Comparative Study of Water Sorption and Solubility of Soft Lining Materials in the Different Solutions

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In this study, two acrylic based materials and three silicone rubber soft lining materials were investigated to determine the percentage of absorption and solubility in artificial saliva, distilled water, and denture cleanser. In addition, the effect of denture cleanser on surface properties of soft lining materials was also evaluated.

For sorption and solubility testing, 75 discs (50 mm × 0.5 mm) were prepared and divided into 5 groups with 15 samples in each group. The specimens were stored in different solutions, and tested after 1, 4, and 16 weeks.

Analysis of variance was used to find the significant differences between the materials at all time intervals. The acrylic resin soft lining materials had higher solubility (3.432% Visco-gel in artificial saliva) and absorption (3.349% Visco-gel in distilled water) than Molloplast-B after 16 weeks of aging. The greatest hardness and color change were shown in the acrylic soft lining materials.

Key words: Water sorption, Solubility, Soft lining materials

INTRODUCTION

The health the denture-bearing mucosae may be adversely affected by high stress concentrations during function. The patients with heavy bruxing or clenching habits may suffer the same consequence.

Soft denture-bearing mucosae are confined to the hard denture base and bone. The use of soft lining materials is designed to distribute functional and nonfunctional stresses more evenly because of elastic behavior.

These properties make soft denture lining materials useful for treating patients with 1) Ridge atrophy or resorption, 2) Bony undercuts, 3) Bruxing tendencies, 4) Congenital or acquired oral defects requiring obturation, 5) Xerostomia, 6) Dentures opposing natural dentition in the opposing arch, 7) Knife-edge and soreness ridges.

These materials fail for many reasons, such as hardening, sorption of odors, support of bacteria, color changes, and debonding from the denture base.

The most common problems encountered while using soft denture liners are water sorption and solubility. In use, they are constantly bathed in saliva, and when out of the mouth, they are usually immersed in either solution of denture cleansers or water for storage. During such immersion, soft lining materials undergo 2 responses: Plasticizers and other soluble components are leached out and water or saliva is absorbed.

An ideal processed soft liner should have no soluble components and low water sorption.

The purpose of this investigation is to measure the water sorption and solubility of 5 laboratory processed soft denture liners in different environments at various time intervals.

MATERIALS AND METHODS

Five soft denture liners (Laboratory-processed type) were chosen on the basis of different chemical compositions (Table 1).

Sorption and solubility were determined by use of the method described in American Dental Association (ADA) specification 12 for denture base polymers.

Fifteen samples of each material were processed into disks 50 mm in diameter by 0.5 mm in thickness. The disks were dried in a desiccator containing

| Table 1 List of materials and manufacturers |
|---|---|---|
| Materials | Type | Company |
| Fixo-Gel | Cold-cured acrylic resin | Fortex, England |
| Mollosil plus | Cold-cured silicone based | Detax, GmbH a Co KG, Ettingen, Germany |
| Molloplast-B | Heat- cured silicone based | Detax, GmbH a Co KG, Ettingen, Germany |
| Ufi Gel P | Cold-cured silicone based | Voco, Cuxhaven, Germany |
| Visco-gel | Cold-cured acrylic resin | Dentsply, De Trey GmbH, Konstanz, Germany |
anhydrous calcium sulfate until a constant weight (±0.5 mg) was obtained. This was considered to be the initial weight of the specimen (W1). The disks were then immersed in distilled water, artificial saliva, and denture cleansing solution (Fittydent cleansing tablets, Fittydent international GMBH A-7423 Pinkafeld, Austria).

The artificial saliva was of the following composition:14) NaCl, 0.400 g; KCl, 0.400 g; CaCl2H2O, 0.795 g; NaH2PO4, 0.69 g; Na2S.9H2O, 0.005 g; Urea 1.0 g; distilled water 1000 mL. The pH was then adjusted to 4, 7, 8 with NaOH or HCl and the volume was increased to 1 L.

Of the 30 disks processed for each material, groups of 5 were tested after one, 4 and 16 weeks. Each group of 3 specimens was stored in sealed polyethylene containers at 37°C ±2°C. In the periods of 1, 4 and 16 weeks, the disks were removed from their containers; excess water was removed by blotting with filter paper, and the disks were weighed by an electronic precision balance (Sartorius AG, Gottingen, Germany) capable of measuring to 0.001 g. This was the weight of the specimen after absorption or desorption (W2).

The amount of soluble material lost was measured by placing the specimens back in the desiccator after each sorption cycle and then weighing them at regular intervals until a constant weight was reached. This weight was the final weight after desiccation (W3).

