

# Aspects of Swallowing in Healthy Dentate Elderly Persons Older Than 80 Years

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**Background.** Although age-related changes resulting in slowing of the swallowing reflex and a decline in the neuromuscular control system have been reported, there have been few reports on swallowing function in dentate elderly persons. The purpose of this study was to clarify the primary influence of aging on swallowing in healthy dentate elderly persons older than 80 years who have more than 20 teeth.

**Methods.** Dentate elderly persons (12 male, 7 female; mean age: 81.2 years) and dentate young participants (9 male, 5 female; mean age: 26.8 years) as a control group participated voluntarily. Participants reported no clinical symptoms relating to dysphagia, neurologic impairments, or degenerative diseases, and were asked to swallow 10 ml of barium sulfate solution (10% w/v) three times. Functional swallowing was recorded on 35 mm cinefilm at 30 frames per second with a digital subtraction angiography system. Lateral images of cinefluorography of seated participants' mouth, pharynx, and larynx were obtained. Visual image analysis for qualitative and quantitative evaluation was made with a cine projector.

**Results.** No participants exhibited aspiration during three trials. Occurrence and frequencies of piecemeal deglutition, premature loss of liquid, oral and pharyngeal residues, and laryngeal penetration were significantly greater in dentate elderly persons ( $p < .05$ ) than in the dentate young participants. Oral transit time, pharyngeal delay time, and pharyngeal transit time in dentate elderly persons were prolonged significantly compared with those in dentate young participants ( $p < .01$ ).

**Conclusion.** Physiological swallowing functions deteriorate even in healthy dentate elderly persons. This deterioration may be explained primarily by the influence of aging on swallowing.

MANY studies have reported the deterioration of the swallowing function in elderly persons. Most studies have focused on pharyngeal function and reported about larynx, hyoid bone, pharynx, upper esophageal sphincter, residue, and tongue function by using cinefluorography, videofluorography, and manometry. It has been assumed that aging has a deteriorating influence on the preparatory and oropharyngeal stages of swallowing (1). The association of such deterioration with the presence or absence of teeth has not been clarified in earlier studies, however (1–16). As a result, it is still unknown whether the degree of deterioration of swallowing function in elderly persons is primarily influenced by aging itself or, secondarily, by the loss of teeth. In recent years, the number of dentate elderly persons has been increasing in Japan, and this tendency is expected to continue. A better understanding of the influence of aging on swallowing in dentate elderly persons is needed.

In this study, by using cinefluorography, we compared the preparatory and oropharyngeal stages in the process of swallowing in a sample of dentate elderly persons with the same stages in a sample of dentate young participants to clarify the primary influence of aging on swallowing.

## METHODS

### Participants

Nineteen dentate elderly volunteers (12 male, 7 female; 80–87 years, mean age: 81.2 years) participated in this study. Each individual possessed 20 or more of his or her

own teeth (20–32 teeth, mean: 25.5 teeth) with minimum premolar occlusal contacts. Participants reported no complaints of masticatory difficulty. Fourteen dentate young participants from the Graduate School of Biomedical Sciences, Hiroshima University (9 male, 5 female; 24–32 years, mean age: 26.8 years), participated as controls. All volunteers provided written informed consent to participate in this study.

To screen for symptoms related to dysphagia, neurologic impairments, and degenerative diseases, all participants were interviewed following completion of a questionnaire (17). The purpose of the questionnaire was to establish baseline information concerning swallowing function and to screen for the possibility of dysphagia. Following the method of Dr. Fujishima (17), participants were asked to respond to 15 questions asking whether swallowing disorders were present now or in the past 3 years (e.g., “Have you ever been diagnosed with pneumonia?” “Do you cough when eating?” “When swallowing, do you feel that something sticks in your throat?”). All participants were interviewed to rule out any neurologic, pulmonary, or head and neck disorders.

Volunteers were also examined using the repetitive saliva swallowing test (RSST) (18), a screening test for observing the ability to perform repetitive voluntary swallowing. In this test, participants are asked to “dry swallow” as many times as possible during a 30-second period; when they can swallow fewer than three times, they are said to have a deterioration of the function that triggers voluntary swallowing. Because participants are not asked to swallow

