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Impacts of wearing complete dentures on bolus transport during feeding in elderly edentulous

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SUMMARY Prosthetic treatment with dentures is often required for the elderly who have reduced swallowing function. Therefore, it is important to understand the relationship between denture-wearing and feeding function from the perspective of swallowing. To clarify changes in bolus transport during feeding in elderly edentulous patients with or without complete dentures. Subjects were 15 elderly edentulous without dysphagia who were treated with maxillary and mandibular complete dentures. The test food was 10 g of minced agar jelly containing barium sulphate with a particle diameter of 4·0–5·6 mm. Lateral videofluoroscopy was performed to assess the position of the leading edge of the bolus, the bolus volume in each area at swallow onset, bolus transit time and the mandibular position during pharyngeal swallowing. There were significant changes between the bolus transport with and without dentures. Without dentures, the leading edge of the bolus at swallow onset fell from the valleculae area to the hypopharynx, and the bolus volume in the hypopharynx increased. Bolus transit time increased in the oral cavity, valleculae and hypopharynx. The mandibular position shifted anterosuperior direction. The results arose owing to anatomical changes in the oral and pharyngeal structure and the following functional changes: poor food manipulation, poor bolus formation and delayed swallowing reflex. Removing dentures in elderly edentulous individuals influences bolus transport during feeding, resulting in the exacerbation of the reduced swallowing reserve capacity that accompanies ageing, and may increase the risk of dysphagia.

KEYWORDS: dentures, deglutition, mastication, fluoroscopy, dysphagia, rehabilitation

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Introduction

Decline in masticatory and swallowing functions in elderly people strongly influences their health and quality of life because it is related to food selection, aspiration pneumonia, nutritional status and general enjoyment of eating (1, 2). In particular, decreased swallowing function could be caused either by common conditions of the elderly, such as strokes and degenerative diseases, or simply by ageing itself (3). Thus, even minor changes in swallowing function in the elderly may represent a significant risk of dysphagia, because their swallowing reserve capacity has already been compromised by ageing or other illness. These minor changes often include anatomical and functional changes related to the oral cavity, which are common in the elderly because they are often edentulous (4), and the structure of the oral cavity and masticatory function changes easily when dentures are not worn (5). However, prosthetic treatment with dentures is often performed inadequately for the elderly, who experience dysphagia and

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impaired swallowing function (6). Indeed, in a survey by Minakuchi *et al.* (7), about 54% of people aged 75 or older did not wear dentures when eating foods. Furthermore, about 60% of elderly patients wore ill-fitting dentures, forcing them to consume minced food that required less masticatory function. In other words, not wearing dentures may result in an increased risk of dysphagia in these individuals. Therefore, it is important to understand the relationship between denture-wearing and feeding function from the perspective of swallowing; however, it is still mostly unknown. If, by removing dentures from the oral cavity, elderly edentulous patients were negatively impacted by their swallowing function in the pharynx, then prosthetic treatment with dentures would be highly significant as a part of comprehensive rehabilitation for elderly edentulous patients. Eating without dentures could cause suffocation and aspiration in the patients even if they have no dysphagia (8–10). This is largely due to poor bolus formation and unorganised pharyngeal swallowing by removing dentures.

Some previous studies have reported the physiological relationship between dentures and swallowing and that wearing complete dentures reduces the time required for edentulous patients to swallow liquids (8–10). In particular, a videofluorographic swallowing study (VFSS) is recognised as the gold standard to evaluate swallowing function. Hattori (9) reported that, without dentures, the hyoid and larynx moved further upward and forward, respectively. In addition, Yoshikawa *et al.* (10). reported that laryngeal penetration increased during liquid swallowing when dentures were not worn. Unfortunately, these studies focused only on liquid swallowing, which does not require mastication. Recently, it has been revealed that the bolus transport dynamics during feeding of solid food (termed as stage II transport, or STII) differs from liquid swallowing (11). Previous studies also ignored the reality that many edentulous elderly eat without dentures (7). Thus, the impact of wearing dentures while ingesting solid food has yet to be fully elucidated. In particular, bolus transport dynamics from the oral cavity to the oesophagus during feeding would vary depending on whether dentures were worn.

