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Can oral health promotion help develop masticatory function and prevent dental caries?

Reiko Sakashita[1], Naohiko Inoue[2] and Testuya Kamegai[3]

[1]Nursing Foundation, College of Nursing Art & Science, University of Hyogo; [2]Department of Oral Surgery, Branch Hospital, the University of Tokyo (Retired); [3]Department of Orthodontics, the Iwate Medical College (Retired)

Objective: In an effort to promote adequate development of the masticatory system and prevent dental diseases, the Oral Health Promotion Project (OHPP), which focuses on diet, was started in 1984. The intervention was carried out over eight years and then followed up for a further nine years, in a district with no regular dental service, on Miyako Island, Okinawa, Japan. The aims of this study were to evaluate the project's effect on dental caries and masticatory function. ***Research design:*** Longitudinal data on the complete deciduous dentitions(IIA) at age 4 (n=163) and on the permanent dentition (IVA) at age 13-15 (n=112) were compared to control age-matched groups , aged 4 (n=105) and aged 13-15 (n=70). The control data were collected from a neighbouring district. Instructions on diet were gradually introduced to those in charge of the subjects' food regimes. ***Results:*** Mothers reported that children born after the OHPP was begun took less snacks and caloric drinks ($p<0.001$) and more fibre-rich food ($p<0.05$) than those who born before the start of the project. The number of carious teeth decreased significantly among subjects born after the start of the project. The masticatory function was summarized in one factor using chewing performance, bite force, muscle activity duration time (using EMG) and mean amplitude of muscle activity. The factor score was higher for those born after 1984 than for those born in 1981-1983 and for those in the control district (GLM, $p<0.001$). ***Conclusion:*** It is suggested that OHPP can promote the masticatory function and prevent dental caries, but that it would be crucial to begin intervention soon after birth.

Key words: Breast feeding, dental caries, dentition, development, diet, electromyography, mastication, masticatory function, oral health

Introduction

It has been suggested that the underdevelopment of the masticatory system seems to be on the increase among young Japanese (Inoue, 1993). For example, 63.1% of young Japanese people have crowding of the teeth, while more than 33.5% of high school students have a juvenile temporo-mandibular joint problem (Inoue, 1993). The current early dietary regime, with its too-soft and too-nourishing food, bottle feeding and long-lasting pureed baby food, have all been suspected of making an important contribution to the underlying problem (Inoue *et al.*, 1995). Experiments have shown that breast fed mice had a better developed masticatory system than those who were bottle fed (Ito *et al.*, 1982). A diet of liquidized or pureed food reduced the height of the mandible, the length of the body of the mandible and the condylar width, and widened the gonial angle (Ito *et al.,* 1988). It also reduced the size of the masseter and temporal muscles as well as that of the salivary glands (Ikeda, 1998). Experiments with rats have also shown that a liquid diet after weaning affects the critical-period imprinting of both mastication and the motor performances of jaw and tongue muscle (Liu *et al.*, 1998).

If diet can be a main cause of not only dental disease but also insufficient development of the masticatory system, it follows that a healthy oral condition can be brought about by a change in dietary regime from a young age. In the hope that we would be able to redress the insufficient development of the masticatory system, and prevent dental problems through health education focusing on diet, we set up the Oral Health Promotion Project (OHPP) and a longitudinal study in a selected district on Miyako Island in 1984 (Inoue, 1986). The OHPP lasted eight years with another nine years of follow-up. In this paper we discuss the effect of the intervention on dental caries and masticatory function.

Subjects And Method

The Oral Health Promotion Project (OHPP)

Two small communities, Ikema and Karimata, Miyako Island, Okinawa were selected as model venues for OHPP. There is no regular dentist serving these communities, and public health nurses requested our help in improving the poor oral condition of the population. The Project was begun in April 1984, to coincide with the school year, which runs from April to the following March. During the first eight years the OHPP focused mainly on health education with special emphasis on diet and on thrice-yearly dental examination and treatment such as the filling of cavities and tooth extraction.

