ショートネスに欠けて砕けにくく，高グルテニン画分単独のクッキーは，硬いがショートネスがあり，砕けやすかった．両者より構成されるクッキーは，その中間的性質を示した．これらの結果より，グリアジンとグルテニンの比率を変化させることにより，クッキーの物性改変は可能であることが判明した．

2．若年健常者による官能検査では，高グリアジン画分単独のクッキーは硬くて粘着性が低く，高グルテニン画分単独のクッキーは脆くて粘着性が高いと評価された．高グリアジン画分と高グルテニン画分の比率が1：2のクッキーは，1：1のものよりも砕けやすく，唾液と混ざると滑らかであり，食塊形成も容易であることから，高齢者食や介護食としてより適していると評価されたことが推察された．

3．高グリアジン画分単独のクッキーは，吸水性が低いために，モデル食塊は硬く，付着性と凝集性が低かった．高グルテニン画分単独のクッキーは，吸水性が高いために，モデル食塊は付着性と凝集性が高かった．両者より構成されるクッキーのモデル食塊は，その中間的性質を示した．

4．以上の結果より，高齢者食や介護食に適した物性を有するクッキーを調製するためには，グリアジンとグルテニンの構成比率が等しい小麦粉よりも，グルテニンの占める比率が高い小麦粉を使用した方が，より適していると推察された．

5．クッキーの物性改変要因としては，グリアジンとグルテニンの吸水性の差異が，でんぷんの糊化状態に影響を与えたことが示唆された．

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Effects of Gluten-Constituent Protein Compositions on Chewing and Swallowing Characteristics of Cookies

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Using five types of reconstituted flour having different compositions of the gluten-constituent proteins glutenin and gliadin, we prepared cookies with physical properties that were suitable as food for the elderly or as nursing food for patients with slight dysphagia. The breaking properties of cookies whose glutenin and gliadin component ratios were altered were evaluated by instrument measurements, and the eases of cookie swallowing was evaluated by a sensory test and measurements of water absorption of cookies and model bolus physicality. When the component ratio of gliadin-to-glutenin was changed from a ratio resembling that of marketed flour of 1：1 to 1：2, the cookies began to crumble easily, and when they were mixed with saliva their texture improved. This made it easier to form a bolus. A sensory test on young volunteers also demonstrated that cookies with a gliadin-to-glutenin ratio of 1：2 were more suitable food for the elderly and as nursing food than cookies with a gliadin-to-glutenin ratio of 1：1. These results prove that to manufacture cookies that are suitable as such food, it is beneficial to increase the glutenin portion of gluten-constituent protein. The main reason why an increase in glutenin alters the physicality of cookies might be because an increase in glutenin decreases the water content absorbed by gluten during dough preparation, which in turn causes the water content absorbed by the starch to increase, thereby promoting starch gelatinization.

Key words: cookie, gluten composition, breaking property, water absorption

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Oral behavior from food intake until terminal swallow☆

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Abstract

We analyzed oral behavior from food intake until terminal swallow for mastication and swallowing under a freely eating condition with a natural food. Measurements, including movement of the mandible and tongue, the size of the gape, different sequences involved in the oral aspect of the swallowing action, and bolus size and movement were carried out in five "freely eating subjects" using videofluorography. During food intake, the tongue moved forwards and backwards to introduce food into the mouth, to compress the food against the hard palate, and to transport food to the occlusal surface of the molar teeth. Most of the food was swallowed in the first swallow, and any residual food was aggregated by the tongue into a bolus and then swallowed in the last swallow. These findings suggest that 1) tongue manipulation plays an important role in recognizing and evaluating the volume of bite taken, 2) the intra-oral compression of food has a role in the recognition of food texture, 3) stage I transport is closely bound to the texture recognition process, 4) humans need at least two swallows, even with one bite of food, when ingesting food freely, and 5) the duration time of the oral stage of swallowing may depend on the bolus volume and be longer for smaller volumes unlike those measured under the command swallow.

Keywords: Food intake; Natural bite; Natural swallowing; Mandibular movement; Freely eating subjects

1. Introduction

Swallowing mainly occurs during eating, and thus is part of a continuum of feeding behaviors, which include food intake into the mouth, mastication, oral food transport, and swallowing [1,2]. However, ever since Magendie [3] introduced the concept of swallows to include oral, pharyngeal, and esophageal stages, swallows have been mostly regarded as an isolated behavior from mastication, and swallow-related events were studied in the command swallow [4,5].

In a study using videofluorography (VFG) and electromyography, Palmer et al. [6] reported that part of the food entered the oropharynx prior to swallow onset, while most of the food was still in the oral cavity at swallow onset. Based on these results, they applied the concept of stage II transport, which was defined in an animal study [7], to humans. Interestingly, stage II transport may be inhibited when subjects keep test food in the mouth until an examiner allows them to swallow (command swallow) [6]. Thus, it may be expected that swallows during a complete feeding sequence in humans differ from the command swallow.

In order to understand the coordination of mastication, oral food transport, and swallowing, swallows have been studied during the complete feeding sequence in humans [1,6,8,9] and animals [10,11]. Hiiemae and Palmer [9] have reported the intra-oral food management for solid food as follows, i.e. the masticatory sequence has four main components: (1) stage I transport, in which food is ingested and positioned on the occlusal table if reduction is required; (2) processing, in which trituration occurs; (3) oropharyngeal accumulation time, in which food ready for bolus formation is moved distally through the fauces (stage II transport) although processing may

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continue; and lastly, (4) hypopharyngeal transit time, in which the bolus is swallowed. However, previous human studies were carried out with fixed amounts of food under rather restricted conditions for food intake. Thus, their findings should be confirmed under freely eating conditions with natural food.

