Gnathohexagraphic evaluation of ingestion and swallowing in elderly

Yuichi Higuchi, Akiyo Kawamoto, Takatsugu Asai, Kazuya Takahashi and Joji Okazaki
Department of Geriatric Dentistry, Osaka Dental University, 8-1 Kuzuhaianazono-cho, Hirakata-shi, Osaka 573-1121, Japan

We compared ingestion and swallowing in elderly and young people using a gnathohexagraphic (GC Corp., Tokyo) with 6 degree of freedom. The test foods used were 5 cc of water, 5 g of jelly and 5 g of kamaboko fish paste. Gnathohexagraphic measurements were made with microphones attached on the zygomatic bone and the cricoid cartilage to record jaw movements and the sounds of occlusion and swallowing. In order to evaluate pharyngeal bolus transit, we measured the number of chewing strokes and the time of between occlusal and swallowing sounds.

We found that the elderly had simple mouth opening and closing, short and clear occlusal sounds and a short swallowing with water. During jelly swallowing, a few chewing and occlusal sounds were recorded, as well as a short swallowing sound. When kamaboko was ingested, chewing was complicated, and several occlusal sounds and a long swallowing sound of low amplitude was recorded. The temporalis and the masseter muscles were activated during occlusion, whereas the temporalis, masseter and digastrics muscles were all actively coordinated during swallowing of the test foods. The mode of chewing was the same for both young adults and the elderly, although the number of chewing cycle varied.

The time difference between the last occlusal sound in the chewing cycle and the swallowing sound is called the O-S lag. We found that the elderly had prolonged O-S lag compared with younger subjects. The difference was greatest and most varied for water.

These results suggest that the ingestion/swallowing reserve of elderly deteriorates regardless of their health due to natural deterioration of the physiological functions as well as the anatomical changes. We would like to evaluate various conditions of ingestion and swallowing based on the results of this study. (J Osaka Dent Univ 2002; 36: 61–66.)

Key words: Ingestion and Swallowing; Elderly; Gnathohexagraph

INTRODUCTION

Many elderly have underlying health issues. Among them, cerebrovascular diseases greatly affect ingestion and swallowing.1,2 Even without this problem, aging causes dysfunction of the peripheral nervous systems, decline in the masseter muscle, reduction in saliva secretion and lowering of the laryngeal position, resulting in deterioration of ingestion and swallowing functions.3-5

There has been considerable discussion about the relationship between dental treatment and chewing, but little on its effect on swallowing. The aging society presents challenges in dealing with problems of ingestion and swallowing in the elderly.

Video fluoroscopy6-7 and endoscopy8 are often used to assess ingestion and swallowing. These techniques are not good for evaluating chewing which is an important element in bolus formation, which leads to ingestion and swallowing. The authors9 used a gnathohexagraph to assess ingestion and swallowing of healthy adults by studying their jaw movements, muscle activities, occlusal sounds and swallowing sounds. The study revealed different chewing numbers, swallowing sound wave forms and chewing cycles depending on the test foods used. The time difference between the occlusal sound at the last chewing cycle and the swallowing sound (O-S lag) differed for different test foods. The authors did experiments on elderly
subjects and healthy young adults for comparison.

**METHOD**

The five elderly subjects had more than 24 remaining teeth with molar intercuspation on both sides, and had an average age of 78 years. The five young adults had normal dentition and an average age of 27 years. The test foods were 5 cc of water, 5 grams of kamaboko fish paste and 5 grams of jelly. Microphones were attached over the zygoma and cricoid bone for the gnathohexagraphic study. Jaw movement, occlusal sounds and swallowing sounds were recorded. The subjects were instructed to chew and swallow the test foods freely. Measurements were made 5 times on each test food. The number of chewing cycles and the O-S lag were measured to evaluate bolus transit in the pharyngeal phase.

Bipolar leads were taken from the temporalis, the masseter and the digastrics muscles using a surface electromyogram 6 R 21-KF (NEC MEDICAL SYSTEMS Co., Tokyo) (Fig. 1). The position to collect bite sound was set based on the motor tract of the anterior teeth. The swallowing sound was recorded at the start of the waveform with reference to coordination of the opening and closing muscles.

**RESULTS**

Figures 2 through 4 show cases of ingestion and

![Fig. 1 Evaluation of ingestion and swallowing using the gnathohexagraph.](image1)

![Fig. 2 Record of voluntary swallowing of water from the mandibular rest position.](image2)

![Fig. 3 Record of voluntary swallowing of jelly.](image3)

![Fig. 4 Record of voluntary swallowing of kamaboko.](image4)
Fig. 5  Measurement of time difference between the occlusal and swallowing sounds.

Fig. 6  Average of the time difference between the occlusal and swallowing sounds in young and the elderly.

Fig. 7  Average of the time difference between the occlusal and swallowing sounds for each test food.
swallowing of water, jelly and kamaboko. Figure 5 depicts measurement of the time difference between the occlusal sound and swallowing sound, while Figure 6 and 7 show the average values.

The number of chewing cycles was recorded from the jaw movements (Table 1). Waveforms of the swallowing sound varied depending on the test foods. For all test foods, the temporalis muscle and the masseter muscle were activated during occlusion and the temporalis, masseter and digastrics muscles were coordinated during swallowing.