The percentage absorption and solubility were determined in detail by Kazanji and Watkinson10) as follows:

\[ \text{Percent sorption:} \left( \frac{W2-W3}{W1} \right) \times 100\% \]
\[ \text{Percent solubility:} \left( \frac{W1-W3}{W1} \right) \times 100\% \]

W1: The initial weight
W2: The weight after absorption
W3: The final weight after desiccation

The above procedure was repeated, and sorption and solubility data were collected for one, 4 and 16 weeks.

Surface porosity and distortion of soft lining materials were examined according to the methods described by Harrison et al.15) and Goll et al.16). The specimens were inspected visually at 1, 4 and 16 weeks.

Each sample was graded by two independent examiners. A score of 0 (no change), 1 (slight change), 2 (moderate change), 3 (marked change), 4 (severe change) was recorded, compared with those of standard samples immersed in distilled water, and the ratings were averaged to determine the severity of porosity or distortion.

The data were analyzed by use of two way ANOVA and Duncan’s multiple range test.

RESULTS

According to the analysis of variance, the type of materials, time and solution of storage were statistically significant on water sorption (P<0.001).

The solubility and water sorption percentages after 1, 4 and 16 weeks are graphically displayed in Figs. 1 and 2.

After one week, the water sorption of the plasticized acrylic resin soft liners was 2.136% for Visco-gel and 2.118% for Fixo-Gel in distilled water.

Mollosil Plus, self-curing silicone, exhibited a marked increase in the percentage absorption of artificial saliva (0.913% in pH: 7, 0.909% in pH: 4, 0.911% in pH: 8), distilled water (0.923%), and denture cleansers (0.930%) over a 4 week immersion period. The percentage solubility in artificial saliva (0.712% in pH: 7, 0.721% in pH: 4, 0.718% in pH: 8) was statistically higher than that of Molloplast-B (0.573% in pH: 7, 0.577% in pH: 4, 0.575% in pH: 8).

Ufi Gel P, self-curing silicone, exhibited a marked increase in the percentage absorption of artificial saliva (1.024% in acidic, 1.018 in basic, 1.013% in neutral pH), distilled water (1.067%), and denture cleansers (1.091%) over a 4 week immersion period.

According to the Duncan’s multiple range test:
- The values of percentage solubility and absorption were not statistically significant in different pH of artificial saliva (pH: 4, pH: 7, pH: 8).
- The soft lining materials showed different absorption at different times of storage.
- The water solubilities between the time and solution of storage were not statistically significant.

According to the methods described by Harrison et al.15) and Goll et al.16), marked change (3) was observed in Visco-gel and Fixo-Gel soft liner materials.

DISCUSSION

The rate at which the materials absorbed water or lost soluble components varied considerably with the type of material, the amount of plasticizer or filler content and the solution in which they were immersed10).

This study has demonstrated that the percentage solubility of Fixo-Gel and Visco gel in artificial saliva was significantly higher than that in distilled water.

The observed weight loss probably occurred because the plasticizers are more soluble in ionic solutions than in water. Conversely, the percentage absorption of artificial saliva by Fixo-Gel and Visco gel was significantly lower than that of distilled water (P<0.001).

Kazanji et al.10) determined that with the exception of Molloplast-B, all the soft materials studied
Fig. 1 The water sorption percentages of soft lining materials after 1, 4 and 16 weeks.
Fig. 2 The solubility percentages of soft lining materials after 1, 4 and 16 weeks.
showed higher solubility in artificial saliva than in distilled water. The value obtained in this study was similar when compared with the one observed by Kazanj et al. The percentage absorption of these materials was lower in artificial saliva than in distilled water.

The lower uptake in artificial saliva is explicable in terms of the ionic impurities in the polymer. This leads to an enhanced uptake in distilled water since water droplets will form at the impurity sites until elastic and osmotic forces balance. The osmotic pressure will be proportional to the difference in ionic concentrations between the polymer and external liquid, this difference being greater for water than for artificial saliva.

For the acrylic resin linings, the absorption of water (3.368% for Viscogel, % 3.214 for Fixo-Gel in distilled water over 4 weeks) considerably exceeded the loss of plasticiser and other soluble materials. These values were similar to the results of Kazanj and Elhadary.

Conversely, in artificial saliva, these materials showed a high percentage solubility after one month’s immersion with a much higher value (2.561% for Viscogel, % 2.307 for Fixo-Gel) following more extended immersion.