The mode of mastication of soft foods (agar and gelatin gels) was examined by Arai and Yamada [12] in humans. They found that there were two types of management modes and that the mode altered from compression with the tongue and hard palate to shearing with the dentition as the hardness of the model samples increased. The thresholds of hardness were 0.08 kg for the agar gel and 0.03 kg for the gelatin gel. Visual analysis of VFG revealed that the food texture may be recognized by initial compression (deformation rate: about 12%) between the tongue and hard palate around the incisive papilla. They concluded that the mastication mode of a food either by compression or shearing may be determined according to the texture, and that the process of initial compression of food is the first step of texture recognition. Although this study may have introduced a very important phenomenon, it was carried out with artificial foods, and no other study has since confirmed this. Thus, it is now necessary to examine the texture recognition process in studying under natural feeding condition.

Swallows affect both respiration and mastication. McFarland and Lund [13] investigated interactions among respiration mastication and swallowing to study the neural mechanism underlying oral motor behavior in humans. They then observed three characteristic swallowing patterns, i.e. interposed, terminal, and spontaneous swallows. The interposed swallow occurred within chewing cycles, while the terminal swallow ended the masticatory sequence. On the other hand, most masticatory sequences end with a period characterized by irregular jaw movement and a swallow. Hiiemae et al. [14] and Palmer et al. [15] named the whole process 'clearance,' which is a process to aggregate food particles from the mouth including buccal vestibules. However, in the aforementioned studies, no attempt was made to apply quantitative analysis to these different sequences of the oral part of the swallowing action during complete feeding sequences. In addition, there is some disagreement regarding the terminology used, such as 'masticatory sequence' vs. 'feeding sequence' and 'terminal swallow' vs. 'clearance,' among investigators which is largely dependent on their respective research areas. This indicates the need for a quantitative study on the complete sequence from food intake to the swallow.

The aims of the present study were 1) to learn how 'normal' food was managed in the mouth throughout the feeding sequence, 2) to analyze oral behavior during food intake, and 3) to characterize, quantify, and compare interposed and terminal swallows in freely eating human subjects using videofluorography (VFG).

2. Materials and methods

2.1. Subjects

Five healthy adults (two females and three males, average age: 21±2 years) participated in this study. None of the subjects had a history of major medical problems, including dysphagia. Informed consent was obtained from all subjects and the study protocol was approved by the Ethical Committee of the Niigata University Faculty of Dentistry in accordance with the Helsinki Declaration.

2.2. Data collection

The feeding events in the subjects were observed using a VFG (MULTISKOP; Siemens-Asahi Medical Technologies Ltd., Tokyo, Japan) installed at Niigata Medical and Dental Hospital. The technical parameters for the VFG settings were as follows: speed: 25 frames/s; focus size: 1.0 mm; working voltage: 74 kV; working current: automatic control; and distance between subject and detector: 60 cm. Using these settings, the VFG exposure time was limited to a maximum of 2 min/subject, and the total radioactivity exposure/subject was estimated to be equivalent to approximately 10 dental X-ray exposures [16].

The test food was a stick of sushi rice with a small amount of barium powder (diameter, 25 mm; length, 100 mm; weight, 50 g), which could be handled by hand. Radiopaque markers (1 mm diameter lead balls) were glued to the buccal surfaces of the upper and lower incisors to measure the jaw gape. A calibrator (20 mm long lead bar) was attached between the nose tip and the upper lip and was used to calculate the actual dimensions and movements of the organs on the VFG images. During the recording, each subject sat on a stool and turned laterally to the image intensifier. Each subject was instructed to hold their head in a neutral position, and no cranial constraints were used. Each subject was asked to take a single natural bite of test food, which they were then required to chew and swallow naturally until it was cleared from the mouth. A recording session began when the subject moved their hand to bring the food to the mouth, and it ended when all the food was cleared from the mouth. The time when all the food was cleared from the mouth was indicated by the subjects by raising a hand. The test was repeated three times per subject.

2.3. Data analysis

To determine the weight of one bite of food, the amount of the given food remaining after the subject took one bite was weighed to determine the amount of food that had been bitten off. VFG images were recorded on a digital video recorder (DCR-TRV10; Sony), and each recording was immediately replayed at a slower speed for review by two experienced investigators. The recording was judged as acceptable if the image was of good quality, head movements were minimal, and a complete feeding sequence was included. The VFG recordings were then examined frame-by-frame by direct visual observation using the stop-frame/slow-motion function of the video recorder. The mandibular movement trajectory with time was reconstructed from the distance between the lead balls on the recording images using a software program (Micro Analyzer; Japan Poladigital Inc., Tokyo, Japan) for each subject (Fig. 1). A chewing cycle was defined as the period from one maximum jaw opening to the next, and was divided into three

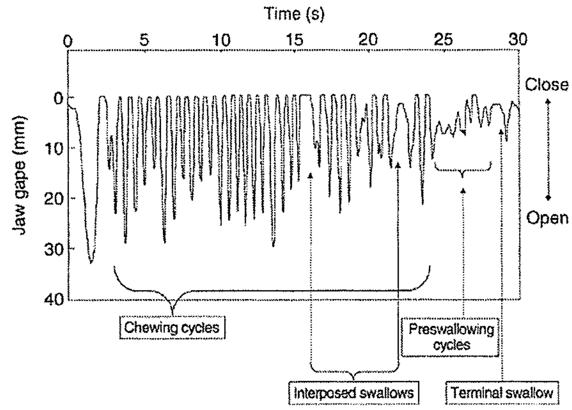

Fig. 1. Mandibular movement trajectory with time generated from VFG images during a complete feeding sequence. Chewing cycles: the mandible moved rhythmically following three phases (closing, occlusal, and opening). Interposed swallows: occurred once or twice within the chewing cycles. Preswallowing cycles: the maximum gape decreased, and small irregular mandibular movements were seen. Terminal swallow: occurred at the end of the sequence.

phases; closing (CL), occlusal (OC), and opening (OP), on the basis of the directional changes in mandibular movement (Fig. 2A). The CL phase began at the maximum jaw opening and ended at the uppermost jaw position. The OC phase followed the CL phase and was defined as the period within a chewing cycle during which there was no measurable change in

