Influence of water immersion on the transmitted load of home reliners

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INTRODUCTION

Home reliners are denture adhesives made from a gum mainly comprising vinyl acetate and ethyl alcohol. By filling the gap between an ill-fitting denture and the denture-bearing mucosa, home reliners attenuate the pain caused to thin mucosa\(^1\). Previous studies have shown that the denture shift and the concentration of stress on the denture-base mucosa may be reduced by the appropriate use of home reliners\(^2-9\). Furthermore, several researches have shown that chewing ability and patient satisfaction levels are improved using home reliners\(^10-14\). Udo and Kawai conducted a randomized controlled trial on maxillary edentulous patients using home reliners by themselves compared with those using tissue-conditioning materials provided by dentists. Their results show no difference in patient satisfaction levels and functional outcomes between the two groups\(^7\). Therefore, the use of home reliners appears helpful as a temporary countermeasure for patients who cannot immediately visit dental clinics, such as those who require care or those who are hospitalized. However, because the patients need to manage the use of a home reliner by themselves, it is liable to be poorly positioned, which leads to a concern about the absorption of the jaw\(^8-10\). In addition, home reliners lose flexibility after extended use. Moreover, it becomes difficult to detach them from the denture base\(^11\). Furthermore, difficulties due to poor oral hygiene constitute another possible problem\(^12\). Therefore, dentists must instruct patients to promptly change their dental prostheses before their reliners lose flexibility.

Niekawa analyzed the composition analysis, conducted creep tests on tissue-conditioning materials that contain polymer and ethyl alcohol as main ingredients, and reported that molecular weight affects viscoelasticity\(^13\). To evaluate how the physical properties of home reliners evolve over time, Murata et al. measured the dynamic viscoelasticity and water absorption and solubility amount for 12 h and after immersion in water for 1, 2, 4, and 7 days. Their results revealed a significant change in viscoelasticity after 24 h and an increase in the elution of ethyl alcohol and weight due to water absorption\(^14\). Conversely, Takahashi et al. noted changes in surface properties due to water absorption in home reliners. Consequently, swelling due to water absorption appears immediately after dipping and elution of ethyl alcohol is reported to influence weight change\(^15\). Based on these studies, the effect of molecular weight, elution of ethyl alcohol, and water absorption on the physical properties, such as viscoelasticity, is considered to begin after several hours rather than several days. Thus, clarifying changes in viscoelasticity up to 24 h after immersion in water is vital in order to advise patients regarding an appropriate replacement time for home reliners.

Therefore, in this study, a pressure sensor sheet was applied under the quasi-mucosa and the transmitted load of home reliners was evaluated within 24 h. Furthermore, we used gel permeation chromatography (GPC) and gas chromatography (GC) to investigate whether composition, such as molecular weight and ethyl alcohol content, affects the attenuation of the transmitted load. The null hypothesis was that no change of the transmitted load of home reliners occurs within 24 h.

MATERIALS AND METHODS

Materials

The three home reliners tested in this study are listed in Table 1, together with their product name, code, manufacturer, and composition. Heat-cured acrylic resin specimens (Akron live pink, GC, Tokyo, Japan) are used
Table 1  Study Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Code</th>
<th>Manufacturer</th>
<th>Composition*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tafugurippu Pink A</td>
<td>TG</td>
<td>Kobayashi Pharmaceutical, Osaka, Japan</td>
<td>Polyvinyl acetate, Ethyl alcohol, Aminoalkyl methacrylate copolymer RS</td>
</tr>
<tr>
<td>Liodent Pink</td>
<td>LD</td>
<td>Lion, Tokyo, Japan</td>
<td>Polyvinyl acetate, Ethyl alcohol, White beeswax, Light calcium carbonate</td>
</tr>
<tr>
<td>Cushion Correct</td>
<td>CC</td>
<td>Shionogi, Osaka, Japan</td>
<td>Polyvinyl acetate, Ethyl alcohol</td>
</tr>
</tbody>
</table>

* Composition as given by manufacturers

for the denture-base resin.

