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Reduction of masseter muscle activity in bottle-fed babies ☆

Naohiko Inoue*[a,1], Reiko Sakashita[b], Tetsuya Kamegai[c]

[a]*Department of Oral Surgery, Branch Hospital, University of Tokyo, Tokyo, Japan*
[b]*Department of Preventive Dentistry, Kagoshima University Dental School, 8-35-1 Sakuragaoka, Kagoshima, Kagoshima 890, Japan*
[c]*Department of Orthodontics, Faculty of Dentistry, Iwate Medical College, 1-3-27 Chuodori, Morioka, Iwate 020, Japan*

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Abstract

Our previous studies suggested that there are significant differences in the growth of the jaw and in muscle activity between breast- and bottle-fed infants. To confirm these differences quantitatively, myoelectric activities of the masseter muscles of bottle-fed babies were studied. Twelve bottle-fed babies, as well as 12 breast-fed babies as a control group, were examined electromyographically during bottle or breast feeds. The duration time of sucking bursts, interval time, cycle time, 0-to-peak amplitude, integrated amplitude of bursts, and integrated amplitude/duration time were measured and the number of bursts over 30μV was counted. All differences of means were significant by *t*-test. The masseter muscle activity in bottle-fed babies is significantly reduced. Our results are contrary to previous papers in which almost the same sucking actions in both breast and bottle feeding were reported. The reason why previous researchers thought that the sucking patterns in breast- and bottle-fed babies are essentially the same is considered, and the implications of the differences for dental health are discussed.

Keywords: Baby nursing; Bottle feeding; Electromyograph; Development; Retardation of growth; Masticatory system

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* Corresponding author, 1-32-3 Fuda, Chofu, Tokyo 182, Japan; Tel./Fax: +81 424 996017.
[1] Retired.

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1. Introduction

It has been believed that the sucking patterns in breast- and bottle-fed babies are essentially the same. In 1958, Ardran et al. recorded by cineradiography the jaw movements of suckling infants during bottle feeding [2,3]. He studied several newborn babies and 14 bottle-fed babies from 6 weeks to 6 months after birth. The number of individuals decreased, during the course of the study, because some of the older babies disliked either the taste of the barium sulfate used for the contrast medium for the X-rays, or the shape of the nipples which differed from those to which they were accustomed. Ardran did not record the history of feeding style except that the babies were being bottle fed at the time of the examination. The bottle-fed babies varied in the age of starting to use the bottle, duration of using bottles, the time of changing completely to bottle feeding, as well as in the proportion of breast and bottle feeding during mixed feeding. It seems that Ardran believed in the commonality of breast and bottle feeding, since he did not check the history of nursing. He concluded that the sucking patterns in breast- and bottle-fed babies are essentially the same [3]; but the number of babies in his sample did not encompass the widely distributed backgrounds of babies. In 1986, Weber et al. also reached almost the same conclusion from their ultrasonagraphic study of the organization of sucking and swallowing in newborn infants [35]. Other researchers have since followed these views [4,5].

In 1955, a little earlier than Ardran, Ueshiba presented his observation that breast-fed babies have a stronger sucking force than do bottle-fed babies [33]. Evidently this means that the difference of sucking between breast- and bottle-fed babies is in the power, not in the quality, of the mechanisms. In his experiment, the negative pressure induced by the sucking action of babies was measured by a thin tube attached to the mother's teat, a parallel arrangement of the tube to the teat. The pressure sensor was placed in the other end of the tube. In the case of bottle feeding, the negative pressure was measured by a tube connected to the bottle, a series arrangement, with the pressure sensor on the other end. Using these devices Ueshiba found that the sucking force was much stronger in the breast-fed babies than in the bottle-fed ones. According to an interpretation by Sakashita, it is possible to obtain a fairly correct approximate value in the case of the bottle-fed babies, but in the case of the parallel arrangement for the mother's teat, the measured value is quite different from the sucking force, since it is just for the air in the tube itself [26].