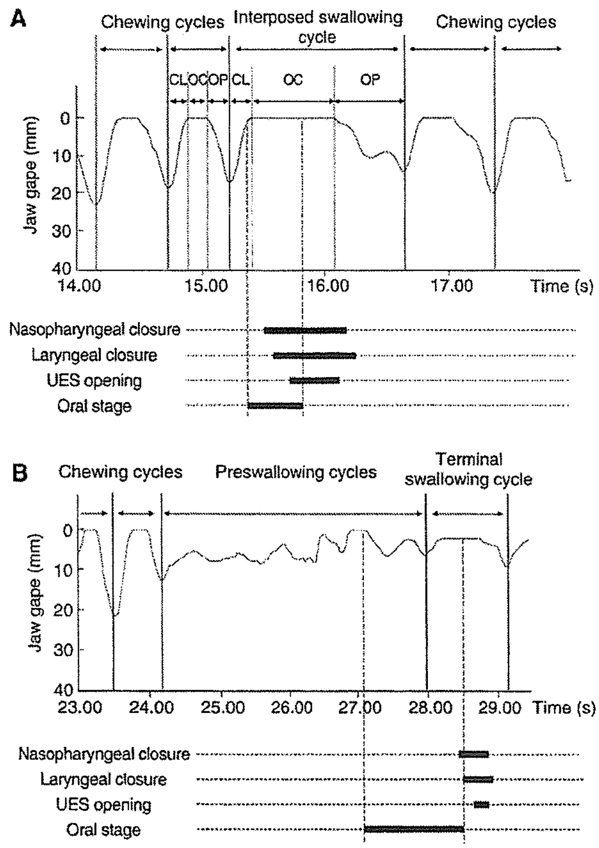

Fig. 2. Temporal relationships among mandibular movements and swallow-related events during interposed and terminal swallowing cycles. (A) Three phases (CL: closing; OC: occlusal; OP: opening) were identified in the chewing and interposed swallowing cycles. (B) Preswallowing cycles followed the chewing cycles and preceded the terminal swallowing cycle. Preswallowing cycles were characterized by a decrease in the maximum gape and irregular small mandibular movements. The jaw gape in the terminal swallowing cycle was similar to that in the preswallowing cycles. Thick bars indicate the interval of each swallow-related event: nasopharyngeal closure, laryngeal closure, UES opening, and the oral stage of swallowing. Dotted vertical lines indicate the onset and offset of the oral stage of swallowing.

the distance between the upper and lower jaw. The OP phase followed the OC phase and ended at the subsequent maximum jaw opening. Consequently, the duration of each phase and total cycle duration were analyzed.

Swallowing was identified on the basis of the following events: nasopharyngeal closure, laryngeal closure, and upper esophageal sphincter (UES) opening. Onset and offset of these events were obtained from the VFG images by direct visual observation, and the duration of each event was analyzed. Cycles involving these events were termed swallowing cycles and distinguished from the chewing cycles (Fig. 2A). Swallowing cycles were divided into phases, as were the chewing cycles, and the total cycle duration and duration of each phase were consequently analyzed. In the case of swallowing cycles, the timing of the movement of the tongue tip against the anterior of the hard palate just prior to swallowing was determined [17]. This tongue movement may represent the onset of the oral stage in swallows. Therefore, we examined the duration of the oral stage of swallowing on VFG images as the time interval between movement of the tongue tip toward the anterior of the hard palate just prior to swallowing and movement of the bolus tail passage over the fauces, as reported previously [17–19]. The bolus volume in each swallow was estimated as the area of food bolus on the VFG image at the time of passing the UES. This area was analyzed using the Micro Analyzer software program.

2.4. Statistical analysis

Means plus the standard deviation (S.D.) were calculated and analyzed by ANOVA followed by a post-hoc Bonferroni or *t*-test. A p-value of <0.05 was considered statistically significant.

3. Results

3.1. Food intake

Frame-by-frame analyses of the VFG images clearly revealed the oral structures and food movements during food intake. The mouth opened wide to make room and the tongue moved forward over the incisors to receive the food (Fig. 3A). The initial opening was 34.2±3.4 mm (mean±S.D., $n=15$) and 36.8% larger than the diameter of the given food. The time when the food touched the lower lip and tongue tip was defined as food capture for further measurements. Just after capture, the tongue immediately retracted as the food was introduced into the mouth and the tongue was depressed anteriorly but domed posteriorly to make space for the food (Fig. 3B). The jaw then closed to bite the food, and the tongue slipped its tip below the food and began to dip up the food (Fig. 3C). The weight of one bite of food was 11.5±3.7 g (mean±S.D., $n=15$) and varied among subjects.

The distance of tongue tip movement measured between the position at capture and at the end of the first retraction was analyzed using the Micro Analyzer software program. The distance of tongue tip movement for food intake was obtained as 23.3±6.7 mm (mean±S.D., $n=15$).

Immediately after biting the food, the tongue compressed the food against the hard palate at the incisive papilla with incomplete jaw closure. Thus, the profile of the food was deformed by being shortened anteroposteriorly so that the long axis of the food was vertical to the occlusal plane (tooth row) (Fig. 3D). Thereafter, the food was transported to the occlusal surface of the molar teeth with a second rapid retraction of the tongue during jaw opening; the movement was as if the food had rotated so that the long axis of the food particle was parallel to the row of teeth (Fig. 3E). This entire process was designated stage I transport, as these characteristics of food intake and stage I transport were observed in all subjects. The duration of this process, i.e. the time elapsed from the initial ingestion (maximum opening) to the first tooth-food-tooth contact of molar teeth, was obtained as 1.91±0.31 s (mean±S.D., $n=15$) and was not significantly different among the subjects (Fig. 4).

3.2. Mastication

The jaw movements, which were reconstructed after frame-by-frame analysis, showed a regular trajectory during mastication before the first swallow, in which the closing (CL), occlusal (OC), and opening (OP) phases were clearly identified (Fig. 2A). Mean phase durations in the chewing cycle are shown in Table 1. Each duration in the three phases was stable across the recordings.

