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Color and gloss evaluation of titanium dioxide coating for acrylic resin denture base

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ABSTRACT

Purpose: We examined the clinical appearance (color, gloss, and surface roughness) of TiO_2 coating on polymethyl methacrylate (PMMA) resin dentures.
Methods: A spraying method, using air brushes, was used to generate thin uniform TiO_2 coating. PMMA resin, primer-coated PMMA, and TiO_2-coated PMMA (with primer) specimens were compared.
Results: The Commission Internationale de l'Eclairage (CIE) color system revealed color variations between the with/without coated samples. The TiO_2-coated PMMA specimen displayed high levels of glossiness, highlighting the efficient self-cleansing actions of the denture. The measured surface roughness decreased upon primer coating, and increased following TiO_2 coating.
Conclusions: The thin TiO_2 coating afforded high levels of glossiness while maintaining the color of the denture base material.

1. Introduction

Acrylic resin is frequently used as a denture base material owing to its physical properties and esthetics [1]. However, acrylic resin degrades because of bacteria and fungi adhesion onto it [2,3], microbial invasion and colonization owing to water absorption [4], and surface roughening owing to mechanical and chemical cleaning [5]. Therefore, to improve the quality of the surface of resin, the titanium dioxide coating is used. The titanium dioxide coating on acrylic resin denture bases improves wettability, reduces adhesion of food bolus [6], and suppresses adhesion of bacteria and fungi [7]. We have reported that the use of a primer agent, which primarily consists of acryloxypropyl methoxysilane, for pre-treatment of the titanium dioxide coating affords durability of the titanium dioxide coating against brushing [8]. Moreover, the biocompatibility of a primer agent and TiO_2 coating agent has been already demonstrated [9].

To produce satisfactory dentures for patients, it is necessary to not only consider functionality, but also esthetic aspects [10,11]. Although self-cleansing action can be added by titanium dioxide coating, there is a possibility that the color of dentures will change by white color of titanium dioxide materials. Furthermore, final polishing is not performed before the coating process to increase the surface area of

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coating; therefore, the surface is constant rough (R_a: about 0.3 μm). This may influence the esthetic features of dentures. Therefore, it is necessary to evaluate the clinical appearance of the titanium dioxide coating.

Rough surface of denture bases has no high level glossiness. However, the addition of glossiness has a positive influence on patients' satisfaction. Regarding the self-cleansing action and esthetic features of denture base materials, although there are differences in the re-contouring and polishing work among clinicians and dental technicians depending on the methods used and clinical experience, these processes are generally time-consuming regardless of the type of polishing instrument [12,13]. The polishing of morphologically complicated denture areas is not regular; consequently, the self-cleansing action and esthetic features of denture bases deteriorate. Furthermore, because the lubrication and glossiness of the surface acrylic resin denture base are lost during long-term use, it is difficult to retain good esthetic properties for a long period. Therefore, to simplify the manual process of denture polishing, to avoid long hours of dental laboratory work and to standardize products, surface glazing agents are used [14]. The characteristic requirements of surface glazing agents are lubrication and surface durability following treatment [15]. Furthermore, the surface glazing agent should not influence the color of the base material following application. So this coating material may also be able to be used as the surface glazing agent if it could afford the high levels of glossiness to dentures.

In this study, we investigate the influence of the titanium dioxide coating on the appearance of resin denture bases. We compare the color and degree of glossiness in the presence and absence of titanium dioxide coating.

2. Materials and methods

2.1. Plate specimens

Polymethyl methacrylate (PMMA) samples were prepared from wet-heat-curing acrylic resin (Acron, GC Corporation, Tokyo, Japan). The powder-to-liquid volume ratio was 1:0.43. The resulting mixture was packed into a plaster mold (18 mm in diameter, 1.0 mm in depth), and immersed in water at 60 °C for 60 min (for primary polymerization) and then in boiling water for 60 min (for secondary polymerization). Specimens were lapped up to the equivalent of grit #1000 using wet abrasive paper to make rough surface (R_a: about 0.3 μm).

2.2. TiO_2 coating

The PMMA specimens were pre-treated with a primer agent (Paltitan PTI5603S, Nihon Parkerizing, Kanagawa, Japan), of which the main component is acryloxypropyl trimethoxysilane in ethanol, that was sprayed for 2 s using an air-brush gun (Super Airbrush Advance, WAVE, Tokyo, Japan) connected with 0.6 MPa compressed air, then dried for 10 min at 70 °C in air. TiO_2 coating agent (Paltitan PTI5603S, Nihon Parkerizing, Kanagawa, Japan), containing 2.0% anatase TiO_2 (5–10 nm in diameter) in water and ethanol, was then sprayed onto the substrate for 2 s and dried in an oven for 10 min at 70 °C. The specimens are denoted as PMMA, primer-coated PMMA, and TiO_2-coated PMMA (with primer). These specimens were sterilized with ethanol and stored in a dark room during one month until the experiment.

2.3. Measurements

The Commission Internationale de l'Eclairage (CIE) $L^*a^*b^*$ values were obtained using a reflective colorimeter (Shade Eye NCC, Shofu, Kyoto, Japan). All measurements were performed in triplicate with blocking out light on a black back ground. The measurement range was 3 mm in diameter. The number of specimens used per measurement was five ($n = 5$) and the means of L^*, a^*, and b^* were calculated. ΔE^*ab was calculated using the formula $\Delta E^*ab = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, where ΔE^*ab represents the color difference, and ΔL^*, Δa^*, and Δb^* represent differences in lightness, red–green scale color, and yellow–blue scale color, respectively [16]. Because the color system can be used as a color transfer standard with absolute color scales, the use of a control for comparison for each measurement is unnecessary. Thus, the color system is suitable for the evaluation of the different specimens in this study. Furthermore, ΔE^*ab can be used as an index to evaluate color differences when digitized colors are compared; when ΔE^*ab is large, color differences become clear.

The glossiness of each specimen was measured with a glossmeter (IG-331, Horiba, Tokyo, Japan) at an angle of 60° from the surface normal with blocking out light on a black back ground. The measurement range was 3 × 6 mm ellipse. Three measurements were obtained at different directions on each specimen. The number of specimens used per measurement was five ($n = 5$) and the mean glossiness was calculated to analyze.

The surface roughness of each specimen was measured with a profilometer (Surfcom 130A, Tokyo Seimitsu Co., Tokyo, Japan) using a tracing length of 4 mm and a cut-off value of 0.8 mm. Five tracings were recorded at different locations on each specimen. The number of specimens used per measurement was five ($n = 5$) and the mean roughness (R_a) was calculated to analyze.

The surface morphology was assessed using field-emission scanning electron microscopy (SEM) on a scanning electron microscope (SU6600, Hitachi, Tokyo, Japan).

2.4. Statistical analysis

One-way ANOVA with Bonferroni multiple comparison was used to examine differences between the three specimen groups; $p < 0.05$ was considered statistically significant.

3. Results

Fig. 1 shows the color data of each specimen. The means of the L^*, a^*, and b^* values of PMMA were 50.27 ± 0.62, 21.01 ± 0.37, and 11.77 ± 0.32, respectively. The primer-coated specimen featured L^*, a^*, and b^* means of 50.17 ± 0.73, 21.31 ± 0.47, and 12.07 ± 0.43, respectively. The TiO_2-coated specimen featured L^*, a^*, and b^* of 50.61 ± 0.39, 20.33 ± 0.36, and 11.09 ± 0.46, respectively. There were significant differences between the