Relationship between Viscoelastic Properties of Soft Denture Liners and Clinical Efficacy

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Running title: Clinical Efficacy of Soft Denture Liners

Table: 0; Figure: 2

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日本補綴歯科学会
Mini Review

Abstract
Soft denture liners are applied for denture wearers who cannot tolerate a hard-based denture due to a thin and non-resilient oral mucosa and/or severe alveolar resorption. This material distributes and absorbs masticatory forces by means of the cushioning effect. Clinical success of the materials depends both on their viscoelastic properties and on durability. Acrylic resins and silicones are mainly available for permanent soft liners. The acrylic permanent soft liners demonstrate viscoelastic behavior while silicone permanent soft liners demonstrate elastic behavior. The improvement in masticatory function is greater in dentures lined with the acrylic materials than in those lined with silicone products. However, the acrylic materials exhibit a more marked change in viscoelastic properties and loss of cushioning effect over time than silicones. From the standpoint of durability, the silicones are preferred. It is important to understand viscoelastic properties and durability of each soft denture liner and to select the material according to the clinical situations and purposes. The ideal permanent soft liners have a relatively high value of loss tangent and storage modulus, and high durability. Further research is necessary to develop the ideal soft denture liner.

Key words: Soft denture liner, Viscoelasticity, Masticatory function, Reline

INTRODUCTION

Soft denture liners are widely used for denture wearers who complain of masticatory pain (Wright[1]; Qudah *et al.*[2]; Hamada and Murata[3]). These patients have a thin and non-resilient oral mucosa and/or severe alveolar resorption. When functional forces are transmitted to the basal seat mucosa through a hard denture base during mastication, this oral mucosa will be injured, which will cause the sore spots, masticatory pain, further resorption of alveolar bone and so on. Soft denture liners are not necessary for the patients who adjust well to wearing the dentures. Such patients have resilient basal seat mucosa and sufficient residual ridges. However, the well-formed residual ridges described in a textbook are infrequent. It is expected that clinical cases of application of soft denture liners will increase with increasing in elderly patients.

Clinical efficacy of soft denture liners has been reported previously. In a 6-year retrospective study, 93% of edentulous patients felt more comfortable when the denture lined with soft liners (Schmidt and Smith[4]). Randomized controlled clinical trial also demonstrated that the application of soft denture liners to mandibular complete dentures improved masticatory ability of edentulous patients and provided the patients with few problems affecting the alveolar ridge during the first adjustment following the setting of dentures compared to conventional hard denture base (Kimoto *et al.*[5), 6)]).

The clinical effect of soft denture liners is considered to be influenced by their bond strength to denture bases (Wright[7)]; McCabe *et al.*[8)]), setting characteristics (Murata *et al.*[9)]; McCabe[10)]), water absorption, solubility (Kazanji and Watkinson[11)]; Kawano *et al.*[12)]), and especially viscoelastic properties (Jepson *et al.*[13)]; Wagner *et al.*[14)]; Waters *et al.*[15)]; Saber-Sheikh *et al.*[16)]; Murata *et al.*[17)]) and durability (Murata *et al.*[17)]; Wagner *et al.*[18)]; Saber-Sheikh *et al.*[19)]). This mini review will describe the classification, viscoelastic properties, durability of permanent soft liners, and their effect on masticatory function.

CLASSIFICATION

Denture liners are of two types, hard, direct denture reline resins and soft denture liners. The permanent soft liners can be classified into mainly: (1) autopolymerized silicone, (2) heat-polymerized silicone, (3) autopolymerized acrylic resin, and (4) heat-polymerized acrylic resin. Previously fluoroethylene and polyolephin type were available (Murata *et al.*[9)]; Hayakawa *et al.*[20)]). The acrylic temporary soft liner is classified as tissue conditioner. Fig.1

Previously autopolymerized silicones were hand-mixed type using either paste/paste or paste/liquid dispensation. The fundamental composition and setting reaction will be similar to that of condensation silicone rubber impression materials. Ethyl alcohol is produced as a by-product. The autopolymerized silicone permanent soft liners developed recently are supplied in the form of a two-paste cartridge. These silicone products are based on a polyvinylsiloxane system and similar to that used in polyaddition silicone rubber impression materials (McCabe[10)]). These materials do not involve the production of by-product after setting and these characteristics would contribute to the stable nature.