In the chewing cycles, the tongue often moved rhythmically in a regular pattern along with the jaw. The tongue kept food in the postcanine area during the CL phase. Food reduction then occurred after tooth-food-tooth contact until minimum gape during the CL and OC phases. The tongue tip began to move forward and contacted the region of the incisive papilla in the late CL phase. The contact area of the tongue with the hard palate then enlarged distally, so that the food was squeezed distally toward the molars. The tongue moved backward during the OP phase and a chewing cycle ended.

The triturated food was transported from the oral cavity to the oropharynx during mastication along with the ongoing chewing (i.e., stage II transport). Stage II transport was not a one-time event. Once a part of the food was ready for transport, it was propelled into the oropharynx by the tongue, so that the tongue tip first contacted the region of the incisive papilla and then aggregated the particles of food from the incisal area of the hard palate during the late CL phase. The posterior part of the tongue dorsum descended during the OC phase, and the tongue dorsum was flattened against the occlusal plane. The tongue pushed upward and distally against the hard palate during the early OP phase, squeezing the food back into the oropharynx. The above mentioned process was repeated until the bolus was accumulated in the oropharynx, and a swallow followed, clearing the food from the oral cavity and pharynx.

3.3. Swallows

An example of the mandibular movement trajectory during a complete feeding sequence is shown in Fig. 1A. A complete feeding sequence normally involved one or two swallows,

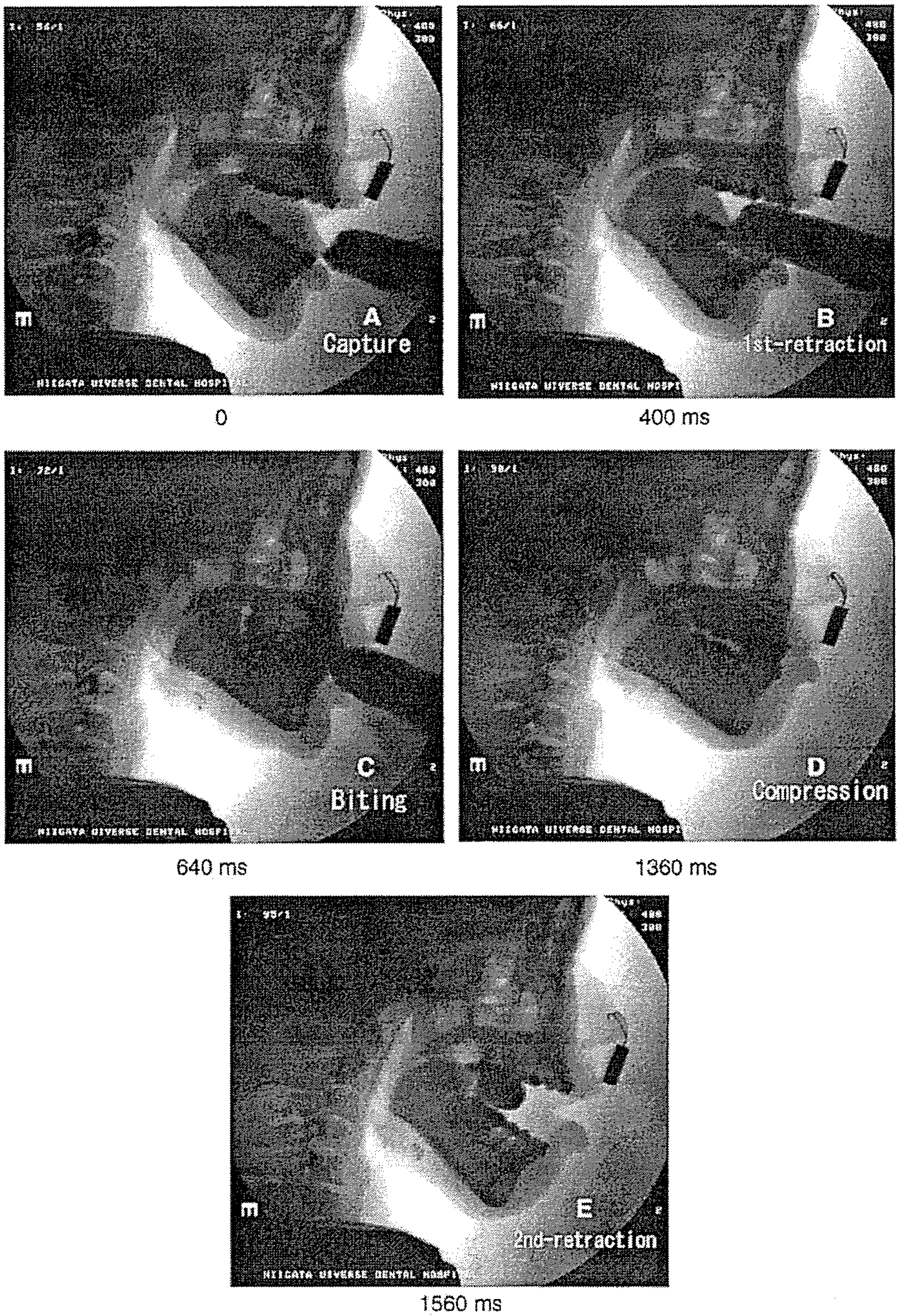

Fig. 3. Tongue movements during food intake as shown by VFG images. (A) The mouth opened wide to make room for the food, and the tongue moved forward over the incisors until it touched the lower lip to receive the food. (B) The tongue introduced the food into the mouth by its retraction. (C) Biting of the food. (D) Just after biting, the tongue compressed the food against the hard palate. (E) The food was transported to the occlusal surface of the molar teeth with a second retraction of the tongue.

preceded and succeeded by chewing cycles (interposed swallows), and ended with an isolated swallow (terminal swallow) to clear the food from the oral cavity and pharynx. This was the case for all subjects, and second interposed swallows were observed in 40% of the trials.

