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A determination of bite force in northern Japanese children

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SUMMARY The bite force of 2594 school children (1248 males and 1346 females) living in northern Japan was investigated during oral health examinations in May and June 2001, using a new type of occlusal force gauge. The subjects were recruited from a variety of educational institutes and comprised: 73 nursery (3–5 years old), 1019 primary (6–11 years old), 902 junior high (12–14 years old) and 600 high (15–17 years old) school children. The measuring apparatus consisted of a hydraulic pressure gauge, with a bite element encased in a plastic tube. The bite force was measured at the first molar or second primary molar in the children presenting in the permanent and primary dentitions, respectively.

The findings revealed significant variations in bite force between children of different ages. The average bite force was 186.2 N in males and 203.4 N in females of nursery school children; 374.4 N in males and 330.5 N in females of primary school children; 514.9 N in males and 448.7 N in females of junior high school children; and 545.3 N in males and 395.2 N in females of high school children. The prevalence of malocclusion in the nursery school children was found to be less than 30 per cent, which contrasted with almost 70 per cent in the high school children.

Introduction

The number of Japanese children presenting with an increase in their tooth to dental base ratio appears to be increasing, with reported reductions in their masticatory capability throughout their dental developments (Inoue, 1996). Furthermore, it has been proposed that this phenomenon not only disturbs normal dentofacial growth, but can also increase the risk of dental disease (Inoue *et al.*, 1986). In addition, it has been hypothesized that reduced mastication may weaken masseter muscle activity and, therefore, affect masticatory efficiency (Beecher and Corruccini, 1981; Nakano *et al.*, 1994; Sakashita *et al.*, 1996).

Thus, the aim of this study was to examine the hypothesis that a reduction in muscle activity results in a reduced bite force.

Subjects and methods

In total, 1248 males and 1346 females, ranging from nursery to high school children (3–17 years of age) and living in the northern districts of Aomori Prefecture (Japan), were recruited to the study between May and June 2001. The subjects were divided into five age groups (A–E) for subsequent analysis: A: 3–5 years old, B: 6–8 years old, C: 9–11 years old, D: 12–14 years old and E: 15–17 years old (Table 1).

The occlusion in these children was examined according to Inoue and Suzuki (1971) and classified into the following criteria: normal occlusion, malocclusion, maxillary protrusion, anterior crossbite, dental crowding and/or open bite. In addition, any pathogenic features related to skeletal discrepancy, functional impairment and habitual factors were also noted, as classified by Inoue and Suzuki (1971). Bite force was measured bilaterally in the first molar region, for children presenting in the mixed and permanent dentitions, and in the second primary molar region for those in the primary dentition. The measurement of bite force was undertaken using a new portable type of occlusal force gauge (GM10, Nagano Keiki, Japan), during a scheduled programme of oral health examinations (Figure 1a, b). The force gauge consisted of a hydraulic pressure gauge and a biting element made of a vinyl material encased in a plastic tube (Figure 1a). The bite force was calculated (N) and displayed digitally. The accuracy of this occlusal force gauge has been previously confirmed (Sakaguchi *et al.*, 1996).

Results

The mean and maximum bite force values for each of the age groups (A–E) were determined (Table 2, Figure 2). Bite force magnitude showed an overall trend, for both males and females, to increase with age (Figures 2, 3). The mean bite force values for males and females were 186.2 N and 203.4 N in group A, 313.0 N and 281.7 N in group B, 416.1 N and 369.5 N in group C, 514.9 N and 448.7 N in group D and 545.3 N and 395.2 N in group E, respectively. Interestingly, females showed a reduction in mean bite force after 14 years of age, which then gradually increased up to the age of 17 years, but did not exceed the mean force value attained at 14 years of age.

Table 1 Number of subjects.

Group	Age (years)	Male	Female	Total
A	3–5	36	37	73
B	6–8	226	260	486
C	9–11	276	257	533
D	12–14	441	461	902
E	15–17	269	331	600
Total		1248	1346	2594

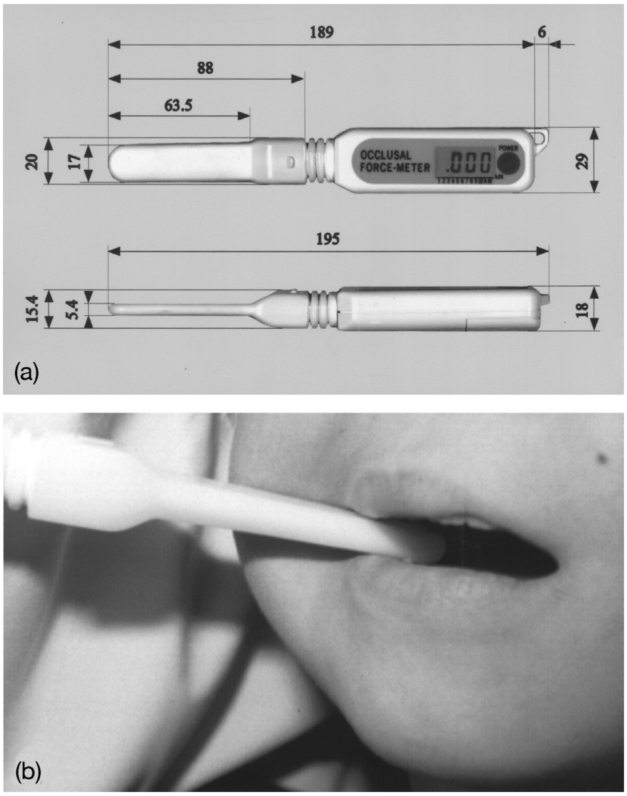

Figure 1 The occlusal force gauge used to measure bite force at the first molar region. (a) The occlusal force gauge, (b) applied to the first molar.