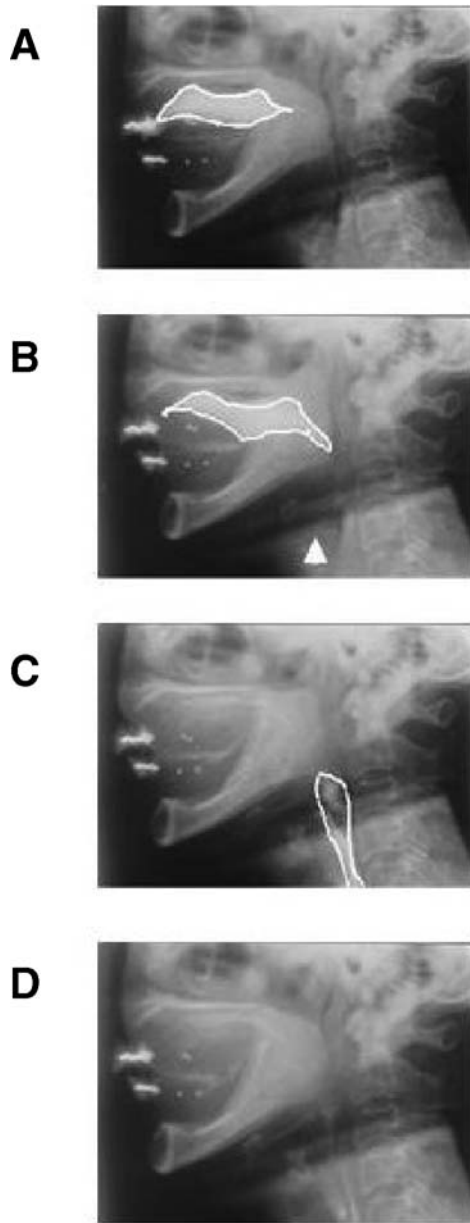


Figure 1. Typical pattern of swallowing and items of measurement. Oral transit time (A–C) is the time taken from the beginning of tongue movement to the beginning of the voluntary oral stage until the tail of bolus reaches the point where the lower edge of the mandible crosses the tongue base. Pharyngeal delay time (B) begins when the bolus head reaches the point where the lower edge of the mandible crosses the tongue base, and ends when laryngeal elevation begins in the context of the rest of the swallow. Pharyngeal transit time (B–D) is the time elapsed from the triggering of the pharyngeal swallow to when the bolus tail passes through the cricopharyngeal region or 1 segment.

water during the RSST, this test is quite simple and noninvasive, and the risk of aspiration is low.

#### Cinefluorography

The participants were examined with cinefluorography. Each participant was seated in a relaxed position with the head fixed by ear rods, then were asked to swallow 3 ml of barium sulfate solution (10% w/v, a density close to that of plain water) to check for severe aspiration. After confirma-

tion that no severe aspiration occurred, participants were asked to swallow three 10-ml cups of the solution at intervals. Functional movement was recorded on 35-mm cine film (MICF; Fuji Film, Tokyo, Japan) using a digital subtraction angiography (DSA) system (DIGITEX 2400UX; Shimadzu, Kyoto, Japan) at the speed of 30 frames per second. The cinefluorographic images were analyzed in slow motion and by single-frame analysis using the playback capability of a Cineangio projector (CAP35B; ELK, Aichi, Japan).

#### Qualitative Evaluation

Qualitative evaluations of each swallow in terms of piecemeal deglutition, premature loss of liquid, oral and pharyngeal residues, and laryngeal penetration were performed. Presence of oral and pharyngeal residues was determined after the first swallowing in each trial. The following terms were used to characterize each individual's swallowing behavior and the presence or absence of this behavior noted for the three trials of each participant.

*Piecemeal deglutition* means that the participant repeated two or more swallowings to empty a bolus from the oral cavity. Ten milliliters of liquid is considered a normal and safe-sized swallow. With *premature loss of liquid*, part or all of the bolus falls over the tongue base into the pharynx prematurely, while the preparatory or oral stage is still processing, and before triggering of the pharyngeal swallow. The soft palate should be pulled inferiorly and anteriorly against the back of the tongue to seal the bolus in the mouth posteriorly, when liquid boluses are placed in the mouth. When this seal is defective, part or all of the bolus can fall into the pharynx prematurely. *Oral residue* denotes a residue of barium remaining on the tongue surface, on the floor of the mouth, or on both, after the first swallowing on each trial. In contrast, the density of barium sulfate solution was so thin that no residue of barium was observed remaining on the palate in any participant. *Pharyngeal residue* describes the residue of barium in the valleculae, in the pyriform sinus, or in both, after the first swallowing on each trial.

*Laryngeal penetration* describes entry of liquid or food into the larynx at some level down to, but not below, the true vocal cords. *Aspiration* is defined as the entry of liquid or food into the airway below the true vocal folds.

