DOI: 10.7860/JCDR/2017/23950.9754

Original Article

Dentistry Section

# Applicability of the CIELAB and CIEDE2000 Formulae for Detection of Colour Changes in Colour-Changeable Chewing Gum for Evaluating Masticatory Function

YESIBOLI YEERKEN[1], TAKAFUMI OTOMARU[2], MOHAMED SAID[3], NA LI[4], HISASHI TANIGUCHI[5]

## ABSTRACT

**Introduction:** Mastication is one of the essential stomatognathic functions and is impaired when mandibulectomy is performed for removal of head and neck lesions.

**Aim:** The purpose of this study was to investigate the correlation between perceived chewing ability {Masticatory Score (MS)} and objective mixing ability (ΔE) in patients who had undergone marginal mandibulectomy.

**Materials and Methods:** Twenty normal dentate subjects as control group and twenty mandibulectomy patients who had undergone marginal mandibulectomy and wearing a dentomaxillary prosthesis were enrolled. Perceived chewing ability MS and objective ΔE were evaluated using a food intake questionnaire and the colour-changeable chewing gum, respectively. They were instructed to chew the gum continuously for 100 strokes on their usual side. The chewed gum was measured using the CIELAB colour space defined by a colourimeter and L, a* and b* were obtained. The change in colour of the gum after chewing was calculated using CIELAB (ΔEab) and the CIEDE2000 (ΔE00) formula. The relationships of a*, ΔEab, and ΔE00 with MS score were analyzed using the Spearman's rank correlation coefficient.

**Results:** A correlation was found between perceived chewing ability (MS) and objective mixing ability (index of the masticatory function {ΔE}) in marginal mandibulectomy patients. (ΔE00 = 0.481, a* = 0.587, ΔEab = 0.668).

**Conclusion:** Within the limitations of this study, it can be concluded that the CIEDE2000 formula for calculation of colour difference can be used to evaluate masticatory function in patients who have undergone marginal mandibulectomy.

**Keywords:** Dentomaxillary, Marginal mandibulectomy, Objective evaluation, Objective mixing ability, Prosthesis

## INTRODUCTION

Mastication is one of the essential stomatognathic functions and is impaired when mandibulectomy is performed for removal of head and neck lesions. Masticatory function can be assessed by objective measurements such as masticatory efficiency, bite force, and food mixing ability [1]. It can also be evaluated subjectively from the patient's perception of chewing ability [2]. In patients who have undergone mandibulectomy and have a dento-maxillary prosthesis, mixing ability can be assessed objectively by using colour-changeable chewing gum to evaluate masticatory function. A strong correlation has been found between the mean colour score and the a* value [3]. Using a* as the index of masticatory function, variations in a* correspond to the visible colour change in the colour-changeable gum [4]. This gum changes from a green to red colour depending on the degree of mixing. The a* value is measured by a colourimeter (negative values indicated by green, positive values indicated by magenta). For the chewed gum, ΔE is calculated using the CIELAB (or CIE 1976 Lab) colour-difference formula, which has a significant positive correlation with maximum closing velocity and a significant negative correlation with closing angle [5]. Based on CIE Technical Report 142-2001, the CIELAB formula has recently been developed into the CIEDE2000 formula, where ΔEab has become ΔE00 [6]. Thus ΔE has been recently focused in the field of the masticatory evaluation. In a previous study, our research group reported that the perceived chewing ability MS and objective mixing ability {index of the masticatory function (a*)} were significantly associated in mandibulectomy group. The focus was a* as the index of the masticatory function [4]. However, there have been no reports on the perceived chewing ability (MS) and objective mixing ability (ΔE). In the present study, colour-changeable chewing gum was used to evaluate the masticatory function, focusing on ΔE as the index of the masticatory function in marginal mandibulectomy subjects and compared the same with the normal dentate subjects.

The aim of this study was to investigate the correlation between perceived chewing ability (MS) and objective mixing ability (ΔE) in marginal mandibulectomy patient. The null hypothesis was that treatment outcomes as measured by perceived chewing ability (MS) would not correlate with objective masticatory function (ΔE) in marginal mandibulectomy patients.

