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# ASSESSMENT OF ORAL FUNCTION AND PROPER DIET LEVEL FOR FRAIL ELDERLY INDIVIDUALS IN NURSING HOMES USING CHEWING TRAINING FOOD

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**Abstract:** *Objectives:* We aimed to investigate the relationship between the ability to press Process Lead (PL) in the oral cavity and the tongue pressure and recommended diet form for elderly individuals in nursing homes, using PL normalized physical properties. *Design:* Cross-sectional observation study. *Setting:* Geriatric facilities. *Participants:* A 100 elderly individuals aged between 67-96 years. *Measurements:* PL was pressed between the tongue and palate to evaluate its deformation. The thickness was set at 6, 9, and 18 mm. The tongue pressure was measured with a JMS tongue pressure manometer. The number of chewing cycles until an 18-mm thick PL was first swallowed was measured (PL chewing test). The diet was set to level 4, and the recommended form was evaluated by video endoscopic evaluation of swallowing (VE). The results of the PL pressing test and correlations between PL chewing test, tongue pressure, and diet level were statistically examined. *Results:* The tongue pressure was significantly decreased in groups that could not press the PL. The PL pressing test and recommended diet form showed a significant correlation, and the elderly with difficulty in pressing the PL had a lower diet level. In addition, the diet level decreased with decreased PL chewing test performance in those without molar occlusion. *Conclusions:* The PL pressing and chewing tests may aid in ascertaining the appropriate diet level. In the future, we would like to verify the usefulness of these tests in determining the diet level of elderly people requiring long-term care at the time of entering the facility.

**Key words:** Process Lead, tongue pressure, chewing cycle, diet form level.

## Introduction

The number of older individuals with suspected dysphagia are increasing in a super-aged society. Individuals with suspected dysphagia run a risk of malnutrition and respiratory complications owing to aspiration (1, 2). In nursing homes, proper selection of diet level for residents with dysphagia is essential to prevent aspiration of ingested food (3). Dysphagia diet is classified into several levels (4), but the important point for deciding a proper diet form is to assess not only swallowing but also the masticatory function.

Mastication is the integrated function of the jaws, hyoid, tongue, and other soft tissues. Masticatory function deteriorates in elderly individuals owing to various factors. Deteriorated masticatory function may affect eating and thus the diet level of frail elderly individuals. Eating function in people with dysphagia is generally assessed by videofluoroscopy or videoendoscopy (5). Instrumental examination can aid in comprehensive visible evaluation of masticatory and swallowing functions, which is useful for determining the diet level of patients with dysphagia. However, the access to those medical instruments is limited for individuals living at nursing homes. Thus, a concise assessment of the eating (mastication and swallowing) function is desirable to determine safe and present diet levels for residents at nursing homes. There are simple swallowing screening tests using water or jelly food(6), but few masticatory evaluation tests for people with dysphagia.

Masticatory function is conventionally measured with gummy or gum. Masticatory performance is generally assessed based on the grindability and distribution of gummy particles (7) or visual color change (8). Although these methods are effective for evaluating masticatory ability in healthy adults, it is difficult to apply these assessments to people with dysphagia because of the increased risk of choking or aspiration due to the high elasticity and adhesiveness of the test materials.

The tongue plays a critical role in both mastication and swallowing. The tongue carries food to the occlusal surface of the teeth during chewing, then transports the chewed bolus to the oropharynx prior to swallowing. The transported food bolus is accumulated at the back of the tongue, and is eventually propelled to the esophagus by tongue retraction and pharyngeal constriction (9, 10). Since tongue pressure is correlated with swallowing function (11, 12), decreased tongue pressure is often observed in patients with dysphagia (13), sarcopenia (13, 14), neuromuscular disease (15), or cerebrovascular disorders (16), and is thus related to the diet level in patients in nursing care facilities (17). Hence, the maximum tongue pressure (MTP), which could be an indicator of the diet level, needs to assessed using a measuring device.