The heat-polymerized silicone permanent soft liners are supplied as a one-paste system with a free radical initiator. This products consist of a poly dimethylsiloxane polymer with pendant or terminal vinyl group that cross-linking occurs (McCabe [21)]).

Both the autopolymerized and heat-polymerized acrylic permanent soft liners are supplied as a powder and liquid. The powder generally consists of poly (ethyl methacrylate) or poly (butyl methacrylate) along with some peroxide initiator. The liquid of autopolymerized acrylic material consists of 2-ethylhexyl methacrylate, tertiary amine and plasticizer. Those of heat-polymerized material are a mixture of methyl methacrylate and plasticizer.

The tissue conditioner also supplied as powder and liquid components. The main component of the polymer powder of most of the materials is poly (ethyl methacrylate) or a related copolymer. The liquid is a mixture of a plasticizer, such as butyl phthalyl butyl glycolate, dibutyl phthalate and dibutyl sebacate, and ethyl alcohol. Some material based on poly (butyl methacrylate) or a related copolymer contains no ethyl alcohol in the liquids (Murata *et al.*[22]).

Tissue conditioners contain no monomers in the liquid and no initiator in the powder. Thus the materials are uncross-linked amorphous polymers. On the other hand, both the silicone and acrylic permanent soft liners are cross-linked amorphous polymers. The differences in structure would influence the clinical behavior of the relined denture.

VISCOELASTIC PROPERTIES AND DURABILITY

Permanent soft liners should distribute and absorb the functional forces during mastication by means of viscoelastic behavior (Murata *et al.*[9]). Viscoelastic properties of the materials have been evaluated in a variety of ways that include the creep test (Jepson *et al.*[13]), stress relaxation test (Murata *et al.*[9]), Shore-A hardness test (Dootz *et al.*[23]), penetration test (McCabe *et al.*[24]), dynamic test (Murata *et al.*[17]). The dynamic test would be most precise among these methods. In the clinical situation, soft denture liners are subjected both to rapid force such as mastication and to the continuous and weak pressure from the basal seat mucosa. It is necessary to measure the viscoelastic properties over a wide range of frequencies in order to allow predictions of behavior under the situations. Therefore, the dynamic test using viscoelastometer based on the principle of a non-resonance forced vibration would be more effective method than the others. In the dynamic test, 3 rheological parameters are generally used for evaluation of the dynamic viscoelasticity of materials: storage modulus (E'), loss modulus (E'') and loss tangent (tan δ). The storage modulus describes elasticity of materials and the loss modulus describes viscosity. Loss tangent is the ratio of the loss modulus and the storage modulus (E''/E'), and is considered to express the cushioning effect against masticatory forces. A wide range of frequencies are applied to the specimen in this dynamic test. The frequency value of 1 Hz is considered to be important in assessing the clinical significance of the obtained data because a value of 1 Hz shows masticatory conditions.

The previous study (Murata *et al.*[17], [25]) demonstrated that large differences in dynamic viscoelastic properties and their durability were found among the soft denture liners due to differences in composition and structure. The dynamic viscoelasticity of acrylic materials was sensitive to changes in frequency and temperature, while than that of silicone products was not markedly frequency dependant. Acrylic permanent soft liners and silicone permanent soft liners had higher storage moduli than tissue conditioners at 1 Hz. Acrylic permanent soft liners also had higher loss moduli. The values of loss tangent at 1 Hz of acrylic materials were higher than those of silicones. That is, acrylic materials exhibited viscoelastic behavior, while silicones exhibited elastic behavior. The acrylic soft liners would have a greater ability to cushion the masticatory forces.

This study also evaluated changes in viscoelastic properties over a 3 year period. Changes in dynamic viscoelasticity over time in water storage varied markedly among the soft denture liners. The acrylic permanent soft liners demonstrated a greater increase in the storage modulus, loss tangent and especially loss modulus with time than the silicone permanent soft liners. The low molecular weight plasticizer contained in the acrylic materials is leached out into the water, and, at the same time, water is absorbed into the materials (Kazanji and Watkinson[11]). This will lead to loss of viscoelastic properties, dimensional change, deterioration in the surface conditions. The silicone products remained stable over time. This would be due to the low water absorption and low solubility of components (Kalachandra *et al.*[26]).