There is a concept called 'tooth-to-denture-base discrepancy', which is known as a causative factor of the crowded teeth and the wisdom tooth impaction. It is the insufficiency of dental arch length to the sum of the mesiodistal crown diameter of all the teeth of the jaw, due to the evolutionary reduction of jaw bones in mammals generally, and modified by the insufficient growth in the moderns to be more serious [10,14,20,28,31,32]. In our previous studies on the etiology of the tooth-to-denture-base discrepancy, we showed that the morphological and functional reduction of the human masticatory system is progressing very rapidly today [10,12–15,17–19]. Regarding the causes of these changes, present dietary style with a too soft and too nutritious food, and the manner of nursing are suspect.

Table 1
Subjects and measured values from EMG

ID	Month	Sex	Quit	DUR		INT		CYT		PEK		ITG		ITG/s		No. of bursts		Time	Amount	g/min
				Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.			
Bottle feeding																				
A1	2	M	1	0.283	0.074	0.332	0.251	0.482	0.167	20.2	11.6	1.039	0.534	3.722	1.828	20		6'50	100	14.6
A2	3	M	2	0.356	0.062	0.296	0.115	0.647	0.165	29.2	9.4	2.096	0.632	5.926	1.671	43		9'10	100	10.9
A3	3	F	2	0.350	0.067	0.289	0.155	0.641	0.206	26.0	9.2	2.196	0.642	6.272	1.422	20		6'00	100	16.7
A4	3	F	1	0.298	0.047	0.221	0.170	0.500	0.124	23.7	6.8	1.981	0.827	6.703	2.842	18		3'52	100	25.9
A5	3	M	2	0.350	0.072	0.167	0.098	0.529	0.171	28.4	10.0	2.216	0.892	6.295	2.023	41		4'38	100	21.6
A6	3	M	1	0.276	0.042	0.227	0.137	0.501	0.146	24.7	8.1	1.628	0.582	5.930	1.983	23		5'54	100	16.9
A7	3	F	1	0.313	0.080	0.215	0.174	0.525	0.204	33.2	15.0	2.371	1.342	7.404	2.752	51		6'20	100	15.8
A8	4	F	1	0.331	0.126	0.199	0.070	0.549	0.171	24.2	10.5	1.725	0.563	5.592	1.962	20		4'20	100	23.1
A9	4	M	1	0.369	0.071	0.311	0.241	0.643	0.213	32.4	15.9	2.631	1.263	7.139	3.205	37		5'23	100	18.6
A10	4	F	0	0.290	0.058	0.183	0.044	0.508	0.161	21.1	7.0	1.140	0.476	3.918	1.252	10		3'25	100	29.3
A11	5	F	3	0.310	0.059	0.329	0.156	0.629	0.169	39.3	17.8	2.695	0.952	8.584	2.090	72		6'15	100	16.0
A12	6	F	1	0.347	0.081	0.163	0.096	0.506	0.151	32.9	11.1	2.435	0.762	7.016	1.31	56		4'48	100	20.8
Mean and S.D.				0.323	0.032	0.244	0.063	0.555	0.065	27.9	5.7	2.013	0.538	6.208	1.376	34.3	18.0	5'35	100.0	19.1
Significance of inter-group difference																				
					*		**		**		***		***		***		***			
Breast feeding																				
B1	2	F		0.312	0.048	0.366	0.081	0.678	0.099	59.0	12.6	4.164	0.909	13.360	2.166	89		4'03	65	16.0
B2	3	F		0.331	0.117	0.300	0.220	0.639	0.208	51.0	17.2	3.356	0.900	10.377	2.004	88		2'10	43	19.8
B3	3	M		0.268	0.049	0.485	0.155	0.752	0.169	55.9	15.6	3.421	0.896	13.168	5.019	80		3'41	62	16.8
B4	3	F		0.271	0.043	0.448	0.155	0.714	0.182	53.9	21.6	3.234	1.106	11.762	2.864	82		4'01	40	10.0
B5	3	M		0.325	0.046	0.329	0.066	0.655	0.083	59.8	11.0	4.434	0.879	13.657	2.084	92		3'15	50	15.4
B6	3	M		0.308	0.046	0.349	0.068	0.657	0.085	62.9	11.6	4.518	0.848	14.773	2.323	91		2'56	42	14.3
B7	3	M		0.286	0.039	0.275	0.128	0.562	0.144	56.7	20.2	3.686	1.241	12.988	4.284	82		4'30	57	12.7
B8	4	M		0.327	0.037	0.470	0.119	0.805	0.166	48.0	16.8	3.697	1.352	11.197	3.623	63		3'02	43	14.2
B9	4	F		0.278	0.056	0.276	0.058	0.590	0.173	43.9	11.9	2.787	0.966	10.105	2.703	90		3'40	70	19.1
B10	4	F		0.263	0.032	0.478	0.149	0.739	0.59	69.4	27.9	3.847	1.297	14.614	4.802	80		3'03	38	12.3
B11	5	M		0.243	0.039	0.313	0.118	0.556	0.120	70.1	23.0	4.088	1.150	17.202	6.465	108		5'32	90	16.3
B12	6	F		0.284	0.039	0.386	0.265	0.533	0.118	44.6	15.2	2.809	0.721	9.968	2.598	102		3'43	54	15.1
Mean and S.D.				0.291	0.029	0.373	0.079	0.657	0.086	56.3	8.6	3.670	0.574	12.764	2.186	87.3	11.5	3'38	78.5	15.2