Based on the previous studies (Ito *et al*., 1982; Inoue, 1986; Ito *et al.*, 1988; Inoue, 1995) our guideline for oral health promotion was created, (Table 1) (Sakashita, 1993). At the first stage, the suckling period, breast feeding was recommended. At the second step, that of

Correspondence to: Dr Reiko Sakashita, College of Nursing Art & Science, University of Hyogo, 13-71 Kitaoji-cho Akashi Hyogo 673-8588 JAPAN. E-mail: reiko_sakashita@cnas.u-hyogo.ac.jp

Table 1. Guideline for better oral health (Sakashita, 1993)

	The 1st Step *Suckling period.*	*The 2nd Step* *Transitional period from milk to solid food.*	*The 3rd Step* *Period of establishing good diet.*
Biological stage	Birth to eruption of the 1st deciduous tooth.	Until the completion of deciduous dentition.	Until the eruption of the 1st permanent tooth.
Development of chewing system	Initial growth of chewing muscles. Achieve primitive muscle and jaw movement and swallowing pattern.	Maturation of chewing and swallowing pattern. Completion of transition to regular food.	Further growth of muscles and jaws. Increase chewing ability. Establishment of good diet
Important notice	Avoid using "easy sucking" type nipple.	Avoid ongoing liquid food regime.	Prevent excessive consumption of high- calorie drinks.
Recommendation	1st choice: Breast feeding 2nd choice: Chewing- type nipples (Sakashita *et al.*, 1996)	Natural weaning: Introduce fibre-rich foods, such as vegetables.	Control caloric drinks before and during the meal. Offer enough fibre-rich food.
Effects of failure at either step	Delayed transition to solid food (2nd step)	Chewing and swallowing problems (3rd step)	Multiple oral problems throughout life

Table 2. Number of subjects, by birth year and sex

	Age 4 y			Age 13-15 y		
Birth year (School year)	Male	Female	Total	Male	Female	Total
Model district						
1979-1980	12	9	21	6	3	9
1981-1983	31	41	72	22	36	58
1984-1985	14	21	35	9	18	27
1986-1987	16	19	35	9	9	18
Total	73	90	163	46	66	112
Control district						
1980	48	57	105			
1986-1987				26	44	70

transition from milk to solid food, a "natural weaning" was recommended, through introduction of different foods at the proper time. At the third step, after about three years of age when the deciduous dentition is complete, it was recommended that a good dietary regime should be established. In the OHPP, two main points of dietary instructions were emphasised: 1) Stop drinking large amounts of high-calorie drinks like juice or lemonade, especially before meals; and 2) Eat fibre-rich food such as vegetables at all meals. We sent a letter to each infant's home two weeks prior to examination, encouraging them to pay special attention to the two points outlined above, and we held meetings with grandparents as well as parents who often took care of the children while the mothers worked outside the home.

The OHPP was run in co-operation with Miyako Public Health Centre and the local community's Women's Society and was partly supported by the Japanese Ministry of Health and Welfare.

Subjects

All children born between April 1979 and March 1992 were eligible for enrolment in the OHHP. Informed consent was obtained and the total number of participants was 250.

For the purposes of assessing masticatory function, data was taken on completed deciduous dentition (IIA) and completed permanent dentition (IVA) among those who took part in 1979 - 1987. Records for 163 subjects at age 4 and 112 subjects at age 13-15 (mean 14.2 +/- 0.5) were collected and used in the study (Table 2). Fifty one subjects could not be followed up as 48 had moved too far away and three were absent at the examination.

To evaluate the data, control data from the neighbouring district on Miyako Island were collected. Records were made for 105 4-year-olds (born in the 1980 school year), and 70 13-15-year-olds (mean 14. 2 +/- 0.8) born during 1986 and 1987 school years.

Examination

A. Dietary regime.

Mothers of participants in the OHPP were asked about children's dietary regime, such as breastfeeding /bottle feeding, regularity of meals, intake of snacks and/or caloric drinks, the use of fiber-rich food and oral health practice. Information on feeding style was collected for 1-2 year-olds. Other information was obtained when children were four year-olds.

B. Dental caries

Two dentists recorded the dental caries status for each

tooth as intact, decayed, missing or filled at four years and 13-15 years. Indices of dmft (a total number of decayed, missing and filled deciduous teeth) at four years and DMFT (a total number of decayed, missing and filled permanent teeth) at 13-15 years were used.

