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Research Report 2021----04

Sucking research : **Swallowing**

Research on the coordinated movement
of swallowing and breathing in infancy

Searching for milk flow
that promotes
infant's natural breathing

Pigeon Corporation

Address 4-4, Nihonbashi Hisamatsu-cho, Chuo-ku, Tokyo 103-8480, Japan (Head Office)
Tel+81-3-3661-4200

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Pigeon Research Report
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Research on the coordinated movement of swallowing and breathing in infancy
Searching for milk flow that promotes infant’s natural breathing

The final step in the sucking behavior is the action of “swallowing” that transfers milk down to flow into the esophagus. Adults stop breathing and resume breathing by exhaling breath after swallowing. On the other hand, infants are known to continue breathing from the nose while drinking milk with their mouth half open having the nipple in their mouth¹⁾. Pigeon has been investigating the “infant swallowing” that exists only in infancy and uses knowledge obtained from this mechanism to develop products.

Things that have been elucidated
in a series of swallowing research by Pigeon

Infant swallowing was observed every day during sucking, but we did not know the details of the mechanism that enabled breathing and swallowing coordination. Thus, various hypotheses were suggested²⁾⁻⁴⁾. Pigeon has been investigating the coordinated movement of breathing and swallowing during “infant swallowing” and confirmed the following mechanism of sucking: Infant’s breathing during swallowing is comprised of several patterns⁵⁾; there is a coordinated movement that suppresses respiration during swallowing⁶⁾; breathing lasts during sucking without swallowing⁷⁾; and at the same time, milk is retained around the intraoral epiglottic vallecula⁷⁾. These research results have revealed the importance of breastfeeding skills such as feeding posture to prevent retention of milk and choking as well as adjustment of feeding intervals. It has also revealed the importance of adjusting milk flow of an artificial nipple according to the development of infants.

Background of the research

- Infancy specific “infant swallowing” different from swallowing in adults¹⁾
In swallowing in adulthood, it is known that breathing is often suspended and started by exhaling breath after swallowing. It is characterized by a system that precisely controls breathing and swallowing by stopping breathing, closing the larynx, and transferring food and drink safely to the esophagus⁸⁾ (Figure 1).
On the other hand, in swallowing in infancy, it is routinely observed that infants continue sucking without stopping breathing. The following is pointed out as a background: The larynx of an infant is positioned high and the distance between palatine uvula and epiglottis is short, which allows an infant to swallow while breathing^{1) 9)} (Figure 2). However, the esophagus and respiratory tract are not completely separated in infants. A number of observational research studies have shown that swallowing significantly affects breathing^{1) 10) -12)}.

● Differences in swallowing between infants and adults

	Infant swallowing	Adult swallowing
Breathing	Synchronize with breathing, but cessation of breathing is short.	Stop breathing.
Lips / jaw	Open the jaw and also the upper and lower lips	Close lips and swallow
Position of the tip of the tongue	Between the alveolar ridge of the lower jaw and nipple	Fixed by pressing against the palate

(Quoted from Otsuka, 2006¹⁰⁾)

Pigeon’s research
on the coordinated movement
of breathing and swallowing in infancy

Based on these findings, Pigeon has been conducting research by observing and measuring “respiratory dynamics during sucking.” We have been examining changes in the respiratory dynamics of infants in NICU during the sucking behavior in a series of joint research started in 2006.
In the research in 2006⁵⁾, we conducted observational research on breathing conditions of three infants during sucking using a nasal airflow sensor. The results showed that the respiratory curve at rest repeatedly exhibited mild rise and attenuation. On the other hand, exhalation and inhalation during sucking exhibited a changing pattern that shows a steep-up(like a spike) and speed-down, and it presented a period of suspension of airflow (about 500-600 msec) before and after the pattern. They also showed that breathing of infants during swallowing is comprised of several patterns.
In the research in 2007⁶⁾, the respiratory rate per minute at the time of suspension of swallowing was higher than that at rest in all 13 infants in NICU by the same research method. This suggested that the sucking behavior suppressed breathing.
In the research in 2008⁷⁾, the following was confirmed by synchronizing the movement observation with a nasal sensor and video camera and the intraoral observation by an ultrasonography diagnostic device: Nasopharyngeal closure occurred in association with elevation of the soft palate/palatine uvula during swallowing, and airflow was transiently suspended (within 500 msec) in the observational research in 5 subjects. On the other hand, at the time of sucking without swallowing, it was shown that milk was drawn

by sucking and retained around the intraoral epiglottic vallecula without suspension of airflow and breathing continued.
These research outcomes have revealed the imperfect part in the coordinated movement of breathing and swallowing of infants. We further proceeded with the research in 2009, and we have been conducting the research focusing on the relationship between intraoral milk intake and respiratory dynamics.