The purpose of this study was to clarify the impacts of wearing complete dentures on bolus transport during feeding in edentulous elderly patients.

Methods

Subjects

The subjects were 15 edentulous adults (four men and 11 women; mean age: 78·0 ± 5·6 years) with no swallowing function abnormalities who hoped VFSS examination. Each participant received complete dentures made by a prosthodontist at the same clinic more than 3 months ago and were determined to have good clinical prognosis according to the Japanese version of the Oral Health Impact Profile for the edentulous (14). This study was approved by the ethics committee of School of Dentistry at Iwate Medical University (Approval No. 01150). After fully explaining the purpose and methods of this experiment verbally and in writing, we were able to obtain written informed consent from each subject.

Observation of feeding sequence by VFSS

Lateral videofluoroscopy was performed in an upright sitting position using fluoroscopic diagnostic equipment (Sonial vision Safire II*;) to observe feeding sequence. The test food was 10 g of minced agar jelly with a particle diameter of 4·0–5·6 mm, which was shown in preliminary experiments to be consumable without dentures and chewable when wearing dentures. Agar jelly was made from 2·4 g of agar (Kanten Cook†;), 18·0 g of sugar, 160 mL of water and 80 mL of 120 w/v % barium sulphate. To standardise the size of the agar pieces, the agar was chopped as uniformly as possible, and only those pieces that passed through a 5·6-mm mesh sieve but remained on a 4·0-mm mesh sieve were used for the experiment.

A 5·8-mm-diameter lead ball was attached to their neck for calibration of actual size. Each subject performed a total of six oral ingestions in two different conditions: (i) with dentures: three ingestions of 10 g of minced agar jelly while wearing upper and lower dentures, (ii) without dentures: three similar ingestions while dentures were removed. Subjects wore their dentures every day during waking hours and ingested foods with dentures in place. On the day of the experiment, subjects were asked to attend the clinic more

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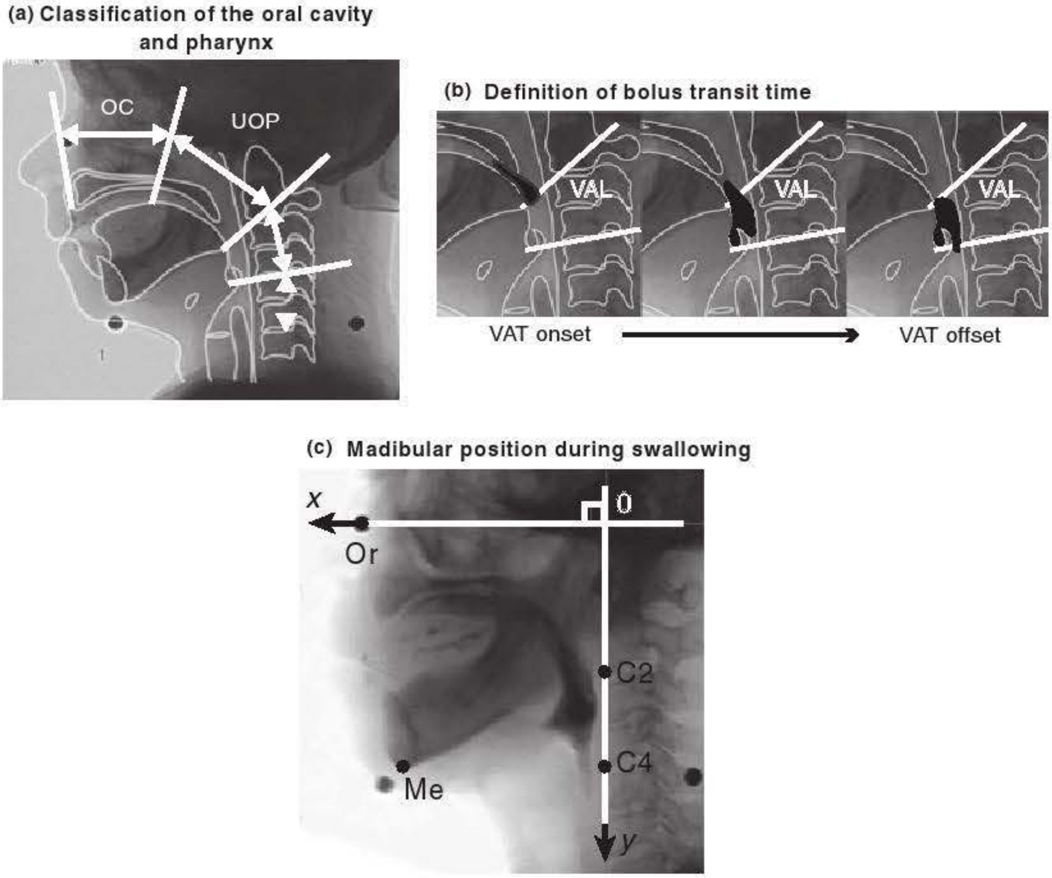

