Influence of oral sensation on mastication and deglutition

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Mastication, deglutition, and respiratory movements were analyzed before and after application of topical anesthesia to the oral cavity to investigate the how sensation in the oral cavity affects swallowing and influences respiratory movement. Videofluorography was performed on 10 adult subjects using an X-ray TV system. Nasal respiratory dynamics were measured using a differential pressure flowmeter. The subjects were instructed to hold 10 mL of an oral topical anesthetic in their mouths for 5 minutes to paralyze oral sensation. Each subject freely chewed and swallowed 8 g of barium-containing corned beef as a test food. Videofluorographic images and respiratory flow waveforms were simultaneously recorded in a data recorder and analyzed on a computer. Because of the oral hypesthesis, the valleculae aggregation time (VAT) were significantly prolonged. Although VAT was less than one second before anesthesia, the time was prolonged after anesthesia in some subjects. The transport phase from the oral cavity to pharynx, starting from transport movement of the tongue to passage of the bolus tail through the posterior nasal spine, was significantly prolonged. The period from the start of hyoid bone elevation to breath-holding was significantly prolonged, showing that breath-holding for deglutition was delayed. These findings suggest that, in mastication-deglutition, oral sensation influences early movement including the occurrence of deglutition movement and breath-holding. (J Osaka Dent Univ 2013; 47: 139–148)

Key words: Oral; Sensation; Mastication; Deglutition; Respiration

INTRODUCTION

Ingestion/deglutition functions are impaired in the elderly due to age-related dysfunction, sequelae to cerebrovascular disorders and oral cancers, dementia, and Parkinson’s disease.1, 2 inducing malnutrition, dehydration, and quality of life (QOL) issues.3 To clarify the mechanism of deglutition movement, mastication and deglutition functions have been investigated with electromyograms,4 swallowing pressure,5 movement,6-7 and swallowing volume.8 Based on these, videendoscopic examination of swallowing,9 videofluorography,10 ultrasonography,11 and a swallowing pressure test12 have been performed to evaluate impairment for rehabilitation in clinical practice. Respiratory movement is closely coordinated with deglutition movement, and aspiration occurs when the interactive relationship is destroyed.13 Respiratory movement has also been investigated, and respiratory dynamics during deglutition have been reported with regard to the type of respiration,13 14 duration of apnea,15 and timing of breath-holding.16 However, previous studies mostly investigated liquid and command swallowing, represented by single swallowing,5, 13, 16 and many unclear points remain with regard to mastication and deglutition during normal food ingestion.

Reportedly, the neurological control system of deglutition is divided into three elements: peripheral input, the deglutition center in the brainstem, and cortical input, and these elements influence each other to induce normal deglutition.17 In mastication-deglutition, deglutition starts on mastication, which is a semiautomatic movement.18 Voluntary elements decrease, compared to those in command deglutition,
and bolus transport (Stage II transport\textsuperscript{19}) to the pharynx occurs while masticating. Although an influence of changes in the physical property of food is assumed because deglutition occurs when a bolus is formed by mastication, the details are unclear.\textsuperscript{20} It has been reported that sensory input from the pharynx is not an essential factor for the induction of mastication-deglutition,\textsuperscript{21} and that the oral phase of deglutition has already begun at the start of hyoid bone elevation and breath-holding,\textsuperscript{22} suggesting that the oral sensation of changes in the physical properties, volume, and bolus position are transmitted to the deglutition center, which induces deglutition.

In this study, we paralyzed oral sensations and simultaneously recorded videofluorography and nasal respiratory dynamics during mastication-deglutition, and analyzed mastication, deglutition and respiratory movements before and after anesthesia to investigate the involvement of oral sensations in swallowing during mastication-deglutition and to investigate its influence on respiratory movement.

