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Comparison of adhesiveness of chewing gum to hard and soft denture base materials

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[Abstract]

Purpose: The purpose of this study was to compare the adhesiveness of chewing gum to hard and soft denture base materials to investigate food retention associated with the basal surface of the denture. Methods: Test specimens were fabricated using acrylic resin[Re], cobalt-chromium alloy[Co], zirconia[Zr], silicone soft relining material[SS], and acrylic soft relining material[AS]. Samples were set on a top-and-bottom pair lifting platform equipped with a digital force gauge. The experimenter chewed 3.0g of chewing gum for 5 minutes. After surface saliva was wiped off, the chewing gum was placed on the lower test fragment and compressed until the distance between the upper and lower test fragments decreased to 1mm. The upper test fragment was pulled at a crosshead speed of 100mm/min. Adhesiveness was measured under dry conditions, and under wet conditions with inter-positioned artificial saliva.

Results: Under dry conditions, the adhesive strength was 17.04±1.99N for Re, 12.88±2.20N for Co, 3.80±1.03N for Zr, 5.76±1.41N for SS, and 12.54±2.44N for AS. Under wet conditions, the adhesive strength was 5.26±1.64N for Re, 0.96±0.21N for Co, 3.32±0.40N for Zr, 5.20±1.35N for SS, and 6.78±1.97N for AS.

Conclusions: Among the hard denture base materials, zirconia recorded low adhesiveness and Re recorded high adhesiveness under both wet and dry conditions. The adhesiveness of Co was low under wet conditions but high under dry conditions. Among the soft denture base materials, SS under dry conditions recorded lower adhesiveness than that of AS. The adhesiveness of SS was low under both wet and dry conditions.

1. Introduction

With the increase in the elderly population, the number of older adults requiring nursing care has also been increasing. Many older persons requiring nursing care cannot adequately clean their mouth, and food debris is often found adhering to the basal surface of the denture on removal. Wearing a
denture for a long time without sufficient cleaning of the basal surface may result in denture stomatitis and aspiration pneumonia [1,2].

Acrylic resin is generally used as the material for the basal surface of dentures. Metals, such as cobalt-chromium alloy, and ceramics, such as zirconia, are also used. Generally, most of dentists hesitate using silicone soft relining materials for elderly because silicone materials get dirty more easily. On the other hand, the thinning of denture underlying tissue, ridge of alveolar bone after tooth extraction, and large bite force may cause pain and may not improve even if removable dentures are adjusted. In these cases, relining of the denture with soft relining material is effective in reducing pain. In Japan, silicone and acrylic soft relining materials have become more widely used by dentists since their inclusion under national health insurance in 2016. Japan, as a super-aging society, has many elderly patients, including many in whom the condition of the residual ridge is poor. Thus, soft relining materials may be increasingly used in the future.

We previously investigated the adhesiveness of chewing gum to acrylic resin, cobalt-chromium alloy, and zirconia as materials used for the polished surface of dentures, and clarified that zirconia has low adhesiveness to chewing gum under both wet and dry conditions [3]. However, retention of food on the basal surface of dentures was not investigated.

In this study, we selected chewing gum as a food likely to adhere to dentures and compared the adhesiveness of chewing gum to hard and soft denture base materials to investigate the differences in food retention associated with the basal surface of dentures.

The null hypothesis of this study was that the adhesive strength of chewing gum to the materials used for the denture mucosal surface does not significantly differ among resin, soft relining materials, cobalt-chromium alloy, and zirconia.

2. Materials and Methods

2.1. Test fragment
Five types of test fragment were prepared (Figure 1): acrylic resin [Re], cobalt-chromium alloy [Co], zirconia [Zr], silicone soft relining material [SS], and acrylic soft relining material [AS].

Using Acron (GC, Tokyo, Japan) for Re, Cobalt Chrome MC alloy (Dentsply Sirona K.K., Tokyo, Japan) for Co, and Ce-TZP/Al₂O₃ nano composite (P-Nano ZR, Panasonic Healthcare Holdings Co. Ltd, Tokyo, Japan) for Zr, 10 test fragments (20 × 20 × 4 mm) were prepared with each material. Using GC Reline II Soft (GC) for SS, and Physio Soft Rebase (Nissin, Kyoto, Japan) for AS, samples (20 × 20 × 2 mm) were affixed to acrylic resin (20 × 20 × 2 mm).

To simulate the basal surface of a denture, Re, SS, and AS samples were cleaned by ultrasonication for 10 minutes after deflasking without polishing. The Co sample was cleaned by sandblasting after casting, and the Zr sample was cleaned using Zircon-Brite (Dental Ventures of America, Inc., California, USA) after milling. In cleaning by blasting, alumina powder with a mean particle size of 25 µm was injected at 0.45 MPa, followed by removal of alumina adhering to the test fragment using compressed air.