An interposed swallowing cycle was associated with the preceding and succeeding chewing cycles (Fig. 2A). In this case, the swallow-related events of the interposed swallowing cycle began almost exclusively during the OC phase and ended during the OP phase. As shown in Table 1, the duration

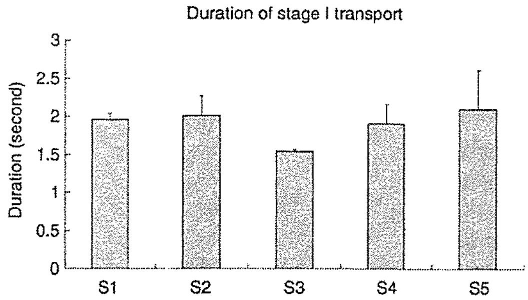

Fig. 4. The duration of stage I transport, (ANOVA); means and S.D. for a total of 15 first-bite records. Data was obtained from five subjects. Difference was analyzed using ANOVA and Bonferroni test. Significance level: $p<0.05$. Total elapsed time during stage I transport is defined starting with the maximum gape and ending with the first teeth-food-teeth contact of molar teeth. This period was not significantly different between the subjects.

of the CL phase of the interposed swallowing cycles (0.25± 0.07 s) was similar to that of the chewing cycles (0.22± 0.02 s). However, the duration of the OC and OP phases in the interposed swallowing cycles (0.39±0.15 and 0.60±0.09 s, respectively) was significantly longer than that of the OC and OP phases in the chewing cycles (0.17±0.03 and 0.24±0.02 s, respectively) ($p<0.001$). Accordingly, the total duration of the interposed swallowing cycles (1.23±0.09 s) was much longer than that of the chewing cycles (0.63±0.06 s, $p<0.001$).

Similar tongue movements during stage II transport were seen during the interposed swallow, i.e. the tongue squeezed the bolus with the palate toward the oropharynx through the fauces. At the beginning of interposed swallows, the tongue tip rose from the depressed position contacting with the hard palate at the incisal area while aggregating the triturated bolus on its dorsum. The contact area of the tongue with the hard palate enlarged distally, so that the aggregated food was transported backwards to be added to the bolus at the pharynx, which had been transported by stage II transport. The bolus went into the esophagus after nasopharyngeal closure and then laryngeal closure began. Thereafter, the food bolus passed the fauces to end the oral stage. After the food bolus passed through the upper esophageal region, nasopharyngeal closure and then laryngeal closure ended when the jaw opened slowly (Fig. 2A).

A terminal swallow was preceded by characteristic mandibular movements known as preswallowing cycles (Fig. 2B).

Table 1
Comparisons among the phase duration of jaw movement trajectories in the chewing and interposed cycles

	Chewing cycle	Interposed swallowing cycle	P
CL phase	0.22±0.02	0.25±0.07	$P=0.281$
OC phase	0.17±0.03	0.39±0.15	$P<0.001$
OP phase	0.24±0.02	0.60±0.09	$P<0.001$
Total cycle	0.63±0.06	1.23±0.09	$P<0.001$

Values are mean±S.D.
Individual differences were tested using a t-test.
Significance level: $p<0.05$.

Table 2
Duration of the oral stage of swallowing in the interposed and terminal swallows

	Interposed swallow	Terminal swallow	P
Duration of oral stage	0.38±0.05	0.94±0.47	$P<0.05$

Values are mean±S.D.
Difference was analyzed using a t-test.
Significance level: $p<0.05$.

These cycles were characterized by a decrease in the maximum gape followed by limited irregular mandibular movements. The preswallowing cycles began after maximum opening of regular chewing or interposed swallowing cycles, and they ended just before the onset of the terminal swallowing cycle. During preswallowing cycles, the tongue moved in a way that aggregated the residual food in the mouth in preparation for swallowing. The terminal swallow cycle as well as preswallowing cycles were often incomplete, irregular, and had a low-amplitude of jaw movement, as evaluated from the mandibular movements. Therefore, they could not be divided into three phases, as was the case for the chewing and interposed swallowing cycles (Fig. 2B).

Examples of the oral stage of interposed and terminal swallows are shown in Fig. 2A and B, respectively. The oral stage of the interposed swallow started at the end of the CL phase and ended during the OC phase. On the other hand, the oral stage of the terminal swallow started during the preswallowing cycles and continued until midway through the terminal swallowing cycle. Consequently, the duration of the oral stage in the terminal swallow (0.94±0.47 s) was significantly longer than that in the interposed swallows (0.38±0.05 s, $p<0.05$) (Table 2).

Examples of the swallow-related events, nasopharyngeal closure, laryngeal closure, and UES opening of interposed and terminal swallows are shown in Fig. 2A and B. As shown in Table 3, the durations of both nasopharyngeal and laryngeal closure tended to be longer in the interposed swallows than in the terminal swallows (0.61±0.02 and 0.61±0.03 s, respectively, vs. 0.54±0.08 and 0.53±0.07 s, respectively). However, the duration of UES opening in the interposed swallows (0.35± 0.03 s) was significantly longer than that in the terminal swallows (0.22±0.03 s, $p<0.001$).

In this study, the estimated volume of bolus that passed the UES in each swallow was irregular. The area of swallowed bolus in the interposed swallow (569±49 mm^2) was significantly larger than that in the terminal swallow (130±70 mm^2, $p<0.001$).

Table 3
Duration of the swallow-related events in the interposed and terminal swallows

	Interposed swallow	Terminal swallow	P
Nasopharyngeal closure	0.61±0.02	0.54±0.08	$P=0.097$
Laryngeal closure	0.61±0.03	0.53±0.07	$P=0.056$
UES opening	0.35±0.03	0.22±0.03	$P<0.001$

Values are mean±S.D.
Individual differences were analyzed using a t-test.
Significance level: $p<0.05$.

4. Discussion

The complete feeding sequence in humans has previously been studied using various soft and hard foods, e.g., chicken spread, bananas, hard cookies and peanuts [9], and carrots [13]. However, there appear to be great differences in the preferences and intake frequencies among individuals for these test foods. The purpose of the present study was to examine intra-oral events associated with the management of food during the natural complete feeding sequence. Therefore, we sought a test food of which it was easy for subjects to take one natural bite. Since steamed rice is a staple food in Japan, and Imai et al. [20] recommended it as a test food for the evaluation of masticatory and swallowing functions, we employed it as the test food in this study. Steamed rice also has the advantage of being easy to mix with barium powder for the VFG contrast medium and can be served as a lump without the use of either a spoon or a straw.