**MATERIALS AND METHODS**

**Subjects**
The subjects were 10 adults, 9 males and 1 female with a mean age of 28 years, who had no subjective or objective abnormality in deglutition or respiratory function. The objective and methods of the study were explained to them beforehand, and consent was obtained. The study was performed in conformity with the Declaration of Helsinki (Ethics Review Board of Osaka Dental University, No. 100507).

**Videofluorography**
Videofluorography (VF) was performed using an X-ray TV system (Shimavision 3500 X\textsuperscript{5}, Shimadzu, Kyoto, Japan). The frame rate was set at 30 frames/sec, a tube voltage of 88 kV, a tube current of 1.2 mA and a total X-ray irradiation time of less than 5 minutes.

**Nasal respiratory dynamics**
The nose was entirely covered with a custom-made nasal mask (CM 1397\textsuperscript{6}, Hansrudolph, Shawnee, Kansas, USA), and the nasal respiration flow was measured after confirming the absence of air leakage, using the Pneumotach System (RSS 100 HR\textsuperscript{6}, Hansrudolph). The sensor flow range was set at 0–160 L/min.

**Block diagram**
A block diagram of this experiment is shown in Fig. 1. The VF image and respiratory flow waveform were synchronized and simultaneously recorded using a visual data recorder (AQ-VU\textsuperscript{8}, TEAC, Tokyo, Japan). The recorded images and waveforms were input into a personal computer, and analyzed using analysis software (NI DIAdem\textsuperscript{20} 2011, Kyowa Electronic Instruments, Tokyo, Japan).

**Experimental methods**
Oral sensation paralysis was induced after the subject was informed about the anesthesia. The subjects held 10 mL of a topical anesthetic (Xylocaine\textsuperscript{5} Viscous 2\%, AstraZeneca, Osaka, Japan) in their mouth for 5 minutes.\textsuperscript{8,22} The response to anesthesia was confirmed based on the presence or absence of a subjective sensation in the subjects. The test food was 8 g of combed beef mixed with 4 g of X-ray contrast medium (Baritop P\textsuperscript{5}, Kaigen, Osaka, Japan). Free mastication-deglutition movements were examined. The subjects were instructed to freely eat as usual, and the process from the start to finish of ingestion was regarded as one trial. The trial was performed twice each before and after anesthesia. The subjects sat upright on a chair, and the experiment was performed avoiding the first few hours after meals to mitigate the influence of a feeling of fullness on deglutition.

**Analytical items**
The first deglutition of each trial was analyzed. The oral cavity and pharyngeal region were divided in the lateral VF image, as reported by Takeda et al.\textsuperscript{21} (Fig.

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**Fig. 1** Block diagram of experiment.
2). The bolus head and tail were identified in the VF motion image, and the transit time was measured in each region. In addition, the time-points of termination of mastication, start of hyoid bone elevation, and start of transport movement of the tongue with deglutition movement, and the time-point of breath-holding from respiratory dynamics were identified and measured. Termination of mastication is represented by termination of mandibular movement, the start of hyoid bone elevation is represented by the start of rapid upper anterior elevation of the bone, the start of transport movement of the tongue is represented by contact of the tongue apex around the incisive papilla, and breath-holding is represented by flattening of the nasal respiratory flow waveform. The analytical parameters are shown below.

**Bolus head transit time**
- Oral cavity time (OCT): Time required to pass through the oral cavity area (OC)
- Postfaucial aggregation time (PFAT): Time required to pass through the upper oropharynx (UOP)
- Valleculea aggregation time (VAT): Time required to pass through the valleculea (VAL)
- Hypopharyngeal transit time (HTT): Time required to pass through the hypopharyngeal (HYP) region
- OCT + PFAT: Oral and upper oropharyngeal transit time
- PFAT + VAT: Stage II transport time
- OCT + PFAT + VAT + HTT: Oral and pharyngeal transit time

**Bolus tail**
- From the start of transport movement of the tongue to passage through the posterior nasal spine: Time required to transport a bolus from the oral cavity to pharynx by the tongue
- Transit from the posterior nasal spine to the esophageal orifice: Pharyngeal transit time

