Original Article

Comparison of Adhesive Resistance to Chewing Gum among Denture Base Acrylic Resin, Cobalt-Chromium Alloy, and Zirconia

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Received 12 June, 2015/Accepted for publication 6 August, 2015

Abstract

The purpose of this study was to compare the adhesiveness of chewing gum to acrylic resin, cobalt-chromium alloy, and zirconia. Test specimens were fabricated using acrylic resin (resin), cobalt-chromium alloy (Co-Cr), and Ceria stabilized tetragonal zirconia polycrystal-based nanostructured zirconia/alumina composite (zirconia). Specimens of each material were attached to the upper and lower terminals of a digital force gauge. The operator masticated chewing gum, wiped off any saliva, and placed the gum on the lower specimen. The gum was compressed to a thickness of 1 mm between the upper and lower specimens. Thereafter, traction was applied to the upper specimen at a cross-head speed of 100 mm/min under 3 different conditions (dry, wet with distilled water, and wet with artificial saliva) to determine the maximum adhesive strength of the chewing gum. The statistical analysis was performed using the Bonferroni test after a one-way analysis of variance ($\alpha=0.05$). Under dry conditions, adhesive force was 14.8 ± 6.8 N for resin, 14.0 ± 4.8 N for Co-Cr, and 4.3 ± 2.3 N for zirconia. Significant differences were noted between resin and zirconia, and between Co-Cr and zirconia. When distilled water was applied to the specimen surface, the adhesive strength was 16.8 ± 1.7 N for resin, 8.3 ± 2.1 N for Co-Cr, and 2.7 ± 0.8 N for zirconia. Significant differences were noted between resin and Co-Cr, resin and zirconia, and Co-Cr and zirconia. When artificial saliva was applied to the specimen surface, the adhesive force was 18.5 ± 2.8 N for resin, 5.3 ± 0.8 N for Co-Cr, and 3.0 ± 1.7 N for zirconia. Significant differences were noted between resin and Co-Cr, and resin and zirconia. Chewing gum adhered less strongly to zirconia than to acrylic resin or cobalt-chromium alloy.

Key words: Denture — Zirconium oxide — Ce-TZP- Al_2O_3 — Chewing gum adhesion

Introduction

Acrylic resin and cobalt-chromium alloy are often used to fabricate the palatal area of denture bases. Using a metal material

enhances ease of wear as thickness can be reduced. Furthermore, the high thermal conductivity of metal enhances wearer perception of change in temperature. All these factors serve to increase comfort, and patient

satisfaction is known to be high with such dentures. Some patients are allergic to metal, however, while others simply find the idea of wearing metal in the oral cavity unpleasant. This means that a metal base is often out of the question in such patients.

Zirconia has excellent mechanical characteristics¹⁾, is highly stable, and impermeable to water. It is used in fixed prosthetic appliances and oral implants. In addition, the results of four-point bending tests have shown that it can bear the same load as cobalt-chromium⁵⁾. This allows zirconia dentures to be fabricated with the same palatal thickness as that of metal-based dentures, but without the risk of causing an allergic reaction.

Among other effects, mastication induces an increase in salivary secretion, activating the brain, and relieving stress^{10,11)}. It is thought that these effects are particularly marked while chewing gum, because of the long duration of masticatory movement required. However, gum is apt to adhere to conventional denture base materials such as resin and metal, making it difficult for denture-wearers to chew. Bacteria do not readily adhere to zirconia⁶⁾, and highly adhesive foods such as chewing gum may also adhere less readily to this material. The purpose of this study was to compare the adhesiveness of chewing gum to acrylic resin, cobalt-chromium alloy, and zirconia.