PICK UP
PIGEON’S
research

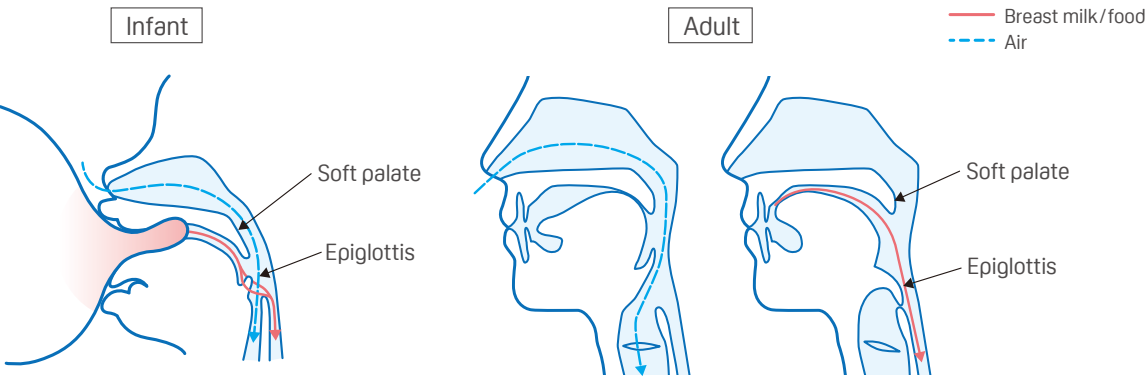
Changes in respiratory dynamics during
sucking behavior using an artificial nipple /
5th report¹³⁾

Satoru Saito^{*1)}, Erika Okano^{*2)} *1) Pigeon Corporation Central Research Institute
*2) Department of Pediatrics, the Jikei University School of Medicine (at that time)

Objective of the research

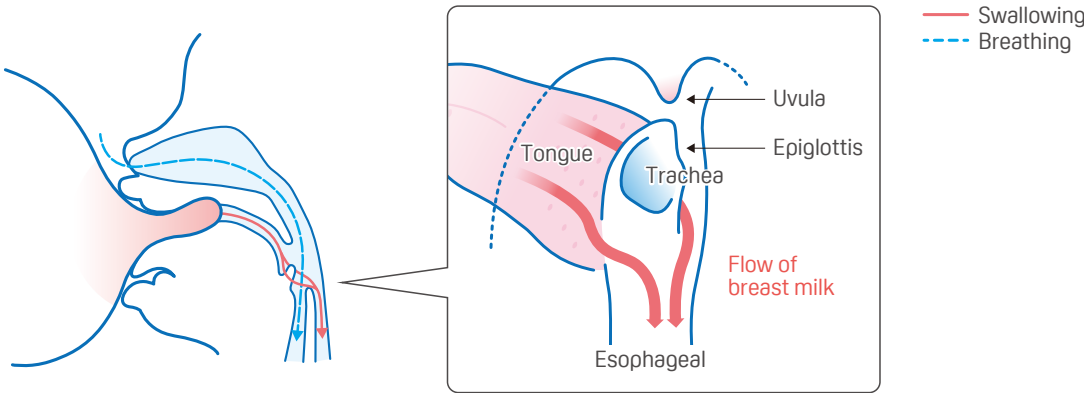
We examined changes in respiratory dynamics of infants in NICU during the sucking behavior by bottle feeding. We closely examined particularly the relationship between the amount of milk for a single sucking, the number of swallowing times, and respiratory suppression by ultrasonic tomography. Thus, we tried to clarify the relationship between the amount of milk flow, sucking, and swallowing as well as the relationship between milk flow and nasal breathing.

Figure 1 Comparison of head and neck sections between infant and adult



Quoted from and partially modified of Figure 1 Masaru Tatsuno, 1996¹⁰⁾

Figure 2 Characteristics of swallowing of newborn infants¹⁰⁾



Methods

Subjects Three infants in the NICU of a university hospital who were able to orally take all required amounts of milk

