International Journal of Orofacial Myology and Myofunctional Therapy
Official Journal of the International Association of Orofacial Myology

Volume 26 | Number 1 | pp. 24-29 2000

Original Research

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The Development of Normal Feeding and Swallowing: Showa University Study of the Feeding Function

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ABSTRACT
Since the 1980s the Department of Hygiene and Oral Health at the Showa University School of Dentistry has focused its research efforts on the development of feeding function and disorders. In addition, we have treated dysphagic children and dysphagic elderly using our feeding training program approach. The developmental course of the feeding function includes the following steps: 1) Suckle feeding and pre-feeding period; 2) Acquiring the ability to swallow with lips closed; 3) Acquiring the ability to take food with lips closed; 4) Acquiring the ability to push mashed food with the tongue and anterior hard palate; 5) Acquiring the ability to perform mastication; 6) Beginning self-feeding; 7) Beginning finger feeding; 8) Beginning using table ware

INTRODUCTION

The Department of Hygiene and Oral Health at the Showa University School of Dentistry mainly focuses its studies on the development of feeding function and its disorders (Kaneko, 1987). Many children affected with moderate to severe cerebral palsy and mental retardation are suffering from dysphagia. The Showa University faculty treat dysphagic children, and our approach is also used in the feeding training program for dysphagic elderly.

Since 1980, our research and development has focused on developmental therapy. An overview of some of this research follows. The eight steps of our developmental feeding program reflects the physiomotor development (Mukai, 1995) (Figure 1). These eight steps are grouped into two major categories - care giver assisted feeding, and self-feeding. Various sensory stimulation in the face and mouth create the feeding movement, which is a coordination activity of the oral structure.

CARE GIVER ASSISTED FEEDING

First step: Suckling feeding and pre-feeding period

Feeding function starts with suckling feeding which entails reflex feeding organized at the subcortical level. Figure 2 is the sucking action of an infant. The lip seals the areola of the mammary gland and steady pressure is applied. The tip of the tongue remains over the upper alveolar ridge and touches the nipple. The cervix of the nipple is placed on the upper alveolar ridge and tongue. The tongue makes peristaltic wave motions and pushes the nipple against the sulcus, which is made of para alveolar walls for sucking against the hard palate. Then, with the oral cavity sealed by the lips, the jaw and tongue drop down, creating negative pressure, and milk is drawn out into the oral cavity.

Tongue motion can be observed during suckle feeding using Ultrasound (Tatuno, 1988). Showa University faculty uses ultrasound imaging to assess tongue movement by using a small size probe set against the inferior edge of the mandible, and sagittal section. Ultrasound imaging reveled that the upper line of the nipple touches the hard palate while the posterior of the tip of the nipple touches the soft palate. A large movement by the soft palate when suckle feeding was observed. The contact for the lower part of the nipple is the tongue surface (Figure 3).

It was noted that the tip of the tongue was almost fixed. There was a wave-like motion from the middle of the tongue to the back of the tongue. In suckling feeding, the tongue and jaw move together, rather than independently.

Figure 4 is a picture of the oral cavity of a 2 month-old infant. At this age, the structure of the oral cavity is suited for the motion of suckling feeding. The accessorius alveolar ridges are inside the alveolar ridge making a narrow groove. The nipple fits into this groove.

Figure 5 is a picture of the oral cavity of a 12 month-old infant. The accessorius alveolar ridge gradually disappears, and the structure of the

oral cavity changes. There is a transition not only in the structure of the oral cavity but also in oral motor function. The suckling reflex disappears at the 6 month stage for normally developing infants.

Second step: Acquiring the ability to swallow with the lips closed.

After the suckling reflex disappears, infants acquire the first feeding function necessary for swallowing. When starting to eat solid food, the oral structure develops characteristic motions. The oral structures begin to move separately rather than together as in suckling motion.

When a child swallows, we can see the lower lip go into the oral cavity (Figure 6). These actions prevent tongue thrust and guide the tip of the tongue to touch the rugue of palate and begin to make peristaltic waves. The food brought in by the lips is moved to the pharynx by the tongue.

The development of tongue motion observed using ultrasound

Showa faculty also studied the development of tongue motion by using ultrasound (Ohtsuka, 1998). The subject was a healthy infant. Observation began when she was 4 months old. The probe was touched against the inferior edge of the mandible and ultrasound imaging was performed in the coronal section of tongue surface to assess movements during swallowing.

At 5 months of age, central grooves in the tongue were not observed, but at 8 months of age, central grooves in the tongue appeared (Figure 7). Figure 8 is the mean value of grooving depth by age. With increasing age, the depth of the central grooves of the tongue surface increased.

In evaluating tongue motion during swallowing, a standardized method was developed for taking ultrasound images of the tongue surface during eating and during swallowing in the sagittal section and the coronal section.

Sagittal standardization method

The method for standardized ultrasound imaging of the tongue surface in the sagittal section is as follows (Ohtsuka, 1994) (Figure 9).

