# Chewing ability and desaturation during chewing in patients with COPD

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## Abstract

Chewing ability is essential to maintain nutrition status and can be associated with oral conditions, sarcopenia, and lung function in patients with chronic obstructive pulmonary disease (COPD). Herein, our pilot study investigated the chewing ability and degree of desaturation during chewing in patients with COPD (n=41) and control subjects (n=22). Subjects chewed a color-changing chewing gum for 1 minute and chewing ability was assessed by the color of the chewed gum, which was scored from 1 (very poor) to 5 (very good). Arterial oxygen saturation ($SpO_2$) was monitored using a pulse oximeter and the difference in $SpO_2$ was determined by comparison between before and during chewing. The mean color score of the chewed gum was lower in the COPD group than in the control group (3.1±0.7 *vs* 4.2±0.9, p<0.0001). Muscle mass loss (p<0.05), <20 remaining teeth (p<0.005), and COPD (p<0.001) were risk factors for poor chewing ability. The mean $SpO_2$ decreased by 0.78±1.46% during gum chewing for 1 min. The mean $SpO_2$ during gum chewing (95.1±2.4%) was lower than before gum chewing (95.9±1.7%) (p<0.05). The reduction of $SpO_2$ was greater in COPD patients who had fewer remaining teeth (p<0.05). COPD patients with $SpO_2$ reduction >4% during the 6-minute walk test showed greater reduction during gum chewing (p<0.05). Our results suggest that COPD patients with fewer remaining teeth exhibit poor chewing ability and greater desaturation during chewing.

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## Introduction

Chronic obstructive pulmonary disease (COPD) is an inflammatory disease that manifests as pulmonary dysfunction, as well as systemic comorbidities (*e.g.*, cardiovascular diseases, osteoporosis, and skeletal muscle wasting) that worsen the patient's quality of life (QOL) [1]. Sarcopenia is common in patients with COPD, and its prevalence is associated with age, disease severity, symptoms, and comorbidity burden [2,3]. Sarcopenia is a known independent prognostic factor for COPD [4]. For example, the fat-free mass index was a predictor of mortality, independent of lung function among patients with COPD [5]. Muscle strength is a reliable prognostic factor of COPD [6]. Adequate nutrition is important for COPD patients [7]. It has been shown that, in COPD patients, a well-balanced diet is beneficial for pulmonary function, as well as for metabolic and cardiovascular function [8,9].

Maintaining chewing ability is essential to maintain balanced nutritional intake [10]. Sarcopenia, body mass index (BMI), and skeletal muscle mass index are associated with chewing ability and the number of remaining teeth in the aging population [11,12]. Periodontitis comprises a wide range of inflammatory conditions that affect the supporting structures of the teeth and can lead to tooth loss [13]. We previously reported that COPD was an independent predictive factor for periodontitis and that patients with COPD had fewer remaining teeth [14]. Therefore, we presumed that chewing ability may be impaired in patients with COPD.

COPD patients develop desaturation during walking and eating [15]. The degree of desaturation during the 6-minute walk test (6MWT) is associated with patient prognosis [16, 17]. However, no study has investigated chewing ability or degree of desaturation during chewing in patients with COPD. Therefore, in this study, we examined both chewing ability and the degree of desaturation during chewing in patients with COPD.

## Materials and Methods

The ethics committee of Tokyo Dental College approved the study protocol (No. 268). Patients with COPD were recruited from

Tokyo Dental College, Ichikawa General Hospital. Current or previous smokers with a forced expiratory volume in 1 second ($FEV_{1.0}$)/forced vital capacity <0.7 were included in the COPD group (n=41). Subjects who had malignant neoplasms within the past 3 years, as well as those who had diabetes or other serious diseases, were excluded from the study. From the same hospital, non-smokers (n=9) and smokers (n=13) without COPD were selected as controls (n=22).

Spirometry was performed in accordance with the guidelines of the American Thoracic Society. Severity of obstruction was classified based on the guidelines of the Global Initiative for Chronic Obstructive Lung Disease [18]. The degree of dyspnea was evaluated using the modified Medical Research Council (mMRC) dyspnea scale. To assess functional status and exercise capacity, we used the patients' 6MWT distance, which comprises the distance that a patient can quickly walk along a corridor. To evaluate QOL, we used the Japanese version of the COPD assessment test (CAT), which is a questionnaire consisting of eight questions scored on a 0-5 scale.