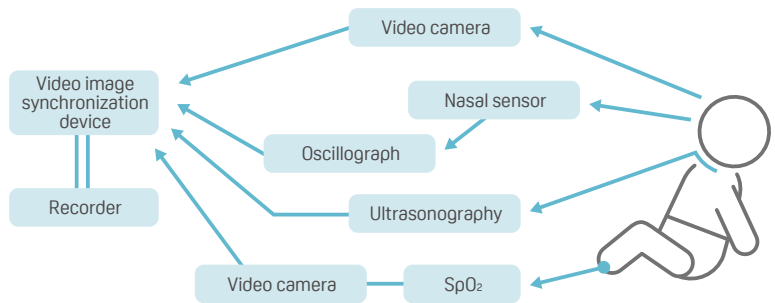
Mean gestational age	Mean birthweight	Mean age in days at observation	Mean corrected age	Mean body weight
35.0 weeks (Week 34 Day 1 - Week 35 Day 4)	1,794 g (1,770g to 1,834g)	20 days old (10-31 days old)	37.6 weeks (Week 37 Day 0 - Week 39 Day 6)	2,123g (1,852g to 2,586g)

**Observation
method**

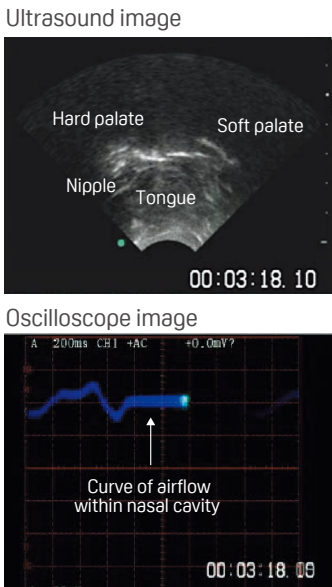
When infants were fed with a bottle, we recorded the lateral views of infants' faces from the side using a video camera (image of lateral facial view). We then collected the information on breathing with an airflow sensor installed in the nasal cavity and also took the ultrasound images of the sagittal section from the lower jaw using ultrasonography. We synchronized facial lateral images, respiration curve of nasal cavity, and ultrasound images with the image synchronization device. We also measured arterial oxygen saturation (SpO₂) during the observation period. We used two types of artificial nipples (Type A and Type B) for nursing bottles to perform measurement. Types A and B have the same appearance and material with different diameters of the milk holes on the tips. Type B was designed to slightly suppress milk flow by reducing the diameter of the milk hole of Type A by about 20%.

● Schematic diagram of observation and measurement methods

We synchronized facial lateral images, respiration curve of nasal cavity, and ultrasound images.

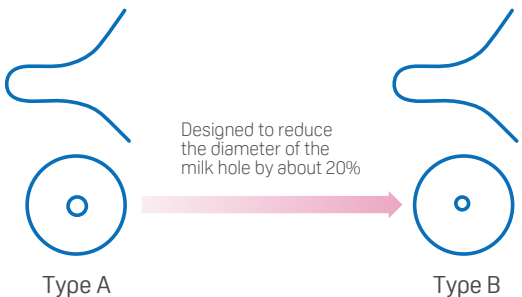


Intraoral ultrasound image (sagittal section)
Measurement of nasal airflow Measuring method of intraoral ultrasonography and nasal airflow



● Two types of artificial nipples used in the research

Types A and B have the same appearance and material with different diameters of the milk holes on the tips.