The sitting position is the Frankfort Horizontal (FH) plane vertical to the floor, and the mandible is in the restbite position. The FH plane is described as a plane passing through the most superior points of each bony external auditory meatus and the lowest point of the inferior border of the left bony orbit. Submental midline transducer placement was not suitable for sagittal scanning of the mid tongue motion, because it disturbed the natural forward-upward displacement of the hyoid bone during swallowing and the probe was moving up and down during swallowing, resulting in failure to obtain clear images. These disadvantages were resolved by changing the probe position from the submental midline to the submandibular region along the inferior border of the mandible.

Coronal standardization method

The method for standardized ultrasound imaging of the tongue surface in the coronal section includes the following (Watanabe, 1995) (Figure 10). The sitting position is the FH plane vertical to the floor, and the mandible is in the restbite position. The probe is positioned perpendicular to the FH plane which corresponds to the plane that links to either side of the second premolars. This standardized scanning method was used to analyze tongue motion when swallowing changed according to the bolus volume (Shishikura, 1997).

In addition, this standardization method may be used for ultrasound analysis in the coronal section for tongue surface movements during articulation (Amemiya, 1997) (Figure 11). Showa faculty studied 13 healthy volunteers between the ages of 19 and 33 years, who had normal oral morphology and speech. The location of the ultrasound probe was on the coronal plane passing through the distal surface of both the right and left lower canines, second premolar and first molars. Phonetic transcriptions from the Japanese language [ka], [ta], [ra] were selected as speech models for observation. (For further information on the results of articulation ultrasound, please contact the author.)

Third step: Acquiring the ability to take food with the lips closed

After acquiring swallowing ability with the lips closed, infants acquire the ability to take food

with the lips closed. When taking in food, the food on the spoon touches the lower lip and then the jaws close. Next, the upper lip wipes the food from the spoon. This behavior permits the upper lip to feel the texture of the food as if it was wiped against the upper lip. Taking food in this way is useful for helping the food drop into the anterior of the mouth. The tongue can easily take in food by making peristaltic waves.

The lips have one of the most important functions for feeding. However, little attention has been paid to the functions of the lips in taking in food. The function of the lips during feeding includes not only taking in food, but also, the closing the of the lips and the jaws during mastication and swallowing, permit the oral cavity to be separated from other oral cavities like the larynx and nasal cavity to assist in swallowing and mastication.

Developmental aspects of lip closing pressure when taking food

We studied lip pressure when taking food to determine the development of lip function during feeding (Chigira, 1994). The subjects were 104 healthy infants and children aged 5 months to 5 years, 11 children showing developmental delay with mean age 4.5 years, and 10 children with cerebral palsy with mean age 5.0 years.

We used a strain gauge transducer embedded in a spoon to measure lip pressure. The bowl of the spoon was level acrylic resin formed with a smooth surface. The operator offered yogurt placed on the tip of the spoon to the subject. The lip closing pressure was measured at the point at which the subject took the yogurt into the mouth with a natural feeding position.

Results indicated that lip closing pressure for healthy infants and children increased steadily from 5 months to 3 years and continued to increase slightly from 3 to 5 years. The mean age of the children with developmental delay and cerebral palsy was 4.8 years. There was no significant difference between the disabled children and normal infants aged 5 months to 2 years old. On the other hand, there was a statistically significant difference between the 3 to 5 year-old disabled children and normal children. We found that the level of lip pressure of the disabled group was similar to that of the normal group aged 5 months to 2 years, suggesting that development of lip function for taking food was delayed (Figure 12).

In addition, we investigated lip pressure in children with cleft lip and palate when taking in food (Chigira, 1995). The lip pressure in all groups of children increased steadily with age. However, the lip pressure level for the unilateral cleft palate group and the bilateral cleft palate group were similar to the subjects aged 0 to 2 years in the normal group (Figure 13).

Fourth step: Acquiring the ability to push mashed food with the tongue against the anterior hard palate

Feeling and discrimination of food texture are very important to integrate the following process of mastication and swallowing. After infants acquire the ability to take food with the lips into the anterior oral cavity, the food is pushed by the tongue against the rugae of the palate to mash the food (Figure 14). As a part of this mashing process centripetal impulses from the rugae of the palate and the tongue touching the food provide important information about food texture in a manner similar to the information provided by the upper lip and periodontal tissue of incisors during taking in food.

At the same time the angle of mouth as it pulls to the left and right can be recognized. This motion indicates feeling the size and texture of the food. We consider this motion to lead to the development of the mastication motion. In this period of development, the tongue moves upward and downward and then the tongue mashes the food against the anterior hard palate.

The food is then pushed and mixed with saliva to make a bolus and swallowing is performed. The swallowing sequence cannot be accomplished safely without bolus formation that is a mixture of the processed (mashed) food and saliva. The ability to make a bolus using the tongue is also developed during this period. The tongue changes shape to form a groove that makes the bolus.