## MATERIALS AND METHODS

### Subjects

The present cross-sectional study was conducted at the Department of Maxillofacial Prosthetics, Dental Hospital, Tokyo Medical and Dental University, Tokyo, Japan. A clinical difference (δ) of five in a* value between the two groups was considered clinically significant when the standard deviation within each group (σ) was also five. With exacts method based on the T distribution and the power and sample size calculations software (version 3.1.2, 2014), a sample of 17 was required in each group to provide a power of 0.8. The Type I error probability (α) associated with test of this null hypothesis was 0.05. Twenty fully dentate subjects (control group) and Twenty patients who had undergone marginal mandibulectomy (marginal mandibulectomy group) due to head and neck lesion and who were satisfied with their dento-maxillary prosthesis (i.e., did not require adjustment of the device at enrolment), and had worn the prosthesis for at least six months were included in the study. The segmental mandibulectomy, maxillectomy as well as glossectomy

patients were excluded. All the subjects were instructed to chew colour-changeable chewing gum continuously for 100 strokes. The subjects were asked to rest for a sufficient time between each trial. The study protocol was approved by the Ethics Committee of Tokyo Medical and Dental University (No.865). All study participants received a written and verbal description of the study and gave their written informed consent prior to participation.

## Clinical and Demographic Characteristics

Intraoral photographs and clinical examination details from the patients' medical records were gathered for age, sex, mandibulectomy characteristics, reconstruction type, pathological diagnosis, and number of mandibular teeth, dento-maxillary prosthesis type {removable partial denture (clasp partial denture), overdenture and complete denture} [Table/Fig-1].

## Perceived Chewing Ability

Patient perception of chewing ability was rated using a food intake questionnaire consisting of 35 food items list. Previously reported list by Hisashi Koshino was used to develop a new food intake questionnaire method [Table/Fig-2] [7].

The participants rated their ability to chew each of the 35 food items using the following scale: 0- cannot eat; 1- can eat with difficulty; and 2- can eat easily. An additional two categories of "do not eat because of aversion" and "have not eaten since starting to wear dentures" were scored as 0. To represent the ability of mastication using the questionnaire, masticatory score was calculated as follows, after the sum for the five categories had been calculated by multiplying the total points by the difficulty rate of each category, the percentage of this value of the maximum possible total was represented as MS. Thirty-five foods classified into five grades as A, B, C, D and E of masticatory difficulty [4]. The maximum point in calculating method (MS) was 111.4 point. The sum of the difficulty ratio was 7.96 (1.00+1.14+1.30+1.52+3.00), the total point value in calculating method (MS) was 14 point (Total Point=Sum of the points for 7 foods in each grade: Full point=7 foods x 2 point = 14). The points for each grade were summed and the MS was calculated as follows [7]:

$$MS = \frac{(A + 1.14B + 1.30C + 1.52D + 3.00E)}{111.4} \times 100\%$$

| | Sex | Age | Mandibulectomy Type | Reconstruction Type | Pathological diagnosis | Number of mandibular teeth | Denture type |
|---|---|---|---|---|---|---|---|
| Marginal mandibulectomy group, n=20 | | | | | | | |
| 1 | M | 70 | Marginal | None | Amelo | 6 | Removable partial denture |
| 2 | M | 70 | Marginal | None | DC | 12 | Removable partial denture |
| 3 | M | 69 | Marginal | None | KOT | 11 | Removable partial denture |
| 4 | M | 70 | Marginal | FA | VC | 10 | Removable partial denture |
| 5 | M | 48 | Marginal | FA | SCC | 0 | Complete denture |
| 6 | M | 65 | Marginal | FA | SCC | 8 | Removable partial denture |
| 7 | M | 38 | Marginal | FA | SCC | 8 | Removable partial denture |
| 8 | F | 57 | Marginal | None | Amelo | 11 | Removable partial denture |
| 9 | F | 82 | Marginal | FA | SCC | 4 | Removable partial denture |
| 10 | F | 74 | Marginal | RA | SCC | 0 | Complete denture |
| 11 | F | 63 | Marginal | None | RC | 3 | Overdenture |
| 12 | F | 71 | Marginal | FA | SCC | 0 | Complete denture |
| 13 | F | 76 | Marginal | FA | SCC | 2 | Overdenture |
| 14 | F | 76 | Marginal | None | Amelo | 0 | Complete denture |
| 15 | F | 86 | Marginal | None | SCC | 7 | Removable partial denture |
| 16 | F | 70 | Marginal | None | SCC | 9 | Removable partial denture |
| 17 | F | 50 | Marginal | None | Amelo | 7 | Removable partial denture |
| 18 | F | 63 | Marginal | None | Amelo | 8 | Removable partial denture |
| 19 | F | 66 | Marginal | None | Amelo | 9 | Removable partial denture |
| 20 | F | 71 | Marginal | None | SCC | 5 | Removable partial denture |
| Normal dentate group, n=20 | | | | | | | |
| 1 | M | 28 | None | None | None | Full dentate | Without prosthesis |
| 2 | M | 28 | None | None | None | Full dentate | Without prosthesis |
| 3 | M | 28 | None | None | None | Full dentate | Without prosthesis |
| 4 | M | 28 | None | None | None | Full dentate | Without prosthesis |
| 5 | M | 28 | None | None | None | Full dentate | Without prosthesis |
| 6 | M | 30 | None | None | None | Full dentate | Without prosthesis |
| 7 | M | 30 | None | None | None | Full dentate | Without prosthesis |
| 8 | M | 30 | None | None | None | Full dentate | Without prosthesis |
| 9 | M | 32 | None | None | None | Full dentate | Without prosthesis |
| 10 | M | 32 | None | None | None | Full dentate | Without prosthesis |
| 11 | F | 25 | None | None | None | Full dentate | Without prosthesis |
| 12 | F | 25 | None | None | None | Full dentate | Without prosthesis |
| 13 | F | 25 | None | None | None | Full dentate | Without prosthesis |
| 14 | F | 25 | None | None | None | Full dentate | Without prosthesis |
| 15 | F | 25 | None | None | None | Full dentate | Without prosthesis |
| 16 | F | 32 | None | None | None | Full dentate | Without prosthesis |
| 17 | F | 32 | None | None | None | Full dentate | Without prosthesis |
| 18 | F | 32 | None | None | None | Full dentate | Without prosthesis |
| 19 | F | 32 | None | None | None | Full dentate | Without prosthesis |
| 20 | F | 32 | None | None | None | Full dentate | Without prosthesis |

SCC, squamous cell carcinoma; Amelo, ameloblastoma; RC, radicular cyst; FA, forearm flap; DC, dentigerous cyst; KOT, keratocystic odontogenic tumor; carcinoma; RA, rectus abdominis flap; VC, verrucous

**[Table/Fig-1]:** Clinical and demographic characteristics of the 20 marginal mandibulectomy and 20 normal dentate patients.

| Please fill in the blanks as follows | | | |
|---|---|---|---|
| [2] Easily eaten □ [1] Eaten with difficult [0] Cannot be eaten [Δ] Do not eat because of dislike [□] Have not eaten since starting to wear dentures | | | |
| 1 [ ] Fried rice cracker | 2 [ ] Rice cake | 3 [ ] Raw abalone | 4 [ ] Sliced raw cuttlefish |
| 5 [ ] Strawberries | 6 [ ] Boiled fish paste patty | 7 [ ] Raw cabbage | 8 [ ] Boiled beef |
| 9 [ ] Boiled cabbage | 10 [ ] Raw cucumbers | 11 [ ] Jellyfish | 12 [ ] Konnyaku |
| 13 [ ] Boiled taro | 14 [ ] Dried cuttlefish | 15 [ ] Boiled chicken | 16 [ ] Pickled radish |
| 17 [ ] Pickled eggplant | 18 [ ] Takuwan | 19 [ ] Raw carrots | 20 [ ] Fried chicken |
| 21 [ ] Banana | 22 [ ] Roast chicken | 23 [ ] Peanuts | 24 [ ] Raw trepan |
| 25 [ ] Pork cutlets | 26 [ ] Boiled carrots | 27 [ ] Sliced raw tuna | 28 [ ] Harm |
| 29 [ ] Apples | 30 [ ] Roast pork | 31 [ ] Vinegared octopus | 32 [ ] Pudding |
| 33 [ ] Boiled onions | 34 [ ] Pickled scallion | 35 [ ] Boiled kombu | |
| Notice; konnyaku - a paste made from the starch of the devils tongue plant taro - Japanese taro potato; taku-wan harder to masticate than pickled radish; kombu tangle weed: trepang cucumber. | | | |