The body fat ratio and muscle mass were measured by bioelectrical impedance analysis using a body composition monitor (Inner Scan 50, Tanita Corporation, Tokyo, Japan). Fat-free mass was calculated by subtracting fat weight from total body weight. To determine muscle strength, handgrip strength (HGS) was measured using a grip strength dynamometer (Takei Physical Fitness Test, Niigata, Japan). A patient was diagnosed with sarcopenia when both muscle mass and strength were low. Low muscle mass was defined as values <41.60 kg for men and <31.14 kg for women; these were equal to or below the mean minus two standard deviations of that of healthy persons between 20 and 30 years of age in the same ethnic group [19]. In addition, low muscle strength was defined as HGS <26 kg for men and <18 kg for women [20].

The number of remaining teeth was examined by trained dentists who were blinded to the patients' pulmonary function results. Chewing ability was assessed by using test chewing gum (70 mm × 20 mm × 1 mm; 3.0 g) that contained red, yellow, and blue dyes, as well as xylitol and citric acid (Masticatory Performance Evaluating Gum, XYLITOL, Lotte Co., Ltd., Tokyo, Japan) [21]. The red dye is pH-sensitive and changes color under neutral or alkaline conditions. Citric acid maintains a low internal pH of the yellowish-green gum before chewing. During chewing, the gum changes from yellowish-green to red, as yellow and blue dyes escape into saliva and red dye appears due to citric acid elution. The subjects chewed the gum at a frequency of 1 stroke per second until they reached 60 strokes [22]. The color of the chewing gum was scored from 1 (yellow-green) to 5 (red), based on the color scale provided by the manufacturer. The color was assessed independently by two medical doctors and three dentists who were blinded to patients' lung function and oral condition and the mean of the five scores was used. Subjects with scores of 1-3 and 4-5 were assigned into a relatively low chewing ability group and a relatively high chewing ability group, respectively [10].

Data are presented as mean±standard deviation. The Van der Waerden test was performed to assess differences between continuous variables in the two groups. Categorical variables were compared by the $\chi^2$ test with Pearson's correction. Percutaneous saturation of oxygen ($SpO_2$) before and during gum chewing was compared using a paired *t*-test. A p value <0.05 was considered significant. Odds ratios (ORs) were estimated using both univariable and multivariable logistic regression analysis, with chewing ability as a dependent variable. Age (<75 or ≥75 years), muscle mass (low or normal), HGS (low or normal), number of remaining teeth (<20 or ≥20), and presence of COPD (yes or no) were considered independent variables. All data were analyzed using JMP software for Windows, version 9.0.2 (SAS Institute Japan, Tokyo, Japan).

## Results

The basic characteristics of patients with COPD and the control subjects are presented in Table 1. In the COPD group, a total of seven patients had low muscle mass, five had low HGS, and three patients had both, based on the sarcopenia criteria. In the control group, two subjects had low muscle mass, four had low HGS, and one had both. The numbers of remaining teeth were 11.5±9.0 and 20.1±10.8 in the COPD and control groups, respectively (p<0.005). The average minimal $SpO_2$ during the 6MWT was 90.7±4.5% in the COPD group.

The mean color score of the chewing gum was lower in the COPD group than in the control group (3.1±0.7 *vs* 4.2±0.9, p<0.0001). The proportions of subjects with a color score ≤3 were 48.8% (20/41) and 9.1% (2/22) in the COPD and control groups, respectively (p<0.001) (Table 2). Based on univariable logistic regression analysis, the unadjusted ORs for poor chewing ability (color score ≤3) were 2.04 (95% confidence interval [CI], 0.70-6.32; p=0.19) for age ≥75 years *vs* <75 years; 4.75 (95% CI 1.11-24.8; p<0.05) for low versus normal muscle mass; 0.43 (95% CI 0.06-1.96; p=0.29) for low versus normal HGS; 9.39 (95% CI 2.29-64.3; p<0.005) for <20 *vs* ≥20 remaining teeth; and 9.52 (95% CI 2.36-64.6; p<0.001) for the presence of COPD *vs* the absence of COPD. In the multivariable regression analysis, COPD and the number of remaining teeth were significant independent factors predictive of poor chewing ability (Table 3).