Our definitive goal in this study was to develop a technique for the concise assessment of eating function and proper diet level for frail elderly individuals living in nursing homes. First, we tested if a novel chewing training food, named Process Lead (PL), could be used to evaluate eating function and,

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thereby, the proper diet level without any devices. PL has been developed as a chewing training food for dysphagic individuals (18, 19). It is a hard jelly made from sesame paste; its hardness requires chewing at a preparatory stage (Ishibashi N et al., in press). However, after chewing, the transported chewed bolus in the pharynx changes to a swallowable puree-type texture. We hypothesized that PL can be used to assess the tongue pressure by placing between the tongue and palate; this can also be used for standardized masticatory assessments in patients with dysphagia because of its safer texture compared to the other gummy or gums. To test this hypothesis, we investigated the relationship between the ability to press PL in the oral cavity and the tongue pressure and recommended diet form for elderly individuals in nursing homes.

## Materials and Methods

### *Participants*

This study protocol was approved by the Institutional Review Board of Fujita Health University (Approval ID: 16-425).

A 100 elderly individuals who lived at geriatric facilities and had 3 oral meals per day were recruited in this study. The exclusion criteria were unstable physical or mental status, functional disability requiring assistance for eating, structural abnormality of the oral cavity, and insufficient comprehension of the instructions. All participants and a family member or other proxy provided written informed consent prior to enrollment in this study.

### *Data collection*

*Preparation of Process Lead*

The physical property of PL has been reported in a previous study (Ishibashi N et al., in press). Based on the results of that study, we determined the thickness of PL for the pressing test as follows: 6, 9, and 18 mm (Fig. 1A). The PL with 18-mm thickness was a square cube and those with 6- and 9-mm thickness were 1/3 and 1/2 of a rectangular cube.

*Process Lead pressing and chewing tests*

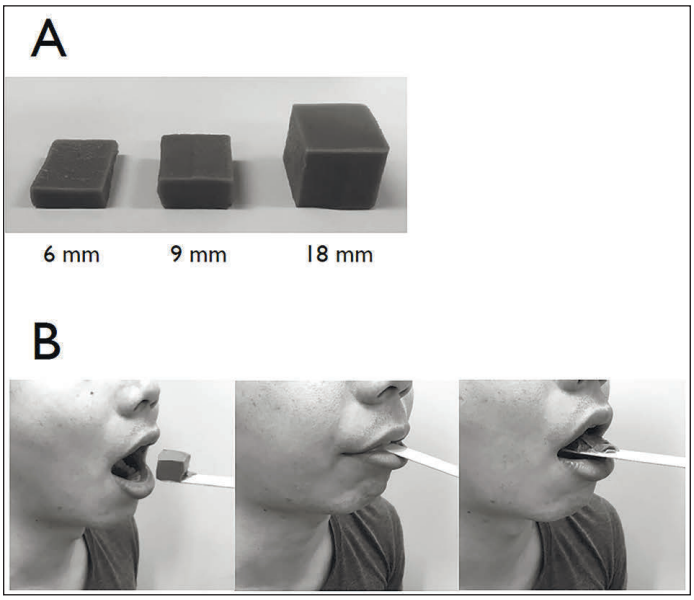
The PL pressing test was performed by pressing the cube of PL between the tongue and hard palate. The PL, placed on a tongue depressor, was inserted into the participant's mouth. The participants were instructed to press the PL cube between the tongue and palate; we then evaluated if the cube was deformed (Fig. 1B). The trial was started with the 18-mm thick cube, followed by the 9-m and 6-mm thick cubes if successful. We recorded the least thickness of PL deformation.

The PL chewing test was performed using an 18-mm thick PL cube. Participants were asked to eat the 18-mm thick cube naturally, and the number of chewing cycles from ingestion until the first swallow were counted. The PL chewing test was repeated three times, and the mean was calculated.

In the preliminary study, we examined and concluded the following 3 points on the physical properties of PL: (1) There was reproducibility in rupture stress at the same thickness of PL, (2) The deviation of the expected tongue pressure from the rupture stress was within the range of tongue pressure for patients with dysphagia, (3) The PL did not disperse and release water on crushing.