**[Table/Fig-2]:** A 35-item food intake questionnaire on masticatory function.

## Objective Masticatory Function

Objective masticatory function was measured using a colour-changeable chewing gum (masticatory performance evaluating gum Xylitol, 70 mm×20 mm×1 mm, 3.0 g; Lotte Co., Ltd., Saitama, Japan). Participants were instructed to chew the gum continuously for 100 strokes on their unaffected side for mandibulectomy patients, and normal dentate participants were instructed to chew the gum continuously for 100 strokes on their habitual chewing side. The chewed gum was collected immediately after chewing, wrapped in polyethylene film, and compressed to a thickness of 1.5 mm between glass plates. Using a colourimeter (CR-13; Konica-Minolta, Tokyo, Japan) colour was read at five sites on the gum specimen: at the center and approximately 3 mm above, below, and to the right and left of the center. The colour of the gum was assessed in the CIELAB colour space and the a* value, denoted by redness, was measured as an indicator of food mixing ability (a higher score indicating greater mixing ability). From each mean values of L*, a* and b*(with dimensions L* for lightness and a* and b* for the colour-opponent dimensions, the red/green opponent colours were represented along the a* axis, with green at negative a* values and red at positive a* values. The yellow/blue opponent colours were represented along the b* axis, with blue at negative b* values and yellow at positive b* values). The difference between two colours (before and after chewing) in the CIELAB colour space (ΔE) was calculated for 100 strokes using the following equation [8]:

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_1 - a^*_2)^2 + (b^*_2 - b^*_1)^2}$$

The CIEDE2000 colour distance formula (ΔE00) was used to calculate the colour difference as follows [9]:

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)}$$

$$\Delta C' = C^*_2 - C^*_1 \quad \Delta L' = L^*_1 - L^*_2 \quad \Delta H' = 2\sqrt{C^*_1 C^*_2}\sin(\Delta h'/2)$$

$$S_C = 1 + 0.045\bar{C}' \quad S_H = 1 + 0.015\bar{C}'T$$

$$S_L = 1 + \left(0.015(\bar{L} - 50)^2 \div \sqrt{20 + (\bar{L} - 50)^2}\right)$$

$$R_T = -2\sqrt{\frac{\bar{C}'^7}{\bar{C}'^7 + 25^7}}\sin\left[60^\circ \cdot \exp\left(-\left[\frac{\bar{H} - 275^\circ}{25^\circ}\right]^2\right)\right]$$