Fifth step: Acquiring the ability to perform mastication

After the tongue acquires the function of mashing food, it is able to bring the food that can

not be mashed to the alveolar ridge where the molars will develop in the future. The function of grinding the food, as in mastication, is acquired. What we call mastication is the coordinated motion of the teeth, jaws, lips, and cheeks with saliva mixing in the food to break down the food. Coordination of the tongue and jaw, and cheek and molar areas is an important factor for mastication (Figure 15).

During the motion of mastication, the tongue surface slants toward the lower alveolar ridge, then the tongue and cheeks draw up close to the food on lower alveolar ridge and prevent the food from dropping off. It is possible to observe the side to side tongue movement using ultrasound imaging. The foods that were not able to be mashed by the tongue were treated in this way. Figure 16 is an ultrasound image of a soft rice cookie being fed to a 10 month-old infant. Feeding using the mouth as shown here requires the lips, tongue and other oral parts to work together.

SELF FEEDING

The oral feeding function for infants in the pre-feeding stage and the weaning stage is acquired through feeding assistance provided by the parents or caregivers. The goal of the feeding function development progression is self-feeding using tableware. For self-feeding, it is necessary to coordinate the mouth as a catcher of food and the upper limb as the carrier of food. Before self-feeding, it is necessary to acquire mastery of the feeding posture and the single-bite size. When appropriate, myofunctional therapy is based on the feeding development progression. So, we think feeding therapy needs to consider not only oral function but also self-feeding behavior.

Starting self-feeding before acquiring the oral feeding function not only holds back the feeding function development but also may bring about aspiration. For example, during the mealtime of cerebral palsy patients, we at times see a patient open up his mouth widely, bring the spoon or fork above his head, and then drop off the food into his mouth.

Through this behavior the food is not able to be brought from the anterior oral cavity to the posterior oral cavity. That is to say, this behavior drops off the food directly towards the pharynx. Little attention, however, has been given to this point in papers and feeding treatment approaches. In addition, only few attempts have so far been made regarding the developmental aspects and path of movement of hand to mouth coordination during feeding.

Sixth step: Preparation for self-feeding

For self-feeding, food is first looked at and recognized. Then it is brought to the mouth by the hand and upper limb. In terms of the developmental progression of the motor function, the upper limb function develops later than the oral motor feeding function. Therefore, training time is required. At the beginning of self-feeding, infants lick and bite toys or teethers to acquire hand to mouth coordination. Biting toys or teethers also help in acquiring the one bite-size.

Seventh step: Beginning finger feeding

From the last half of the weaning period, infants begin to pick up food and bring it to their mouth by themselves (Ishii, 1998; Chigira,1998). At the first stage, infants push the food into to the mouth without using the lips, gradually acquiring the ability to bite food using their incisors. Using incisors allows them to feel the size and texture of the food through odontoperiostem. After this, biting force is acquired.

At first, with the upper limb touching the trunk, the neck area turns laterally to take in food, or the food is pushed in from the side of the mouth. Gradually, the junction of the elbow comes away from the trunk and food is taken through the center of the lips (Figure 17).

Hand and mouth coordination during finger feeding

In addition to children, Showa faculty studied mouth and hand coordination during finger feeding in normal adults who had acquired normal self-feeding functions (Ayano, 1997). The subjects were 20 healthy volunteers. The food item used was a very small, round, bite-sized cookie. Subjects were seated at a table and the cookies were set on the table to the right, left and directly in front of them. The process of finger feeding was videotaped using two Charge Coupled Device (CCD) cameras. The movements were broken down into 1/60-second frames and analyzed by a 3D-motion analysis system.

Results of the analysis revealed the following segments: 1. From picking up food to placing it on the lip (P-I); 2. From picking up food to opening opening of the mouth (P-O); From opening the mouth to placing the food on the lip (O-I); 4. From picking up the food to pointing the food and the index finger perpendicular to the lip (P-V); 5. From pointing the food and index finger perpendicular to the lip to placing the food on the lip. As a result, subjects could be classified into 3 groups. Group 1: The length of movement for P-V was longer than P-O. Group 2: The length of movement for P-O was longer than P-V. Group 3: The length of movement for P-V and P-O was different according to food location.

Eighth step: Beginning to use tableware

From the age of one and half years, infants acquire mouth-to-hand coordination through finger feeding and start to acquire the ability to use table ware (Tamura, 1998; Nishikawa,1999). The one-bite size is learned through use of a spoon being used to drop off the food into the mouth, or the infant biting the food with the incisors during finger feeding.

At first the spoon is put into the mouth from the side, or the whole bowl of the spoon is put into the mouth. This is repeated over and over until gradually the ability to take food through the center of the lips is developed.

CONCLUSIONS AND RECOMMENDATIONS

The results of our research are used as the basis of our assessment program. These results also provide the foundation for our feeding training program approach that is used to treat dysphagic children and elderly. It is recommended that replication studies be conducted on greater numbers of children to confirm the results we have obtained identifying the characteristics of the development progression for feeding.

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