Fig. 1. (a) Oral cavity and pharynx areas in the videofluoroscopic images were demarcated and labelled as follows (13, 14): the oral cavity area (OC) was from the lips to the posterior nasal spine; the upper oropharynx area (UOP) was from the posterior nasal spine to the lower border of the mandible; the vallecular area (VAL) was from the lower border of the mandible to the vallecula; and the hypopharynx area (HYP) was from the edge of the epiglottis to the upper oesophageal sphincter. (b) The bolus transit time starts as the leading edge of the bolus enters the area and ends as the leading edge moves to the next area. The bolus is shown as the black portion in the oral cavity and pharynx. Bolus transit time for each area was termed as follows (13, 14): processing; post-faucial aggregation time (PFAT); vallecular aggregation time (VAT); hypopharyngeal transit time (HTT). (c) Mandibular position during pharyngeal swallowing. The videofluoroscopic image when the leading edge of the bolus passed through the upper oesophageal sphincter was obtained from videofluorographic swallowing study (VFSS) video. The mandibular position was defined by the Menton, an anatomical landmark used in orthodontics. The *y*-axis is the line through the anterior–inferior edge of the second and fourth cervical vertebrae (C2, C4). The *x*-axis is the line through the lead ball at the orbitale (or) crossing perpendicular to the *y*-axis. The zero point (0) is the intersection point of the *x*- and *y*-axes at a 90° angle. The distance from the zero point in both the *x*- and *y*-axes was calculated, calibrated against the lead ball at the neck.

than 1 h in advance of the planned start time, and their dentures were removed. Subjects were allowed to practise feeding without dentures sufficiently until they felt they could do easily. The test food was placed on the tongue using a spoon, and they were instructed to eat as normal, in the manner that was easiest for them.

Data analysis

Videofluorographic swallowing study videos of all measurements were scanned to a computer. To analyse bolus transport with video analysis software (Adobe Premiere Pro CS5 Extended[‡];), the oral cavity and pharynx were subdivided into four areas based on a classification introduced by Hiimae *et al.* (13), as shown in Fig. 1a. Measurement parameters related to bolus transport were assessed as follows:

1 Position of the leading edge of the bolus at swallow onset, defined as the area closest to the oesophagus in which the bolus was observed.

[‡]Adobe Systems, CA, USA.

2 Proportion of bolus volume in each area at swallow onset. Still images at swallow onset and image analysis software (Adobe Photoshop Pro CS5 Extended; [‡]) were used to measure the area of the bolus in each area, using the area of the lead ball for calibration. With the sum of the bolus areas in each area totalling 100%, the proportion of the bolus volume that was in each area was calculated.

3 Bolus transit time for each interval in the feeding sequence assessed according to the process model used in some previous studies (13, 14). The four intervals of bolus transit [processing, post-faucial aggregation time (PFAT), vallecular aggregation time (VAT), and hypopharyngeal transit time (HTT)] were defined, as shown in Fig. 1b.