**Figure 1**

(A) The thickness of Process Lead (PL) for the pressing test was set at 6, 9, and 18 mm. (B) The pressing test using PL; the participant could press the 18-mm PL cube sufficiently




*Maximum tongue pressure*

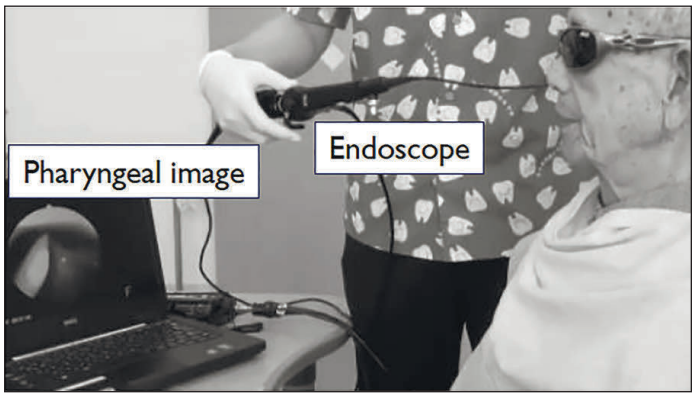
MTP (kPa) was measured using a digital tongue pressure meter equipped with a sensor balloon probe (TPM-01, JMS Co. Ltd., Hiroshima, Japan). The sensor balloon was set between the tongue and hard palate, and participants were instructed to raise their tongue and compress the balloon toward the palate at maximum strength. The maximum value was measured three times, and the mean was calculated.

The presence of functional occlusal support area by natural teeth or properly fabricated denture(s) was also evaluated.

*Videoendoscopic examination of eating functions*

Videoendoscopic examination of swallowing (VE) was performed to evaluate eating functions. A fiberoptic endoscope (3.6 mm in diameter, ENF TYPE P4, Olympus, Tokyo, Japan) was inserted through the nostril, and the tip of the endoscope was positioned behind the soft palate to observe the pharyngeal region. Participants were instructed to eat the 18-mm thick PL cube, and the pharyngeal images during evaluation were recorded on a digital video (Fig. 2). Pharyngeal bolus formation was classified into 3 levels: 0, good; 1, not bad; 2, bad (20), and the residue in the oral cavity and pharynx was classified into 4 levels (21): 1, none; 2, punctuate/trace; 3, less than half; and 4, half or more.

**Figure 2**
Participant eating a Process Lead (PL) cube or recommended diet, and video images from an endoscope were recorded simultaneously by digital video camera. We counted the number of chewing cycles from PL ingestion to the first swallow using these images (PL chewing test)




Recommended diet level was evaluated with the VE and classified into 4 levels (regular, chopped, minced, and soft).

***Data analysis***

The PL pressing test was more difficult with cubes of lesser thickness, i.e., the 6-mm thick cube was the most difficult to deform. Based on the PL pressing test results, the participants were classified into 3 groups: those who could deform cubes of all thickness (6 mm), those who could deform cubes of 9-mm and 18-mm thickness (9 mm), and those who could deform 18-mm thick cubes only (18 mm). All participants could deform 18-mm thick cubes.

The one-way ANOVA was used to examine the difference in MTP based on the PL pressing test group or recommended diet level. Then, the receiver operating characteristic (ROC) curve was used to test the cutoff points for MTP to distinguish between the PL pressing test results (6 mm vs 9 mm, and 9 mm vs 18 mm, respectively). The area under the curve (AUC) was obtained from the ROC curve, and the point closest to the coordinate point of the upper left corner (sensitivity 1, specificity 1) was calculated as the cutoff value. The relationship between the PL pressing test group and recommended diet level was tested by the chi-square test.

The difference in the number of chewing cycles among the PL pressing test groups and molar occlusion were tested by two-way ANOVA. The Bonferroni test was used for multiple comparisons. The differences in the number of chewing cycles was also compared by the recommended diet level and molar occlusion using two-way ANOVA.

The chi-square test was used to compare bolus formation and residue in the pharynx.

Statistical significance was set at $p = 0.05$. Statistical analyses were performed with SPSS 25.0 (SPSS, Chicago, IL).

