < 0.01$). On the other hand, when 80% and 40% glycerin aqueous solution were intervened, RT-M and RT-S showed significantly higher retention forces than HR ($P < 0.01$).

**Discussion**

In this fundamental in vitro study, simple relined test specimens were used to evaluate the retention force of different relining materials with intervening liquids of different viscosities as simulated saliva. In theory, the retention force is affected by the physical properties and thickness of the intervening saliva layer. The area coverage of the denture base over the alveolar ridge mucosa is also an influencing factor (29). Thus, this study used three types of intervening liquids with low, medium, and high viscosities to simulate three intraoral salivary conditions. The intervening liquids were combined with simple relined test specimens (two resilient relining materials with different viscoelasticity and one hard relining material) in a standardized in vitro experimental system. The null hypotheses of this study were that there would be no differences in retention force between relining materials with the same intervening liquid, and that the interaction between the materials and intervening liquid would not affect the retention force. Both null hypotheses were rejected.

The results indicated that the two resilient denture relining materials had a significantly higher retention force than the hard relining material for each respective intervening liquid. The retention force tended to increase with the viscosity of the intervening liquid for all denture liners. Based on the theoretical proposal, this study’s results seem valid since the retention force increases according to the intervening liquid’s viscosity (29).

The resilient relining materials, RT-M and RT-S, had a significantly higher retention force than the hard relining material (HR) with all three intervening liquids. This result indicates that resilient denture lining materials have a higher retention than hard denture lining materials. Notably, the retention force of RT-M and RT-S were significantly different when purified water was used as the intervening liquid. However, the difference was not significant compared to the 40% and 80% glycerin aqueous solutions. This result indicates that when the solution viscosity increases, the materials and intervening solution interact, and the difference observed with RT-M is compensated and nears that of RT-S. However, this assumption and the mechanism by which it occurs remain unclear. The resilient relining materials have greater elastic deformation and elastic recovery properties than the hard resin relining material (30). In this experiment, the relining materials were pressed against the PTFE plate before the retention force measurements. The silicone resilient relining materials would deform elastically and generate negative pressure at the plate’s interface, while this would not occur with the hard relining material.

The interaction mechanism (i.e., the phenomenon of retention of RT-M and RT-S in the medium- and high-viscosity solutions) is also interesting. However, the mechanism is unclear. Assuming the viscosity of the intervening liquid plays an important role, it is not clear why the interaction occurs only with RT-M and RT-S in the medium-viscosity intervening liquid (40% glycerin aqueous solution). Precise testing of the materials, such as examining the creep behavior, may help to clarify the mechanism of this phenomenon. It is also assumed that the difference between the wettability of the resilient and hard denture lining materials may also affect the retention force. Contact angle measurements of the respective relining materials should be conducted to consider this in detail.

There are several differences between the simple relined test specimens used in the study and clinical dentures; thus, the results are limited with regard to the clinical implications. However, the present study suggests that the retention force is affected by the viscosity of the intervening solution (i.e., the patients’ saliva) and the thickness of the saliva layer between the simulated denture base and alveolar ridge mucosa. The study demonstrated that the viscosity of the intervening liquid affects the retention force. However, further research is required to examine whether this applies to actual denture and saliva. For example, an experimental system should be considered that approximates the model to the oral cavity and actual dentures.

**Conclusion**

1. The interaction between the type of denture lining material and viscosity of the intervening liquid demonstrated that resilient liners with low viscosity should be chosen carefully to gain an adequate retention force.
2. When the viscosity of the intervening liquid was low,
low-resilience silicone gained higher retention than high resilience materials.

3. Relining using resilient denture lining materials may provide a higher retention force than using hard denture lining material in high-viscosity intervening liquids.

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None.

Conflict of Interest

There are no conflicts of interests to declare.

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