| Number | Marginal mandibulectomy patient | | | | | | Normal dentate subject | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | a* | b | ΔEab | ΔE00 | MS | L | a* | b | ΔEab | ΔE00 | MS |
| 1 | 52.2 | 29.3 | -0.1 | 58.8 | 46.1 | 92% | 53.0 | 28.4 | 8.6 | 53.3 | 42.3 | 100% |
| 2 | 54.3 | 23.1 | 3.0 | 51.7 | 41.3 | 87% | 52.2 | 29.6 | 7.8 | 54.9 | 43.5 | 100% |
| 3 | 56.7 | 20.5 | 8.2 | 46.0 | 36.9 | 49% | 53.1 | 29.3 | 7.9 | 54.3 | 42.9 | 100% |
| 4 | 68.2 | -5.5 | 27.9 | 11.5 | 7.0 | 41% | 53.0 | 28.5 | 8.0 | 53.7 | 42.6 | 100% |
| 5 | 55.1 | 18.1 | 4.2 | 47.1 | 37.9 | 89% | 52.7 | 30.5 | 3.1 | 57.8 | 45.3 | 100% |
| 6 | 60.5 | 9.5 | 14.8 | 32.6 | 24.8 | 66% | 51.6 | 31.6 | 2.2 | 59.5 | 46.5 | 100% |
| 7 | 56.2 | 16.3 | 6.7 | 43.9 | 35.3 | 89% | 51.0 | 33.3 | 1.0 | 61.7 | 47.9 | 100% |
| 8 | 60.9 | 11.8 | 14.4 | 34.5 | 26.9 | 69% | 52.1 | 31.8 | 2.8 | 59.2 | 46.2 | 100% |
| 9 | 63.3 | 6.4 | 19.1 | 27.0 | 19.6 | 26% | 52.4 | 32.2 | 5.1 | 58.2 | 45.5 | 100% |
| 10 | 57.9 | -0.2 | 17.7 | 25.6 | 17.0 | 43% | 52.6 | 31.7 | 2.5 | 59.1 | 46.1 | 100% |
| 11 | 60.0 | 11.2 | 15.1 | 34.0 | 26.3 | 60% | 51.7 | 32.9 | 4.8 | 59.2 | 46.2 | 100% |
| 12 | 65.8 | 1.4 | 23.2 | 20.1 | 39.4 | 42% | 51.9 | 31.1 | 5.0 | 57.6 | 45.2 | 100% |
| 13 | 58.2 | 14.1 | 12.4 | 38.3 | 30.4 | 51% | 53.0 | 33.0 | -1.3 | 62.0 | 47.9 | 100% |
| 14 | 60.5 | 4.7 | 18.2 | 27.2 | 19.3 | 80% | 57.4 | 22.5 | 2.9 | 50.3 | 40.1 | 100% |
| 15 | 56.9 | 13.4 | 10.9 | 39.1 | 31.1 | 90% | 57.5 | 24.3 | 2.9 | 51.6 | 41.0 | 100% |
| 16 | 56.5 | 15.5 | 9.7 | 41.4 | 33.2 | 54% | 52.5 | 29.2 | 4.7 | 56.0 | 44.2 | 100% |
| 17 | 58.5 | 11.1 | 11.6 | 36.4 | 28.4 | 100% | 53.0 | 30.9 | 6.1 | 56.5 | 44.4 | 100% |
| 18 | 57.3 | 17.1 | 8.8 | 42.8 | 34.4 | 97% | 53.5 | 30.4 | 4.6 | 56.7 | 44.5 | 100% |
| 19 | 59.4 | 12.3 | 9.0 | 38.5 | 30.3 | 85% | 57.5 | 26.2 | 7.9 | 50.4 | 40.0 | 100% |
| 20 | 61.6 | 9.0 | 17.0 | 30.7 | 23.2 | 38% | 57.6 | 26.3 | 4.3 | 52.3 | 41.4 | 100% |
| Median | 58.4 | 12.1 | 12.0 | 37.3 | 30.4 | 0.7 | 52.9 | 30.5 | 4.7 | 56.6 | 44.4 | 100% |
| The a* axis from green (-a) to red (+a) and the b axis from blue (-b) to yellow (+b); The Lightness(L) increases from the bottom to the top of the three-dimensional mode; ΔEab, CIELAB; ΔE00, CIEDE2000; MS (masticatory score) p<0.01. | | | | | | | | | | | | |

**[Table/Fig-3]:** Compared to normal dentate subject's data, related details of the masticatory function in marginal mandibulectomy patients.

| | ΔEab | ΔE00 | a* | MS |
|---|---|---|---|---|
| ΔEab | | | | |
| ΔE00 | 0.792** | | | |
| a* | 0.985** | 0.811** | | |
| MS | 0.668** | 0.481* | 0.587** | |

**[Table/Fig-4]:** Correlations between the variables assessed in this study.
MS, masticatory score; a*, food mixing ability;
**p < 0.01
*p < 0.05 (Spearman's rank test).

calculation formula, weighting Functions: SL, SC, SH, RT, Neutral. Positional corrections to the lack of uniformity of CIELAB. Compensation for lightness (SL), Compensation for chroma (SC), Compensation for hue (SH). Parametric factors: kL, kC, kH. Corrections accounting for the influence of experimental viewing conditions where kC and kH are usually both unity and the weighting factors kL depend on the application. L*, a*, and b* before chewing were measured as 72.3, -14.9, and 33.0 [10], respectively. Details of the calculation formula and calculation system are shown on the "ColourMine.org" website [11].

## STATISTICAL ANALYSIS

Wilcoxon signed-rank test was applied for the comparison between normal dentate subjects and marginal mandibulectomy patients. Relationships between the scores in each group were examined using Spearman's rank correlation coefficient. The statistical analysis was performed using SPSS version 21.0 software (SPSS Japan Inc., Tokyo, Japan), with the level of significance set at $p<0.05$.

## RESULTS

Compared to normal dentate subject's data, related details of the masticatory function in marginal mandibulectomy patients are presented. The Wilcoxon signed-rank test revealed a significant difference between normal dentate and marginal mandibulectomy groups ($p<0.01$) [Table/Fig-3].