Since the VFG required neither head restriction nor any special apparatus attached to the body, we could qualitatively observe natural tongue and jaw movements during food intake. The present study showed that preparatory forward movement of the tongue to receive the food occurred during food intake and that the tongue movement was followed by retraction of the tongue (23.3±6.7 mm) to introduce the food into the mouth. Such tongue manipulation has not been reported previously. We therefore sought to investigate the role of this tongue retraction. There may be two parameters involved in making space for food during food intake into the mouth, i.e., the jaw gape and tongue retraction. Since the coefficient of variation was much smaller in the jaw gape (9.9%) than in the tongue movement (28.8%), it would be reasonable to consider that the food volume could be measured by the distance of tongue retraction. Consequently, we conclude that individual oral stereognosis by tongue manipulations when receiving food and introducing it into the mouth plays an important role in recognizing and evaluating the size of one bite of food.

After biting, one bite of food was immediately placed in the region of the incisive papilla and was slightly compressed by the tongue. Since the test food needed to be processed by dentition, it was transported to the posterior part of the oral cavity (stage I transport). During the compression process, we observed changes in food dimension, movement of the tongue tip, and a close association with the tongue and hard palate. This suggests that the intra-oral compression of food plays a role in the recognition of food texture. In fact, using artificial foods (agar and gelatin gels), Arai and Yamada [12] reported that the process of slight food compression with the tongue and hard palate may be the first step toward texture recognition. A large number of investigators have studied the effects of intra-oral sensory input on the activities of tongue muscles [21–24]. Yokota et al. [21] observed responses of the genioglossal and styloglossal motor units when tactile stimulation was applied to the anterior part of the tongue dorsum. Similarly, Iida et al. [23] observed inhibitory and excitatory responses elicited in the genioglossal and styloglossal muscles, respectively, by stimulating the incisive papilla. These responses elicited in the extrinsic tongue muscles may play a role in the recognition process, in which the tongue tip moves upwards and backwards against the anterior hard palate to evaluate the food texture. The hard palate was found to be one of the most sensitive areas to tactile stimulation [22,24]. The results of this study, therefore, suggest that an important process, i.e., texture recognition, acts on natural food under freely eating conditions.

The duration of stage I transport was measured as 1.91± 0.31 s. However, it was reported to be 280 ms by Hiiemae and Palmer [9]. Why was such a large difference observed? In their study, the subjects were asked to open their mouths to accept 8 g of food, and the food was deposited on the depressed anterior tongue by an examiner directly. On the other hand, the food was taken by the subjects freely in this study. As discussed above, a texture recognition process may precede stage I transport. The present study was able to, therefore, present the novel finding that stage I transport is closely bound to the recognition process when humans take natural food freely.

Interestingly, all subjects ate an amount of food that was more than one swallow volume even though they were instructed to take a bite that would be appropriate for eating sushi. This result is similar to that described by Hiiemae et al. [14] in that a complete feeding sequence involved more than one swallow event after taking a single natural bite of hard food. As described by Ertekin and Aydogdu [25], after ingesting 20 ml of water, normal subjects tended to divide the liquid between two or more swallows; they called this 'piecemeal deglutition.' On the other hand, patients with neurogenic dysphagia were obliged to divide a bolus of less than 20 ml of water into two or more successive swallows. In the present study, regardless of the volume of food in a single natural bite (11.5±3.7 g), two or three swallows were required during a complete feeding sequence. From the VFG images, it was evident that after one interposed swallow, some of the food still remained in the oral cavity, requiring at least one further swallow to clear the residual from the mouth. Since this was the case for all subjects without exception, it could be concluded that humans might need at least two swallows, even with one bite of food, when ingesting food freely. To explain this matter more clearly, however, it will be necessary to take data from additional subjects into consideration.

The present study showed that normal rhythmic chewing cycles immediately precede and succeed an interposed swallowing cycle; i.e. an interposed swallowing cycle is inserted in between chewing cycles. Moreover, swallow-related events in interposed swallowing cycles begin almost exclusively during the occlusal phase and end during the opening phase. In this study, the interposed swallowing cycles had a 0.6 s longer total cycle duration than the chewing cycles due to prolongation of the occlusal and opening phases. This difference in duration was equivalent to the mean duration of nasopharyngeal (0.61± 0.22 s) and laryngeal closure (0.61±0.03 s). Therefore, the interposed swallowing cycle can be interpreted simply as insertion of the swallowing reflex into the occlusal and opening phases of the chewing cycles. These findings were identical to those described by Palmer et al. [6,15] and Hiiemae et al. [14] for humans, and Uchida et al. [26], Meng et al. [10] and Naganuma et al. [11] for animals.

A terminal swallow occurs after characteristic mandibular movements termed preswallowing cycles [27,28] or clearance [14]. Hiiemae et al. [14] reported that regardless of whether such periods were long, short, or absent, they were correlated with the nature of the food, its wettability in saliva, and intra-oral 'food management strategies.' In this study, preswallowing cycles were confirmed from VFG frames as long periods in which the residual food was aggregated within the mouth.

Dantas et al. [18] reported that the duration time of the oral stage of swallowing was unaffected by bolus volume. However, the present study showed that the duration time was longer for smaller bolus volumes. This difference may be due to the experimental conditions, in which Dantas et al. studied the duration with command swallow while we studied it with natural swallow. In general, the oral stage of swallowing is thought to be a voluntary movement [29,30] and highly variable in duration depending upon the kind of food, taste, and, for humans, consciousness [25,31]. In the current study, therefore, we could yield the new finding that the oral stage of swallowing is variable in duration depending upon the food volume.