Month, months after birth; **quit**, month when breast feeding ended; DUR, duration time of a burst (s); INT, interval time (s); CYT, cycle time (s); PEK, 0-to-peak amplitude (μV); ITG, integrated amplitude of a burst ($\mu V \cdot s$); ITG/s, integrated amplitude per duration (μV); no. of bursts, number of bursts per min.

t-test, $*P < 0.05$, $**P < 0.01$, $***P < 0.0001$.

The results of a survey in a kindergarten showed that 24.5% of the infants had a chewing and swallowing disability, one of the expressions of retarded growth of the masticatory system; and 66.7% of bottle-fed infants were unable to chew and swallow normally, while only 6% of the breast-fed children had these problems [9,25]. These facts seem to suggest that there are some differences in the growth of jaws and in muscle activity between breast- and bottle-fed infants.

We have been studying the differences between breast- and bottle-fed babies in electromyographic records of the masseter muscle, which is the principal muscle for mastication, and have already shown, qualitatively, the presence of important differences [16,25,26,39]. In order to confirm these differences quantitatively we have attempted, in the present study, to record and to analyze the myoelectric activity of the masseter muscle of bottle-fed babies.

2. Materials

The subjects in this study were 12 bottle-fed babies aged from 2 to 6 months after birth, who had had no experience of breast feeding or who had quit breast feeding within 2 months of birth and subsequently had been fed by bottle only. For the control group we studied 12 breast-fed babies of the same age range, who had had no experience of bottle feeding except for a few days before leaving hospital and who had never used a bottle even for water or juice. Before examination, it was explained to the mothers the purpose of our research and that the babies would have neither pain nor injuries. The mothers willingly agreed and even wanted to know about the activity of their babies' mouths. The composition of both groups is shown in Table 1.

The masseter muscle activity of the bottle-fed babies during a feed of 100 ml of the milk, and of the breast-fed babies during a feed from the first breast on either side was recorded by electromyograph. The breast-fed babies were weighed before and after the feed in order to know the amount of milk ingested. The recording was carried out once only for each baby, because no repeat is possible after the babies have satisfied their appetite. The stability and reproducibility of the electromyograph in adults [1,6,29], infants and babies [22,23,36] has been established.

A specially improved low noise type amplifier (MicroAmplifier Unit: Iwate Medical College Type: R Electric mfr., 2 channel, gain: 600–10 000, wide frequency 50 Hz–2 kHz, net nose: 1.9 μV) was used for the recordings. Two disposable surface electrodes ('Lec Trode': Nihon Electric San-ei Factory) were pasted onto the skin over the masseter muscle 15 mm apart, and the action potential was induced by bipolar derivation and recorded on magnetic tape.

The electromyographic data for the first minute were analyzed on a personal computer by 'Wave Master II' program. Duration time of a burst (s), interval time (s), cycle time (s), 0-to-peak amplitude (μV), integrated amplitude of a burst (μV·s), and integrated amplitude/duration time (μV) were measured, and the number of the bursts over 30 μV was counted.

3. Results

Examples of electromyographs for bottle- and breast-fed babies are shown in Fig. 1.