INFLUENCE OF VISCOELASTIC PROPERTIES ON MASTICATORY FUNCTION

Relationship between dynamic viscoelasticity and masticatory function has been determined (Murata *et al.*[25]). The masticatory function of 10 complete-denture wearers was evaluated by means of maximum bite forces, chewing times and frequencies for test food samples (ham, pickled radish). The patients' subjective assessments of satisfaction with the relined denture were also conducted by means of visual analogue scales (VAS). These subjects had severe mandibular alveolar bone loss and complained of masticatory pain. They were not satisfied with the conventional hard-based dentures after several adjustments though the fit, stability, extension of the denture bases and occlusion were good. The specialists judged it better to apply a denture soft liner to them. One tissue conditioner, 1 silicone permanent soft liner and 1 acrylic permanent soft liner were applied to the mandibular dentures at a thickness of 2 mm. Hard resin-based dentures were also evaluated as control. Functional tests were performed after the patients wore the relined dentures for 1 week.

The use of soft denture liners resulted in improvement in masticatory function and satisfaction compared with hard resin-based dentures significantly (Fig. 1). The mean rank in terms of maximum bite forces was: acrylic permanent soft liner > silicone permanent soft liner > tissue conditioner > hard resin. That of chewing times and frequencies for the 4 types of base for a hard food (pickled radish) was: acrylic permanent soft liner < silicone permanent soft liner < tissue conditioner < hard resin. That of chewing times for a soft food (ham) showed almost the same tendency as that for hard food, however, the differences among the 4 types were very small. No differences were found among the chewing frequencies for a soft food by the 4 types of base. Fig.2

The viscoelasticity of soft denture liners was found to have a great influence on the masticatory function of the complete denture wearers. The greater improvement in masticatory function was observed in dentures lined with the acrylic permanent soft liners, which have higher loss tangent and storage modulus, than in those lined with the silicone permanent soft liners, which have lower loss tangent and higher storage modulus. The improvement by dentures lined with the tissue conditioners, which have higher loss tangent and lower storage modulus, was smaller than that by the other soft denture liners.

A higher value of loss tangent (*i.e.*, viscoelastic properties) is likely to exhibit a degree of stress relief under masticatory forces. A lower value of loss tangent exhib its elastic properties. It was found that the soft denture liners having viscoelastic properties lead to more marked improvement in masticatory function than those having elastic properties.

Theoretically the physical properties of basal seat mucosa should be equal to those of soft denture liners. The previous study (Inoue *et al.*[27]) has reported that the Young's moduli E of the oral mucosa range from approximately 0.4 to 4.4 MPa. E of tissue conditioners is lower than that of oral mucosa, while E of both acrylic and silicone permanent soft liners is within the range of E for mucosa. Higher storage modulus may produce more ability of instantaneous crush of food by the soft-lined dentures

EFFECTIVE USE OF SOFT DENTURE LINERS

First, complete dentures should be fabricated using hard denture bases but not using soft denture liners. The denture must meet the demand that fit, stability, extension of the denture bases are well and occlusion and tooth arrangement are satisfactory. When the patients claim masticatory pain, the dentists must repeat adjustment of dentures. The dentists should judge it better to apply a soft denture liner to the patients when they are not satisfied with their denture in spite of repeated adjustment.

These patients usually have the traumatized basal seat mucosa caused by ill-fitting dentures. Tissue conditioners should be applied for several days to recondition of abused oral mucosa and make functional impressions (Harrison [28]). After this treatment, soft denture liners are applied to the functional impressions surface of the dentures. To be effective, a thickness of 1.5 to 2 mm is recommended. Indirect method relined at a laboratory is more favorable than direct method relined at chair side because flasking is easier to produce the optimum thickness of the soft denture liners by.

Selection of permanent soft liners from many types according to the clinical situations is very important. In our opinion, a silicone permanent soft liner, which has higher durability and lower cushioning effect than an acrylic material, are applied to the denture by means of the indirect method. When the patient complains of masticatory pain and does not satisfied with the denture lined with the silicone permanent soft liner, an acrylic permanent soft liner having higher cushioning effect is selected. In that case, the acrylic materials should be replaced more frequently than silicone products because of lower durability.

