The initial viscosity and adhesive strength of denture adhesives and oral moisturizers

Guang Hong, DDS, PhD,[a] Hiroki Tsuka, DDS, PhD,[b] Maimaitisawuti Dilinuer, DDS,[c] Wei-Qi Wang, DT,[c] and Keiichi Sasaki, DDS, PhD[c]

[a]Liaison Center for Innovative Dentistry, Graduate School of Dentistry, Tohoku University, [b]Department of Advanced Prosthodontics, Graduate School of Biomedical Sciences, Hiroshima University, Hiroshima, and [c]Division of Advanced Prosthetic Dentistry, Graduate School of Dentistry, Tohoku University, Sendai, Japan

Purpose: The purpose of this study was to determine the initial viscosity and adhesive strength of commercial denture adhesives and oral moisturizers.
Materials and Methods: Four cream-type denture adhesives, one gel-type denture adhesive and three gel-type oral moisturizers were used in the study. The initial viscosity was measured using a controlled-stress CarriMed CSL500 rheometer. The adhesive strength was measured according to the ISO-10873 recommended procedures using a constant load compression testing machine and a materials testing machine.
Results: Significant differences in initial viscosity were found among the materials ($p<0.05$). Similar viscosity values were recorded in all materials except Tafugrip Gel and Corect Cream. The adhesive strength of denture adhesives increased significantly with time, but the adhesive strength of oral moisturizers decreased significantly with time.
Conclusion: Cream-type denture adhesives and gel-type oral moisturizers exhibit similar initial viscosity, and denture adhesives and oral moisturizers function with different adhesion behaviors.
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Key Words: adhesive strength, denture adhesive, oral moisturizers, viscosity

Introduction

Denture adhesives have been widely used by denture wearers with well-fitting and ill-fitting dentures as a means to enhance denture retention, stability and function.[1-5] The American Dental Association first reported the use of a denture adhesive in 1935.[6] Clinical opinion about denture adhesives has often been negative,[7-10] and dentists have been slow to accept these products. Reported reasons for trying denture adhesives include to improve fit, comfort, chewing ability, and also to improve patient confidence in wearing dentures.[5,11] In the US in 1980, 15% of denture wearers used denture adhesives.[12,13] Wilson et al.[14] reported in 1990 that 30% of denture wearers used, or had used, denture adhesives. However, Coates[15] reported that a significant number of subjects in his study did not know that denture adhesives existed. However, denture adhesives still hold a legitimate and indispensable place in prosthetic dental treatment.

Dry mouth, or xerostomia, is a common symptom of the elderly population. In recent years, the number of edentulous patients with dry mouth has increased, resulting in more patients suffering from poor denture retention and reduced quality of life. Dry mouth may compromise oral health and interfere with oral function.[16-18] Dry mouth is caused by a number of factors, including Sjögren's syndrome, the administration of medicine, age, diabetes, and radiotherapy of the head and neck during cancer treatment.[18-22] Österberg et al.[23] reported that 16% of men and 25% of women complained of oral dryness. Several investigators have reported that the prevalence of dry mouth among the aged population varies between 12% and 39%, and the prevalence increases with age and the number of medications being taken.[24-27] Yet no effective treatment for dry mouth has been available except for symptomatic therapies such as taking frequent sips of water, the use of saliva substitutes (oral moisturizers), artificial saliva, glycerin, troches and sugar-free gum, salivary gland hormones, and herbal medicine.[18] Oral moisturizers are available as gels, mouth rinses and sprays,[28,29] and are currently the

most commonly used treatment for dry mouth.

The mechanical properties and cytotoxicity of denture adhesives have been widely investigated using a variety of testing methods.[30-32] However, few studies have examined the initial viscosity and adhesive strength of denture adhesives. Furthermore, almost no research has investigated the mechanical properties of oral moisturizers. Information about these characteristics may be important for the clinical use of these materials. Patients would benefit greatly from a dental professional's guidance regarding the use of denture adhesives and oral moisturizers. However, in clinical situations, patients and dentists fail to select the most appropriate product.

The purpose of this study was to examine the initial viscosity and adhesive strength of commercial denture adhesives and oral moisturizers.

