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 (SpO₂) was monitored using a pulse oximeter and the difference in SpO₂ 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<0.001). 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 SpO₂ decreased by 0.78±1.46% during gum chewing for 1 min. The mean SpO₂ during gum chewing (95.1±2.4%) was lower than before gum chewing (95.9±1.7%) (p<0.05). The reduction of SpO₂ was greater in COPD patients who had fewer remaining teeth (p<0.05). COPD patients with SpO₂ 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.

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...
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 SpO2 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; 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 SpO2 decreased by 0.78±1.46% during gum chewing in the COPD group. The mean SpO2 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 SpO2 decreased by 0.32±0.72% during gum chewing; the difference in SpO2 was not statistically significant. Comparisons of the reductions of SpO2 during gum chewing among COPD patients with varying numbers of remaining teeth are shown in Figure 1a. The reduction of SpO2 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 SpO2 reduction of at least 4%. Comparisons of each variable of the COPD patients between SpO2 reduction <2% (n=31) and SpO2 reduction ≥2% (n=10) are shown in Table 4. The mean age of patients in the SpO2 reduction <2% group was 73.8±7.0 years, while that in the SpO2 reduction ≥2% group was 78.7±5.9 years (p=0.055). COPD patients with SpO2 reduction ≥2% during gum chewing showed lower minimal SpO2 during the 6MWT than those with SpO2 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 SpO2 reduction ≥2% than in those with SpO2 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 SpO2 during gum chewing in COPD patients with SpO2 reduction ≤4% (n=20) and in COPD patients with SpO2 reduction >4% (n=21) during the 6MWT. COPD patients with SpO2 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 SpO₂ was reduced during 1 min of gum chewing, and that the number of remaining teeth was associated with the extent of SpO₂ 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 SpO₂ 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 SpO₂ between before and during gum chewing in the control group. The reduction of SpO₂ was remarkable in patients who showed SpO₂

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 SpO₂ (%)                       | 95.9±1.7          | 97.3±1.1        | <0.005|
| FEV₁ (ml)                              | 1584±545          | 2224±589        | <0.0005|
| FEV₁% predicted (%)                   | 73±22             | 95±22           | <0.0005|
| FEV₁/FVC (%)                           | 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 distance (m)             | 383.8±93.1        | NA              |       |
| Minimal SpO₂ (%) 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/m²)                | 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/FVC: forced vital capacity (%); GOLD: Global Initiative for Chronic Obstructive Lung Disease; mMRC: modified Medical Research Council; CRP: C-reactive protein.

Table 2. Chewing ability and reduction of SpO₂ 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 SpO₂ (%)    | 0.78±1.46   | 0.32±0.72      | <0.05  |
| Proportion of subjects with SpO₂ 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 (1.17-29.8)    | <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 SpO2 has been reported to be clinically significant [24]. Although only two patients showed reduction of ≥4% in SpO2 during gum chewing and the mean reduction was only 0.78%, the finding that COPD patients with >4% reduction in SpO2 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 SpO2 could be observed with additional chew-

![Figure 1](image1.png)

Figure 1. a) Reduction of SpO2 during gum chewing compared with the numbers of remaining teeth in COPD patients. Reducions in SpO2 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 SpO2 in patients with 0-7 remaining teeth was greater than that in other groups (p<0.05). b) Reduction of SpO2 during gum chewing compared between COPD patients with SpO2 reduction ≤4% (n=20) and COPD patients with SpO2 reduction >4% (n=21) during the 6-minute walk test; there was a greater decrease during gum chewing in the SpO2 reduction >4% group than in the SpO2 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 SpO2.

| Variable                                      | SpO2 reduction ≤4% (n=20) | SpO2 reduction >4% (n=21) | p    |
|-----------------------------------------------|--------------------------|---------------------------|------|
| Age (years)                                   | 73.8±7.0                 | 78.7±5.9                  | 0.055|
| Sex (male/female)                             | 38/1                     | 9/1                       | 0.38 |
| Smoking (pack-years)                          | 56.6±33.8                | 68.1±38.5                 | 0.36 |
| FEV1.0 (mL)                                   | 1655±534                 | 1360±542                  | 0.16 |
| FEV1.0% 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 SpO2 (%)                              | 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 SpO2 (%) 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/m²)                       | 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 SpO₂ 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 SpO₂ 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 SpO₂ 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 SpO₂ decreased during chewing in patients with COPD. The presence of fewer remaining teeth was associated with poor chewing ability and reduction of SpO₂.