4 Mandibular position during pharyngeal swallowing as shown in Fig. 1c. The videofluoroscopic image when the leading edge of the bolus passed through the upper oesophageal sphincter was obtained from VFSS. The mandibular position was defined by the position of the Menton, an anatomical landmark used in orthodontics. The *y*-axis was the line through the anterior–inferior edge of the second and fourth cervical vertebrae; the *x*-axis was the line through the lead ball at the orbitale crossing perpendicular to the *y*-axis. The zero point was the intersection of the *x*- and *y*-axes. The distance from the zero point was calculated in both the *x*- and *y*-axes, calibrated against the lead ball at the neck.

Statistical analysis

To detect significant differences between bolus transport with and without dentures in each individual, we used a Wilcoxon signed-rank test for all measurements as a nonparametric method. All statistical analyses were performed using a statistical software package (IBM SPSS Statistics ver. 20[§];). A *P*-value < 0·05 ($P < 0{\cdot}05$) was considered statistically significant.

Results

Figure 2 shows typical VFSS images acquired during the feeding sequence with and without dentures. With dentures, STII was followed by swallowing after mastication of minced agar, as efficiently as in dentate adults. Conversely, without dentures, chewing-like motions and hyperactive tongue and lip movements were observed instead of mastication. The feeding movements were less stable without dentures. Furthermore, the bolus was transported into the pharynx as a single body with dentures, but was more fragmented without dentures.

As shown in Fig. 3, the leading edge of the bolus was significantly deeper into the hypopharynx at swallow onset without dentures than with dentures. This deepening of the bolus occurred in 13 of 15 subjects. Other results from the present study are shown in the box-and-whisker plot. The box shows the first quartile, median and third quartile. The upper and lower whiskers are, respectively, the highest and lowest data still within 1·5 times the length of the interquartile range (i.e. between the first and third quartile). Figure 4 shows significant differences observed in the proportion of bolus volume in each area. The bolus volumes in the oral cavity and hypopharynx were significantly lower with dentures, whereas the bolus volume in the upper oropharynx and valleculae were significantly higher. Figure 5 showed that the processing, VAT and HTT were significantly longer without dentures, whereas PFAT was not significantly different. Figure 6 shows that the mandibular position during pharyngeal swallowing was significantly shifted anteriorly in the *x*-axis and superiorly in the *y*-axis without dentures.

Discussion

The focus of this study was to elucidate any alteration in bolus transport during feeding with and without dentures. The absence of dentures in edentulous patients alters the anatomical structure and functional movements in the oral cavity and pharynx, resulting in poor bolus transport in the feeding sequence. Furthermore, swallow onset is delayed without dentures, despite a greater volume of bolus penetrating into the hypopharynx. The prolonged residence of the bolus in the hypopharynx may also increase the risk of dysphagia.

Without dentures, we observed chewing-like motions, and hyperactive tongue and lip movements during feeding as shown in Fig. 2, interpreted to be compensatory movements to aggregate and transport the bolus for swallowing in the absence of actual mastication. Dentures help to stabilise the feeding sequence by normalising oral function, resulting in a mass bolus

[§]IBM Japan, Tokyo, Japan.