Methods

1. Transmitted load measurement

Acrylic resin disks were obtained by polymerizing an acrylic resin denture base using the wet heat polymerization method; they were placed in a metal mold according to the manufacturer’s instructions. Each acrylic resin disk was prepared in a uniform size (ϕ20×1.5 mm). A total of 90 acrylic resin disks were created. Next, home reliners (ϕ20×1.0 mm) were placed on the acrylic resin disks. For each home reliner tested, 30 combined home reliner–acrylic resin disk specimens were prepared. These combined specimens were immersed in distilled water at 37°C for 0, 1, 3, 6, 12, and 24 h (n=5). Specimens with no home reliner were used as control.

As shown in Fig. 1, the transmitted load measurement was implemented by applying a pressure sensor sheet (ϕ8×0.35 mm) (Single Tact miniature force sensor, Syscom, Tokyo, Japan). It was placed under the quasi-mucosa (ϕ20×1.5 mm) (Fit Checker II, GC). The combined home reliner–acrylic resin disk specimens were placed on the quasi-mucosa. The home reliner side was faced toward the quasi-mucosa so that we can replicate the actual clinical situation. Transmitted load was measured by applying a load of 4.9 N on the acrylic resin side of the combined specimens. The transmitted load data acquired by the pressure sensor were converted to USB by the sensor interface (I2C, Syscom) using ACDC convertor board (Arduino UNO) into a personal computer every 20 ms. The load change was measured 2 min after the load was applied. Thus, the average of ten measurements after 5 s of reaching the maximum load was considered the transmitted load. For the measured values, loads were added and data on 10 measured static load values were collected after 5 s of stability were collected and the average was calculated.

2. Composition analysis

GPC was used to obtain the molecular weight distribution. From each specimen, 20 mg was dissolved in 10 mL of a tetrahydrofuran (THF) solution and measured by using the GPC apparatus (HLC-8220 GPC, Tosoh, Tokyo, Japan) under the following conditions: measurement conditions: column manufactured by Shodex (KF-G+KF-805L×2+K-800D); column temperature, 40°C; flow rate 1.0 mL/min; injection amount, 100 μL; pretreatment filtration (0.2-μL filter) and detector, differential refractometer. Number-average molecular weight Mn, weight-average molecular weight Mw, and polydispersity Mw/Mn were calculated by using polystyrene as a molecular weight marker. In addition, specimen LD contains some insoluble components.

Approximately 200 mg of each specimen were taken in a 20 mL volumetric flask, dissolved in THF, and then weighed. Next, a GC apparatus (Model GC2010, Shimadzu, Kyoto, Japan) was used with the following measurement conditions: measurement conditions, column; DB-17 (0.25 mmL.D φ×30 m, df=0.25 μm); temperature, 50°C for first 3 min and subsequently, 15°C/min increase till 300°C; injection volume, 1 μL; He flow rate, 1.0 mL/min; split ratio, 50:1; and injection temperature, 260°C. The ethyl alcohol content was measured twice and calculated based on the peak area.
and the average was calculated.

3. Statistical analysis
We used a two-way analysis of variance and then analyzed the results by using a multiple comparison test (Tukey’s honest significant difference test) to determine whether statistically significant differences occur between the materials and immersion times for the transmitted load measurement. The significance level was set to 0.05 (statistical software SPSS 16.0 Japanese for Windows).

RESULTS

Transmitted load measurement
Figure 2 shows the results of the measurements. In specimen TG, no significant difference appears between immediately after attachment and 1 h after attachment, and the measured load continues to rise after 3, 6, and 12 h. After 24 h, it decreased somewhat, with no significant difference after 6 h. In specimen LD, transmitted load after 1 h of immersion in water is somewhat greater than that immediately after attachment, although this is probably due to the large plastic flow at the time of attachment of the specimen and the large deformation at the time of loading. A gradual increase in the load occurs after 3, 6, 12, and 24 h. In specimen CC, no significant difference occurs between immediately after attachment and 1 h after attachment, although the load increases significantly after 3 h. The load remains relatively constant from 3 to 6 h, which then increases significantly after 12 h. Finally, the load decreases somewhat after 24 h.