C. Masticatory function

1. Masticatory performance in the chewing gum method (Hirose and Ito, 1988)

Masticatory performance was estimated using the chewing gum masticatory test by measuring the amount of sugar elution after 60 seconds chewing for 4-year-olds and 30 seconds chewing for 13-15-years-olds. (Chewing gum used: 3.23 +/- 0.02g, Juicy Fruit, Lotte Co.).

2. EMG recording of the masseter muscle (Inoue *et al*., 1995)

The EMG activity of subjects' masseter muscles was recorded during chewing of gum for 60 seconds for 4-year-olds and 30 seconds for 13-15-year-olds, using surface electrodes (Lec Trode; Advance Co.) and recorded on magnetic tape with a digital data recorder (PC-204: Sony Magnetic Scale Co.). The amplifier used was a low noise type (Micro-Amplifier Unit: Iwate Medical College Type: R Electric Mfr., 2 channel, Gain: 600-10,000, Wide frequency: 50HZ-2KHz, Net noise: 19mV). Two disposable surface electrodes were pasted onto the skin over the masseter muscle 20mm apart, and the action potential was induced by bipolar derivation. The burst duration time of the masseter muscle(sec), chewing cycle time (sec), burst 0-to-peak amplitude (mV), and mean amplitude (mV) were measured for 20 successive bursts, from the second to the twenty-first.

3. Bite force measurements

The bite force in the 13-15-year-olds was measured using a bite force transducer (Occluser, Nagano Seiki Co.). The block portion of the transducer was inserted into the subject's mouth and the bite block positioned parallel to the occlusal plane and centred on the mandibular second molar. Maximum bites were measured twice on both side and the average calculated.

Method of analysis

Analysis was performed using SPSS statical software package

1. To measure association for subjects' dietary regime and birth year groups, Goodman and Kruskal's gamma with ordered categories was used (SPSS Inc., 1997a).
2. Differences in dmft, DMFT, the amount of sugar elusion in the chewing gum method (masticatory performance), bite force among birth year groups and the control group, and between genders were evaluated using General Linear Model (GLM) general factorial analysis. Differences in the mean for each group were tested using the Scheffé post hoc multiple comparison test (SPSS Inc., 1997b).
3. Pearson's correlation coefficient among variables was used to ascertain relations between variables (SPSS Inc., 1997a).
4. To summarize masticatory function tested as described above, principal component analysis was performed. The factor was then compared among birth year groups and the control group, and between genders using General Linear Model (GLM) general factorial analysis (SPSS Inc., 1997b).

Results

1. Dietary regime (Table 3)

The dietary regime reported by mothers of participants in the OHPP is shown in Table 3. The percentages breast feeding increased from 23.8% in children born in 1979-1980 to 40.0% in children born in 1986-1987; this was not statistically significant. The percentage of children with snack intake controlled by mothers significantly increased from 28.6% in children born in 1979-1980 to 80.0% in children born in 1986-1987 ($p<0.001$). Intake of caloric drinks fell significantly from 3.3 cups a day to 1.6 cups a day ($p<0.001$). The percentage of children who seldom accepted fibre-rich food such as leaf vegetable fell significantly from 14.3% in children born in 1979-1980 to 3.3% in children born in 1986-1987 ($p<0.05$). The percentage of mothers who paid attention to the level of fibre-rich food increased form 38.1% to 70.0%, while that of mothers not showing concern for the children's oral health fell from 38.1% in children born in 1979-1980 to 16.7% in children born in 1986-1987.

2. Changes in dental caries (Table 4)

A significant difference was seen both in deciduous caries (dmft) and permanent caries (DMFT) between the groups (GLM, $p<0.001$). Deciduous caries (dmft) fell significantly from 16.5 in children born in 1979-1980 to 8.6 in children born in 1986-1987, though children born after 1984 in the model district and in 1980 in the control group showed the same level of caries. Permanent dental caries (DMFT) fell significantly from 7.7 in children born in 1979-1980 and 7.9 in children born in 1981-1983 to 4.0 in children born in 1986-1987. DMFT in children born in 1986-1987 was less than that of the control district born in 1986-1987 (Scheffé test, $p<0.05$).