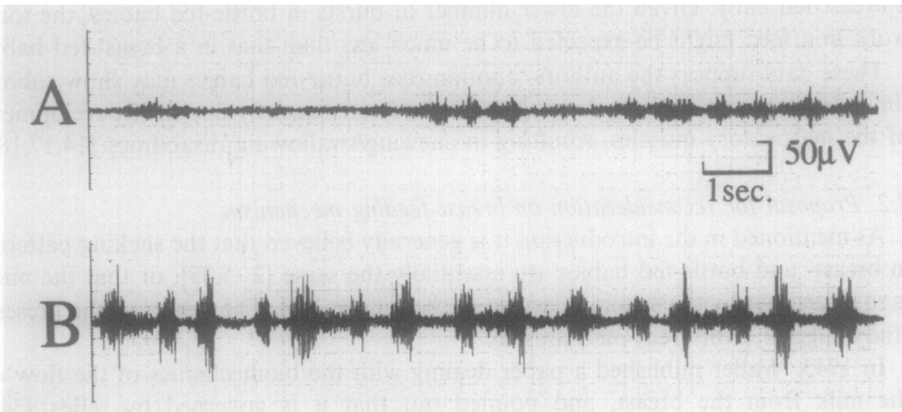

Fig. 1. Examples of EMG from masseter at ingestion of milk. (A) From a bottle-fed female baby 4 months after birth (Case No. A-10). Breast feeding: 0–2 weeks after birth. Bottle feeding: 0–4 months after birth. (B) From a breast-fed female baby 4 months after birth (Case No. B-10). Breast feeding: 0–4 months after birth. Bottle feeding: 0–3 days after birth.

The means and the standard deviations of the measured variables, as well as the feeding time and amount of milk ingested in experimental and control groups are shown in Table 1. Standard deviations of each variable are generally low, an indication of the stability of the measurements. Mean values of the duration time of a burst and the cycle time in the experimental group differ from those of the control group. Of the other variables the differences between the two groups are quite marked. These differences of means were significant at the level of $P < 0.05$ in duration time, $P < 0.01$ in cycle time, and $P < 0.0001$ in the other variables by *t*-test.

4. Discussion

4.1. Evaluation of the experimental results

As shown in Fig. 1, there are visible differences in the electromyographs of bottle-fed and breast-fed babies. For the bottle-fed baby the peaks of the bursts are much lower and even almost disappear for a time. The data obtained from the analysis of the electromyographs were stable and expressed the presence of the muscle action satisfactorily as indicated by the relatively small value of the standard deviation of each variable. The means in the experimental group are clearly distinguished from those in the control group, indicating the difference of the muscle action in the two groups.

The unit of the integration of each burst, $\mu V \cdot s$, is approximately proportional to the dimension of work or energy, because the outer resistance is a constant as far as the circuit for measurement is concerned. It is very striking that there are particularly profound intergroup differences. It means that for every burst the amount of work done by the masseter muscle of a bottle-fed baby is much less than that of a breast-fed baby. Given the lower number of bursts in bottle-fed babies, the total work in a feed might be expected to be much less than that in a breast-fed baby.

These data support the authors' opinion that bottle-fed babies may show suboptimal development of their chewing action and consequently impaired development of the masticatory muscles, resulting in chewing/swallowing disabilities [14,17,18].

4.2. Proposal for reconsideration on breast feeding mechanism

As mentioned in the introduction it is generally believed that the sucking patterns in breast- and bottle-fed babies are essentially the same [2–5,35], or that the milk is squeezed out by the stripping action of the tongue [38]. The results of the present study suggest a different mechanism.

In 1943, Waller published a paper dealing with the biomechanics of the flow of the milk from the breast, and pointed out that it is governed by reflex [34]. Hashiguchi also showed the biochemical sequence of secretion and ejection of breast milk [11]. If these interpretations are correct, then there is no need for a sucking action nor for a stripping pressure to obtain the mother's milk, it is only necessary to receive the milk by the tongue and to bring it posteriorly by a peristaltic movement of the tongue for swallowing as illustrated by Woolridge [38].

We have already pointed out that the method of measuring the negative pressures in breast feeding was unsuitable [33]. Sakashita [26] measured the sucking pressure using a bottle connected with a pressure sensor through a plastic tube, and found that the bottle-fed baby does suck the milk, and the longer the baby's experience of bottle feeding the easier and the more strongly it sucks. On the other hand, the breast-fed baby cannot suck milk, although after a few days, the baby does gradually learn to suck. Inoue et al. [16] also reported that within 7 days of birth all of the babies showed the chewing-like jaw movement, but they did not show any sucking pressure except for a very obscure sign in 3 of them who had mainly been bottle fed. This means that the breast-fed baby does not need and is not using the sucking action for ingesting breast milk.