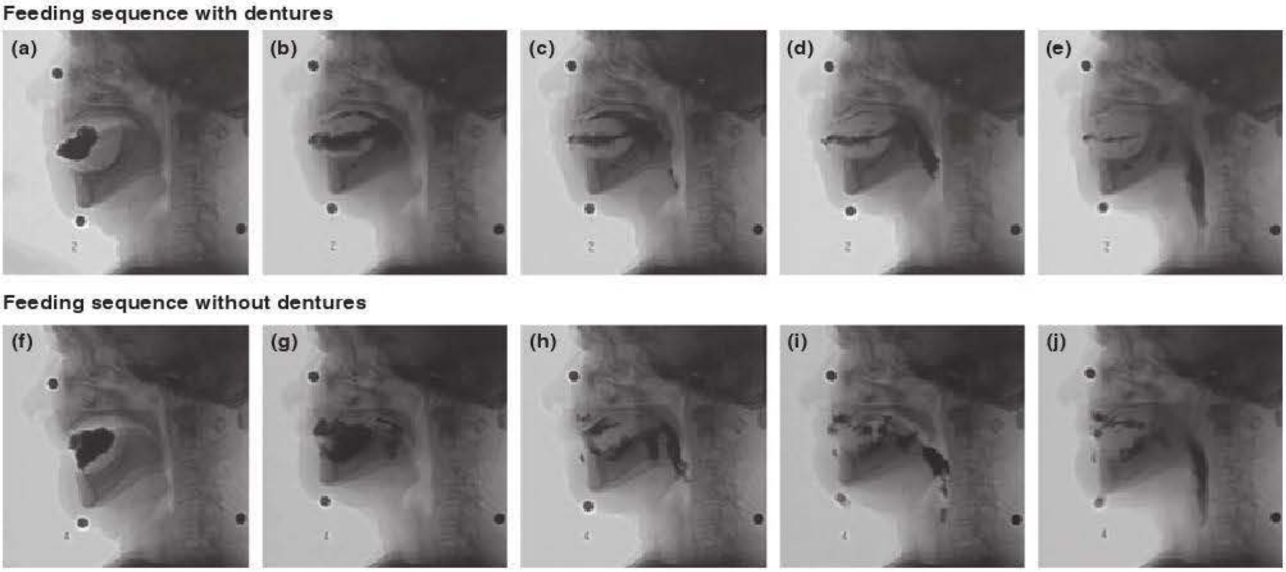

Fig. 2. Typical videofluorographic swallowing study (VFSS) images in the feeding sequence of the same subject with and without dentures. The bolus is shown as the black portion in the oral cavity and pharynx. Images from (a) to (e) show the bolus transport with dentures: (a) feeding onset; (b) during mastication; (c) STII; (d) bolus aggregation at the vallecula just before swallowing; (e) during swallowing reflex. Oral residue was rarely observed. Images from (f) to (j) show bolus transport without dentures: (f) feeding onset; (g) during chewing-like motion. The bolus is more disintegrated in the oral cavity, and there was difficulty manipulating the bolus; (h) bolus transport to the pharynx by compensatory oral movement; (i) bolus disperses into the oral cavity and pharynx and reaches the hypopharynx prior to swallowing; (j) during swallowing reflex. Bolus residue can be seen in the oral cavity.

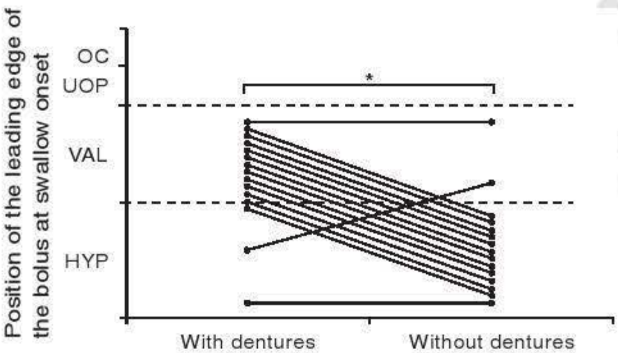

Fig. 3. Position of the leading edge of the bolus at swallow onset. Vertical axis shows the area in which the leading edge of the bolus is located at swallow onset in subjects with and without dentures. In most subjects, the position was the vallecular area with dentures, but was significantly lower (in the hypopharynx) without dentures ($P = 0{\cdot}004$). *Denotes statistically significant differences ($P < 0{\cdot}05$).

that is easy to swallow. The bolus is actively transported by STII tongue movement from the oral cavity to the valleculae, and the bolus rarely exists in the hypopharynx with dentures (15). As shown in Fig. 6, without dentures, the mandible shifted in an anterosuperior direction during pharyngeal swallowing, and the pharynx shape might become shortened vertically and expanded in the anterior–posterior direction (5). In addition, the loss of support from the buccal denture surface caused slackening of buccinator and superior constrictor muscles (16). Thus, anatomical changes in the oral cavity and pharynx might account for the deepening bolus position as shown in Fig. 3. Another reason may be the difficulty in manipulating the bolus in the oral cavity without dentures. The tongue, cheeks and mandible work with the dentures during mastication (18) to form an aggregated and lubricated bolus for easy swallowing (19). However, without dentures, subjects were less able to aggregate the food into a bolus, because the food dispersed throughout the oral cavity as processing time was significantly increased in Fig. 5. This may facilitate gravitational transport from the upper oropharynx and valleculae to the hypopharynx as suggested in Fig. 4 and allow the fragmented bolus to disperse deeper into the hypopharynx before swallow onset as shown in Fig. 3. Because a deepening bolus position occurs naturally in elderly people anyway (17), these results suggest that removing dentures further exacerbates the decline in swallowing reserve in elderly denture wearers.