**Intervals between each deglutition movement**
- From termination of mastication to start of hyoid bone elevation
- Termination of mastication to breath-holding
- Start of hyoid bone elevation to start of transport movement of the tongue
- From start of hyoid bone elevation to breath-holding
- From start of transport movement of the tongue to breath-holding

**Intervals between mandibular inferior margin transit of the bolus head and each movement**
- From mandibular inferior margin transit of the bolus head to termination of mastication
- From mandibular inferior margin transit of the bolus head to start of hyoid bone elevation
- From mandibular inferior margin transit of the bolus head to start of transport movement of the tongue
- From mandibular inferior margin transit of the bolus head to breath-holding

Excel Statistics 2008 (Ver. 1.12, SSRI, Tokyo) was used for statistical analysis of data collected before and after anesthesia. Each parameter was analyzed employing the paired t-test, setting the significance level at 5%.

**RESULTS**

**Transit time of bolus head**
Setting the origin at the time-point when the bolus head passes through the posterior nasal spine, transit time-points of the bolus head are shown in Fig. 3 and Table 1. The mean oral and pharyngeal transit time from the start of mastication to the end of pharyngeal transit (OCT + PFAT + VAT + HTT) in all subjects was...
Table 1  Transit time of the bolus head before and after anesthesia

<table>
<thead>
<tr>
<th>Anesthesia</th>
<th>OCT</th>
<th>PFAT</th>
<th>VAT</th>
<th>HTT</th>
<th>OCT + PFAT</th>
<th>PEAT + VAT</th>
<th>OCT + PFAT + VAT + HTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>8.60 ± 5.07</td>
<td>2.73 ± 2.12</td>
<td>0.92 ± 1.58</td>
<td>0.45 ± 0.09</td>
<td>11.33 ± 4.26</td>
<td>3.65 ± 2.54</td>
<td>12.70 ± 4.02</td>
</tr>
<tr>
<td>After</td>
<td>10.80 ± 6.34</td>
<td>3.46 ± 5.49</td>
<td>2.41 ± 3.38</td>
<td>0.47 ± 0.09</td>
<td>14.25 ± 6.37</td>
<td>5.87 ± 4.87</td>
<td>17.13 ± 7.18</td>
</tr>
</tbody>
</table>

Significance

Mean ± SD, *p < 0.05, **p < 0.01, (sec).

Fig. 3  Transit time of the bolus head before and after anesthesia.

OCT, PFAT, VAT, HTT, Start mastication, SM: Stop mastication, SH: Start of hyoid bone elevation, H-PNS: Passage of the bolus head through the posterior nasal spine.

12.70 seconds before and 17.13 seconds after anesthesia, showing that anesthesia significantly prolonged the time (p < 0.01). No significant differences were noted in the oral cavity time (OCT) or postfaucial aggregation time (PFAT) before and after anesthesia, although the values tended to be longer with anesthesia. The mean valleculae aggregation time (VAT) in all subjects was 0.92 seconds before and 2.41 seconds after anesthesia, showing that anesthesia induced a significant prolongation (p < 0.05). No significant difference was noted in the hypopharyngeal transit time (HTT) before and after anesthesia. The mean oral cavity time plus postfaucial aggregation time (OCT + PFAT) in all subjects was 11.33 seconds before and 14.25 seconds after anesthesia, showing a significant, anesthesia-induced prolongation (p < 0.01). The mean stage II transport time (PFAT + VAT) was also significantly prolonged from 3.65 to 5.87 seconds after anesthesia (p < 0.05).

The valleculae aggregation time (VAT) in each subject is shown in Fig. 4. Before anesthesia, VAT was 2.34 and 5.01 seconds in 2 (A and B) of the 10 subjects, although it was less than 1 second in the others (C-J), who had almost no VAT. After anesthesia, almost no VAT was detected in 5 subjects (C, D, E, F and G) similar to that before anesthesia. However, VAT of less than 1 second before anesthesia was prolonged to 3 seconds or more after anesthesia in 3 subjects (H, I and J), and the mean in all subjects was prolonged from 0.92 seconds before to 2.41 seconds after anesthesia, showing a significant prolongation with anesthesia (p < 0.05).