CONCLUDSIONS

This paper reviewed relationship between dynamic viscoelasticity of soft denture liners and masticatory function of complete denture wearers. The use of a soft denture liner with a relatively high value of loss tangent (*i.e.*, viscoelastic properties) and storage modulus to mandibular complete denture produces the greatest improvement in masticatory function of the patient who complains of masticatory pain caused by a conventional hard denture base. However, the materials having both high cushioning effect and high durability have not been developed. Additional research needs to be performed to produce the ideal soft denture liners.

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Legends

Fig. 1. Classification of denture liners.

Fig. 2 Maximum bite force, chewing ti me and chewing frequency for chewing of two foods, and VAS value for a subject (female, 74 years old).

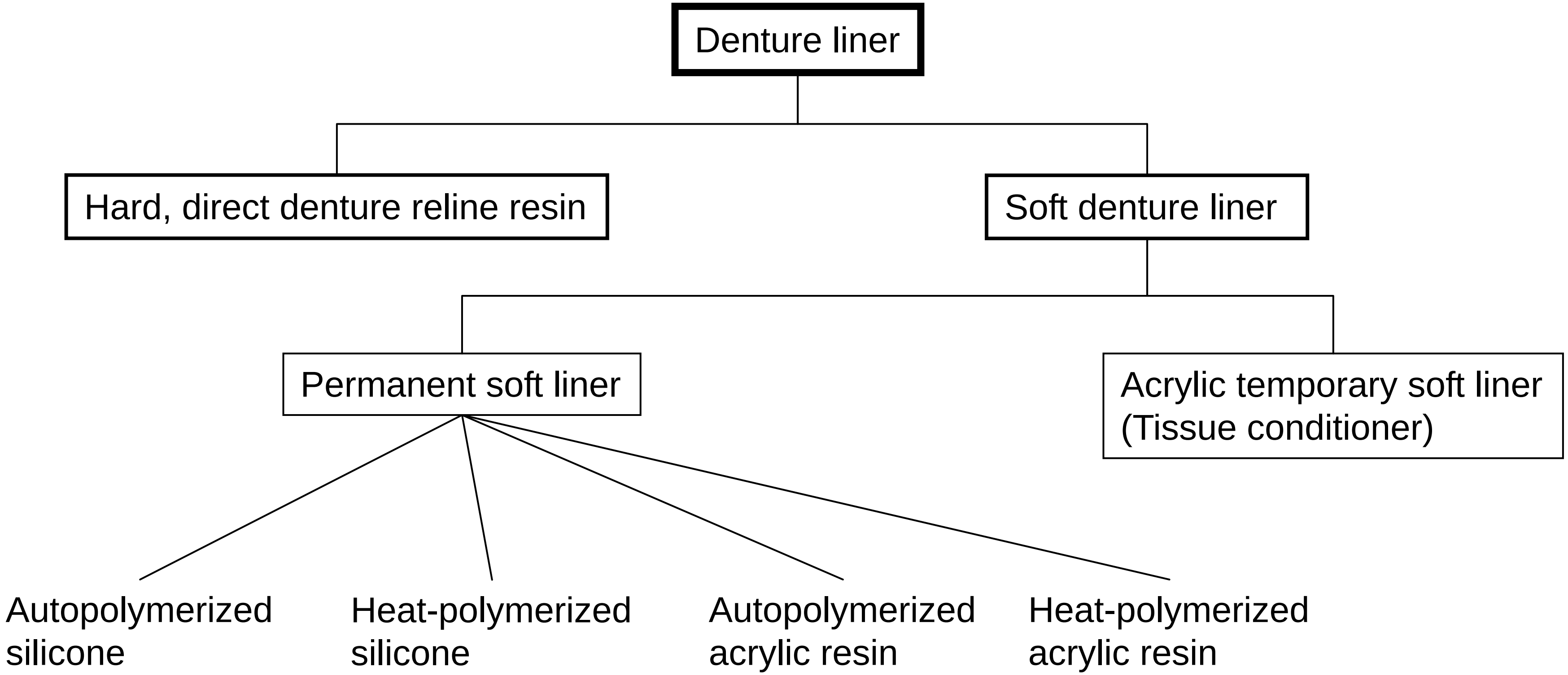

Fig.1. (Murata, Hamada and Sadamori)