The bolus should be in the hypopharynx only during pharyngeal swallowing (14, 15). However, bolus transit times were significantly longer in the vallecula

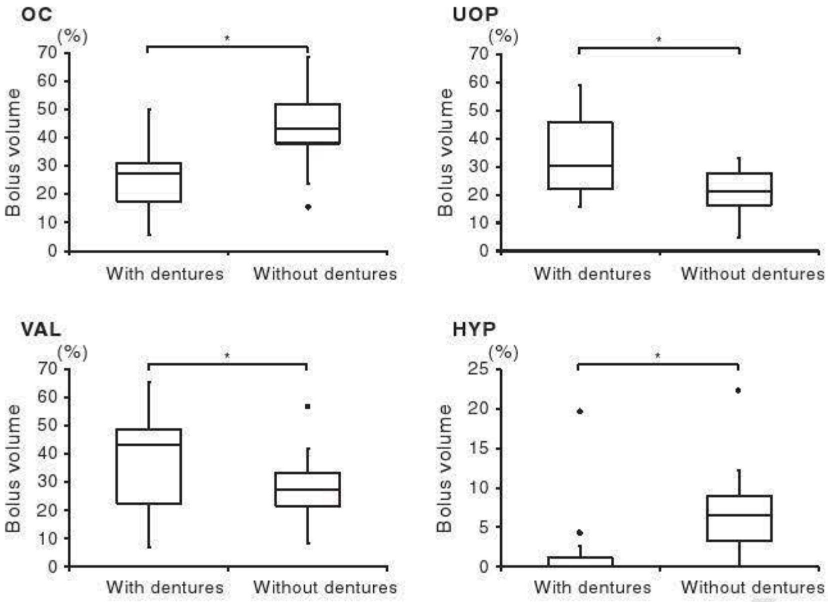

Fig. 4. Proportion of bolus volume in each area at swallow onset. The bolus volume in the oral cavity (OC) and hypopharynx (HYP) was significantly lower with dentures than without dentures ($P = 0{\cdot}002$ and $P = 0{\cdot}001$, respectively), whereas the bolus volume in the upper oropharynx (UOP) and valleculae (VAL) was significantly higher ($P = 0{\cdot}005$ and $P = 0{\cdot}031$, respectively). * denotes statistically significant differences ($P < 0{\cdot}05$). Box consists of the median and the first and third quartiles. Whiskers are the maximum and minimum values. Black circles indicate outliers.