Materials and Methods

1. Test specimens

Pairs of specimens $20 \times 20 \times 20$ mm in size were produced (Fig. 1) in each of the 3 following materials: 1) acrylic resin (resin; Acron, GC, Tokyo, Japan); 2) cobalt-chromium alloy (Co-Cr; Wironium, BEGO, Bremen, Germany); and Ceria stabilized tetragonal zirconia polycrystal-based nanostructured zirconia/alumina composite (Ce-TZP/ Al_2O_3 nanocomposite) (zirconia; P-Nano ZR, Panasonic Health Holdings Co., Ltd., Tokyo, Japan). Each specimen was polished according to the conventional method; Blazing Quick (BSA

Fig. 1 Test specimens
(a) resin, (b) cobalt-chromium, (c) zirconia

Sakurai Co., Ltd., Aichi, Japan) was used for final polishing of resin and Co-Cr, and ZIRCON BRITE (Dental Ventures of America Inc., California, USA) for that of zirconia.

2. Surface roughness

The arithmetic average roughness (Ra) of each surface of the test specimens was measured using a contact-type roughness test machine (Surfcom 130A, Tokyo Seimitsu Co., Ltd., Tokyo, Japan). Twelve measurements were performed under each of 3 conditions: dry, wet with distilled water, and wet with artificial saliva. The cut-off value was 0.8 mm. The measurement length was 4.0 mm.

3. Wettability

Four micro-liters distilled water was dropped onto each specimen and the contact angle measured with an image analyzer (ImageJ, National Institutes of Health, Bethesda, MD, USA) to determine wettability. Twelve measurements were performed under each condition.

4. Chewing gum adhesion test

Each pair of specimens was mounted on a digital force gauge, one attached to the upper and one to the lower terminal (DSN-50N, Imada Co., Ltd., Aichi, Japan) (Fig. 2). The operator was required to masticate 3 grams of chewing gum (Xylitol gum, Lotte Co., Ltd., Tokyo, Japan) for 5 min and then place it on the lower specimen after wiping away any adhered saliva. The gum was then compressed to a thickness of 1 mm between the upper and lower specimens. Traction was then applied to the upper specimen at a cross-head speed of 100 mm/min and 5 measurements performed, setting maximum

Fig. 2 Chewing gum adhesion test

Specimens of each material were attached to upper and lower terminals. Chewing gum was masticated for 5 min and then placed on lower specimen after wiping saliva from surface. Gum was compressed to thickness of 1 mm between upper and lower specimens. Thereafter, traction was applied to upper specimen at cross-head speed of 100 mm/min. Five measurements were performed under each condition.

stress as the adhesive strength for each test. Each of the 3 materials (resin, Co-Cr, and zirconia) was tested under each of the 3 set conditions: dry, wet with distilled water (40 μ l), and wet with artificial saliva (60% glycerol aqueous solution). The experiments were conducted in a quiet room at a temperature of $20 \pm 2^\circ\text{C}$ and humidity of $50 \pm 10\%$.

5. Statistical analysis

Surface roughness, wettability, and adhesive strength of chewing gum were analyzed using a one-way analysis of variance. Comparisons among groups were performed using the Bonferroni test ($\alpha = 0.05$). Statistical software (SPSS, standard version 16, International Business Machines Corporation, NY, USA) was used for the analysis.

Fig. 3 Surface roughness (Ra) test

Surface roughness (Ra) was measured using contact-type roughness test machine (Surfcom 130A, Tokyo Seimitsu Co., Ltd.). Ra was $0.30 \pm 0.02 \mu\text{m}$ for resin [R], $0.28 \pm 0.02 \mu\text{m}$ for Co-Cr [C], and $0.40 \pm 0.03 \mu\text{m}$ for zirconia [Z]. Significant differences were noted between R and Z, and between C and Z.

Results

1. Surface roughness

Figure 3 shows the Ra for each test specimen (resin, $0.30 \pm 0.02 \mu\text{m}$; Co-Cr, $0.28 \pm 0.02 \mu\text{m}$; and zirconia, $0.40 \pm 0.03 \mu\text{m}$). Significant differences were noted between resin and zirconia, and between Co-Cr and zirconia.

2. Wettability

Figure 4 shows the wettability of each test specimen as determined by contact angle (resin, $71.5 \pm 3.2^\circ$; Co-Cr, $84.9 \pm 3.9^\circ$; and zirconia, $78.9 \pm 2.2^\circ$). Significant differences were noted between resin and Co-Cr, and between resin and zirconia.