3. Changes in masticatory function (Table 5)

The masticatory performance (amount of sugar elusion) for 4-year-olds as well as for 13-15-year-olds was significantly different between males and females (GLM, $p<0.001$), and between the birth groups of the model district and the control group (GLM, $p<0.001$). The masticatory performance at four years of age was greater for the model district group born after 1981 and the control group than for those born in 1979-1980 (Scheffé test, $p<0.05$). The masticatory performance at 13-15 years of age was greater in children born after 1981 than in those born in 1979-1980 and the control group (Scheffé test, $p<0.05$).

The maximum bite force was significantly different between the genders (GLM, $p<0.001$), while there was no significance difference among groups.

The chewing cycles measured by EMG, at 13- 15 years old were significantly different between groups (GLM, $p<0.05$). There was no gender or group difference in the duration time of a burst of the masseter muscle. 0-to-peak burst amplitude and mean amplitude

Table 3. Subjects' dietary regime, as reported by mothers who answered the relevant questions'

Birth year	*'79-'80*	*'81-'83*	*'84-'85*	*'86-'87*	*Significance*
N	21	70	35	30	
%	100	100	100	100	
Feeding %					
Breast feeding	23.8	34.3	40.0	40.0	
Mixed feeding	57.1	51.4	40.0	46.7	
Bottle feeding	19.0	14.3	20.0	13.3	
Meal time %					
Regular	90.5	85.7	91.4	100.0	
Irregular	9.5	14.3	8.6	0.0	
Snack %					*** 2)
Controlled, at fixed time	28.6	41.4	60.0	80.0	
Whenever on demand	71.4	58.6	40.0	20.0	
Fibre-rich food %					* 2)
Well accepted	71.4	60.0	85.7	83.3	
Occasionally accepted	14.3	30.0	8.6	13.3	
Seldom accepted	14.3	10.0	5.7	3.3	
Special attention %					
None	38.1	38.6	40.0	16.7	
Offering fibre rich-food	38.1	42.9	51.4	70.0	
Reducing sweet food and drinks	19.0	12.9	5.7	13.3	
Brushing teeth	4.8	5.7	2.9	0.0	
Amount of caloric drinks (cups)					*** 3)
mean	3.3	3.0	2.1	1.6	
s.d.	1.1	1.6	1.1	0.9	

1) Information on feeding style was collected for 1-2 year-olds. Other information were obtained when children were 4 year-olds.
2) Goodman and Kruskal's gamma test (SPSS, 1997)
3) GLM general factorial analysis
Significance * $p<0.05$, *** $p<0.001$

Table 4. Mean dmft (4-year-olds) and DMFT (13-15-year-olds) by birth year group in model and control districts

Group		n	mean	s.d.	GLM Sig.1)	Homogeneous group 2)		
Age 4 y	Model district				***			
dmft	'79-'80	21	16.5	4.2				3
	'81-'83	72	14.7	4.8			2	3
	'84-'85	35	11.7	6.2		1	2	
	'86-'87	35	8.6	4.5		1		
	Control district							
	80	105	10.6	4.7		1		
Age 13-15	Model district				***			
DMFT	'79-'80	9	7.7	3.3			2	
	'81-'83	58	7.9	3.8			2	
	'84-'85	27	6.4	4.3		1	2	
	'86-'87	18	4.0	3.7		1		
	Control district							
	'86-'87	70	5.5	3.3		1	2	

1) Significance tested by general factorial analysis *** $p<0.001$
2) Homogeneity subsets detection based on *post-hoc* multiple comparison test (Scheffé test), $\alpha = 0.05$.

Table 5. Masticatory function by the gender, the birth groups of the model district and the control group