2.2. Chewing gum adhesion test

The sample was set on the top-and-bottom pair lifting platform equipped with a digital force gauge (DS2-50N, Imada Co. Ltd, Aichi, Japan). The experimenter chewed 3.0 g of chewing gum (xylitol gum, Lotte Co. Ltd, Tokyo, Japan) for 5 minutes. Saliva on the surface was wiped off, and the chewing gum was placed on the lower test fragment and compressed until the distance between the upper and lower test fragments decreased to 1 mm. The upper test fragment was then pulled at a crosshead speed of 100 mm/min. The maximum stress was measured five times in each group as an index of the adhesive strength of the gum. Measurements were performed under two conditions for each of the Re, Co, Zr, SS, and AS samples: dry conditions, and wet conditions with inter-positioned artificial saliva (40 µL of 60% aqueous glycerin solution). The experiments were conducted in a quiet room with a temperature of 20 ± 2 °C and a humidity of 50 ± 10%.
2.3. Surface roughness

Surface roughness was measured using a contact-type surface roughness tester (Surfcom 130A, Tokyo Seimitsu Co. Ltd, Tokyo, Japan). The arithmetic mean roughness (Ra) of each test fragment was measured (n = 10).

2.4. Wettability

To measure wettability, purified water was dripped on the test fragment and the contact angle was measured using an image analyzer (ImageJ, National Institutes of Health, Bethesda, MD, USA) (n = 10).

2.5. Statistical analysis

Kolmogolov-Smirnov test was used for the test of normality. Levene test was used for the test of homscedasticity (chewing gum adhesion under dry condition p=0.280, chewing gum adhesion under wet condition p=0.157, surface roughness p=0.141, wettability p=0.221). Chewing gum adhesion, surface roughness, and wettability were analyzed using one-way analysis of variance followed by the Scheffe test. The significance level was set at 0.05. Statistical analysis was performed using SPSS (Standard Version 25, IBM Corporation, NY, USA).

3. Results

The results of the chewing gum adhesion test for each test fragment are shown in Figures 2 and 3. Under dry conditions, the adhesive strength was 17.04 ± 1.99 N for Re, 12.88 ± 2.20 N for Co, 3.80 ± 1.03 N for Zr, 5.76 ± 1.41 N for SS, and 12.54 ± 2.44 N for AS. Significant differences were noted between Re and Co (p=0.041), between Re and Zr (p<0.001), between Re and SS (p<0.001), between Re and AS (p=0.024), between Co and Zr (p<0.001), between Co and SS (p<0.001), between
Zr and AS (p<0.001), and between SS and AS (p<0.001). Under wet conditions, the adhesive strength was 5.26 ± 1.64 N for Re, 0.96 ± 0.21 N for Co, 3.32 ± 0.40 N for Zr, 5.20 ± 1.35 N for SS, and 6.78 ± 1.97 N for AS. Significant differences were noted between Re and Co (p=0.001), between Co and SS (p=0.002), between Co and AS (p<0.001), and between Zr and AS (p=0.011).

The results of the arithmetic mean roughness of each test fragment (Ra) are shown in Figure 4. The arithmetic mean roughness was 0.89 ± 0.20 μm for Re, 0.93 ± 0.10 μm for Co, 0.40 ± 0.03 μm for Zr, 1.05 ± 0.15 μm for SS, and 0.92 ± 0.18 μm for AS. Significant differences were noted between Re and Zr (p<0.001), between Co and Zr (p<0.001), between Zr and SS (p<0.001), and between Zr and AS (p<0.001).

The results of the contact angle of each test fragment (wettability) are shown in Figure 5. The contact angle was 64.4 ± 8.2° for Re, 53.6 ± 3.8° for Co, 61.7 ± 4.7° for Zr, 71.8 ± 3.8° for SS, and 65.1 ± 9.0° for AS. Significant differences were noted between Re and Co (p=0.012), between Co and SS (p<0.001), between Co and AS (p=0.002), and between Zr and SS (p=0.008).

4. Discussion

The adhesiveness of food to each material of the denture mucosal surface was investigated employing the chewing gum adhesion test which was used to investigate the adhesiveness of food in previous studies. Previous studies clarified that chewing gum adheres more readily to resin than metals under wet conditions [4], and is more likely to adhere to denture base material under wet than dry conditions [5]. In our previous study that simulated the polished surface of a denture, chewing gum was unlikely to adhere to zirconia under either wet or dry conditions [3]. Because the present study was performed to simulate the basal surface of the denture, the surfaces of Re, Co, and Zr were rougher than those in the previous study of the polished surface of the denture; however, we found that food adhesiveness was similar in both studies. Chewing gum adhered more readily to Re than to Co under both wet and dry conditions, whereas chewing gum did not readily adhere to Zr under either wet or
dry conditions. The adhesive strength of chewing gum to SS was comparable to that of Zr under wet and dry conditions. The adhesive strength of chewing gum to AS was comparable to that of SS under wet conditions, but AS adhered more readily than SS under dry conditions. From these results, the null hypothesis of this study was rejected.

