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Original article

Color stability of glass-fiber-reinforced polypropylene for non-metal clasp dentures

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ABSTRACT

Purpose: The purpose of this study was to investigate the color stability of a glass-fiber-reinforced thermoplastic (GFRTP), for use in non-metal clasp dentures (NMCDs).
Methods: GFRTPs composed of E-glass fibers and polypropylene with 2 mass% of pigments were fabricated using injection molding. According to our previous study on the optimum fiber content for GFRTPs, we prepared GFRTPs with fiber contents of 0, 10, and 20 mass% (GF0, GF10, and GF20). Commercially available NMCD and PMMA materials were used as controls. The color changes of GFRTPs at 24 h, and at 1, 2, and 4 weeks of coffee immersion at 37 °C were measured by colorimetry, using the Commission Internationale de l'Eclairage (CIE) Lab system. The color stabilities of the GFRTPs were evaluated in two units: the color difference (ΔE^*) and National Bureau of Standards (NBS) units.
Results: After immersion, none of the GFRTPs showed visible color change. From the colorimetry measurement using the CIE Lab system, the ΔE^* values of the GFRTPs were 0.65–2.45. The NBS values of the GFRTPs were 0.60–2.25, all lower than the threshold level of 3.0, demonstrating clinically acceptable color changes. On the other hand, an available polyamide-based NMCD material exhibited "appreciable" color change, as measured in NBS units.
Conclusions: The results indicate that the GFRTPs showed clinically acceptable color stability and might be satisfactory for clinical use. Therefore, GFRTPs are expected to become attractive materials for esthetic dentures.

1. Introduction

Non-metal clasp dentures (NMCDs) made from thermoplastics such as polyamide, polyester, polycarbonate, and polypropylene have been used frequently as esthetic devices in prosthodontic treatment. NMCDs are considered superior to conventional removable partial dentures (RPDs) with metal clasps both in terms of esthetics and prevention of metal allergy [1–3]. However, using NMCDs without metal frameworks may seriously affect the remaining tissues because of such dentures' low rigidity. According to prosthetic principles, non-rigid NMCDs cannot be recommended as definitive dentures, except in limited cases, such as patients with metal allergies [1,2]. There is thus a need to develop NMCDs with improved strength and flexibility.

To address this issue, in a previous study we used injection molding to produce glass-fiber-reinforced thermoplastics (GFRTPs) of two types, made of polyamide and polypropylene, for NMCDs [4,5]. We also examined how the fiber content, from 0 to 50 mass%, affected the physical and mechanical properties of these GFRTPs, revealing that these materials could be tailored by varying their fiber content. However, GFRTPs made with a polyamide matrix were more brittle than those with a ductile polypropylene matrix, so the polypropylene GFRTPs had better properties for use in NMCDs than the polyamide GFRTPs. Moreover, the polypropylene GFRTPs with fiber contents of 10 and 20 mass% had good properties for use in NMCDs, because they had sufficient rigidity, similar to those of conventional polymethyl methacrylate (PMMA) dentures, and their flexibility was similar to those of available NMCDs [4].

In addition to evaluating such mechanical properties, the color stability of the GFRTPs must also be investigated. Several studies of the color stability of NMCDs have been reported [6–8]. Among them, Jang et al. [7] concluded that thermoplastic polyamide resin had acceptable color stability. In contrast, Takabayashi [8] reported that thermoplastic resins such as polyamide and polyester for NMCDs exhibited low water sorption and thus offered hygienic advantages; however, these resins may experience clinically noticeable staining. Likewise, Fueki et al. [1] concluded that NMCDs had substantial advantages over conventional RPDs with metal clasps, including good esthetics, good wearing feel, and

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prevention of metal allergy; however, NMCDs had some disadvantages, including discoloration, degradation, and difficulty of polishing. It is well known that polymeric materials such as NMCDs and PMMA dentures used for prosthetic treatment experience sorption: absorption of liquids that depends on the environmental conditions. In particular, GFRTPs for NMCDs will experience color changes caused by penetration of colored solutions such as black coffee because of their stainability, which may lower patient satisfaction [9]. Therefore, evaluating the color stability of GFRTPs is important to ensure the success of these dental prostheses and the oral health of patients.

The purpose of this study was to assess the color stability of GFRTPs composed of glass fibers and polypropylene, after coffee immersion, for use in NMCDs.

2. Materials and methods

2.1. Material preparation

The GFRTPs composed of E-glass fibers and polypropylene were injection-molded using pellets (Plastron, PP-GF50-02, Daicel Polymer Ltd, Tokyo, Japan) consisting of polypropylene reinforced with E-glass fibers with a diameter of 17 μm and a length of 10 mm; this process is described in detail elsewhere [4]. To match the denture base to the gingival color, 2 mass% of pigments (Aesthetic Intensive-Colors: Purpur Red, Candulor AG, Glattpark, Switzerland) were added to the pellets before injection molding.