Group	*Male*			*Female*			*GLM*			
							Gender	*Birth Year*		
	n	*mean*	*s.d.*	*n*	*mean*	*s.d.*	*Sig.*[1)]	*Sig.*[1)]	*Homogeneous group*[2)]	
Age 4 y										
Masticatory performance (g)										
Model district							***	***		
‘79-‘80	12	0.815	0.134	9	0.769	0.179			1	
’81-‘83	31	1.028	0.195	41	0.903	0.219				2
’84-‘85	14	1.115	0.260	21	0.905	0.222				2
’86-‘87	16	1.081	0.227	19	0.965	0.199				2
Control district										
‘80	48	1.002	0.148	57	0.944	0.161				2
Age 13-15 y										
Masticatory performance (g)										
Model district							**	***		
‘79-‘80	6	0.893	0.180	3	0.743	0.312			1	
’81-‘83	22	1.053	0.205	37	0.884	0.189			1	2
’84-‘85	9	1.184	0.090	18	1.053	0.161				2
’86-‘87	9	0.984	0.264	9	0.881	0.172			1	2
Control district										
’86-‘87	26	0.838	0.212	44	0.798	0.170			1	
Bite force (kg)										
Model district							***	n.s.		
‘79-‘80	6	36.50	6.89	3	25.70	2.86			1	
’81-‘83	22	45.09	12.65	37	34.71	9.49			1	
’84-‘85	9	52.53	15.19	18	37.21	14.78			1	
’86-‘87	9	47.16	18.96	9	38.00	17.01			1	
Control district										
’86-‘87	26	47.08	15.20	44	40.57	12.53			1	
EMG: Chewing cycle time (msec.)										
Model district							n.s.	*		
‘79-‘80	6	720.4	148.0	3	790.9	180.7			1	
’81-‘83	22	663.8	113.2	37	675.5	150.9			1	
’84-‘85	9	671.2	162.8	18	771.3	183.3			1	
’86-‘87	9	737.7	177.0	9	685.1	173.2			1	
Control district										
’86-‘87	26	593.3	96.9	39	683.0	102.2			1	
EMG: Burst duration time (msec.)										
Model district							n.s.	n.s.		
‘79-‘80	6	374.5	58.6	3	319.9	46.1			1	
’81-‘83	22	323.0	56.3	37	336.5	80.8			1	
’84-‘85	9	347.6	84.1	18	385.5	64.4			1	
’86-‘87	9	328.1	72.1	9	338.4	55.9			1	
Control district										
’86-‘87	26	330.7	47.6	39	369.7	56.0			1	

Continued over...

Table 5. *Continued...*

Group	*Male*			*Female*			*GLM*			
							Gender	*Birth Year*		
	n	*mean*	*s.d.*	*n*	*mean*	*s.d.*	*Sig.[1)]*	*Sig. [1)]*	*Homogeneous group [2)]*	
EMG: 0-to-peak amplitude (mV)										
Model district							n.s.	***		
'79-'80	6	748.0	275.0	3	718.3	296.6				2
'81-'83	22	838.9	394.0	37	567.7	258.6			1	2
'84-'85	9	778.4	208.1	18	601.8	207.2			1	2
'86-'87	9	687.7	264.7	9	763.4	198.6				2
Control district										
'86-'87	26	472.5	221.2	39	426.4	186.6			1	
EMG: mean amplitude (mV)										
Model district							n.s.	***		2
'79-'80	6	111.2	35.9	3	111.2	46.3				2
'81-'83	22	120.7	44.7	37	81.8	33.4				2
'84-'85	9	114.9	34.6	18	92.9	30.4				2
'86-'87	9	118.6	34.7	9	121.4	34.3				2
Control district										
'86-'87	26	67.3	32.0	39	59.6	26.9			1	

1) The difference between the sexes and among the birth groups of the model district and the control district were tested using GLM. * p<0.05, **p<0.01, *** p<0.001
2) Homogeneity subsets detection based on post-hoc multiple comparison test (Scheffé test), a = 0.05. The different number of group suggested there was the difference between groups.

were larger in the model district group than the control group (p<0.0001), which means the subjects in the model district showed greater muscle activity than those in the control group.

4. Correlation between variables (Table 6)

Deciduous caries (dmft) in 4-year-olds was highly related to DMFT at 13-15 y (r= .484, p<0.001). At four years old, an increase in dental caries reduced the masticatory performance (r= -.269, p<0.001). However, their relation could not be observed for 13-15-year-olds.

Masticatory performance at age four showed no significant correlation to that at age 13-15. There was a significant correlation to DMFT at age 13-15 (r= -.293, p<0.001) and in maximal bite force (r= .332, p<0.001).