Composition analysis
The GPC results are shown in Table 2 and Fig. 3. In GPC, the separation state of molecules accompanying the decrease of each specimen is clarified in the chromatogram. Specimen TG reveals a single and continuous peak around 16 min. Specimen LD exhibits two consecutive peaks around 16 and 20 min and two small peaks at 21 and 22 min. Specimen CC has two

![Fig. 2 Temporal evolution of transmitted load to each specimen with up to 24 h immersion in distilled water. For all three specimens, the attenuation of the transmitted load occurs 3 h after immersion in distilled water. Identical letters indicate that no statistically significant difference exists.](image-url)

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Result of molecular weight distribution measurement using GPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>sample</td>
<td>No.</td>
</tr>
<tr>
<td>TG</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>LD</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
The molecular weight distribution differs between the three specimens. Specimen TG has a peak at a single wavelength, specimen LD has peaks at four wavelengths, and specimen CC has peaks at three wavelengths. The molecular weight distribution differs between the three specimens.

![Gel permeation chromatogram](image)

**Fig. 3** Gel permeation chromatogram. The molecular weight distribution differs between the three specimens. Specimen TG has a peak at a single wavelength, specimen LD has peaks at four wavelengths, and specimen CC has peaks at three wavelengths. The molecular weight distribution differs between the three specimens.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ethyl alcohol (wt%)</th>
<th>Average (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>LD</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>CC</td>
<td>27</td>
<td>26</td>
</tr>
</tbody>
</table>

### Table 3 Results of quantitative determination of ethyl alcohol using GC

The results of this experiment show that the three types of home reliners have different molecular weight distributions, molecular weights, ethyl alcohol contents, and attenuation of the transmitted load. In addition, regardless of the difference in composition, ethyl alcohol content in specimens CC, TG, and LD is 26, 19, and 16 wt%, respectively.

The mechanical properties of the polymer material are evaluated by using impact load tests\(^{16}\) to determine the maximum stress upon impact, creep tests\(^{13,17}\) to determine the strain required for constant stress, dynamic viscoelasticity tests\(^{18,19}\) to determine the behavior with respect to a repeated load, and stress-relaxation tests\(^{20}\) to determine stress as a function of constant strain. For the home reliners used in this study, the initial plastic flow is high and it is difficult to predict the behavior upon impact and under significant continuous load. When attached to the denture base, the temporal evolution of water absorption differs between the surface layer of the specimen and the deep part that adheres to the denture base.

Considering these two points, to clarify the transmitted load between the resin bed and the mucosa for actual use, the transmitted load measurement is the most appropriate. For this reason, this experiment was performed. The experimental model involves placing a pressure sensor under the quasi-mucosa and applying a static load on the top of the specimen\(^{21}\). The degree of compression of biological jaw-bone mucosa and silicone compatible test material are almost equal. The thickness of the quasi-mucosa is taken from Terakura’s report\(^{22}\) on the thickness of the jaw mucosa of a mandibular edentulous jaw. The thickness of the home reliners is taken from Nakamura’s report\(^{3}\) in which the thicknesses of the home reliners used were measured with a microfocus X-ray system (the maximum thickness is 1 mm). Takahashi et al. reported that changes occur after 4 h of immersion in water and that holes and wrinkles appear\(^{15}\). In addition, wrinkles appear on the specimen surface 6 h in the present experiment. Thus, to eliminate the influence of the wrinkles, sampling data were acquired 5 s after the load was stabilized.

In GPC, specimen TG is presumed to be a single
polymer because the waveform consists of a single continuous peak and the area is 100%. However, the percent area depends on the refractive index in the THF solution and is an approximation because the polymer may not have the same molecular structure. The molecular weight has significant dispersion because the dispersion degree is large and the distribution is wide at Mw/Mn=4.3 for specimen TG. Note that the aminoalkyl methacrylate copolymer RS added to specimen TG is not detected because it is present only in trace amounts, or it may be contained only in a minute peak in the low-molecular weight region.

Four peaks are detected in the GPC waveform for specimen LD. The two consecutive peaks detected on the polymer side suggest the possibility of plural vinyl acetate polymers. In addition, two small peaks are detected at about 21 and 22 min, which may be due to white beeswax because of the low molecular weight of this material. The insoluble ingredients that appear in specimen LD are presumed from the ingredient table to be calcium carbonate. The molecular weight dispersion is relatively small when Mw/Mn=2.1 for specimen LD.