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「原著」

介護食の提供実態調査について
－新潟市の介護保険施設入所者の場合－

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An investigation into nursing care food at nursing care insurance institutions in Niigata city

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Abstract

Dysphagia presents with various signs and symptoms. It varies from mild masticatory dysfunction such as difficulty in chewing solid food to severe cases such as poor bolus formation caused by a weakened tongue or muscles of mastication, or impaired sensation. In addition, choking while swallowing or poor initiation of swallowing is also observed in swallowing impairments. Thus, it is extremely difficult to develop appropriate methods of home feeding for these disorders.

To understand the actual conditions under which nursing care food is cooked and prepared in nursing homes, we collected basic data to clarify the classification and terminology of dysphagia in accordance with actual feeding methods. Responses were collected from 41 institutions. As expected, disorders ranging from mild masticatory dysfunction to poor initiation of swallowing were managed by changing the consistency of the food. However, we found that thickening agent was overused as a preventive measure with little consideration given to the severity of the disorder. Therefore, we suggest that there needs to be a clearly-defined standard for evaluating masticatory dysfunction and swallowing disorders. There are many patients with cognitive impairment at all types of special nursing homes, including special nursing homes for the elderly (*Tokubetsu yogo rojin homu*), geriatric health care facilities for the elderly (*Kaigo rojin hoken shisetu*) and geriatric medical care facilities for the elderly (*Kaigo ryoyo gata iryo shisetsu*). Thus, we decided to examine dysphagia and cognitive impairment as separate categories.On open format questions, we found that there was confusion in the nursing care field due to lack of guidelines about which feeding methods correspond to specific disorders, and the absence of clear terminology for forms of food. We suggest that a "matching" manual, which correlates degree of dysphagia with different forms of nursing care food, is needed for specialist nursing care insurance homes, and also for home care. Thus, our aim is to produce a manual that can easily be understood in the nursing care environment.

Key word: dysphagia, food forms, nursing care food, a manual for feeding assistance

抄録

摂食・嚥下障害は「硬い食品が噛めない」といった軽度の咀嚼障害から，舌や咀嚼筋の筋力低下または感覚機能の障害により「ほとんど食塊を形成できない」重度の咀嚼障害，さらには「嚥下時にむせる」，「飲み込みが不良」など嚥下障害にいたるまでその症状は様々であり，在宅でこれらの障害にあった適切な食事形態を把握するのはかなり困難である．

そこで，介護保険施設での介護食の調理・調製の実態を把握することで，食事からみた摂食・嚥下障害の介護現場に即した分類と，また食事形態の用語を明確にするための基礎データの収集を試み，41の施設より回答を得た．咀嚼障害軽度から飲み込み不良までの各障害の対応では，調理の硬さの調製について予想どおりであったが，とろみ材の使用は障害の程度からすると，過度な予防策として実施されていることがわかった．このことから，咀嚼障害・嚥下障害の評価基準を明瞭にする必要があることが示唆された．特養・老健・療養型のいずれの施設においても認知障害者が多かった．そこで摂食・嚥下障害と認知症は別の項目として調査することが必要と考えられた．自由回答からは，食品の性状を表す用語，障害に対応した食品形態の基準が明確でないため，現場で混乱が生じていることが指摘された．これらの結果から，在宅だけでなく介護保険施設のような専門職の配置された所でも，著者らの目指す現場で理解しやすい“摂食・嚥下障害の程度と介護食のマッチング”マニュアルが求められていることがわか

った．

緒言

要介護者に摂食・嚥下障害がある場合，障害の程度に応じて食事を調理して口から食べ続けることができるように工夫することは，単に栄養素を補給するためだけでなくQOLをさまざまな形で支える非常に重要な行為である（山田，2004）．

高齢者は咀嚼能力が低下し，食品によっては食べにくくなるが，障害のある高齢者であっても摂取できる食品や調理・調製法の開発が望まれる．このことは，咀嚼能力に応じた食品の提供があれば咀嚼能力の低下した高齢者のリハビリにも活用が可能になる，という意味においても重要なことである．咀嚼障害がある場合は，軟らかく煮たり，切り込みを入れたり，細かくきざむなどの調理上の工夫が行なわれている（手嶋ら，2006；神山，2002）．また，嚥下障害がある場合は，飲料や食品にとろみを加え，物性を調整し誤嚥を防止している．これらの介護食の調理は，病院や介護保険施設の栄養士・調理師が取り組み，健康状態に配慮した栄養面での調整も行っている（黒田，2004，2005；田邉ら，2000）．

一方，在宅での介護が増加するに従い，介護食に慣れ親しむことのなかった家族にとって，要介護者の摂食・嚥下障害の程度に対応した調理が困難であることが懸念される．要介護者の障害に適切に調理された食事を提供できない場合，食事量が低下して低栄養となるほか「食べること」の楽しみや生きがいを失うことにもなりかねない（山

田，2004）．このため，在宅での介護食の調理や加工された介護食を選択する場合に，要介護者の摂食・嚥下障害に対応した介護食の選択を容易にする指標が必要となってくる．介護食の指標を検討するには，食品の性状と要介護者の摂食・嚥下障害の程度とのマッチングを把握しなくてはならないが，食品の性状は介護用加工食品では，物性測定をもとに基準化（日本介護食品協議会，2002）されているものの，摂食・嚥下障害の程度を在宅で要介護者ごとに基準化するまでには至っていない（永井ら，1994；柳沢ら，1996；鎹ら，1999；小城ら，2003，2004）．そのため，現時点ではマッチングについては，要介護者の食事の様子を観察することで把握しなくてはならないが，摂食・嚥下障害の程度は周囲の介護者にはわかりにくく，また本人が正しく表現できない場合も少なくない．そのため，摂食・嚥下能力が残っている場合でも安全を見込んで不必要な対応がなされている．

介護保険施設では，入所した要介護者の摂食・嚥下障害の状態を観察し，最適と思われる食事を提供（神山，2002；黒田，2004）しているが，その対応は施設によって異なっている（小城ら，2004）．そのため，現場（施設・病院）において入所者ごとに選択している介護食について，どのような調理や栄養面での配慮が行なわれているか実態調査することが不可欠である．