The mean $SpO_2$ decreased by 0.78±1.46% during gum chewing in the COPD group. The mean $SpO_2$ values before and during gum chewing were 95.9±1.7% and 95.1±2.4%, respectively (p<0.05). In the control group, the mean $SpO_2$ decreased by 0.32±0.72% during gum chewing; the difference in $SpO_2$ was not statistically significant. Comparisons of the reductions of $SpO_2$ during gum chewing among COPD patients with varying numbers of remaining teeth are shown in Figure 1a. The reduction of $SpO_2$ was greater in patients with 0-7 remaining teeth than in patients in other groups (p<0.05). The maximum reduction was 6% and the group with 0-7 remaining teeth included two patients who had $SpO_2$ reduction of at least 4%. Comparisons of each variables of the COPD patients between $SpO_2$ reduction <2% (n=31) and $SpO_2$ reduction ≥2% (n=10) are shown in Table 4. The mean age of patients in the $SpO_2$ reduction <2% group was 73.8±7.0 years, while that in the $SpO_2$ reduction ≥2% group was 78.7±5.9 years (p=0.055). COPD patients with $SpO_2$ reduction ≥ 2% during gum chewing showed lower minimal $SpO_2$ during the 6MWT than those with $SpO_2$ reduction <2% (88.0±3.7% *vs* 91.6±4.5%; p<0.05). The number of the remaining teeth was lower in COPD patients with $SpO_2$ reduction ≥2% than in those with $SpO_2$ reduction <2% (p<0.05). The lung function, mMRC category, CAT score, 6MWT distance, BMI, HGS, and serum albumin level were not significantly different between the two groups.

Figure 1b shows the reduction of $SpO_2$ during gum chewing in COPD patients with $SpO_2$ reduction ≤4% (n=20) and in COPD patients with $SpO_2$ reduction >4% (n=21) during the 6MWT. COPD patients with $SpO_2$ reduction >4% during the 6MWT showed greater reduction during gum chewing (1.29±1.59% *vs* 0.50±0.83%; p<0.05).

## Discussion

We have shown that patients with COPD have poor chewing ability. Moreover, the number of remaining teeth and muscle mass loss were associated with decreased chewing ability. We also showed that $SpO_2$ was reduced during 1 min of gum chewing, and that the number of remaining teeth was associated with the extent of $SpO_2$ reduction.

Our study showed that the number of remaining teeth was a significant independent risk factor for poor chewing ability. This finding was consistent with the results of a previous study that showed an association between the number of teeth and chewing ability in elderly individuals aged ≥75 years [10]. The association between muscle mass and chewing ability was also consistent with the findings of a previous study that showed an association between masticatory performance and anthropometric measurements [23]. Our study confirmed that both the volume of muscle mass and the number of remaining teeth were important factors in maintenance of chewing ability. To the best of our knowledge, this is the first study to show that COPD is an independent risk factor for poor chewing ability. Further studies are needed to elucidate the mechanism by which COPD contributes to poor chewing ability.

The small difference in $SpO_2$ between before and during gum chewing in the COPD group could be due to normal variability of the assessment device. However, there was no difference in $SpO_2$ between before and during gum chewing in the control group. The reduction of $SpO_2$ was remarkable in patients who showed $SpO_2$

**Table 1. Basic characteristics of the study population.**

| Characteristics | COPD (n=41) | Control (n=22) | p |
|---|---|---|---|
| Age (years) | 75.0±7.0 | 74.6±10.0 | 0.90 |
| Sex (male/female) | 39/2 | 18/4 | 0.09 |
| Smoking (pack-years) | 59.2±34.7 | 20.5±26.7 | <0.0001 |
| Resting $SpO_2$ (%) | 95.9±1.7 | 97.3±1.1 | <0.005 |
| $FEV_{1.0}$ (mL) | 1584±545 | 2224±589 | <0.0005 |
| $FEV_{1.0}$% predicted (%) | 73±22 | 95±22 | <0.0005 |
| $FEV_{1.0}$/ forced vital capacity (%) | 52.5±12.2 | 72.8±8.2 | <0.0001 |
| GOLD COPD stage I/II/III/IV | 19/15/6/1 | NA | |
| mMRC dyspnea scale 0/1/2/3/4 | 15/18/5/3/0 | NA | |
| 6-minute walk test distance (m) | 383.8±93.1 | NA | |
| Minimal $SpO_2$ (%) during 6-minute walk test | 90.7±4.5 | NA | |
| COPD assessment score | 11.2±8.2 | NA | |
| Serum albumin (g/dL) | 4.36±0.28 | 4.19±0.29 | 0.07 |
| Serum CRP (mg/dL) | 0.18±0.31 | 0.08±0.04 | 0.59 |
| Body mass index (kg/m$^2$) | 23.4±3.1 | 24.4±2.8 | 0.21 |
| Fat-free mass (kg) | 49.8±7.6 | 48.9±7.4 | 0.53 |
| Muscle mass (kg) | 46.7±7.2 | 46.3±7.0 | 0.79 |
| Hand grip strength (kg) | 32.6±7.2 | 30.2±7.4 | 0.17 |
| Number of remaining teeth | 11.5±9.0 | 20.1±10.8 | <0.005 |

FEV1.0, forced expiratory volume in 1 second; GOLD, Global Initiative for Chronic Obstructive Lung Disease; mMRC, modified Medical Research Council; CRP, C-reactive protein.