3. Chewing gum adhesion test

Figure 5 shows the adhesive strength of chewing gum under each condition (dry, wet with distilled water, and wet with artificial saliva). Under dry, adhesive strength was $14.8 \pm 6.8 \text{ N}$ for resin, $14.0 \pm 4.8 \text{ N}$ for Co-Cr, and $4.3 \pm 2.3 \text{ N}$ for zirconia. Significant differences were noted between resin and zirconia, and between Co-Cr and zirconia.

When distilled water was applied to the specimen surface, adhesive strength was 16.8

Fig. 4 Contact angle

After dropping distilled water onto test specimen, contact angle was measured using image analyzer (ImageJ, National Institutes of Health). Contact angle was $71.5 \pm 3.2^\circ$ for resin [R], $84.9 \pm 3.9^\circ$ for Co-Cr [C], and $78.9 \pm 2.2^\circ$ for zirconia [Z]. Significant differences were noted between R and C, and between R and Z.

Fig. 5 Adhesive strength of chewing gum

Under dry conditions, adhesive strength of chewing gum was 14.8 ± 6.8 N for resin [R], 14.0 ± 4.8 N for Co-Cr [C], and 4.3 ± 2.3 N for zirconia [Z]. When distilled water was applied to specimen surface, adhesive strength was 16.8 ± 1.7 N for resin, 8.3 ± 2.1 N for Co-Cr, and 2.7 ± 0.8 N for zirconia. When artificial saliva was applied to specimen surface, adhesive strength was 18.5 ± 2.8 N for resin, 5.3 ± 0.8 N for Co-Cr, and 3.0 ± 1.7 N for zirconia.

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Discussion

Yttria-stabilized zirconia (Y-TZP), which can bear the same load as cobalt-chromium according to the four-point bending test⁵⁾, is frequently used in crowns and bridges. However, Y-TZP exhibits low-temperature degradation when exposed to the wet environment of the oral cavity for a prolonged period⁸⁾. The nanocomposite Ce-TZP/ Al_2O_3 does not exhibit low-temperature degradation²⁾, however, and has more favorable physical characteristics than Y-TZP⁹⁾. Therefore, P-Nano ZR is a more appropriate choice for use in

the palatal area of dentures. Ease of fit has been reported to be favorable and patient satisfaction high in dentures incorporating P-Nano ZR in the palatal area⁴⁾.

Generally, adhesiveness increases when the Ra is high and contact angle small. Chewing gum adheres more easily to resin than metals under wet conditions⁷⁾, and adheres more easily to denture base materials under dry than wet conditions³⁾. In the present study, resin showed high adhesiveness under all conditions. The adhesiveness of Co-Cr was equivalent to that of resin under dry conditions; adhesiveness decreased, however, under wet conditions, exhibiting the same degree of adhesiveness as zirconia when artificial saliva was applied to more closely simulate intraoral conditions. The contact angle of Co-Cr was larger than that of resin, possibly because the adhesiveness of chewing gum decreased owing to the presence of water or artificial saliva between the chewing gum and the test specimen. Although the Ra of zirconia was the highest, chewing gum did not easily adhere to it under any condition. We were unable to explain this anomaly and believe

the underlying mechanism involved merits further investigation. The present findings suggest that chewing gum does not readily adhere to dentures when the intraoral cavity is sufficiently wet with saliva, or when the palatal area of the denture is fabricated with metal or zirconia rather than resin. However, the intraoral cavity of denture wearers, particularly elderly denture wearers, is not always as wet as it was under our experimental conditions. Zirconia exhibited low adhesiveness under both wet and dry conditions, indicating that dentures with a zirconia palatal area may allow patients to eat food with high adhesiveness more easily.

Conclusion

The present results revealed that chewing gum adheres less to zirconia than to resin or Co-Cr.

Disclosure

The zirconia specimens were provided by Panasonic Healthcare. The sponsor had no control over the interpretation, writing, or publication of this work. All authors declare that there is no conflict of interest related to this study.

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