**DISCUSSION**

People lose more teeth by caries and/or periodontal diseases as they get older, negatively affecting ingestion and swallowing.\(^3\)\(^-\)\(^5\) The phenomenon, however, has been interpreted as the effect of tooth loss, ignoring the effect of aging of the intra and extra oral tissues on ingestion and swallowing. Ingestion and swallowing functions were performed by continuous voluntary and involuntary movements in the tissues. It is therefore difficult to assess each phase discretely. Not only is it hard to observe intracoral functions externally, but it is also difficult to measure movements and evaluation of function is difficult.\(^6\)\(^-\)\(^8\) The authors used a gnathohexagraph to record jaw movement, muscle activities, occlusal sounds and swallowing sounds during ingestion of test foods near physiological conditions. O-S lag was measured for objective evaluation of bolus transit in the pharyngeal phase.

Both elderly and young subjects show similar jaw movements, muscle activities, occlusal sounds and swallowing sounds for the same test food. While doing the tests for water, we instructed the subjects to hold the water in the mouth for free swallowing. This allowed them to produce a simple opening and closing movements, short and clear occlusal sounds and a short swallowing sound. The chewing movement for jelly contained a component of lateral movement. Little jelly, however, was on the dentition as the chewing proceeded, and most of it was formed into a bolus through compression by the tongue and palate. Some chewing routes and clear occlusal sound were recorded. For kamaboko, chewing was done by mastication on the molars, which presumably generated occlusal contact. Kamaboko required a complicated chewing route and several occlusal sounds, including noise.

The opening and closing muscles coordinate during chewing and swallowing. Swallowing, unlike chewing, requires stabilization of the mandible by the closing muscle and elevation of the hyoid bone by the suprahoid muscles. Coordination of the two muscle groups is indispensable.

Generally speaking, chewing is a function we need throughout life. It has been reported that chewing requires the least assistance of any activity and has little age related change. Healthy elderly people without any abnormalities in their jaws and mouths can maintain chewing patterns very similar to those of healthy younger adults.\(^9\) However, the elderly require more chewing cycles than younger subjects. This results from a reduction in the amount of chewing muscle activity, a decline in oral perception, and decreases salivary secretion. These changes cause a less rhythmical bolus formation and negatively affect the smooth transition from chewing to swallowing. It is thought that such changes in the elderly delay the O-S lag.

In young adults, the initial O-S lag is greater for water and shorter after the fourth. With kamaboko ingestion, the measurements were consistent and the O-S lag short. Jelly produced a shorter O-S lag than kamaboko. The O-S lag was longer for the elderly with all test foods. Prolonged O-S lag is attributable to a decline in the activities of the masseter muscle, the level of oral perception, and salivary secretion. Reduced capacity for bolus transport and anatomical changes may also be involved.

Driving force that centers on the tongue is essential for normal bolus transport. When the bolus is
transported into the pharyngeal and esophageal phases, it is necessary to increase pressure from the previous phase. The mechanism of intraoral pressure increase is shown below. The bolus formed through chewing is moved from the lips to the base of the tongue. Then the floor of the mouth is elevated by the action of the mylohyoid muscle, and the tongue presses against the soft palate from the anterior to the posterior using its intrinsic muscles. This series of actions increases intraoral pressure. The extrinsic muscles of the tongue lower the base of the tongue, letting the bolus pass through the anatomical constriction to the mesopharynx. The elderly have weaker maxillo-oral muscles with less driving force for bolus transport.

It has been reported that the larynx is displaced downward in elderly people by approximately one cervical spine, resulting in a more posterior position of the tongue. Downward displacement of the larynx increases the vertical height of mesopharynx. Age related laryngeal displacement moves the position of the hyoid bone posteriorly. These anatomical changes are thought to prolong the time required for a single swallowing motion.

The O-S lag was greater for water than any other test food. Swallowing is the action of bolus transport and occurs with the lips closed and teeth occluded. We attached a facebow to the mandibular anterior teeth via a clutch. The clutch interferes with closure of the lips at the time of swallowing. Since water is extremely low in viscosity, it tends to leak from the lips unless they are completely closed. These conditions, the authors believe, prolong swallowing time and increase variation in the patterns of swallowing. This is especially true with elderly people whose oral sphincter is weak. The clutch, which passes through the fissured labium, interferes with closure and disrupts measurement of the O-S lag.

Jelly and kamaboko, on the other hand, make the O-S lag shorter and more stable as the number of tests increases. Although the O-S lag for kamaboko was quite different for the elderly subjects and young adults, it was about the same for jelly. Generally speaking, food is swallowed when the bolus is formed into a swallowable state in terms of size and physical properties. Soft jelly, therefore, becomes liquid when mashed by the tongue and mixed with saliva. Since it was formed into liquid, it was easier for the elderly to transport it into the pharynx. On the other hand, kamaboko is more elastic and its bolus contains a greater solid component. It takes more time for the elderly to swallow than jelly because of their weaker muscles.

We found that the ingestion and swallowing patterns of the elderly and the younger adult are different for different test foods. The elderly subjects we studied, however, did not have any pathological problems with ingestion or swallowing. A natural decline in physiological functions and anatomical changes reduced the ingestion and swallowing reserve for these people.

Use of organs generally activates their functions when no disease is present, while disuse induces regression of function. The same is true for the oral cavity. Chewing with the teeth activates the masseter muscles and nourishes the saliva gland and the oral mucosa, delaying age-related declines in oral function. Movement in the masseter system further activates other digestive systems. On the other hand, age-related changes in oral function can adversely affect digestive function. Since the entire digestive system tries to maintain a balance, decline in ingestion and swallowing function can adversely affect gastric function. Dental professionals need to help the elderly maintain normal ingestion and swallowing as well as a healthy daily life through conservation and maintenance of the maxillo-oral system.

REFERENCES