食事には，体内に必要な栄養素を取り込む目的があるが，高齢者に特有な原因により食品の取り込みに障害が発生することがある（山田，2004）．代表的な障害には認知障害，咀嚼障害，嚥下障害

があり，これらの障害により食事を摂取できなくなり低栄養を招いていると考えられる．これらの障害が発生している場合は，食品の性状を改善するなどの調理・調製の工夫が必要である．また，障害により摂取量が低下する場合，栄養素の濃度を高めた介護用加工食品を利用するなどの工夫もなされている（別府，2003）．そのため介護保険施設で提供されている要介護者の食事において，摂食・嚥下障害と栄養状況に対する工夫がどのように行われているか実態を把握する必要があると考えた．

今回は具体的な調査内容を決定し，その解析方法を検索するため，①咀嚼障害軽度，②咀嚼障害重度の段階に応じた食事の選択，③嚥下障害に対するむせや④飲み込み不良への対応，⑤認知障害がある場合への対応について，栄養士を対象に調査し，今後の対応について検討したので報告する．

調査対象と方法

1．対象

調査対象は新潟市の 79 介護保険施設の栄養士に Fig.1 に示す調査表を 2005 年 8 月に送付し，入所者の障害の程度にあわせて下記のようなアンケートへの協力を求めた．

2．調査内容

1）摂食・嚥下障害を A．咀嚼障害軽度，B．咀嚼障害重度，C．嚥下障害むせる，D．嚥下障害飲み込み不良，E．認知障害の 5 ランク（以下，障害別ランク A～E と略す）に分け，その中でそれぞれの障害に対応した①咀嚼と嚥下障害に対応する食事

形態の工夫，②成分調整の工夫，③風味・温度調整の工夫，④その他は①②③以外の工夫があるかどうかを知るために，各大項目に記した全22項目について，各施設での事例の多い順に番号を付けるように依頼した．

2）各施設の入所者を障害別ランクA～Eに分け，それぞれの対象者数の記載を求めた．その他として介護食で困っている点について自由回答で行った．（Fig.2）

3．調査の評価

統計解析は，調査結果における“介護保険施設の種類の違いと摂食・嚥下障害の程度の関連性”同様に“施設の種類別と食事形態，成分・風味調整に関する項目の関連性”について χ^2 検定を有意レベル $P<0.05$ で行った．

結果

1．アンケートの概要

1）新潟市の79介護保険施設である介護老人福祉施設，介護老人保健施設，介護療養型医療施設の栄養士に協力を求め，その結果41の施設（回収率52%）より回答が寄せられた．その内訳は，介護老人福祉施設16件，介護老人保健施設16件，介護療養型医療施設9件である．平均入所者数は102±49.2名（平均±標準偏差）で，調査対象者は総勢4399名であった．

2）全施設での摂食・嚥下障害の対象者数（平均±標準偏差）は，“認知障害”が一施設平均37±28.7名でもっとも多く，次に“障害なし”19±20.3名，“咀嚼障害軽度”17±19.2名であった．

“咀嚼障害重度” 12±11.6名，“嚥下障害飲み込み不良” 11±18.2名，“嚥下障害むせる” 10±8.9名と“その他” 4±9.1名の順であった．また，障害の程度を“特に区別していない”施設が9件あった（Table 1）.

3）施設間における障害別ランク A～E の分布には，以下に示すとおり統計的に有意な差が認められた（χ^2検定，$P<0.05$，Table 2）.
介護保険施設ごとの，ランク E．認知障害の割合は，介護老人福祉施設 637名（36.95%），次に介護老人保健施設 531名（30.64%），介護療養型医療施設 233名（24.73%）の順であった．同様にランク C，D を含む嚥下障害者の割合は，介護療養型医療施設 318名（33.76%），次に介護老人福祉施設 280名（16.24%），介護老人保健施設 264名（15.23%）であった．

4）介護保険施設の障害別ランク A～E の調査項目①から④の結果について，Fig.3に示す．

（1）調査項目①食事形態

軟らかくするため食材や調理を工夫する，きざみ食，ミキサー食，とろみを付ける等の9項目の順位は，咀嚼障害軽度の場合には，「食材や調理を工夫する」29件，「きざみ食」24件であり，「とろみを付ける」5件であった．咀嚼障害重度になると，「きざみ食」22件，「ミキサー食」16件で，「とろみを付ける」9件であった．さらに障害が重度と考えられる嚥下障害むせるには，上位で「とろみを付ける」15件，2位でも「とろみを付ける」20件であり，3位で「ミキサー食」10件で対応する施設もあるが，いずれも「とろみを付ける」と

いう回答が上位を占めた．嚥下障害飲み込み不良に問題のある者では，「その他」12件でもっとも多く，具体的にはゼリー食などが上げられた．次いで「経管流動食」10件，3位は「介護用加工食品（とろみ増粘剤以外）を使用する」7件となっていた．一方，認知障害と判断される場合には特に「食事形態を変更しない」が31件の回答であった．

(2)調査項目②成分調整

成分については，摂食量の減少に対応して成分調整が行われているのではないかと予想していたが，どの障害別ランクA～Eにおいても「調整しない」との回答がほとんどであった．

(3)調査項目③風味などの調整

風味についても，認知症による摂食障害に対応するための調製が行なわれていると予想していたが，温度的調整を回答した施設もあるが，ほとんどが何も調製しないと回答していた．

(4)調査項目④その他

障害別ランクA～Eのなかで，嚥下障害飲み込み不良の場合には，「医師の診断を受ける」と回答していたが，それ以外の摂食・嚥下障害および認知障害には，約半数の施設が「食事形態を各職員に相談する」と回答していた．

(5)各施設の調査回答において統計的に有意な差が認められた項目を以下に示す（χ^2検定，$P <$ 0.05，Table 3）．

①咀嚼障害軽度は，食事形態選択肢のなかで「まとまりの良い食材や調理を工夫する」と回答したのは介護療養型医療施設1件（11.1%），次に介