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Properties of a color-changeable chewing gum used to evaluate masticatory performance

Yohei Hama DDS[a], Manabu Kanazawa DDS, PhD[a,*], Shunsuke Minakuchi DDS, PhD[a], Tatsuro Uchida DDS, PhD[a], Yoshiyuki Sasaki DDS, PhD[b]

[a] Gerodontology and Oral Rehabilitation, Department of Gerontology and Gerodontology, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan

[b] Cariology and Operative Dentistry, Department of Oral Health Sciences, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan

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ABSTRACT

Purpose: To clarify the basic properties of a color-changeable chewing gum to determine its applicability to evaluations of masticatory performance under different types of dental status.

Methods: Ten participants with natural dentition aged 26–30 years chewed gum that changes color during several chewing strokes over five repetitions. Changes in color were assessed using a colorimeter, and then L^*, a^*, and b^* values in the CIELAB color system were quantified. Relationships between chewing progression and color changes were assessed using regression analysis and the reliability of color changes was assessed using intraclass correlation coefficients. We then measured 42 dentate participants (age, 22–31 years) and 47 complete denture wearers (age, 44–90 years) to determine the detectability of masticatory performance under two types of dental status.

Results: Regression between the number of chewing strokes and the difference between two colors was non-linear. The intraclass correlation coefficients were highest between 60 and 160 chewing strokes. Dentate and edentulous groups significantly differed (Wilcoxon rank sum test) and values were widely distributed within each group.

Conclusions: The color of the chewing gum changed over a wide range, which was sufficient to evaluate the masticatory performance of individuals with natural dentition and those with complete dentures. Changes in the color values of the gum reliably reflected masticatory performance. These findings indicate that the color-changeable chewing gum will be useful for evaluating masticatory performance under any dental status.

* *Corresponding author at*: Gerodontology and Oral Rehabilitation, Department of Gerontology and Gerodontology, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8549, Japan.
Tel.: +81 3 5803 5563; fax: +81 3 5803 5586.
E-mail address: m.kanazawa.gerd@tmd.ac.jp (M. Kanazawa).

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1. Introduction

Specialists in dentistry and individuals involved in healthcare and education have become increasingly aware of the importance of mastication [1,2]. Masticatory performance has often been evaluated by measuring the ability to grind or pulverize a test food by chewing. The degree of food breakdown is then determined by sieving [3–5]. Another popular method evaluates the ability to mix and knead a food bolus. Two-color chewing gum [6–9] and paraffin wax [10–13] have been used as test foods to quantify mixing ability. Masticatory performance comprises several factors such as comminution, mixing and shearing, and no single method can evaluate all of these aspects. Thus, several methods are needed to comprehensively evaluate masticatory performance. Sieving has been established as a method of evaluating comminution ability.

Degrees to which two colors can be mixed have been optically [7–13] and visually [6,8,13] determined. Since test foods are soft and form a bolus that can easily be chewed, they are suitable for individuals with compromised oral function, such as denture wearers and oncology patients [9,12]. A reliability and validity study has shown that evaluation using a wax cube is a good alternative to comminution tests [10]. However, tests of mixing ability are problematic; studies have shown that testing mixing ability is less suitable than testing comminution when individuals have good masticatory performance [9,12]. Mixing test foods is too easy for such individuals, and color changes will become saturated, rendering the discrimination of mixing ability inaccurate. In fact, mixed test foods reach saturation at around 30 chewing strokes in dentate participants [7–10,12].

To evaluate mixing ability under any type of dental status, we developed a new color-changeable chewing gum with a wider range of changes. The color of the new gum changes not simply by mixing colors but via a longer-term chemical reaction. Thus, changes are unlikely to reach saturation. The gum does not stick to dentures, it is factory-produced and individually packaged, which assures consistent quality. As it is only necessary to check the color of the gum after chewing, a specialist is not required for evaluating masticatory performance. We previously evaluated masticatory performance by measuring changes in the color of the new gum using a hand-held colorimeter or a dedicated color scale [14–16]. However, this new chewing gum has not been studied sufficiently to precisely evaluate masticatory performance. The basic properties of this new gum, such as color changes with chewing progression and the reliability of evaluations using the gum, have not been investigated.

The present study analyzes the basic properties of the new color-changeable chewing gum to determine its applicability under different types of dental status. We speculated that the range of color changes would be wide enough to accurately and reliably evaluate masticatory performance of dentate and edentulous groups.

2. Materials and methods

2.1. Color measurement of test item

The test chewing gum (70 mm × 20 mm × 1 mm; 3.0 g) contained xylitol, citric acid, and red, yellow and blue dyes that change color when chewed (Masticatory Performance Evaluating Gum XYLITOL, Lotte Co., Ltd., Tokyo, Japan). The red dye is pH-sensitive and it changes color under neutral or alkaline conditions. Citric acid maintains a low internal pH of the yellowish-green gum before chewing. As chewing progresses, the gum changes to red since yellow and blue dyes seep into saliva and red appears because of citric acid elution.

Color was measured immediately after chewing. The chewed gum was flattened to a thickness of 1.5 mm in polyethylene films by compression between two glass plates and measured using a colorimeter (CR-13; Konica-Minolta Sensing, Tokyo, Japan) positioned at about 3 mm above, below and to the right and left of the center of the films. Changes in color were visualized as three-dimensional coordinates organized along L^*, a^* and b^* axes and evaluated using the CIELAB color system defined by the International Commission on Illumination: L^* represents the lightness of the color, a^* represents the degree of color between red and green, and b^* represents the degree of color between yellow and blue. Positive values for a^* and b^* indicate red and yellow, respectively. The mean values of five points for each of L^*, a^*, and b^* were determined. Thereafter, differences between two colors in the CIELAB color space (ΔE), were calculated before and after chewing using the following equation in which the measured L^*, a^*, and b^* values before chewing were 72.3, −14.9, and 33.0, respectively:

$$\Delta E = \sqrt{(L* - 72.3)^2 + (a* + 14.9)^2 + (b* - 33.0)^2}$$

2.2. Color analyses of the gum with chewing progression

Ten participants (male, 70%) aged 26–30 (mean, 27.7; SD, 1.5) years with natural dentition without missing teeth except for the third molar participated in this experiment. Applicants with caries, severe periodontal disease, and clinical signs or symptoms of temporomandibular disorders and salivary dysfunction were excluded. Three participants chewed the gum for 20, 40, 60, 80, 100, 120, 160, 200, 300, 400, 500, and 600 strokes in a preparatory experiment to determine the optimal number of chewing strokes for analysis, and then seven did so for 20, 40, 60, 80, 100, 120, 160, and 200 strokes. Five and three trials of $\leq$200 and $\geq$300 chewing strokes, respectively, proceeded as follows. The participants rinsed their mouths with water for 15 s before chewing the gum on their preferred side at a rate of one stroke per second and rested for at least 5 min between chewing tasks. One examiner measured color changes in the chewed gums and calculated the ΔE values as described above.

The number of chewing strokes and ΔE were assessed by specifying the ΔE value with an infinite number of chewing strokes in a non-linear regression analysis. The