It may be also a problem that many researchers have had very few occasions in which to observe healthy babies when they are ingesting breast milk, since the mother whose baby is healthy and ingests milk without trouble will not visit the specialist to show the feeding scene. If we have the opportunity to watch the scene, the patterns of movement of the mouth at ingesting milk from the breast and the bottle can be easily distinguished. The synchronization of the mandibular movement with the ingesting action will always be observed in breast feeding, as has been observed by Woolridge [38] and by Weber et al. [35] on an ultrasonagraph.

In the field of experimental research using animals, there is a further problem in that usually the babies are not accompanied by the mother animal, but are habituated to bottle feeding [2,7,8,37]. In these experimental cases, it would be difficult to deal with the differences between bottle and breast feeding.

There is an increasing trend in reports for the function of the tongue for ingesting milk to be emphasized [3,4,30,38], while the role of the jaw motion is not often dealt with. Today exposure to X-rays for the purpose of research is restricted, and ultrasonic tomographic methods have assumed the function of obtaining information in-side the living body. It is an excellent method to observe the motion of the teat, palate and tongue, but it can record only a very narrow field. Thus the observation is focused on the motion of the tongue only, resulting in an interpretation that the tongue is playing the leading role in ingestive behavior in breast feeding as well as in bottle feeding. Whether or not we need to know about the motion of jaw seems to be a problem.

The tongue is an organ which consists mainly of muscles as far as its movement is concerned. The arrangement of the muscle fibres is quite different from that of the larger muscles in the general motor system such as the muscles of the hands or legs. A muscle of the motor system is usually a thick bundle of muscle fibres, which run in one direction to develop strong power, and which combined with bones and joints carries out heavy jobs. On the contrary, the arrangement of the muscle fibres in the tongue is multifarious and complicated. There are 6 main muscles in the tongue running in different directions from one another, and none of them is thick enough to bear heavy duty. The tongue seems to be a very sensitive organ, which can move very quickly and freely in mastication and speaking. Therefore, the consideration must be taken into the role of the tongue in ingesting the milk in all aspects again, because it does not seem easy for the newborn baby to strip out the milk effectively by the small tongue alone without the support by jaw movement.

There are so many inconsistencies among these theories and interpretations that an immediate reconsideration of the breast feeding mechanism seems necessary.

4.3. *Influence of decreased activity of masticatory muscles*

Ito et al., comparing 2 groups of mice, one fed with regular solid food and the other fed with paste bait, showed significant reductions in the weight of the masseter muscle and the size of the mandible in the latter group [19]. Kuroe reported that the anteroposterior and lateral diameters of the mandibular condyles as well as the weight of the masseter muscle in mice fed only a liquid diet showed significant reductive changes, with P values less than 0.001; while the body length and the body weight were almost the same as in the control group [21]. He concluded that the masticatory function has distinct effects on the growth and maturation of the mandibular condyles and fossae. Oseko et al. studied the difference in growth of the masticatory system between breast- and bottle-fed mice using the tip of a fountain pen filler as a nipple. They too observed a significant retardation of growth in the masticatory system [24].

Given the retarded growth of the masticatory muscles and the loss of chewing behavior, the increase in infants with chewing-swallowing disabilities is to be expected, together with tooth-to-denture-base discrepancy and malocclusions, juvenile temporomandibular joint disorders, and tooth impaction not only of the wisdom teeth (the third molar), but also of the second molars [14,17,18].

The development of the masticatory efficiency and the growth of the jaw bones under the circumstance of breast feeding are normal and healthy developmental phenomena; whereas the decrease of the muscle function and the retarded growth of the jaw bones in a bottle feeding regime are responses to an unphysiological environment. These interpretations of the functional development of the orofacial unit should be correctly understood and the contrast between growth and adaptation must be emphasized [27]. It remains essential to identify the means to compensate for the loss of development and masticatory abilities of children and to avoid the development of maladapted orofacial conditions in the newborn as would be return to breast-feeding.

5. Conclusion

The masseter muscle electromyographic activity in bottle-fed babies is significantly reduced when compared to that in breast-fed babies.

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