The adhesive strength of both Co and Zr was low under wet conditions, suggesting that food is unlikely to be retained on these materials under wet conditions. However, the oral cavity is dry in many elderly patients, and the adhesive strength of Co under dry conditions was significantly higher than that of Zr and SS. Because the adhesive strength of Zr and SS under dry conditions was as low as that under wet conditions, a denture with low food retention may be prepared for any patient by applying zirconia or silicone soft relining material to the basal surface of the denture. Additionally, zirconia is unlikely to be adhered to by bacteria [6]. Therefore, application of zirconia to the palatal region of dentures may inhibit adherence by not only food but also bacteria, making denture cleaning easier than for other denture base materials. Furthermore, the use of zirconia as the denture base is thought to minimize the effects on the gustatory threshold and to improve comfort for the wearer [7], suggesting that dentures with a zirconia base provide a higher quality of life for patients.

A limitation of this study was that the adhesiveness of food to each material was investigated only immediately after preparation of the denture in vitro and the adhesion and stagnancy of food debris on the mucosa were not investigated in an actual denture-attached state, so that these could not be directly evaluated. However, it is difficult to measure the adhesion and retention of food in patients using a denture prepared with each material because diverse factors are involved. Since the test fragments prepared under the same conditions were subjected to the chewing gum adhesion test, we consider that useful basic information for comparison of adhesiveness of food among the materials could be obtained.

Acrylic soft relining materials are thought to have superior stress breaking effects to silicone soft relining materials [8], but the physical properties deteriorate with time and the stress breaking effect
decreases [9]. In contrast, although the stress breaking effect of silicone soft relining materials is originally weaker than that of acrylic materials, the effect is retained for a long time because less deterioration occurs over time [10]. Accordingly, silicone soft relining materials are used as the first choice. Denture cleaning methods include mechanical cleaning using a denture brush and chemical cleaning using a denture cleanser. A titanium dioxide coating can be applied to acrylic resin to create an antifouling effect [11], but coating of other materials is difficult. Therefore, denture cleaning is important to maintain denture hygiene. However, mechanical cleaning using a denture brush roughens the surface of the soft relining material [12], allowing bacteria to more readily adhere to the surface [13]. For this reason, dentures with soft relining material are generally cleaned chemically with a denture cleanser rather than mechanically. Denture cleaning nevertheless remains more important for soft relining materials because of the higher bacterial adherence compared with acrylic resin [14]. This study confirmed that silicone soft relining materials are less likely than acrylic soft relining material to be adhered to by chewing gum, suggesting that silicone is the first choice for a soft relining material with regard to reducing food retention. Methods are now available for applying a silicone soft relining material to the female part of overdenture attachments, making them easy to wear and exchange [15], suggesting that the attachment part can be maintained in a clean condition using a silicone soft relining material.

5. Conclusions

The following results were acquired under the conditions of this study simulating the basal surface of a denture:

1) Among the hard denture base materials, the adhesiveness of chewing gum to zirconia was low under both wet and dry conditions. The adhesiveness of chewing gum to cobalt-chromium alloy was low under wet conditions but high under dry conditions. The adhesiveness of chewing gum to acrylic resin was high under wet and dry conditions.
2) Among the soft denture base materials, the adhesiveness of chewing gum to silicone soft relining material under dry conditions was lower than that of acrylic soft relining material. The adhesiveness of chewing gum to silicone soft relining material was low under both wet and dry conditions.
[References]


Figure 1. Test fragments

Five types of test fragment were prepared: acrylic resin [Re], cobalt-chromium alloy [Co], zirconia [Zr], silicone soft relining material [SS], and acrylic soft relining material [AS].

Figure 2. Adhesive strength of chewing gum under dry conditions

Re, acrylic resin; Co, cobalt-chromium alloy; Zr, zirconia; SS, silicone soft relining material; AS, acrylic soft relining material. Superscript letters indicate significant differences between each group (p < 0.05). Significant differences were noted between Re and Co, between Re and Zr, between Re and SS, between Re and AS, between Co and Zr, between Co and SS, between Zr and AS, and between SS and AS.

Figure 3. Adhesive strength of chewing gum under wet conditions

Re, acrylic resin; Co, cobalt-chromium alloy; Zr, zirconia; SS, silicone soft relining material; AS, acrylic soft relining material. Superscript letters indicate significant differences between each group (p < 0.05). Significant differences were noted between Re and Co, between Co and SS, between Co and AS, and between Zr and AS.

Figure 4. Surface roughness

Re, acrylic resin; Co, cobalt-chromium alloy; Zr, zirconia; SS, silicone soft relining material; AS, acrylic soft relining material. Significant differences were noted between Re and Zr, between Co and Zr, between Zr and SS, and between Zr and AS.
Figure 5. Contact angle

Re, acrylic resin; Co, cobalt-chromium alloy; Zr, zirconia; SS, silicone soft relining material; AS, acrylic soft relining material. Significant differences were noted between Re and Co, between Co and SS, between Co and AS, and between Zr and SS.
Figure 1
Figure 2
Figure 3
Figure 4
Figure 5