The GPC waveform reveals three peaks for specimen CC, two of which are broad and one of which is continuous. The latter is detected at about 22 min, suggesting that specimen CC also contains multiple vinyl acetate polymers. The side chains of the vinyl acetate, which is the main constituent, are carboxyl groups, although they may be aldehyde groups to provide a different molecular structure. Furthermore, a detailed analysis by infrared spectroscopy and nuclear magnetic resonance is required to clarify the difference in water absorption.

As shown in Fig. 2, the transmitted load gives the load of specimens TG, LD, and CC immediately after being attached as 2.38, 2.49, and 2.49 N, respectively. Compared with the control specimen (3.61 N), attenuation of the transmitted load is 34.3, 31.1, and 31.1%, respectively. No significant difference occurs between the three groups. In TG and LD, the average molecular weight and ethyl alcohol content are similar. Thus, the effect of the average molecular weight on the initial viscoelasticity is large in the preparation mixed with vinyl acetate resins with various molecular weights.

Although specimen CC contains high-molecular weight vinyl acetate, no significant difference appears with regard to the initial, slow attenuation because the ethyl alcohol content is greater than other agents. Based on these results, the initial viscoelasticity of the preparation is adjusted by the ratio of average molecular weight to ethyl alcohol. For the three specimens, the measured load remains the same after 1 h of immersion; however, it decreases significantly after 3 h of immersion. For specimen CC, the stress again increases significantly after 6–12 h because specimen CC consists mainly of two types of vinyl acetate whose molecular weights differ significantly. The attenuation of the transmitted load after water absorption and ethyl alcohol elution causes a characteristic inflection point.

For specimens TG and LD, the transmitted load measurement graph shows that the measured load in specimen LD rises gently until 24 h, whereas that in specimen TG rises greatly after 6 h. The molecular weight and ethyl alcohol content are similar between specimens TG and LD. However, the big difference between the two groups is the number of peaks in the molecular weight distribution and the fact that the molecular weight peak for specimen LD occurs at approximately 20 min. In addition, this component gradually changes with time, which infers that the change may be due to ethyl alcohol elution or water absorption. Thus, the elution of ethyl alcohol must be clarified by GC as a function of immersion time. Takahashi et al. reported that the quantity of imbibition is clearly lower in specimen LD, in particular TG>CC>LD. The fact that the increase in the load is gentle for specimen LD and that water absorption is small maybe due to the addition of an oily plasticizer (i.e., white beeswax).

This experiment differs somewhat from actual practice: A first difference is the limitation of expansion due to water absorption. In reality, home reliners are placed between the mucous membrane and the denture, and deformation due to water absorption may be less than what occurs in vitro because pressure load is applied. A second difference is the occlusal force. In the literature, the occlusal pressure in the molar region of the total-denture patient ranges from several tens of kPa to 300 kPa. In the present experiment, the load was about 16 kPa because the sensor has a maximum load of 10 N. However, we expect a stronger and uneven force to be applied to the chin bank because of differences in pressure displacement of the chin mucosa. In addition, because the transmitted load differs from the load during chewing; its characteristics must be known for repeated loading. A third difference is the specimen thickness. The actual thickness is expected to be 1 mm or less based on the work of Nakamura, and the difference in thickness may appear as a difference in curing.

Within these limitations, the appropriate effect on the transmitted load of home reliners clearly occurs within 3 h and is negligibly influenced by changes in physical properties due to water absorption and ethyl alcohol elution.

As mentioned above, using a home reliner is not recommended because it can cause the absorption of the residual ridge and change of occlusal relationship due to incorrect use. However, depending on the patient’s general condition and living environment, temporary use may help in maintaining the quality of diet. Therefore, dentists must provide appropriate information to the patient and strive to maintain the oral health. Evaluating attenuation of the transmitted load over time of the home reliner is beneficial for providing information on proper use.
CONFLICTS OF INTEREST
The authors declare no potential conflicts of interest with respect to the authorship and publication of this article.

REFERENCES