References

1. Barnes PJ, Celli BR. Systemic manifestations and comorbidities of COPD. Eur Respir J 2009;33:1165-85.
2. Jones SE, Maddocks M, Kon SSC, et al. Sarcopenia in COPD: prevalence, clinical correlates and response to pulmonary rehabilitation. Thorax 2015;70:213-8.
3. Bone AE, Hepgul N, Kon S, Maddocks M. Sarcopenia and frailty in chronic respiratory disease. Chron Respir Dis 2017;14:85-99.
4. Steiner MC. Sarcopaenia in chronic obstructive pulmonary disease. Thorax 2007;62:101-3.
5. Schols AM, Broekhuizen R, Weling-Scheepers CA, Wouters EF. Body composition and mortality in chronic obstructive pulmonary disease. Am J Clin Nutr 2005;82:53-9.
6. Swallow EB, Reyes D, Hopkinson NS, et al. Quadriceps strength predicts mortality in patients with moderate to severe chronic obstructive pulmonary disease. Thorax 2007;62:115-20.
7. Varraso R, Camargo CA Jr. More evidence for the importance of nutritional factors in chronic obstructive pulmonary disease. Am J Clin Nutr 2012;95:1301-2.
8. Schols AM, Ferreira IM, Franssen FM, et al. Nutritional assessment and therapy in COPD: a European Respiratory Society statement. Eur Respir J 2014;44:1504-20.
9. Shalti L, Tierney A, Holland A, et al. Factors that influence dietary intake in adults with stable chronic obstructive pulmonary disease. Nutr Diet 2016;73:455-62.
10. Kimura Y, Ogawa H, Yoshihara A, et al. Evaluation of chewing ability and its relationship with activities of daily living, depression, cognitive status and food intake in the community-dwelling elderly. Geriatr Gerontol Int 2013;13:718-25.
11. Iwasaki M, Kimura Y, Ogawa H, et al. The association between dentition status and sarcopenia in Japanese adults aged ≥75 years. J Oral Rehabil 2017;44:51-8.
12. Murakami M, Hirano H, Watanabe Y, et al. Relationship between chewing ability and sarcopenia in Japanese community-dwelling older adults. Geriatr Gerontol Int 2015;15:1007-12.
13. Kinane DF, Stathopoulou PG, Papapanou PN. Periodontal diseases. Nat Rev Disease Prim 2017;3:17038.
14. Terashima T, Chubachi S, Matsuzaki T, et al. The association between dental health and nutritional status in chronic obstructive pulmonary disease. Chron Respir Dis 2017;14:334-41.
15. Soguel Schenkel N, Burdet L, de Muralt B, Fitting JW. Oxygen saturation during daily activities in chronic obstructive pulmonary disease. Eur Respir J 1996;9:2584-9.
16. Waatevik M, Johannessen A, Gomez Real F, et al. Oxygen desaturation in 6-min walk test is a risk factor for adverse outcomes in COPD. Eur Respir J 2016;48:82-91.
17. Takigawa N, Tada A, Soda R, et al. Distance and oxygen desaturation in 6-min walk test predict prognosis in COPD patients. Respir Med 2007;101:561-7.
18. Rabe KF, Hurd S, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med 2007;176:532-55.
19. Chen M, Sun J, Bai H, et al. Muscle mass reference standard for sarcopenia using bioelectrical impedance analysis. Asian J Gerontol Geriatr 2015;10:16-21.
20. Chen LK, Liu LW, Woo J, et al. Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. J Am Med Dir Assoc 2014;15:95-101.
21. Hama Y, Kanazawa M, Minakuchi S, et al. Reliability and validity of a quantitative color scale to evaluate masticatory performance using color-changeable chewing gum. J Med Dent Sci 2016;61:1-6.
22. Kamiyama M, Kanazawa M, Fujimina Y, Minakuchi S. Validity and reliability of a self-implementable method to evaluate masticatory performance: use of color-changeable chewing gum and a color scale. J Prosthodont Res 2010;54:24-8.
23. Okada K, Enoki H, Izawa S, et al. Association between masticatory performance and anthropometric measurements and nutritional status in the elderly. Geriatr Gerontol Int 2010;10:56-63.
24. Escourrou PJ, Delaperche MF, Visseaux A. Reliability of pulse oximetry during exercise in pulmonary patients. Chest 1990;97:635-8.
25. Schols A, Mostert R, Cobben N, et al. Transcutaneous oxygen saturation and carbon dioxide tension during meals in patients with chronic obstructive pulmonary disease. Chest 1991;100:1287-92.