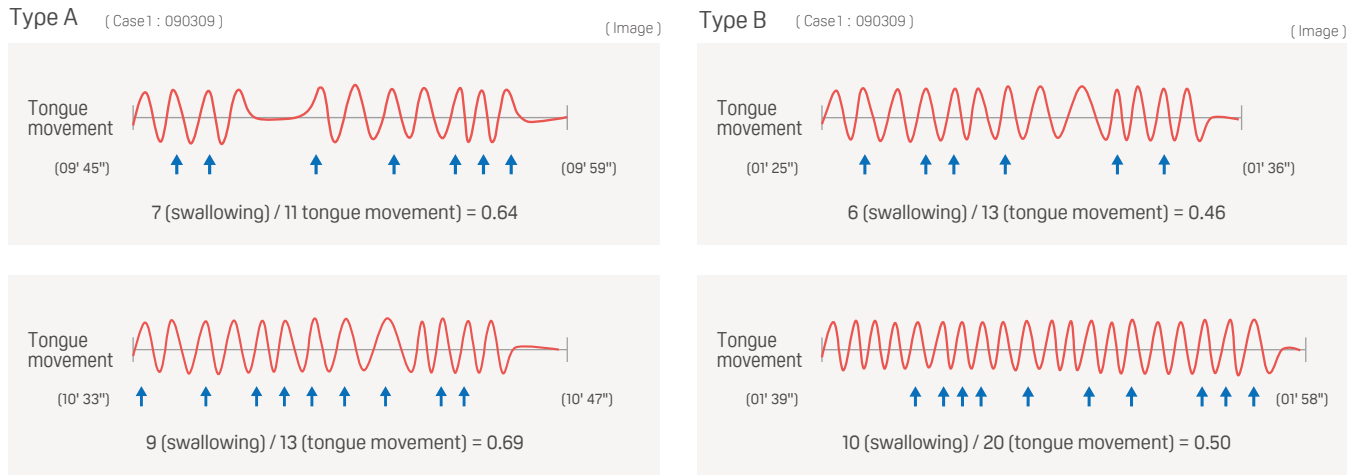


Results

- The sucking behavior is composed of two types of motions: The tongue movement (wave-like movement) and subsequent swallowing. However, it was revealed that the swallowing motion does not occur every time.
- The frequency of sucking with swallowing with an artificial nipple Type A was about once per 1-2 sucking cycles (0.67). On the other hand, with Type B artificial nipple, it was about once per 2 sucking cycles (0.50). This indicates that the frequency of swallowing differs depending on the milk flow of the artificial nipples.

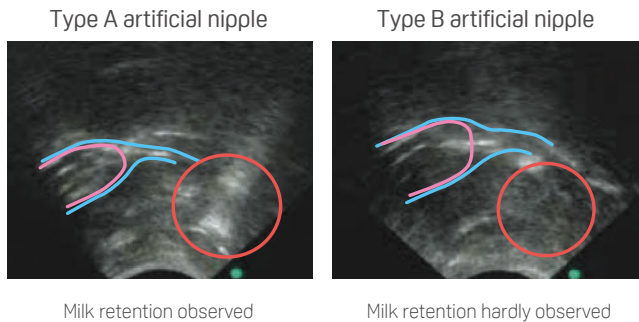
● Result-1 : Occurrence ratio of tongue movement and swallowing

↑ Timing of swallowing

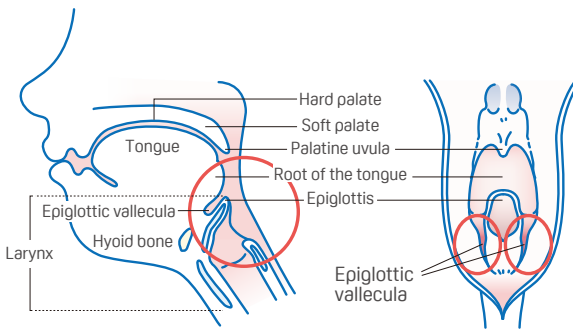


- The following was also confirmed: When an infant performed the sucking behavior without swallowing, milk was squeezed out but swallowing did not occur, and thus, neither elevation of the soft palate nor nasopharyngeal closure occurred. As a result, airflow was not transiently suspended. An intraoral ultrasound image showed that the milk in the oral cavity was retained around the epiglottic vallecula.
- This retention of milk around the epiglottic vallecula was more markedly observed with Type A artificial nipple with higher milk flow.

● Comparison of retention of milk around the epiglottic vallecula



● Schematic diagram of the oral cavity and larynx of infants (position of the epiglottic vallecula)



Discussion of results

Possibility of effect of milk flow on breathing activity

In this research, we found that the swallowing rate per sucking in the infants became higher with Type A artificial nipple than Type B artificial nipple due to the effect of milk flow (the diameter of the milk hole of Type B was smaller by 20% than Type A). It is largely unknown how a high level of the swallowing rate per sucking affects infants. However, since nasal airflow is temporarily suppressed during swallowing,

attention should be paid to the possible burden on respiratory activity when using an artificial nipple with a large milk flow. At the time of the sucking behavior without swallowing, milk retention was observed around the epiglottic vallecula. Since this may cause aspiration, it has been suggested that an artificial nipple with large milk flow should be used carefully to prevent choking and aspiration.

Lineup of flow types to reduce "choking" developed from the research

- SofTouch Series - Choose sizes according to the development
According to the results of swallowing research by Pigeon¹³⁾, when milk flow is too large, the swallowing rate per sucking is high and this may cause a burden on respiratory activity. A series of research has shown that the spouting amount of milk by a single sucking behavior should be appropriate for the infant's ability of sucking and swallowing. "SofTouch Series" reflects these research results and provides a product lineup that helps the adjustment of milk flow according to infants.

Well-designed shape of SofTouch Series

- Providing the milk flow appropriate for age in months / Lineup of hole sizes and shapes
Artificial nipples "SofTouch Series" are available in five sizes of milk holes, which enable infants to drink milk at an appropriate pace according to the age in months. In addition to the size of holes, we have adopted the design of the shape of milk holes considering the sucking strength that changes according to the development of the infant's sucking behavior (Figure 3). One of the characteristics of artificial nipples "SofTouch Series" is to support sucking with an appropriate spouting amount of milk that does not interfere with the coordinated movement of breathing and swallowing.

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Figure 3 Lineup of hole sizes and shapes according to the development of the infant's sucking behavior