Materials and Methods

Four cream-type denture adhesives (Poligrip S, Liodent Cream, Corect Cream, Tafugrip Cream; PGS, LDC, COC, TGC), one gel-type denture adhesive (Tafugrip Gel; TGG) and three gel-type oral moisturizers (Fit Angel Gel, Biotene Oral Balance, Bio Xtra Aqua Mouth Gel; FAG, BOB, BMG) were used in the study (Table 1). The initial viscosity of the materials was measured using a controlled-stress CarriMed CSL500 rheometer (TA Instruments Ltd., New Castle, DE, USA) in dynamic oscillation mode with a cone-and-plate configuration. The radius of the upper cone was 10 mm with a 2° cone angle and the gap between the plates was 54 μm (Fig. 1). The instrument was used in a constant strain mode with an angular velocity of 10 rad/s at 37°C.

Table 1. Used commercial materials

Code	Materials	Manufacturers	Type
FAG	Fit Angel Gel	Panasonic Dental Co., Ltd., Osaka, Japan	Oral moisturizer
BOB	Biotene Oral Balance	Lacleden Inc., Rancho Dominguez, USA	
BMG	Bio Xtra Aqua Mouth Gel	Weltec Co., Osaka, Japan	
TGG	Tafugrip Gel	Kobayashi Pharmaceutical Co., Ltd., Osaka, Japan	Gel-type denture adhesive
PGS	Poligrip S	Glaxo Smith Kline K.K., Tokyo, Japan	Cream-type denture adhesive
LDC	Liodent Cream	Lion Co., Tokyo, Japan	
COC	Corect Cream	Shionogi & Co., Ltd., Osaka, Japan	
TGC	Tafugrip Cream	Kobayashi Pharmaceutical Co., Ltd.	

The adhesive strength was measured according to the ISO-10873 recommended procedures.[33] The hole of the sample holder (Fig. 2) was filled with denture adhesive, and the surface was flattened. The sample holder was then immersed in water at 37°C for 0, 1, and 10 minutes. The holder was removed and shaken once to remove water from the sample surface. The sample holder was fixed on the sample stand, and a load of 9.8±0.2 N was applied to the sample using a constant load compression testing machine (A-001, Japan Mecc Co. Ltd., Tokyo, Japan) at a pressurizing velocity of 5 mm/minute using a 20±0.5 mm pressure sensitive knob, and maintained for 30 s. The sample was then pulled in the reverse direction with tensile velocity using a materials testing machine (Model 5565, Instron Co., Canton, MA, USA) at a crosshead speed of 5 mm/minute. The maximum force on the pressure sensitive knob was measured at that time and the force per unit area was set as the adhesive strength. The sample holder and pressure sensitive knob were prepared using denture base acrylic resin (Acron, Lot No. Powder-030471, Liquid-0112203; P/L:10/4.3 g; GC Corp., Tokyo, Japan), and were polymerized according to the manufacturer's instructions. The surfaces were abraded with 400 grit waterproof abrasive paper, scrubbed

with tap water for 15 s, and allowed to air dry for at least 5 minutes.

All the data were analyzed independently by one-way analysis of variance (ANOVA) and two-way ANOVA combined with a Student-Newman-Keuls (SNK) multiple comparison test at a 5% level of significance. All analyses were computed with PASW Statistics for Windows (PASW Statistics 18, SPSS Japan Inc., Tokyo, Japan).