A correlation was found between perceived chewing ability (Masticatory score {MS}) and objective mixing ability (index of the masticatory function {ΔE}) in marginal mandibulectomy patient. (ΔE00 = 0.481, a* = 0.587, ΔEab = 0.668) $p<0.05$ [Table/Fig-4].

## DISCUSSION

In this study, the null hypothesis between perceived chewing ability (MS) and the objective masticatory function (ΔE) in marginal mandibulectomy patients due to head and neck lesion was rejected, as shown in [Table/Fig-4], a correlation was found between ΔEab and MS was 0.668, ΔE00 and MS was 0.481. This study established that there were significant correlations between perceived chewing ability (MS) and the objective masticatory function (ΔE) in marginal mandibulectomy patients.

As for the comparisons of masticatory function between normal dentate subjects data and marginal mandibulectomy patients, differences in colour difference values determined by the two formulas (CIELAB and CIEDE2000) were also observed. Such differences might arise from the weighting functions (St, Sc, and Sl) introduced in the CIEDE2000 colour difference formula and also from the change of the a* axis of CIELab, affecting mainly colours with low chroma (neutral colours) [Table/Fig-3].

The relationships of a*, ΔEab, and ΔE00 with the outcome, MS, were different in patients with a dento-maxillary prosthesis after marginal mandibulectomy. ΔEab was more strongly correlated with MS than was a*or ΔE00. The ΔEab appears to be a better indicator of masticatory function. Of note, Komagamine Y et al., reported that the difference between two colours before and after chewing is more accurately represented by ΔE than by a* [5]. However, CIE standard is to define procedures for calculating the coordinates of the CIE 1976 Lab (CIELAB) colour space and the Euclidean colour difference values based on these coordinates. The standard does not cover more sophisticated colour difference formulae based on CIELAB, such as the CMC formula, the CIE94 formula, the DIN99 formula, and the CIEDE2000 formula nor does it cover the alternative uniform colour space, CIELUV [12]. CIE has developed a series of formulae to improve the consistency of measurement and visual assessment of colour differences. Thus, ΔE00 calculated using the CIEDE2000 colour-difference formula is better than ΔEab calculated using the CIELAB colour-difference formula. This finding may be attributed to the discrepancies in visible colour tolerance at different regions in the CIELAB colour space. When investigating the colour difference between before and after, ΔE00 rather than ΔEab is recommended by CIE [6]. The formula is an extension of the CIELAB colour-difference formula with corrections for variation in colour-difference perception dependent on lightness, chroma, hue and chroma-hue interaction. However, the standard of the reliability of using the formulas CIELAB determinate ΔEab values to represent the average visual colour assessments needs to be further discussed in the studies for evaluating masticatory function using colour-changeable chewing gum. The advantage of using a* is that a colour change is easily detected. If the chewed gum turns red, this is visible to the eye at the chair side and the redness can be evaluated by a colourimeter. However, a disadvantage of using a* is that a* may not be able to capture the difference in colour of the gum between before and after it is chewed. In our experience, when two pieces of chewed gum are compared, the same a* values are obtained but the b* and L* values can be different, meaning that the two ΔE values (the difference in colour of the gum between before and after it is chewed) in the CIELAB colour space are different. The advantage of using ΔE00 is that it can calculate the colour change of the gum in the CIELAB colour space after it is chewed. However, the disadvantage of using ΔE00 is the difficulty of calculations using L*, a* and b* data. Some colourimeters do not include a ΔE00 calculation function, meaning that a computer system or smartphone application is needed to help calculating the ΔE00.

Although, the literature contains numerous reports on the perceptibility and/or acceptability of colour-changeable chewing gum, these reports seldom mention the separate contributions of lightness, chroma, and hue changes to the total calculated colour difference. Therefore, we cannot continue to use a* just because it is the easiest way of evaluating the masticatory function and we need to explore other methods. A standardized colourimetric measurement approach would be needed to provide more detailed data for both dental treatments of individual patients and in studies with small sample sizes.