**Transit time of bolus tail**

Setting the origin at the time mastication stopped, transit time-points of the bolus head and tail and the values are shown in Fig. 5 and Table 2. The mean time from the start of transport movement of the tongue to passage of the bolus tail through the posterior nasal spine in all subjects was 0.26 and 0.33 seconds before and after anesthesia, respectively, showing a significant prolongation (p < 0.05). In contrast, no significant change after anesthesia was noted in the pharyngeal transit time of the bolus tail.
Fig. 5  Transit time of the bolus head and tail before and after anesthesia.
○SM, △ST, T-PNS: Passage of the bolus tail through the posterior nasal spine, *p<0.05.

Table 2  Transit time of the bolus tail before and after anesthesia

<table>
<thead>
<tr>
<th>Anesthesia</th>
<th>ST to T-PNS</th>
<th>T-PNS to UES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>0.26±0.09</td>
<td>0.51±0.07</td>
</tr>
<tr>
<td>After</td>
<td>0.33±0.17</td>
<td>0.54±0.07</td>
</tr>
</tbody>
</table>

ST: Start transport movement of the tongue, T-PNS: Passage of the bolus tail through the posterior nasal spine, UES: Arrival of the bolus tail at the upper esophageal sphincter, *p<0.05, (sec).

Fig. 6  Relationship between the bolus head position and deglutition movement before and after anesthesia.
□VAT, ○SM, △SH, □ST, ◆BH: Breath-holding, MIM: Passage of the bolus head through the mandibular inferior margin, *p<0.05.

Table 3  Relationship between the bolus head position and deglutition movement before and after anesthesia

<table>
<thead>
<tr>
<th>Anesthesia</th>
<th>MIM to SM</th>
<th>MIM to SH</th>
<th>MIM to ST</th>
<th>MIM to BH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>0.55±1.66</td>
<td>0.62±1.66</td>
<td>0.62±1.63</td>
<td>0.79±1.65</td>
</tr>
<tr>
<td>After</td>
<td>1.90±3.49</td>
<td>1.96±3.46</td>
<td>2.01±3.41</td>
<td>2.24±3.42</td>
</tr>
</tbody>
</table>

Significance * * * * *

MIM: Passage of the bolus head through the mandibular inferior margin, SM: Stop mastication, SH: Start hyoid bone elevation, BH: Breath-holding, *p<0.05, (sec).

Fig. 7  Deglutition movement and breath-holding before and after anesthesia.
○SM, △SH, □ST, ◆BH, *p<0.05, **p<0.01.

mean time-point of breath-holding in all subjects was also significantly prolonged by anesthesia from 0.79 seconds before to 2.24 seconds after anesthesia (p<0.05).

Deglutition movement and breath-holding
The relationship between the deglutition movement and breath-holding, setting the origin at stopping mastication, is shown in Fig. 7 and Table 4. The order of the process (termination of mastication → start of hyoid bone elevation → start of transport movement of the tongue → start of movement of the hyoid bone → start of repositioning of the tongue → start of deglutition movement) was significantly different from anesthesia before to after anesthesia (p<0.05).
the tongue—breath-holding) did not change after anesthesia. The mean time from termination of mastication to the start of hyoid bone elevation in all subjects was 0.07 and 0.06 seconds before and after anesthesia, respectively. These values from the start of hyoid bone elevation to the start of transport movement of the tongue were 0.01 and 0.06 seconds, respectively, and those from the start of transport movement of the tongue to breath-holding were 0.17 and 0.23 seconds, respectively, showing no significant change after anesthesia. In contrast, the mean time from the start of hyoid bone elevation to breath-holding was 0.17 and 0.29 seconds before and after anesthesia, respectively, showing a significant prolongation (p < 0.01). In addition, the time from termination of mastication to breath-holding was also significantly prolonged from 0.24 sec before to 0.34 sec after anesthesia (p < 0.05).