5. Comprehensive masticatory function (Table 7, Table 8)

Each calculated index of the masticatory function seems to express partly the same and partly a different aspect of the masticatory function as shown in Table 6. Therefore, a principal component analysis was performed to clarify the masticatory function factor at 13-15 years. As there were strong correlations between 0-to-peak amplitude and mean integration amplitude (r= .903, p<0.001), and between chewing cycle and burst duration time of the masseter muscle (r= .575, p<0.001), masticatory performance, maximal bite force and burst duration time and mean integration amplitude from EMG were selected for analysis. Only one factor was defined, explaining 42.3% of the chosen variables (Table 7)**.** Factor 1 was defined positively by masticatory performance, maximal bite force and mean amplitude, and negatively by the burst duration time. There were significant differences between the genders (GLM, p<0.01) and groups(GLM, p<0.001). The factor score for the model district groups born after1981 was higher than that for the control district (Scheffé test, p<0.05 – 0.01).

Discussion

Outcomes of longitudinal study

From 70's to 80's dental caries was so widespread to be called 'a flood of dental caries' in Japan. In these two communities, almost all deciduous teeth would suffer from caries soon after their eruption (Inoue, 2003)

It has been reported that the mean dmft at 3 years fell from 12.1 in those born in 1980 to 4.0 in those born in 1986-1987 in the model districts, while it was 9.2 for those born in 1980 and 9.3 for those born in 1986-1988 on the isolated island near Miyako island with a dental clinic (Inoue, 2003).

We have also reported that normal occlusion increased and malocclusion of tooth-to-denture-base discrepancy type (malocclusion with insufficient space in the dental arch compared to the total length of all the teeth) decreased among children born after the establishment of the OHPP, while no similar changes were found in

Table 6. Correlation between variables

	Age 4 y		*Age 13-15 y*					
	1) dmft	*2)Masticatory efficiency*	*3) DMFT*	*4) Masticatory performance*	*5) Max. bite force*	*6) Chewing cycle*	*7) Duration time*	*8) 0-peak amplitude*
Age 4 y								
2) masticatory efficiency	-0.269***							
Age 13-15 y								
3) DMFT	0.484***	-0.293**						
4) Masticator performance	-0.072	0.156	0.094					
5) Max. bite force	-0.215*	0.332***	-0.054	0.421***				
6) EMG: Chewing cycle	-0.081	-0.154	0.141	-0.043	-0.080			
7) EMG: Duration time	0.024	-0.108	0.047	-0.096	-0.101	0.575***		
8) EMG: 0-peak amplitude	0.012	0.098	0.151*	0.283***	0.207**	-0.092	-0.135	
9) EMG: Mean amplitude	-0.028	0.102	0.114	0.308***	0.183*	-0.064	-0.220**	0.903***

Peason's correlation coefficient, * p<0.05, ** p<0.01, *** p<0.001

Table 7. Masticatory function factor component by principle component analysis

	Factor 1
Masticatory performance	0.773
Max. bite force	0.702
Mean amplitude	0.655
Burst duration time	-0.415

Only one factor was defined, explaining 42.3% of the variables.

Table 8. Comparison of score of masticatory function factor by the gender, the birth groups of the model district and the control group

Group	*Male*			*Female*			*Total*			*GLM*			
										Gender	*Birth Year*		
	n	*mean*	*s.d.*	*n*	*mean*	*s.d.*	*n*	*Mean*	*s.d.*	*Sig.[1)]*	*Sig. [1)]*	*Homogeneous group [2)]*	
Model district										***	***		
'79-'80	6	-0.043	0.863	3	-0.474	0.173	9	-0.187	0.721			1	2
'81-'83	22	0.834	0.956	36	-0.259	0.750	58	0.149	0.982			1	2
'84-'85	9	1.183	0.846	18	0.095	0.996	27	0.458	1.069				2
'86-'87	9	0.712	1.363	9	0.211	1.072	18	0.461	1.217				2
Control district													
'86-'87	26	-0.108	0.857	44	-0.568	0.733	70	-0.397	0.807			1	

1) The difference between the sexes and among the birth groups of the model district and the control district were tested using GLM. * p<0.05, **p<0.01, *** p<0.001

2) Homogeneity subsets detection based on post-hoc multiple comparison test (Scheffé test), a = 0.05.
The different number of group suggested there was the difference between groups.

the control district (Sakashita and Inoue, 2002). One of the main causes of tooth-to-denture-base discrepancy is thought to be the underdevelopment of the dentition in relation to the tooth size, and the discrepancy would be expected to grow in severity as the economy progressed, with resultant influence on dietary regimes (Hanihara, *et al.*, 1981; Inoue *et al.*, 1998; Sakashita, 1997; Sakashita *et al.*, 1998). Tooth-to-denture-base discrepancy also increases the risk of caries by making proper cleaning of the teeth difficult (Kuo, 1983). Fibre-rich food has been seen to be the most effective in dealing with this problem, as it produces a greater load on the jaws during mastication and promotes a self-cleaning system, reducing oral pollution (Sakashita 1997).