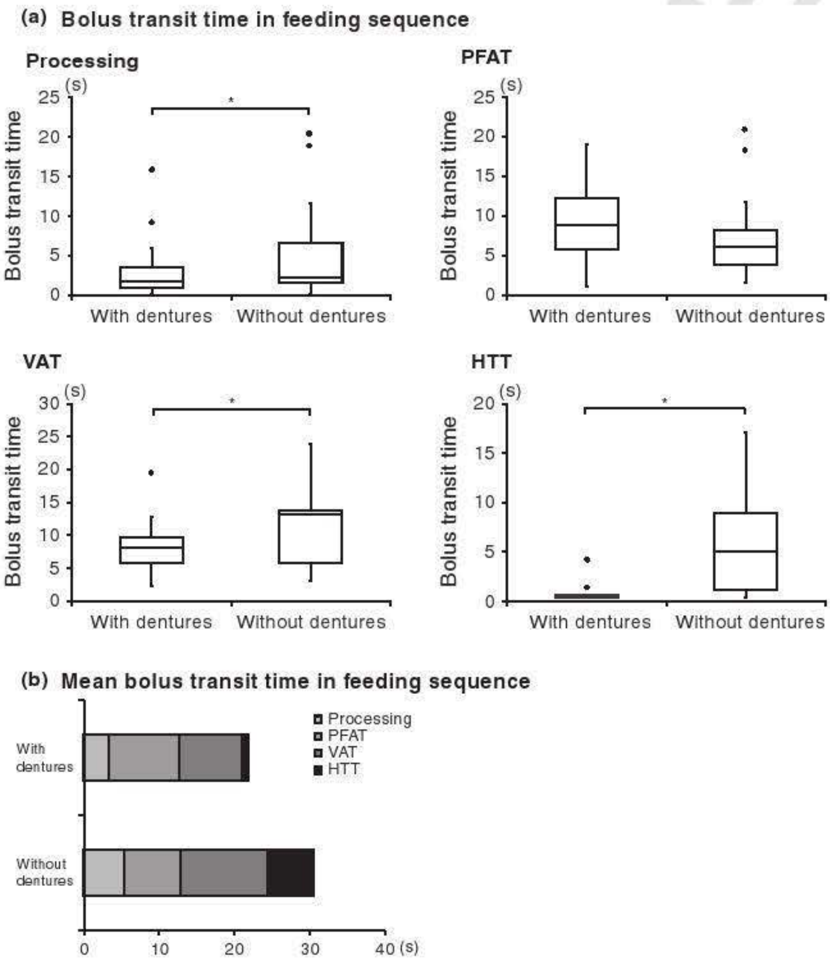

Fig. 5. (a) Bolus transit time of each interval in the feeding sequence according to the process model: processing; post-faucial aggregation time (PFAT); vallecular aggregation time (VAT) and hypopharyngeal transit time (HTT). Processing, VAT and HTT were significantly longer without dentures than with dentures ($P = 0{\cdot}036$, $P = 0{\cdot}031$ and $P = 0{\cdot}002$, respectively), whereas PFAT was not significantly different ($P = 0{\cdot}173$). * denotes statistically significant differences ($P < 0{\cdot}05$). Box consists of the median and the first and third quartiles. Whiskers are the maximum and minimum values. Black circles indicate outliers. (b) Timelines showing the mean bolus transit time in the feeding sequence with and without dentures. Time 0 is the onset of processing.