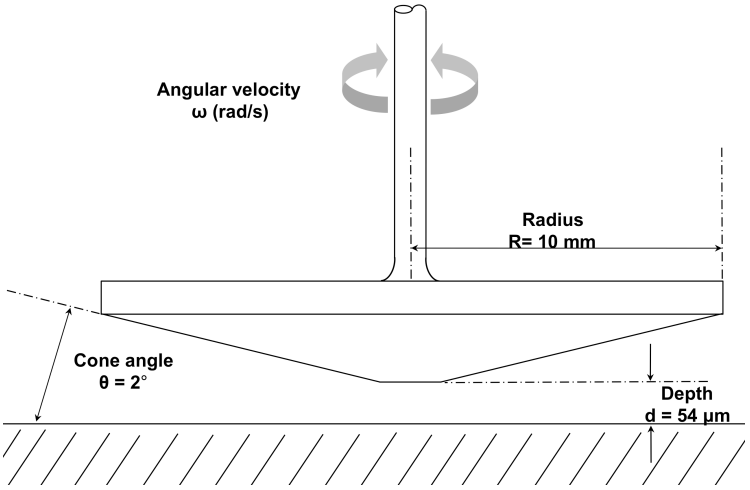


Fig. 1. Cone plate for viscosity test

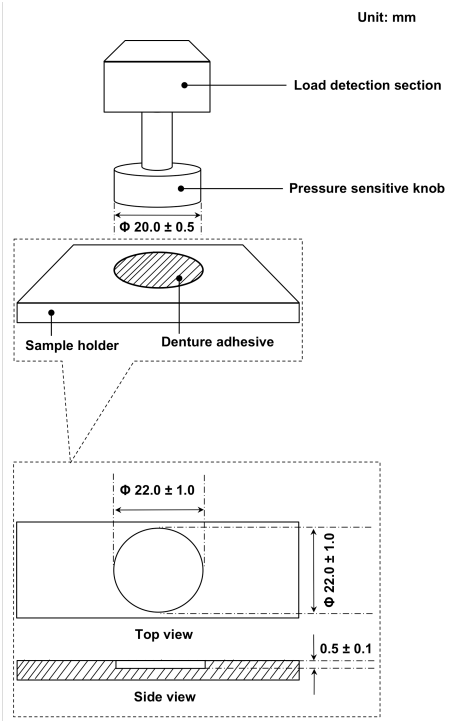
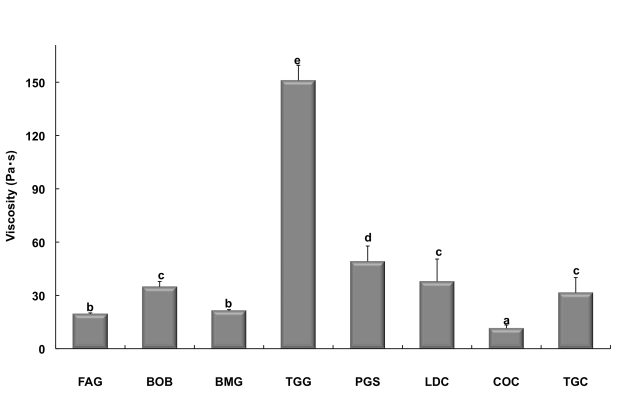


Fig. 2. Sample holder for the adhesive strength test

Results

Figure 3 shows the initial viscosity of materials tested. Significant differences were found between the different materials ($p<0.05$, one-way ANOVA). TGG had significantly higher viscosity than the other materials ($p<0.05$, SNK test), and COC had significantly lower viscosity ($p<0.05$, SNK test). The remaining materials recorded similar viscosity values.



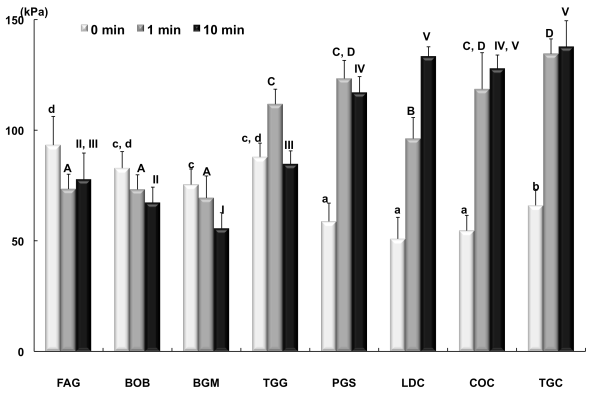


Fig. 3. Mean initial viscosity with standard deviation (left). Identical letters indicate no significant differences ($p>0.05$, SNK-test).
Fig. 4. Mean adhesive strength with standard deviation before and after immersion in distilled water (right). Identical letters indicate no significant differences ($p>0.05$, SNK-test).

Figure 4 shows the variations in adhesive strength of the different materials according to immersion time. The ANOVA results indicated significant differences among the materials and revealed significant effects of immersion time on adhesive strength ($p<0.05$). Before immersion, the oral moisturizers tended to exhibit higher adhesive strength than the denture adhesives. However, after immersion, this tendency was reversed. The adhesive strength of denture adhesives increased significantly ($p<0.05$, ANOVA) with immersion time except for the gel-type denture adhesive (TGG). The adhesive strength of TGG increased significantly up until 1 min after immersion, and then decreased significantly up until 10 minutes. The adhesive strength of the oral moisturizers decreased significantly with immersion time ($p<0.05$, ANOVA).

Discussion

In recent years, increasing numbers of patients have been complaining of dry mouth in line with the aging of society.[16,18] Dry mouth leads to difficulty in chewing food, speaking, swallowing, and considerable discomfort, and results in reduced quality of life.[17] Currently, there is no effective treatment for dry mouth except for symptomatic therapies,[18] with gel-type oral moisturizers being the most commonly used treatment.