#### Quantitative Evaluation

For the quantitative evaluation, instruction–response time (IRT), oral transit time (OTT), pharyngeal delay time (PDT), and pharyngeal transit time (PTT) (Figure 1) were recorded. IRT is defined as the time interval between operator's instruction to swallow and participants' response. OTT is defined as the time from the beginning of tongue movement to the beginning of the voluntary oral stage of the swallow until the tail of the bolus reaches the point where the lower edge of the mandible crosses the tongue base. PDT begins when head of the bolus reaches the point where the lower edge of the mandible crosses the tongue base and ends when laryngeal elevation begins in the context of the completion of swallowing. PTT is defined as the time elapsed from the moment the head of the bolus reaches the point where the lower edge of the mandible crosses the tongue base to the moment when the tail of the bolus passes

Table 1. Qualitative Evaluation\*

Participants	Premature				
	Piecemeal Deglutition <sup>†</sup>	Loss of Liquid <sup>‡</sup>	Oral Residue <sup>†</sup>	Pharyngeal Residue <sup>†</sup>	Laryngeal Penetration <sup>‡</sup>
Dentate elderly (N = 19)	12	6	13	8	6
Dentate young (N = 14)	1	0	4	0	0

Notes: \*Piecemeal deglutition, premature loss of liquid, oral and pharyngeal residues, and laryngeal penetration were found with a significantly greater occurrence and frequency in the dentate elderly ( $p < .05$ ).

<sup>†</sup> $p < .05$ .

through the cricopharyngeal region or the pharyngoesophageal segment.

Qualitative and quantitative observations were performed and recorded by two dentists experienced in evaluating cinefluorographic records. The two observers discussed their observations, arriving at a consensus for each observation or measure.

#### Data Analysis

For statistical testing, the mean of the three trials was statistically analyzed in the following manner: To clarify swallowing deterioration in the dentate elderly participants, the chi-square test was used to compare the qualitative evaluation with that of the young dentate volunteers; one-way analysis of variance was used to compare quantitative evaluation with that of the young dentate participants. In the qualitative analysis, the participant who exhibited some states of each qualitative term once in the three trials was regarded as having those states. Analysis of the values for IRT, OTT, PDT, and PTT was accomplished using the mean values for the three trials by each participant. Statistical analyses were performed using StatView 5.0 (SAS Institute, Cary, NC). A value of  $p < .05$  was considered statistically significant. Values were reported as mean  $\pm$  SD.

#### RESULTS

The results of the questionnaires and medical interviews showed that none of the healthy dentate young participants and none of the dentate elderly participants reported any swallowing disorders, neurologic impairments, or degenerative diseases causing swallowing disorders. They reported no pulmonary state, or neck and head functional problems present or in the past three years. In the RSST, no deterioration of function of triggering a voluntary swallowing was found in any participant.

#### Qualitative and Quantitative Evaluation

No participant exhibited aspiration. Piecemeal deglutition, premature loss of liquid, oral and pharyngeal residues, and laryngeal penetration were found with a significantly greater frequency and occurrence in the dentate elderly participants ( $p < .05$ ) than in the young volunteers. Piecemeal deglutition significantly increased in frequency in the dentate elderly participants, 12 of 19 compared with 1 in 14 dentate young volunteers. Premature loss of liquid significantly increased in frequency in the dentate elderly participants (6 of 19) compared with dentate young participants (0 of

Table 2. Quantitative Evaluation\*

Participants	IRT	OTT <sup>†</sup>	PDT <sup>†</sup>	PTT <sup>†</sup>
Dentate elderly	0.58 $\pm$ 0.19	1.05 $\pm$ 0.31	0.16 $\pm$ 0.14	0.70 $\pm$ 0.15
Dentate young	0.53 $\pm$ 0.16	0.74 $\pm$ 0.26	0.03 $\pm$ 0.07	0.53 $\pm$ 0.08

Notes: \*All values, in seconds, are mean  $\pm$  SD. The values of instruction-response time (IRT), oral transit time (OTT), pharyngeal delay time (PDT), and pharyngeal transit time (PTT) were analyzed using the mean values of three trials for each participant. OTT, PDT, and PTT for the dentate elderly participants were significantly longer than those of the dentate young participants.

<sup>†</sup> $p < .05$ .

14). Oral residue was found with significantly greater frequency in the dentate elderly participants (13 of 19) than in dentate young volunteers (4 of 14). The occurrence of pharyngeal residue increased significantly in frequency in the dentate elderly participants (8 of 19) compared with dentate young volunteers (0 of 14). Penetration significantly increased in frequency in the dentate elderly participants (6 of 19) compared with dentate young volunteers (0 of 14) (Table 1).