In this study, the masticatory function in the model group at 13-15 years old seemed to show a stronger performance than that of the control group and it was indeed greater in the model district group whose children were born after 1981. These results indicate that the OHPP appears to have effected a reduction in dental caries, and in promoting development of occlusion and masticatory function, especially among those born after the instigation of the OHPP.

Promotion of fibre-rich diet through the OHPP

The two main points of the OHPP dietary instructions are, simply put: 1) Stop drinking large amounts of high-calorie drinks like lemonade or juice, especially before meals; and 2) Eat fibre-rich food such as vegetables at all meals. An unceasing consumption of high-calorie drinks results in continually high blood sugar levels, and it becomes impossible to eat adequate meals at breakfast, lunch, and dinner because of a lack of appetite. As a result of inadequate meals, infants soon become hungry again and more juice and snack foods are given. In order to break this vicious circle mothers must control their infants' and children's intake so that their stomachs are empty at mealtime, and then provide enough fibrous food such as vegetables, rather than juice. This promotes the development of the chewing system, chewing ability, and secretion of saliva.

It is clear that both toothbrushing and application of fluoride reduce dental caries (Curnow *et al*., 2002; Marinho *et al*., 2003), but do not appear to have much affect on morphological and functional development. In the survey of 1988 of the model district, 92.1% (n=76) of children aged 2-6 either brushed, or had their teeth brushed, every day (Sakashita and Inoue, 1992), which is close to the data of Japanese national survey in 1993 (Health Policy Bureau, 1995). Though the difference was not significant, children who were given more attention to brushing teeth were given less attention to diet and consequently had a poorer gingival condition (Sakashita and Inoue, 1992). It may be that introducing plural instructions at the same time poses a difficulty. Brushing is an auxiliary means of preventing dental disease. Diet, however, proved effective not only in combating dental disease but also in promoting development of the masticatory morphology and function. We therefore focused on dietary instruction. The OHPP approach can be introduced in different locations, especially where communal dental care facilities are limited.

The timing of health promotion

The previous study showed major improvement only in children born after the OHPP was begun (Sakashita and Inoue, 2002). There was less improvement in children born in 1979-1980, whose deciduous dentitions were already fully developed at the beginning of the project. The present study showed that the caries rate at four years of age was strongly related (r=.484) to that of 13-15 year-olds. In the previous study (Sakashita and Inoue, 2002) three-quarters of the discrepant occlusion seen at age four still remained at age 13-15. This suggests that it would be difficult to change the developmental "direction" and risk of dental diseases with increasing age. Thus, the suckling and weaning stages would seem to be a key period.

Experiments on mice have shown that the masticatory muscles and jaw bone in breast-fed mice developed better than in mice fed maternal milk through artificial teats. The masseter muscles, the ascending ramus and the condylar head all developed a greater size (Oseko *et al.*, 1988). In human babies, the activity of the masticatory muscles is reduced in bottle-fed babies, compared to breast-fed babies (Inoue *et al.*, 1995; Sakashita *et al.*, 1996). Rats or mice fed on soft or liquid food show a lower percentage of oxidative fibres in the ascending rami, and it was demonstrated that altered muscular function can influence the cranio-facial morphology (Kiliaridis and Shyu 1988; Kim, 1990; Ikeda, 1998). A constant diet of liquid food reduces the size of the masseter and temporal muscles and even the salivary glands, as well as affecting the chewing pattern(Liu *et al*., 1998; Ikeda, 1998).

Based on the above, we recommended breast feeding and natural weaning, through the OHPP. The main dietary instructions in the OHPP, described above, are important not only for the masticatory system but for the life-long health of the whole body. Experiences in early life influence later dietary regimes (Westenhoefer, 2001) and could help decrease metabolic risk factors leading to obesity and obesity-related disease (Rolland-Cachera *et al.*, 1997; James, *et al.*, 1997; Pereira and Ludwig, 2001).

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