**DISCUSSION**

**Experimental methods**

**Test food**

Reportedly, the occurrence or non-occurrence of stage II transport and its frequency vary, and these are influenced by the diversity of individual masticatory dynamics and physical properties of food. When food fluidity is high and a bolus rapidly enters the hypopharynx, the reflex mechanism acts to avoid aspiration, inducing deglutition. Since this study aimed at investigating standard mastication-deglutition on normal food ingestion, not the defensive deglutition described above, it was necessary to select a test food with low fluidity. In previous studies on mastication-deglutition, cooked rice, cookies, corned beef, bananas and gummi were used as test foods. It was found that the physical properties of the food influenced the mastication frequency, bolus-forming time, and occurrence of stage II transport. Cookies and corned beef have been frequently used because they are less likely to be influenced by gravity because of their physical properties, the pharyngeal transition time is long, and stage II transport readily occurs. However, mixing with saliva is necessary to form a bolus with cookies. Thus their transport is more likely to be influenced by the salivary volume in individual subjects than other foods, although the mastication and stage II transport time is long. Thus, we selected corned beef for the test food because its fluidity is low due to viscosity, the density is homogeneous, and mastication-induced changes in its physical properties are small. The amount of test food was set at 8 g, for which the occurrence of stage II transport has been confirmed.

**Hypesthesia induction method**

Oral sensation in the tongue, periodontal ligament, palatal mucosa, gingiva, and buccal mucosa is thought to be involved in ingestion and deglutition. There have been reports in which oral sensation was paralyzed by mandibular foramen conduction anesthesia, and deglutition movement was observed, and reports where deglutition movement was observed by blocking sensory input from the palatal mucosa using a palatal plate. Since mandibular foramen conduction anesthesia paralyzes the inferior alveolar and lingual nerves, the lower premolar periodontal ligament, gingiva, and tongue are desensitized. However, this type of anesthesia does not paralyze the maxillary gingiva, palatal mucosa or buccal mucosa. Moreover, it may be accompanied by disturbances in mouth opening, odynophagia and occlusion, and may interfere with normal ingestion and

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**Table 4** Deglutition movement and breath-holding before and after anesthesia

<table>
<thead>
<tr>
<th>Anesthesia</th>
<th>SM to SH</th>
<th>SH to ST</th>
<th>ST to BH</th>
<th>SH to BH</th>
<th>SM to BH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>0.07 ± 0.07</td>
<td>0.01 ± 0.08</td>
<td>0.17 ± 0.09</td>
<td>0.17 ± 0.09</td>
<td>0.24 ± 0.10</td>
</tr>
<tr>
<td>After</td>
<td>0.06 ± 0.10</td>
<td>0.06 ± 0.12</td>
<td>0.23 ± 0.16</td>
<td>0.29 ± 0.14</td>
<td>0.34 ± 0.15</td>
</tr>
</tbody>
</table>

*Significance: *p<0.05, **p<0.01, (sec).
deglutition. On the other hand, although a palatal plate blocks sensation from the palatal mucosa, it does not desensitize the lower jaw or tongue, and strange sensations may occur due to the plate thickness, influencing deglutition. We selected surface anesthesia because it homogenously paralyzes the upper and lower gingiva, tongue, and palatal and buccal mucosa, although it does not paralyze the periodontal ligament. For the surface anesthesia, Xylocaine® Viscous 2% (AstraZeneca, Osaka, Japan) was used because it has been confirmed to reduce the tongue’s capacity for three-dimensional discrimination.6