**Table 2. Chewing ability and reduction of $SpO_2$ during gum chewing.**

| | COPD (n=41) | Control (n=22 ) | p |
|---|---|---|---|
| Color score | 3.1±0.7 | 4.2±0.9 | <0.0001 |
| Proportion of subjects with poor chewing ability (color score ≤3) | 48.8% | 9.1% | <0.001 |
| Reduction of $SpO_2$ (%) | 0.78±1.46 | 0.32±0.72 | <0.05 |
| Proportion of subjects with $SpO_2$ reduction ≥2% | 24.4% | 13.6% | 0.30 |

**Table 3. Multivariable logistic regression analysis to identify significant risk factors for poor chewing ability.**

| | Adjusted OR (95% CI) | p |
|---|---|---|
| Muscle mass, low *vs* normal | 3.07 (0.61-18.2) | 0.17 |
| Number of remaining teeth, <20 *vs* ≥20 | 6.13 (1.34-44.3) | <0.05 |
| COPD, present/absent | 5.47 (1.17-39.8) | <0.05 |

reduction >4% during the 6MWT; this suggested that the reduction observed during chewing was not due to normal variability, but to reduction of the partial pressure of oxygen in the artery.

The amplitude of desaturation was relatively small and had a questionable hemodynamic consequence. A reduction of at least 4% in $SpO_2$ has been reported to be clinically significant [24]. Although only two patients showed reduction of ≥4% in $SpO_2$ during gum chewing and the mean reduction was only 0.78%, the finding that COPD patients with >4% reduction in $SpO_2$ during the 6MWT showed greater reduction during gum chewing suggested that this small reduction could be indicative of a greater reduction by continued effort. The duration of 1 minute was chosen in our study because it was suitable for the assessment of chewing ability using color-changing gum. However, 1 minute could be insufficient length for estimation of oxygen uptake. We presume that a greater reduction of $SpO_2$ could be observed with additional chew-

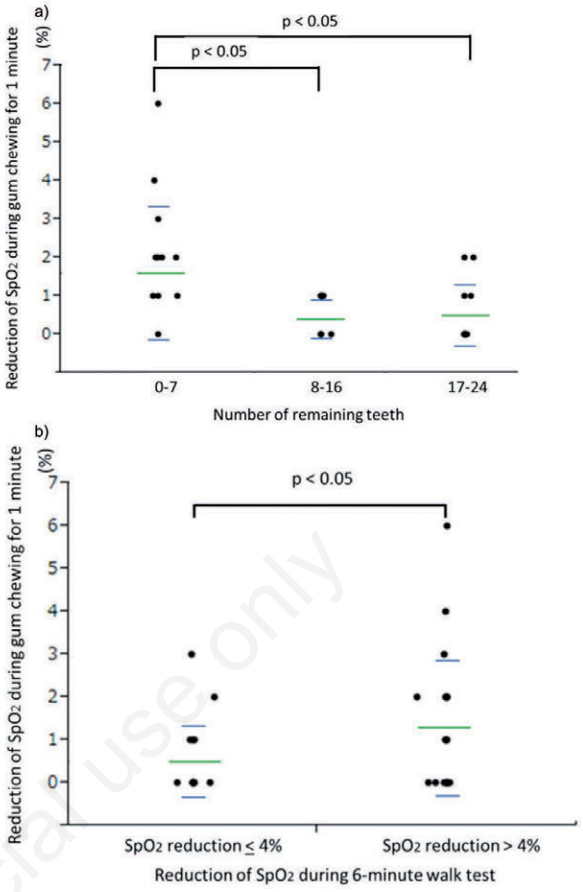


**Figure 1. a) Reduction of $SpO_2$ during gum chewing compared with the numbers of remaining teeth in COPD patients. Reductions in $SpO_2$ were 1.60±0.32%, 0.40±0.39%, and 0.50±0.35% in patients with 0-7, 8-16, and 17-28 remaining teeth, respectively; the reduction of $SpO_2$ in patients with 0-7 remaining teeth was greater than that in other groups (p<0.05). b) Reduction of $SpO_2$ during gum chewing compared between COPD patients with $SpO_2$ reduction ≤4% (n=20) and COPD patients with $SpO_2$ reduction >4% (n=21) during the 6-minute walk test; there was a greater decrease during gum chewing in the $SpO_2$ reduction >4% group than in the $SpO_2$ reduction ≤4% group (1.29±1.59% *vs* 0.50±0.83%; p<0.05). Bars show mean±standard deviation.**