There was no statistical difference in IRT between the two groups (dentate elderly participants: 0.58  $\pm$  0.19 seconds; dentate young volunteers: 0.53  $\pm$  0.16 seconds). OTT (1.05  $\pm$  0.31 seconds), PDT (0.16  $\pm$  0.14 seconds), and PTT (0.70  $\pm$  0.15 seconds) for the dentate elderly participants were significantly prolonged compared with dentate young volunteers (OTT: 0.74  $\pm$  0.26 seconds, PDT: 0.03  $\pm$  0.07 seconds, and PTT: 0.53  $\pm$  0.08 seconds) ( $p < .05$ ) (Table 2).

#### DISCUSSION

In the year 2000, the National Health Promotion Plan for the 21<sup>st</sup> Century (Health Japan 21) joined the decade-long campaign of the Japanese government and the JAPAN Dental Association in working toward the goal of maintaining more than 20 teeth in individuals aged 80 (8020 campaign). A recent epidemiological survey of oral and health conditions in four Japanese prefectures, reported by Ando and Hanada (19), showed that elderly persons who have achieved the goals of the 8020 campaign have not only retained masticatory function but also have maintained a high level of physical activity and high quality of life (QOL). QOL is essentially a sociological term denoting a sense of well being in daily life generally.

In Japan, the number of elderly persons, especially, the aged (older than 75 years) and the very old (older than 85 years) is increasing rapidly; in addition, the number of dependent elderly persons is increasing. In this group, the cause of death is frequently aspiration pneumonia. The lives of aged persons and their QOL are threatened by deterioration of swallowing function and aspiration pneumonia. Oral care is important as a preventive strategy because aspiration pneumonia is caused by oral bacteria (20,21). As yet, there are few strategies to recover deteriorated swallowing function in elderly persons, especially in dependent elderly persons. As a result, understanding the clinical condition of swallowing in healthy elderly persons and establishing a baseline for treatment of swallowing disorders are matters of great urgency. To clarify this issue, determining the extent to which swallowing problems relate to primary aging as

reflected in physiological changes in the nerves and the muscles associated with swallowing function is necessary before further problems relating to changes of anatomical oral form caused by losing teeth can be fully understood.

Use of cinefluorography allows an accurate evaluation of swallowing function with a small radiation dose, approximately equal to that required to produce a few lateral cephalographs as reported by Otsuka (22). As our study demonstrates, even elderly individuals who retain 20 or more teeth may have a deteriorated swallowing function. Because maintaining optimal swallowing function affects life expectancy, the importance of good swallowing function cannot be overestimated.

No participant aspirated in this examination, and our results are similar to those of earlier reports: OTT (3,6), PDT (1,3–5,7,8), deglutitive swallow (1,4,12), and laryngeal penetration (1) were all prolonged. All things considered, we conclude that, in elderly persons, clearance of oral and pharyngeal areas deteriorates, the time required for swallowing is prolonged, and the onset of swallowing reflex is delayed. Dejaeger and colleagues (10) reported that residues in oral and pharyngeal areas are caused by the deterioration of lingual transfer. The deterioration of pharyngeal contraction (1,4) and insufficiency of the elevation of larynx and hyoid bone (11) may have influenced our results, although we did not observe pharyngeal contraction or the distance of elevation of larynx or hyoid bone.

Logemann and colleagues (9) reported that young men have excess laryngeal and hyoid motion in comparison with older men; this difference between necessary movement and actual motion is known as “reserve.” Reduction in “reserve” and flexibility in neuromuscular control has been found to characterize normal aging of the motor system. In our study, although neither healthy young nor healthy elderly participants aspirated, the deterioration of swallowing function found in the healthy elderly participants can be attributable to reduced “reserve” in neuromuscular control in dentate elderly persons and, certainly, aging itself has a great effect on the availability of that reserve. Although some differences between men and women in swallowing function have been reported (1,3,8,9,13–16), no difference was found in our sample.

The results of this study document the effect of primary aging on the swallowing function in dentate elderly persons and the differences between healthy young volunteers and elderly participants in swallowing function. There will be further research in our clinics to examine and compare swallowing function in edentulous elderly persons with and without upper and lower complete dentures.

Because there are few reports related to swallowing in dentate elderly persons, our study provides baseline data from which to clarify the extent to which swallowing is further affected in edentulous individuals. Further study will provide valuable information for maintaining health in our growing population of elderly persons.

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