Soft lining materials undergo two processes when immersed in water. Plasticizers and other soluble materials are leached into the water, and water is absorbed by the polymer. The balance between these two processes affects both the compliance and dimensional stability of the materials. Loss of plasticizers and absorption of water are variable factors which are bound to have an effect on the tear energy of materials. Other studies showed that the plasticized acrylic resin permanent soft lining materials have higher tear energy, solubility and sorption values than the silicone soft lining materials.

An acrylic based Visco-elastic gel exhibited a high percentage absorption (3.368%) of distilled water. A high percentage solubility (3.432% in neutral saliva, 3.418% in acidic saliva, 3.423% in basic saliva) was also observed in artificial saliva. This is probably due to the loss of ethyl alcohol and the leaching out of the low molecular weight plasticiser from the set material.

If a soft lining material is to remain effective over an extended period of clinical use, it must remain compliant, i.e., soft and dimensionally stable, whilst remaining bonded to the denture base material. The absorption of water by the material results in a weight and volume increase. The compliance of the materials tested is dependent either on the presence of a plasticiser as in the case of the acrylic materials, or on the inherent physical properties of the material, as in the case of the silicone rubbers. An ideal material should, therefore, have no component which is soluble in saliva or water and should have a low level of absorption.

Silicone soft liniers had lower absorption and solubility in distilled water and artificial saliva

For silicon-based materials (Molloplast-B, Mollosil Plus, Ufigel-P), there was little difference in the percentage absorption between artificial saliva and distilled water, probably because it does not contain a plasticiser in its composition. These materials also exhibited the lowest water absorption value of the materials tested. This finding is in agreement with the work of Braden and Wright.

The value obtained in this study was relatively high when compared with the one observed by Kawana et al and El-Hadary et al. The differences may be a result of the different processing methods, specimen volumes and periods of immersion in the different studies.

Presently, there is no ADA specification for soft denture liners. However, if ADA specification 12 for denture base polymers is used as a guide, after 1 week the sorption value should not be more than 0.8 mg/cm² and the solubility should not be more than 0.04 mg/cm².

Silicone soft liner (Molloplast-B) showed an absorption of 0.887% in distilled water after 1 week. The absorption values were similar to the values of the studies (Collis and Kazanj). These low values for water sorption and solubility may be due to the improved bonding of the filler to the silicone, which is achieved when the material is cross-linked by heat application. After 1 year, only Molloplast-B soft denture liner had sorption values of less than 0.8 mg/cm².

According to the Kazanj et al, the percentage solubility of Molloplast-B in artificial saliva was 0.074%, and the percentage absorption in artificial saliva was 0.47% after 4 weeks. In this study, the percentage absorption of Molloplast-B in artificial saliva was 0.821%, and the percentage solubility was 0.573% after 4 weeks.

In a study of El-Hadary et al, the sorption values of silicone soft liner were 0.30% and plasticized acrylic resin was 1.18% in distilled water after 4 weeks.

High sorption and solubility of soft denture liners are associated with swelling, distortion, hardening, absorption of odors, support of bacteria, color changes, and debonding of liners from denture bases.
In a study where the cytotoxicity of commercial tissue conditioners was evaluated, it was seen that visco gel materials caused a decolorized zone with minimal cell damage. Visco-gel was most affected by the denture cleansers. In this study, the color changes and hardening were observed in Visco-gel and Fixo-Gel soft liner materials after immersion in denture cleansers.

After silicon resilient denture liner treatment with certain perborate-containing denture cleansers, a greater amount of components could leach from the liner leading to a loss of color if the liner surface is rough.

Although chemical cleansers have been considered an efficacious method to prevent C. Albicans invasion and denture plaque formation, some types of roughness and denture plaque formation have been reported to cause significant deterioration of tissue conditioners in a relatively short time.

The grades of surface porosity of soft liners varied depending on the immersion time and the combination of denture cleansers and soft liner.

CONCLUSION

With the exception of Molloplast-B, all the soft linings studied showed higher solubility in artificial saliva than in distilled water. In addition, the percentage absorption of all the materials was lower in artificial saliva than in distilled water.

This differing behaviour in artificial saliva should be taken into consideration when testing materials since the results for artificial saliva are more likely to be clinically relevant than those for distilled water.

Therefore, sorption and solubility properties are important as a means to evaluate the longevity of a particular liner. Ideally, a soft liner should have low sorption and low solubility values.

More severe changes were observed as hardening and a loss of color in soft liner materials after immersion denture cleansers. These changes varied depending on immersion time and kind of soft liner material.

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