## Results

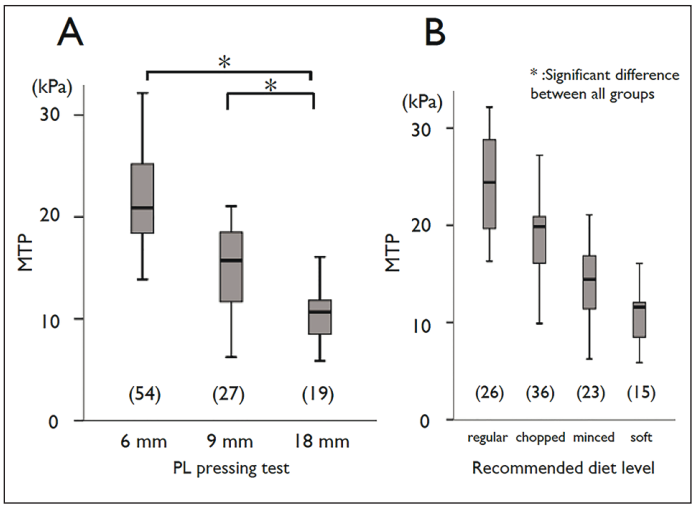
A total of 100 participants (mean age: 87, range, 67-96 years, 34 men and 66 women) were enrolled in this study. The demographic characteristics of the participants is shown in Table 1.

**Table 1**
Basic demographic characteristics of participants

| | Male | Female | Total |
|---|---|---|---|
| | **34** | **66** | **100** |
| age | 82 (range; 67-92) | 89 (range; 69-96) | 87 (range; 67-96) |
| MTP (kPa) | 19.6 (range; 10.2-32.2) | 17.4 (range; 5.9-31.0) | 18.1 (range; 5.9-32.2) |
| PL chewing test | 16.5 (range; 6-33) | 15.5 (range; 4-35) | 16.0 (range; 4-35) |

MTP, maximum tongue pressure; PL, Process Lead

**Figure 3**
The relationship between the maximum tongue pressure (MTP) and (A) Process Lead (PL) pressing test and (B) recommended diet level showed that participants with a low MTP showed low scores on the PL pressing test and recommended diet levels (*p < 0.05 for the correlation with recommended diet levels)




***Relationships among the maximum tongue pressure and Process Lead pressing test and recommended diet level***

The median [interquartile range; IQR] MTP was 20.9 [18.4–25.2] (kPa) in the 6-mm group but was significantly lower in the 9-mm and 18-mm groups (15.3 [11.5–18.9] (kPa)and 10.7 [8.1–12.0] (kPa), respectively) (Fig. 3A). The median MTP was 24.4 [19.6–28.8] kPa for the group with regular diet but was lower for lower diet levels. For the group with the chopped diet, the median MTP decreased to 19.9 [16.1–20.9] kPa and was even lower in the group with minced and soft diets (14.4 [11.3–17.3] (kPa) and 11.6 [8.1–12.1] (kPa), respectively) (Fig. 3B).

With the ROC analysis, the cutoff value of the MTP for

the 6-mm vs 9-mm group was 16.2 kPa (sensitivity, 0.86; specificity, 0.80). The AUC was 0.815 (P < 0.001). The cutoff value of the MTP for 9-mm vs 18-mm group was 11.5 kPa (sensitivity, 0.82; specificity, 0.78), and the AUC was 0.760 (P < 0.001).

The diet level and PL pressing test also showed a significant correlation (P < 0.001) (Table 2). The most recommended diet was regular or diced (91%) for the 6-mm group. In the 9-mm group, 10 individuals (37%) were recommended a diced diet, and 12 (44%) were recommended a minced diet, but only one person was recommended a regular diet. For the 18-mm group who could deform only cubes of 18-mm thickness, the recommendations were mostly for a soft diet (11 people, 58%), followed by minced diet (6 people, 32%).

**Table 2**
Relationships between PL pressing test and recommended diet level

| PL pressing test | Recommended diet level | | | | |
|---|---|---|---|---|---|
| | Regular | Diced | Minced | Soft | |
| Deforms all thickness (6-mm) | 25 | 24 | 5 | 0 | 54 |
| Deforms 9 mm or 18 mm (9-mm) | 1 | 10 | 12 | 4 | 27 |
| Deforms only 18 mm (18-mm) | 0 | 2 | 6 | 11 | 19 |
| Total | 26 | 36 | 23 | 15 | 100 |