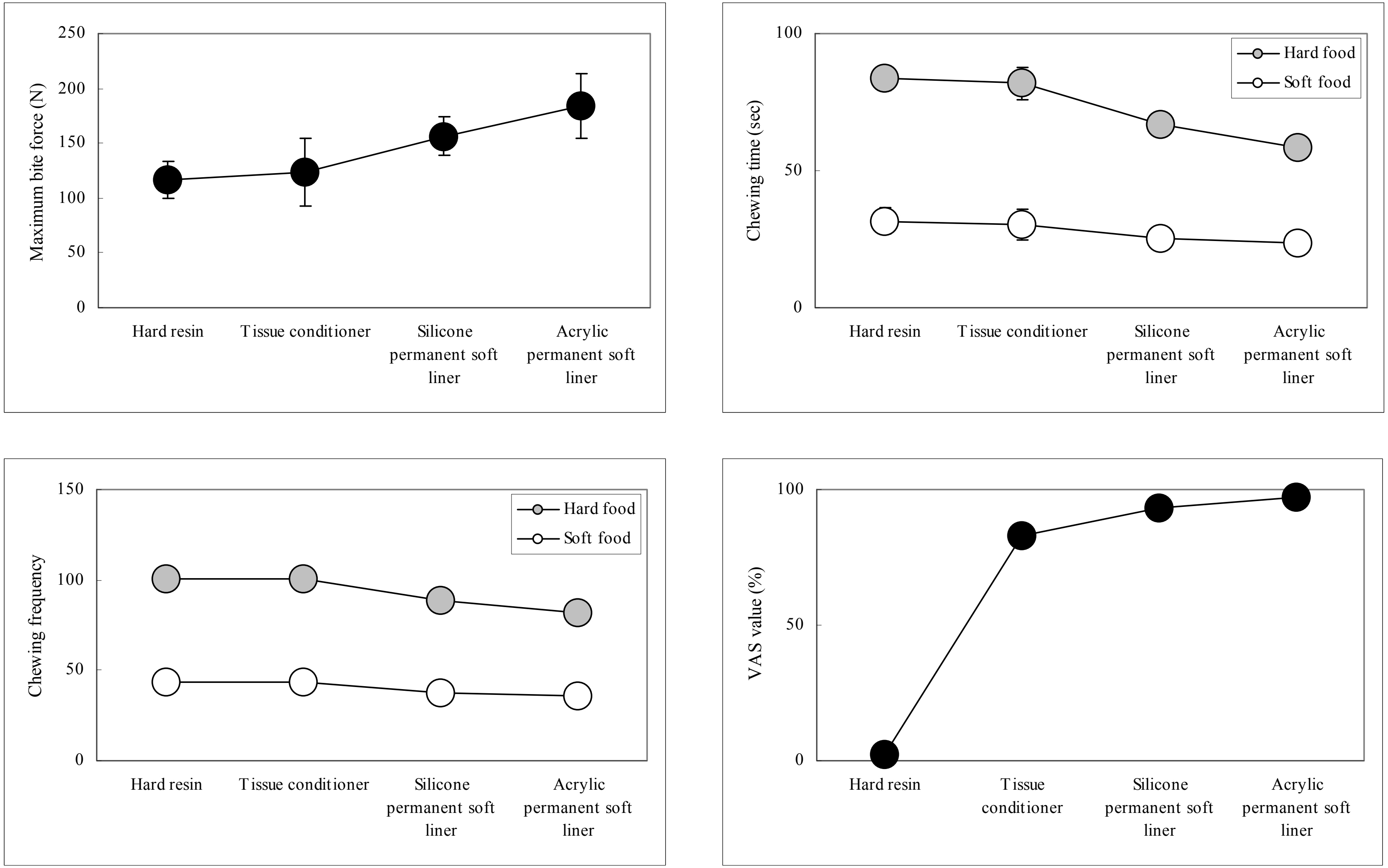

Fig.2. (Murata, Hamada and Sadamori)