**Analytical parameters**

In command deglutition in normal subjects, the bolus head is present in the oral cavity before deglutition starts, and the hyoid bone rises within 1 second after the bolus passes through the mandibular inferior margin, starting the deglutition reflex.37 Accordingly, the mandibular inferior margin has been used as the boundary. On the other hand, in mastication-deglutition, the bolus head passes through the fauces and is transported to the pharynx before deglutition starts (stage II transport), for which a boundary should be set at a site near the fauces for analysis. Furthermore, tongue movement and gravity are involved in bolus passage through the morphologically horizontal oral and upper oropharyngeal area and the horizontal-to-vertical transition region. Gravity is also involved in the passage through the vertical hypopharyngeal area,21 suggesting that the influence of oral sensation varies among different positions. Thus, by adding the posterior nasal spine as a boundary as mentioned by Takeda et al., we divided the oral and pharyngeal regions into 4 areas: the oral cavity area, the oral and upper oropharyngeal area, the valleculae area, and the hypopharyngeal area, setting the boundaries at the posterior nasal spine, mandibular inferior margin, valleculae, and esophageal orifice, respectively.

In mastication-deglutition, the bolus head is transported to the pharynx by stage II transport, and the depth varies. Therefore, it is difficult to present the speed of involuntary deglutition movement as the pharyngeal transit time of the bolus head. In contrast, the speed of involuntary movement can be presented based on the pharyngeal transit time of the bolus tail because it is present in the oral cavity when deglutition starts. Furthermore, its identification is reliable, compared to that of the bolus head, reducing measurement errors.38 To analyze the speed of involuntary movement responsible for the pharyngeal transit of a bolus, we measured the pharyngeal transit time of the bolus tail.

**Results**

**Perception of physical property in oral cavity**

Goto26 reported that bolus transport dynamics vary with differences in the jaw movement pattern during mastication, while Takeda et al.21 reported that stage II transport is a variable phenomenon that does not always occur, and that there is inter-individual variation in its frequency of occurrence. Before anesthesia, the valleculae aggregation time (VAT) in our study was 2 seconds or more in some subjects and less than 1 second in others, showing inter-individual variation of stage II transport. Similarly, inter-individual variation was noted in anesthesia-induced changes in VAT. It was shorter than 1 second before anesthesia, and remained at less than 1 second after anesthesia in some subjects. However, it was prolonged after anesthesia in others. Normally, the physical property of a bolus is perceived through oral sensation before deglutition starts. Anesthesia prolonged VAT, suggesting that the anesthesia paralyzed oral sensation and, subsequently affected perception of the physical property of the bolus. As a result, the onset of deglutition was delayed, and it was ultimately triggered by sensory input from the pharynx.

**Influence on onset of deglutition**

Factors influencing transit time include the physical property of food, chewing method, tongue movements, palatolingual contact, and pharyngeal pressure.11, 21, 39 Not only is the oral and upper oropharyngeal transit time (OCT + PFAT) prolonged, but also the stage II transport time (PFAT + VAT), especially the valleculae transit time (VAT), is significantly prolonged after anesthesia. This suggests that anesthe-
sia made perception of the physical property of the bolus difficult and interfered with smooth ingestion and deglutition movements of various organs, influencing the speed and rhythm of bolus transport.

The time from the start of transport movement of the tongue to passage through the posterior nasal spine of the bolus tail, i.e., the transport time from the oral cavity to the pharynx, was significantly prolonged by anesthesia. Anesthesia of the oral cavity may have elevated the sensory thresholds of the tongue, palate, buccal mucosa, and gingiva, which delayed reflex responses to tongue stimulation and the start of transport movement of the tongue in deglutition. In addition, it slowed tongue movement because various stimulations in the oral cavity induce this movement.

The stimulation of tongue receptors induces tongue muscle activity and movement, and anterior movement of the dorsum of the tongue is delayed in the oral cavity phase in liquid deglutition under tongue surface anesthesia. Although the actual pressure was unclear, it is also possible that the tongue and palatoglossal contact pressures decreased and prolonged the transit time.