PL, Process Lead

***Relationships among Process Lead chewing test, Process Lead pressing test and recommended diet level***

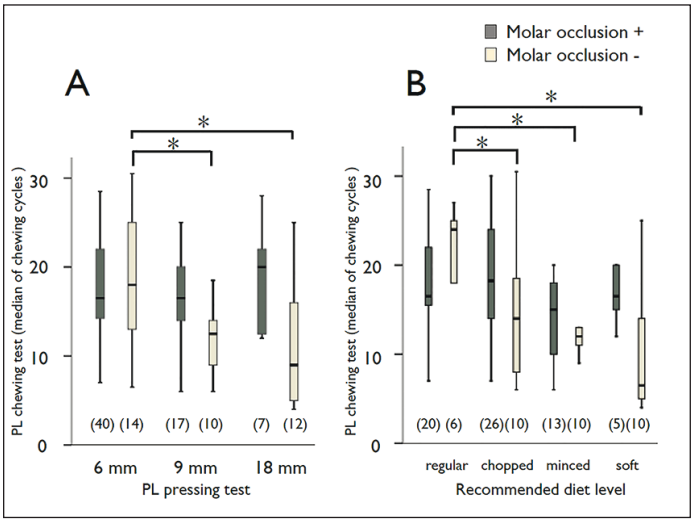
For participants with molar occlusion, the median number of chewing cycles for the PL chewing tests were 16.5 [14.1–22.0], 16.5 [13.5–20.5], and 20.0 [12.0–24.0] for the 6-, 9-, and 18-mm groups, respectively (Fig. 4A). It was not different among the groups of PL pressing test. However, for participants who did not have molar occlusion, the number of chewing cycles were significantly lower in the 9-mm and 18-mm group compared to the 6-mm group. For the 6-mm group, the number of chewing cycles did not differ between the group with and without molar occlusion, but was significantly lower in the participants without molar occlusion in the 9- and 18-mm groups.

In participants with molar occlusion, on comparing between the various recommended diet levels, there was no significant difference in the median number of chewing cycles for the PL chewing test. However, in participants without molar occlusion, the number of chewing cycles significantly decreased in those on a minced or soft diet (Fig. 4B).

***Comparison of bolus formation and Process Lead (18-mm thick) residue in the pharynx***

The differences in bolus formation and residue in the pharynx were compared between the recommended diet forms. In participants who were recommended a soft diet, there was a tendency for bolus formation to become more "bad," but there were no significant differences (Fig. 5A). There was no significant difference in the residue in the pharynx, when statistically examined for each of the molar occlusions and recommended diet forms (Fig. 5B, C).

**Figure 4**
The relationship between the Process Lead (PL) chewing test and (A) PL pressing test and (B) recommended diet level showed that participants with molar occlusion with low scores on PL pressing test/diet level showed significantly fewer chewing cycles (*p < 0.05)




## Discussion

The present study demonstrated that the MTP was significantly different among the groups based on the results of the PL pressing test and diet level recommendation. These findings suggest that the PL pressing test may help identify the appropriate diet level. The results of the PL chewing test showed significantly fewer chewing cycles in dysphagic patients without molar occlusion. Softer foods could be recommended in these individuals because of the decline in their chewing ability. Combining the PL pressing and chewing tests could help identify the diet recommendation for frail elderly individuals in nursing homes; however, further studies are warranted to validate these assessments.