**Table 4. Comparison of patient variables based on reduction of $SpO_2$.**

| | Desaturation during chewing | | p |
|---|---|---|---|
| | $SpO_2$ reduction <2% (n=31) | $SpO_2$ reduction ≥2% (n=10) | |
| Age (years) | 73.8±7.0 | 78.7±5.9 | 0.055 |
| Sex (male/female) | 30/1 | 9/1 | 0.38 |
| Smoking (pack-years) | 56.6±33.8 | 68.1±38.5 | 0.36 |
| $FEV_{1.0}$ (mL) | 1655±534 | 1360±542 | 0.16 |
| $FEV_{1.0}$% predicted (%) | 73.4±21.6 | 73.4±22.7 | 0.98 |
| GOLD COPD stage I/II/III/IV | 15/11/4/1 | 4/4/2/0 | 0.86 |
| mMRC dyspnea scale | 0.9±0.8 | 1.0±1.1 | 0.81 |
| Resting $SpO_2$ (%) | 96.7±2.0 | 96.1±1.9 | 0.29 |
| 6-minute walk test distance (m) | 390.2±98.8 | 361.7±72.2 | 0.19 |
| Minimal $SpO_2$ (%) during 6-minute walk test | 91.6±4.5 | 88.0±3.7 | <0.05 |
| COPD assessment score | 11.0±7.6 | 11.9±10.2 | 0.98 |
| Serum albumin (g/dL) | 4.36±0.27 | 4.36±0.34 | 0.92 |
| Serum CRP (mg/dL) | 0.16±0.22 | 0.25±0.52 | 0.68 |
| Body mass index (kg/m$^2$) | 23.2±2.9 | 24.1±3.8 | 0.90 |
| Fat-free mass (kg) | 50.2±6.3 | 48.6±10.9 | 0.67 |
| Muscle mass (kg) | 47.6±6.0 | 43.7±9.8 | 0.18 |
| Hand grip strength (kg) | 33.3±6.5 | 30.5±9.0 | 0.30 |
| Chewing ability (color score) | 3.1±0.7 | 3.0±0.8 | 0.53 |
| Number of remaining teeth | 13.1±9.0 | 6.6±7.8 | <0.05 |

FEV1.0, forced expiratory volume in 1 second; GOLD, Global Initiative for Chronic Obstructive Lung Disease; mMRC, modified Medical Research Council; CRP, C-reactive protein.

ing time, and tests should be performed with this additional chewing time in the future.

Desaturation during daily activities, such as walking and eating, has been shown in COPD patients [15,25]. Compared to a previous study that reported a mean $SpO_2$ of 89% during eating in patients with moderate-to-severe COPD, the amplitude of desaturation was low in our study. In the previous study, desaturation began within 5 min after patients began their meals [15], whereas desaturation began within 1 min in the present study. This finding provides new information to aid in understanding the mechanism of desaturation during meals. Although the effort during chewing was not similar to that of walking, chewing itself could cause desaturation. Another possible mechanism may involve the metabolic effects of food absorption and digestion [25].

Surprisingly, the number of remaining teeth was associated with chewing ability and with the degree of $SpO_2$ reduction during chewing. One possible explanation is that patients with fewer remaining teeth need more energy for gum chewing. Another explanation is that a lower number of remaining teeth contributed to irregular ventilation while chewing. As such, the preservation of natural teeth is important in patients with COPD, in order to prevent desaturation during chewing.

Our study had some limitations. The magnitude of the reduction in $SpO_2$ induced by gum chewing for 1 min was low. Another limitation is that the power of the statistical analyses was weak because of the small number of participants. Further studies are needed with additional patients for longer test periods to support our results.

## Conclusions

We have shown that chewing ability was poor and that $SpO_2$ decreased during chewing in patients with COPD. The presence of fewer remaining teeth was associated with poor chewing ability and reduction of $SpO_2$.

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