Denture adhesives can be classified as cushion type, cream type, powder type and seal type.[3] In this study, cream-type denture adhesive and gel-type denture adhesives were used. Several cases have been reported of deformation of the mandibular alveolar ridge caused by home reliners (cushion-type denture adhesives), confirming that there is a risk of alveolar bone resorption caused by inappropriate use of home reliners.[7,8] Chew[4] reported that cream-type denture adhesives were significantly more effective in improving the retention between an acrylic disc and rat skin than powder and seat-type denture adhesives. Dental professionals are most likely to recommend a cream-type denture adhesive. A gel-type denture adhesive has been developed that is easier to remove from the oral mucosa than existing commercially available denture adhesives,[34] and whose main components differ from existing cream-type denture adhesives.

The initial viscosity of denture adhesives and oral moisturizers may affect their effectiveness, and is dependent on the composition of the material. Denture adhesives consist of a base and a thickening agent. In cream-type denture adhesives, vaseline is mainly used for the base, and water-soluble polymers, such as sodium carboxymethyl cellulose (CMC) and methoxy ethylene maleic anhydride copolymer (PVM-MA), are usually used for the thickening agent.[3,30,34] These cream-type denture adhesives first exhibit low viscosity. When the adhesive is placed in the mouth, they become viscous and sticky due to water absorption by the water-soluble polymer.[34] However, since PGG uses distilled water as the base,[34] the water-soluble polymer (CMC) of PGG is already saturated with water. This may explain why the initial viscosity of PGG is higher than the other cream-type denture adhesives. Other differences between the initial viscosity of cream-type denture adhesives may be due to variations in the type and content of thickening agent used. Unlike denture adhesives, gel-type oral moisturizers consist of a base (mainly water) and a moisturing component such as glycerin, sorbitol, or hydrolyzed hydrogenated starch. Thickening agents such as CMC are present in small amounts,[28,29] which may explain why the initial viscosity of oral moisturizers is low.

The main reasons for using denture adhesives are to improve fit, comfort, chewing ability, and also to improve patient confidence in wearing dentures.[5,11] Therefore, the adhesive strength of the denture adhesive is the most important factor for clinical use of these materials. According to the ISO standards,[33] the adhesion strength must be 5 kPa or more. The adhesive strength of all denture adhesives used in our experiment was higher than 5 kPa,

thus meeting the ISO standard. Therefore, all denture adhesives used in this study were acceptable for clinical use. The adhesive strength of the gel-type oral moisturizers decreased with immersion time; and the adhesive strength of the cream-type denture adhesives increased with immersion time. According to several reports, cream-type denture adhesives showed higher adhesive strength after application,[2,4,10] due to water absorption by the water-soluble polymer.[34] These materials form water-soluble macromolecules which absorb water over time and increase in viscosity, thus increasing the retention of the denture. According to Chew,[4] denture adhesives are most effective one hour after application. Therefore, if our study had continued measurements over a longer time interval, the adhesive strength of the cream-type denture adhesives may have increased even more. The major component of gel-type oral moisturizers is water, glycerin and sorbitol.[28,29] These components are soluble in water and hygroscopic by nature. This could explain why the adhesive strength of the oral moisturizers decreased with immersion time. Since PGG has water as a base, it is thought that it is initially more soluble in water than cream-type denture adhesives which use a grease component for the base. This may be the reason why the adhesive strength of TGG increased until 1 minute after immersion, then decreased over the next 10 minutes.

The results of this study indicate that cream-type denture adhesives and oral moisturizers exhibit similar initial viscosity, but they possess different adhesion behaviors. Our study did not completely simulate clinical behavior because the specimens were tested for viscosity in a dry state, and all adhesive strength tests were conducted after immersion in distilled water. It is unknown whether these results can be generalized to other samples. To overcome the limitations of the in vitro tests, artificial saliva should be used as an immersion solution. For a more complete understanding of the differences in adhesion behavior between denture adhesives and oral moisturizers, a study should be conducted to assess the influence of denture adhesives and oral moisturizers on the measurement of bite force until denture dislodgement in complete denture wearers.

Our findings indicate that oral moisturizers provide the best properties for denture retention, stability and function. The adhesive strength of gel-type denture adhesive (TGG) was observed to decrease from its initial adhesive strength over the first 10 minutes. Dentists should understand the differences in the properties of denture adhesives and oral moisturizers, and should be careful to choose the most appropriate materials for clinical use.

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Correspondence to:

Dr. Guang Hong
Liaison Center for Innovative Dentistry, Graduate School of Dentistry, Tohoku University
4-1 Seiryo-machi, Aoba-ku, Sendai, 980-8575, Japan
Fax: +81-22-717-8345 E-mail: hong@m.tohoku.ac.jp

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