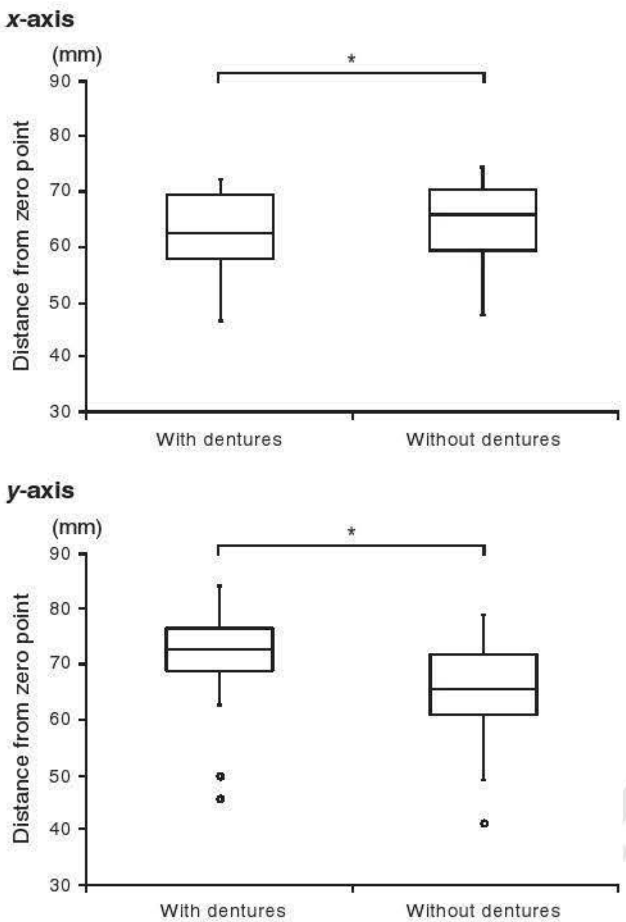

Fig. 6. Mandibular position during pharyngeal swallowing. The mandibular position was significantly shifted anteriorly in the *x*-axis and superiorly in the *y*-axis without dentures ($P = 0{\cdot}012$, $P = 0{\cdot}001$, respectively). Box consists of the median and the first and third quartiles. Whiskers are the maximum and minimum values. Black circles indicate outliers. *Denotes statistically significant differences ($P < 0{\cdot}05$).

and hypopharynx without dentures, indicating that the bolus remained in the hypopharynx without eliciting pharyngeal swallowing, which may increase the risk of aspiration (14). Although mastication may delay the initiation of the swallowing reflex (20), we found that pharyngeal swallowing was more delayed without dentures, despite the compensatory chewing-like motions as shown in Fig. 2. Factors other than mastication may thus directly influence eliciting the swallowing reflex, for example sensory feedback from the oral cavity (21) and volitional control (22). Another factor may be the loss of mandibular fixation to the hyoid elevation, which is required to initiate oral swallowing. Without dentures, only compensatory fixation is achieved (using the tongue and upper and lower residual ridges). The tongue struggles with voluntary tongue–palate contact in the oral stage of swallowing (8), resulting in the hyperactive movements before swallow onset observed in previous studies (23). In addition, insufficient stimulation to pharyngeal receptive fields by the bolus might also delay pharyngeal swallowing, which is evoked by integrated total stimulation to the pharyngeal receptive fields and may be impaired with a poorly formed dispersed bolus. With dentures, the bolus can be aggregated at the vallecular area, controlled by the glossopharyngeal nerve, and might sufficiently stimulate receptive fields to elicit pharyngeal swallowing as soon as the bolus penetrates into the hypopharynx (controlled by the superior laryngeal nerve). Conversely, without dentures, the bolus could not stimulate receptive fields at the valleculae and hypopharynx sufficiently, despite significantly increased VAT and HTT, so that the bolus becomes retained in the hypopharynx without swallowing. Because the bolus was fragmented in the pharynx and receptive pharyngeal mucosa, it might be reduced anatomically by removing dentures.

Our findings suggested that wearing or removing dentures might have a significant effect on the bolus transport of solid food feeding, even when the food has already been minced. Although removing dentures did not immediately evoke pharyngeal dysphagia (e.g. aspiration) because the subjects were generally healthy, it is possible that the swallowing reserve may be negatively affected without dentures (8–10). Wearing dentures can improve anatomical and functional relationships in the oral cavity and pharynx, enabling suitable bolus formation and safe bolus transport during feeding. Thus, wearing dentures helps to maintain the swallowing reserve in the elderly edentulous (8–10, 23, 24). The subjects in the present study have used complete dentures for more than 1 year, and the oral and pharyngeal functional movements during feeding may differ from those of edentulous people who normally eat without dentures. It may also depend on adaptability of each subject and the period that dentures are used. However, it is difficult to evaluate adaptability of subjects on eating without dentures except for patients' subjectivity. In terms of bolus formation, it might take up to 7 days for a healthy dentate adult to adapt to full palatal coverage (25). Presumably, elderly patients would need longer time to adapt to eating without dentures because of their diminished adaptability. Therefore, present results may include an immediate effect at a certain degree. Further studies are needed to elucidate how prosthetic treatment with dentures works as a component of dysphagia rehabilitation for elderly edentulous patients.

Conclusions

Removing dentures in healthy elderly edentulous changed the bolus transport during feeding, resulting in more bolus penetration into the hypopharynx for longer duration, and significant delay of pharyngeal swallowing. Loss of mandibular fixation and poor bolus formation were the underlying factors and produced difficulty in eliciting oral and pharyngeal swallowing, which may exacerbate the natural decline in swallowing reserve seen in the elderly.

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