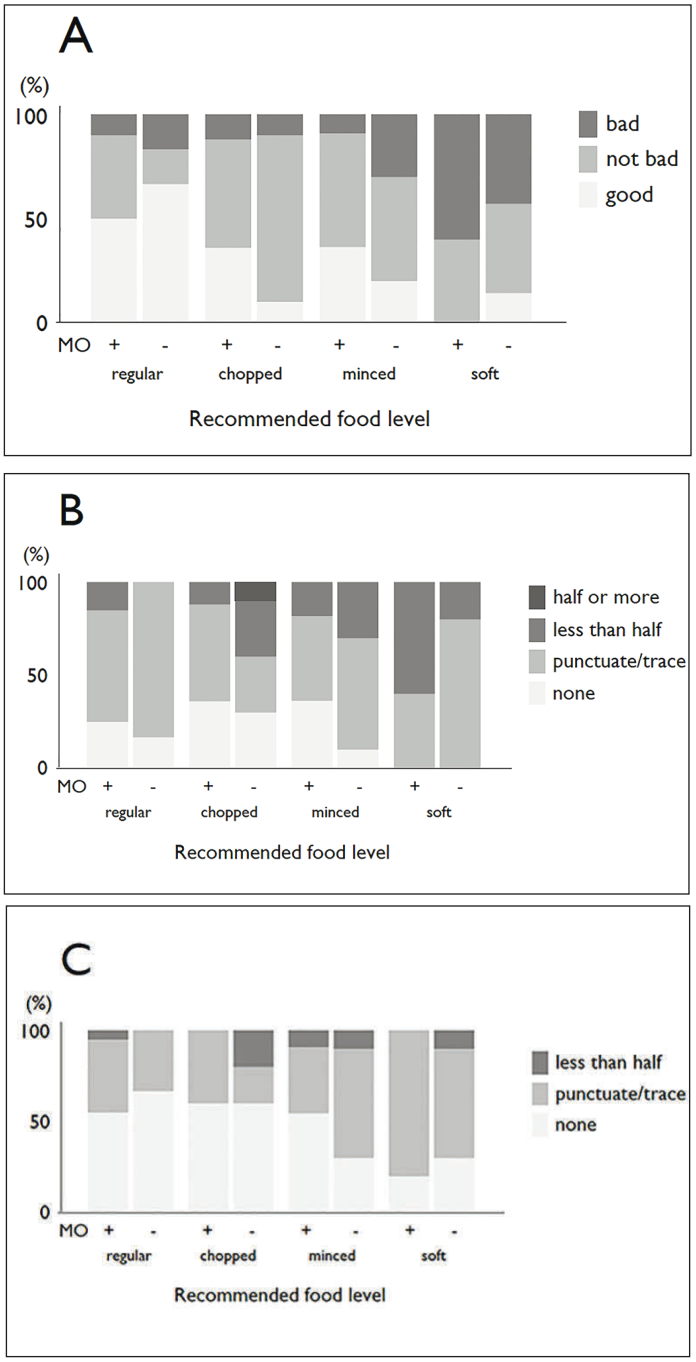
***Relationships among maximum tongue pressure and Process Lead pressing test and recommended diet level***

In this study, we developed the novel PL pressing test to try to assess the MTP without the use of a digital tongue pressure meter. Participants were divided into 3 groups based on their ability to deform 3 PL cubes of different thicknesses. The MTP was significantly different among the 3 groups. For the group who could deform the thinnest cube, the average MTP was 20 kPa. In contrast, the average MTP was 11 kPa for the group who could only press the 18-mm PL cube. By the ROC curve

analysis, the recommended cutoff was 11.5 kPa for the 9-mm vs. 18-mm group and 16.2 kPa for 6-mm vs. 9-mm group, respectively, with high sensitivity. These findings suggest that PL pressing test could be used as a concise screening test to assess the MTP.

**Figure 5**

The relationship between the Process Lead (PL) chewing test and (A) PL pressing test and (B) recommended diet level showed that participants with molar occlusion with low scores on PL pressing test/diet level showed significantly fewer chewing cycles (*p < 0.05)




We found that the MTP was strongly correlated with the diet recommendation level as well. Tanaka et al. reported that MTP showed significant correlation with food intake level in nursing home residents or hospitalized patients, suggesting that the MTP was an effective indicator for determining the dietary recommendation for hospitalized patients and the elderly in nursing homes (17). Our findings confirm their results that MTP can be an indicator for diet recommendation. Our results also showed that PL pressing test is also significantly correlated with diet recommendation. Most participants who could press the thin PL cube were recommended a regular or diced diet, while those who could only press the 18-mm cube were recommended a soft or minced diet. These findings suggest that the MTP, PL pressing test, and diet recommendation were strongly linked, and PL pressing test could be applied as a tool to determine diet recommendation without instrumentation in nursing homes.

Mastication and swallowing are the integrated functional system of the craniofacial organs. In this, the tongue probably plays the most critical role (22-24). The tongue carries the ingested food to the molar, places it on the occlusal surface during chewing, then propels the chewed bolus to the pharyngeal surface of the tongue, and finally pushes the bolus into the hypopharynx during swallowing (25). Structural defects or dysfunction of the tongue significantly hamper the performance of these functions during eating, especially in patients with tongue cancer (26), stroke (16), or neuromuscular diseases (15). The PL pressing test is a simple screening test that could be used to detect decreased MTP in nursing home inhabitants.