According to the previous study on the optimum fiber content for GFRTPs [4], GFRTPs were prepared with fiber contents of 0 mass % (GF0), 10 mass% (GF10), and 20 mass% (GF20). Two commercially available NMCD materials (Valplast, VA; EstheShot Bright, EB) and two commercially available PMMA denture base materials (Polybase, PB; Ivocup, IC) were used as controls. As is described concerning their characteristics in the previous studies [1,4], the VA and EB are polyamide and polyester copolymer, respectively; the PB and IC are auto-polymerized PMMA and heat-polymerized PMMA, respectively. These samples were cut to the desired shape for color stability evaluation, and the specimens were then polished with 600-grit SiC paper under running water.

2.2. Color stability evaluation

Each specimen had a length of 10 mm, width of 7 mm, and thickness of 3.0 mm. The baseline colors of the GFRTP specimens were measured before immersion. The GFRTP specimens were immersed for 4 weeks in 20 mL of black coffee without sugar (NESCAFE Excella®, Nestlé Japan Ltd., Hyogo, Japan) [10], the staining solution, in a Teflon-sealed polystyrene bottle at 37 °C, with the coffee refreshed weekly. After staining, the specimens were washed with distilled water and then dried with paper towels. Color changes after 24 h and after 1, 2, 4 weeks of immersion were measured by a colorimeter (ShadeEye NCC; Shofu Inc., Kyoto, Japan) against a white background, as shown in Fig. 1. This device used a pulsed xenon lamp as an optical light source and a three-component silicon photocell as the optical sensor [11]. The colorimetric measurements were performed by contacting the measurement tip of the optical sensor to the GFRTP specimen. The measurements are averages of 6 specimens ($n = 6$), with each specimen measured three times.

The color parameters are expressed using the Commission Internationale de l'Eclairage (CIE) Lab color system [12,13], relative to the D65 illuminant standard. In this three-dimensional color space, the three axes are L^*, a^*, and b^*. The axis of L^* is a measure of lightness, with 100 for white and 0 for black. The axes of a^* and b^* are measures of the red–green and yellow–blue chromatic coordinates, respectively. A positive a^* or b^* represents a red or yellow shade, respectively, and a negative a^* or b^* represents a green or blue shade, respectively.

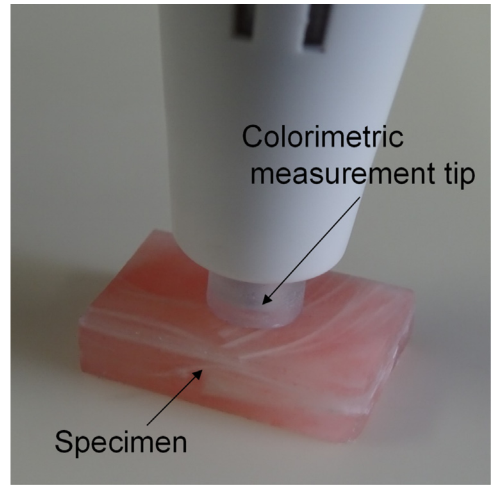

Fig. 1. Photograph of the specimen and device setup during measurement. The elastic tip of the instrument was in contact with the middle of the specimen.

Table 1
National Bureau of Standards (NBS) ratings.

NBS unit	Critical remarks of color differences	
0.0– 0.5	Trace	Extremely slight change
0.5– 1.5	Slight	Slight change
1.5– 3.0	Noticeable	Perceivable
3.0– 6.0	Appreciable	Marked change
6.0– 12.0	Much	Extremely marked change
12.0 or more	Very much	Change to other color

The color difference (ΔE^*), comparing the color before and after immersion, was calculated using the following equation [13]:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (1)$$

Moreover, the ΔE^* values were converted into National Bureau of Standards (NBS) units by the following equation [10,14]:

$$\text{NBS units} = \Delta E^* \times 0.92 \quad (2)$$

These values are shown in Table 1 [10]. We set a threshold value of 3.0 in NBS units for clinically acceptable color change [14,15].

2.3. Statistical analysis

To examine differences among the means of the experimental results, we used analyses of variance and Scheffe multiple comparison tests, with the significance level set at $p = 0.05$.

3. Results

Fig. 2 shows a photograph of each specimen before and after 4 weeks of immersion in the coffee. Visual inspection of the GFRTPs revealed almost no color change before and after immersion. In contrast, the VA seemed to change color, but this change was not visibly certain.

Fig. 3 shows the color differences (ΔE^*) for each specimen after immersion in the coffee. For GFRTPs, the ΔE^* values at 24 h and 1, 2, and 4 weeks after immersion for GF0, GF10, and GF20 ranged from 0.65 to 0.77, from 1.39 to 2.09, and from 1.03 to 2.45, respectively. For controls, the ΔE^* values at 24 h and 1, 2, and 4 weeks after immersion for VA, EB, PB, and IC ranged from 2.48 to 3.87, from 0.52 to 1.07, from 0.39 to 1.59, and from 0.36 to 0.61, respectively.