The above findings suggested that the oral sensation influences the occurrence of deglutition movement in mastication-deglutition.

**Influence on deglutition and involuntary movements**

The period from termination of mastication to the start of hyoid bone elevation reflects a switch in the movement from mastication to deglutition. No significant prolongation of this period was noted after anesthesia, clarifying that oral sensation did not influence the movement switch. Movement switch from mastication to deglutition is assumed to be a stable mechanism because there is no difference in the switch during mastication-deglutition between ingestion of cookies and corned beef. Deglutition subsequently occurs after mastication, which is a rhythmical, semiautomatic movement.

Deglutition movement is divided into voluntary movement in the oral cavity phase and reflex movement in the pharyngeal phase. Deglutition reflex-induced bolus transport in the pharynx is performed by involuntary movement of the pharyngeal constrictor muscle. No significant prolongation of the pharyngeal transit time of the bolus tail was induced by paralysis of oral sensation, showing that the involuntary movement responsible for pharyngeal bolus transport was not influenced by oral sensation. In command deglutition, the pharyngeal transit time of the bolus tail of syrup was longer than that of water and agar. In addition, the bolus viscosity influences the pharyngeal transit time, suggesting that although perception of the physical properties of the bolus through oral sensation does not influence involuntary movement, the physical properties directly prolong the transit time.

**Influence of sensation by region**

Arai et al. reported that the start of deglutition after holding food in the month was delayed in mastication-deglutition when the palate was covered with a plate, showing the involvement of the palatal mucosal sensation in deglutition. When Tei et al. investigated mastication-deglutition of corned beef in subjects treated with bilateral mandibular foramen conduction anesthesia, the period from passage of the bolus head through the mandibular inferior margin to the start of hyoid bone elevation was prolonged in some subjects but shortened in others. We desensitized the oral cavity, except for the periodontal ligament, and observed that the period from passage of the bolus head through the mandibular inferior margin to the start of deglutition movement was significantly prolonged. No shortening of this period was noted in any of our subjects, unlike the findings reported by Tei et al.

It has been reported that paralysis of the periodontal ligament sensation, which is important in perceiving bolus hardness, by mandibular foramen conduction anesthesia interrupted sequential bolus transport to the pharynx. This fact, together with our findings, suggests that the absence of shortening of the time before deglutition may have been due to differences in sensation in the periodontal ligament, gingiva, palatal mucosa and buccal mucosa, as well as differences in the hypesthesias level of the tongue due to differences in the anesthesia method. Based on the above findings, it was assumed that differences in sensation...
among regions influence the start of deglutition.

**Breath-holding**

Closure of the epipharyngeal space and glottis, folding over of the epiglottis, and swallowing apnea occur during deglutition. Since closure of the epipharyngeal space precedes closure of the glottis, breath-holding observed during deglutition on measurement of nasal respiratory dynamics may have been due to closure of the epipharyngeal space, not the glottis. As described above, no significant change was noted in the time from termination of mastication to the start of hyoid bone elevation after anesthesia, while the periods from termination of mastication to breath-holding and from the start of hyoid bone elevation to breath-holding were significantly prolonged. This was due to delayed closure of the epipharyngeal space. In command deglutition, the timing of soft palatal movement changed with hypesthesia of the tongue, suggesting that hypesthesia of the oral cavity slows transport movement of the tongue, delaying deglutition movement and the subsequent closure of the epipharyngeal space during deglutition. Therefore, it was suggested that oral hypesthesia in mastication–deglutition influences movement in the early phase of deglutition, such as tongue movement and closure of the epipharyngeal space.

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**REFERENCES**

24. Hatanaka H, Ono Y, Tanaka E, Yoshioka M, Uesugi N, Takanashid K, Komasa Y. Respiratory movement during mastication-swallowing: simultaneous observation with bolus tran-
sport using videoendoscopy. Ronen Shika Igaku (Jpn J Gerodonto) 2011; 26: 121–122. (Japanese)