In the present study, we determined the thickness of PL for the PL pressing test. Ishibashi et al., investigated the physical property of PL with different thicknesses using a creep meter, and reported that the breaking stress and compressive stress varied with different thicknesses of PL. They also transferred the breaking stress to the expected tongue pressure and reported that the pressure for breaking the 6-, 9-, and 18-mm thick PL cubes were 14.7, 12.7, and 8.7 kPa, respectively. The median MTP for the 6-, 9-, and 18-mm groups were 20.9, 15.3, and 10.7 kPa, respectively, in this study. Our findings approach the findings in the previous study, indicating the validity of the PL pressing test.

Relationships among maximum tongue pressure and Process Lead chewing test and recommended diet level

We found that the results of the PL chewing test depended more significantly on molar occlusion than tongue pressure or recommended diet level, in contrast to results of the PL pressing test which significantly correlated with tongue pressure and recommended diet level. The number of chewing cycles did not differ among the PL pressing test groups in participants with molar occlusion but decreased significantly in participants in the 9- and 18-mm group without molar occlusion. This means that individuals chew the 18-mm PL cube in a certain amount of time if they have molar occlusion, regardless of tongue

pressure. The bolus formation in the pharynx for patients with molar occlusion was not different among the groups, suggesting that a certain amount of chewing induced proper bolus formation in the pharynx.

In contrast, in participants without molar occlusion, those with lower MTP showed fewer PL-chewing cycles. This means that participants with weak tongue strength and no molar occlusion tended to chew less, and swallowed the bolus with large-sized particles because of insufficient chewing. The number of teeth or occlusal support significantly affects masticatory performance (27). With decreased number of teeth, masticatory performance significantly declines (28). If the swallowing function declines, fewer chewing cycles may increase the risk of choking or aspirating the ingested food.

In this study, the average number of chewing cycles was approximately 20. The weight of the 18-mm PL cube was 6 g. The texture of PL is softer than that of regular diet. The number of chewing cycles of testing material (4 g) was 16.9±10.1 in previous studies (18). Thus, 20 or more chewing cycles would be a reasonable number. Thus, the PL chewing test could be a useful screening test for diet evaluation in frail elderly individuals.

### *Comparison of bolus formation and the 18-mm Process Lead residue in the pharynx*

In each recommended diet form, we observed differences in bolus formation and residue in the pharynx. In participants eating 18-mm PL cubes, who were recommended soft food, there was a tendency for bolus formation to become more "bad," but no statistically significant differences were noted. Moreover, when eating an 18-mm PL cube, there was no significant difference in the residue in the pharyngeal cavity after swallowing. Therefore, it was suggested that in participants with or without molar occlusion, 18-mm PL cubes can be eaten relatively safely.

### *Limitation*

This study had several limitations. First, because this study targeted individuals in nursing homes who follow instructions, it was impossible to examine the utility of this test in those who could not comply with instructions to press the PL cube. Individuals with disorders, such as dementia and cerebrovascular disease, often cannot follow the instructions. The feasibility of this text in such individuals will be a future subject.

Second, since we targeted those who ingested 3 oral meals per day, we could not examine the feasibility of these tests in dysphagic patients. Determination of diet form was also assumed in the acute and recovery phases. We plan to investigate these tests in dysphagic patients in the future.

## Conclusion

The present study demonstrated that the results of PL pressing test were significantly associated with the MTP and recommendations of diet level. The PL chewing test presented fewer chewing cycles in participants without molar occlusion ingesting softer food, suggesting that people with deteriorating chewing and swallowing functions exhibited poorer eating performance. Combining these tests could be the indicator for determination of food intake level in frail elderly individuals in nursing homes. In the future, we hope to demonstrate the utility of these findings as concise assessments of eating function and proper diet level for frail elderly individuals living in nursing homes.

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*Conflicts of interest:* Kazuharu Nakagawa and Koichiro Matsuo declare that they have no conflict of interest.

*Ethical standards:* This study protocol was approved by the Institutional Review Board of Fujita Health University (Approval ID: 16-425).

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