## LIMITATION

The study is limited due to the small number of the patient, further studies should enroll more number of subjects, and also different groups based on different reconstruction type should be evaluated in detail. In this study, we focused on the assessment of ΔE calculation, future studies are warranted to assess the significance in the evaluation of colour differences of colour-changeable chewing gum, as well as the relative significance of each correction term introduced in CIEDE2000. There is also the possibility that the calculation formula could change, recording all data from investigations of the relationship between colour changes of colour-changeable chewing gum and masticatory function is imperative.

## CONCLUSION

A correlation was found between perceived chewing ability (MS) and objective mixing ability (ΔE) in marginal mandibulectomy patients,

it is reasonable to assess masticatory function from the aspects of questionnaires and colour-changeable chewing gum. When investigating the colour difference between before and after, ΔE00 rather than ΔEab is recommended by CIE. Thus, in the present study of colour-difference formula CIEDE2000 (ΔE00) was considered to be a useful modality for evaluating masticatory performance after mandibulectomy in patients with head and neck lesions.

## REFERENCES


[1] Otomaru T, Sumita YI, Chang Q, Fueki K, Igarashi Y, Taniguchi H. Investigation of predictors affecting food mixing ability in mandibulectomy and/or glossectomy patients. J Prosthodont Res. 2009;53(3):111-15.

[2] Shibuya Y, Ishida S, Hasegawa T, Kobayashi M, Nibu K, Komori T. Evaluating the masticatory function after mandibulectomy with colour-changing chewing gum. J Oral Rehabil. 2013;40(7):484-90.

[3] Kamiyama M, Kanazawa M, Fujinami Y, Minakuchi S. Validity and reliability of a Self-Implementable method to evaluate masticatory performance: use of colour-changeable chewing gum and a colour scale. J Prosthodont Res. 2010;54(1):24-28.

[4] Aimaijiang Y, Otomaru T, Taniguchi H. Relationships between perceived chewing ability, objective masticatory function and oral health-related quality of life in mandibulectomy or glossectomy patients with a dento-maxillary prosthesis. J Prosthodont Res. 2016;60(2):92-97.

[5] Komagamine Y, Kanazawa M, Minakuchi S, Uchida T, Sasaki Y. Association between masticatory performance using a colour-changeable chewing gum and jaw movement. J Oral Rehabil. 2011;38(8):555-63.

[6] Pub C. 142: Improvement to Industrial Colour-difference Evaluation. 2001.

[7] Koshino H, Hirai T, Toyoshita Y, Yokoyama Y, Tanaka M, Iwasaki K, et al. Development of new food intake questionnaire method for evaluating the ability of mastication in complete denture wearers. Prosthodontic Res pract. 2008;7(1):12-18.

[8] CIE. Technical Report, Vienna, Austria: CIE Central Bureau; CIE pub. 2004;15(3).

[9] Luo MR, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. Colour Research & Application. 2001;26(5):340-50.

[10] Hama Y, Kanazawa M, Minakuchi S, Uchida T, Sasaki Y. Properties of a colour-changeable chewing gum used to evaluate masticatory performance. J Prosthodont Res. 2014;58(2):102-06.

[11] Zack, J. (2016). CIE2000 Delta-E Calculator - ColourMine.org. [online] Colourmine.org. Available at: http://colourmine.org/delta-e-calculator/Cie2000 [Accessed 31 Aug. 2016].

[12] CIE 1976 L*a*b* Colour Space. Colourimetry-Part 4: ISO 2007; 11664-4/ CIE S 014-4/E.



**PARTICULARS OF CONTRIBUTORS:**

1. PhD Student, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University (TMDU), Bunkyo, Tokyo, Japan.
2. Assistant Professor, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University (TMDU), Bunkyo, Tokyo, Japan.
3. PhD Student, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University (TMDU), Bunkyo, Tokyo, Japan.
4. PhD Student, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University (TMDU), Bunkyo, Tokyo, Japan.
5. Professor, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University (TMDU), Bunkyo, Tokyo, Japan.

**NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:**

Dr. Takafumi Otomaru,
1-5-45 Yushima Bunkyo-ku, Tokyo 113-8549, Japan.
E-mail: otomaru.mfp@tmd.ac.jp



**FINANCIAL OR OTHER COMPETING INTERESTS:** None.

Date of Submission: **Sep 07, 2016**
Date of Peer Review: **Oct 10, 2016**
Date of Acceptance: **Feb 01, 2017**
Date of Publishing: **Apr 01, 2017**