The presenting occlusion was classified, as described by Inoue and Suzuki (1971), for each of the five age groups in percentage terms (Table 3). The incidence of normal occlusion in all subjects appeared to reduce with increasing age. The values for males and females were 77.8 and 70.3 per cent in group A, 44.2 and 43.1 per cent in group B, 39.5 and 40.1 per cent in group C, 42.6 and 38.6 per cent in group D and 32.3 and 29.9 per cent in group E, respectively. Malocclusion was classified into one of four subtypes: maxillary protrusion, anterior crossbite, crowding and open bite. The prevalence of malocclusion in the nursery school children was found to be less than 30 per cent, which contrasted with almost 70 per cent in high school children (Table 3). In examining the frequency of pathogenic factors of malocclusion, more than 60 per cent of cases were distributed in groups B–E (Table 4). Figure 3 confirms that with age, bite force increased up to 14 years of age. However, the mean bite force value, in males and females, showed a consistent pattern of reduction in the presence of a discrepancy, which reached statistical significance ($P < 0.01$) in children over 9 years of age (Table 5, Figure 3).

Discussion

Accurate measuring of bite force is difficult and compounded by a number of interrelated factors, such as the occlusion, the presence of dental disease, the architecture of the occlusal surfaces and the intermaxillary space (Kakudo, 1966; Carlsson, 1974). Furthermore, bite force values can be directly influenced by the accuracy of the measuring apparatus itself.

Human bite force has been measured using a variety of methods, including spring-type devices and, recently, electric strain gauges originated by Howell and Manly (1948). In a number of these force gauges, the bite element is constructed from rigid material, making it difficult to measure the bite force accurately in younger children (Nakano *et al.*, 1994). Thus, bite force gauges with a solid biting element may give rise to incorrect data. To address some of these previous shortcomings, in the present study, the bite element consisted of a

Table 2 Mean bite force (N) in each age group.

Group	Age (years)	Male			Female			Total		
		Mean	SD	Maximum	Mean	SD	Maximum	Mean	SD	Maximum
A	3–5	186.2	96.3	327.5	203.4	97.0	483.5	196.0	96.1	483.5
B	6–8	313.0	136.3	695.3	281.7	119.0	577.6	296.3	128.1	695.3
C	9–11	416.1	133.3	827.7	369.5	140.2	836.5	393.3	138.5	836.5
D	12–14	514.9	165.6	1157.2	448.7	153.0	966.0	480.2	162.4	1157.2
E	15–17	545.3	182.8	1108.2	395.2	162.5	1029.7	462.3	187.3	1108.2

SD, standard deviation.

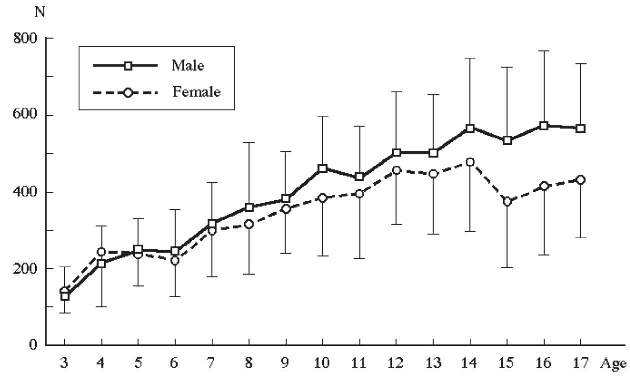

Figure 2 Mean bite force (N) and standard deviation (SD) for male and female children aged between 3 and 17 years.

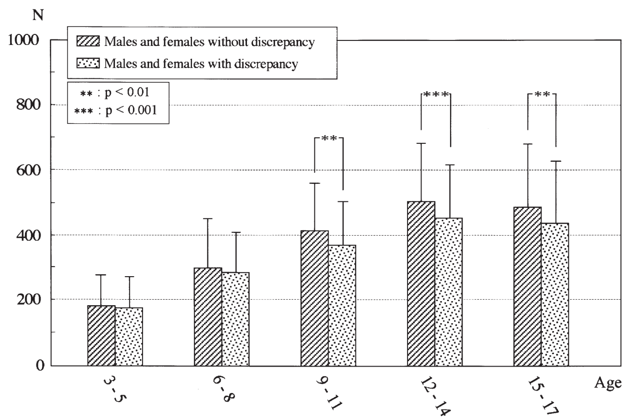

Figure 3 A direct comparison of the mean bite force (N) and standard deviation (SD) in males and females presenting with normal occlusion and malocclusion.

hydraulic pressure gauge encased in plastic. The accuracy of this occlusal force gauge has been previously reported (Nakano *et al.*, 1994).

The mean bite force increased through the various stages of developmental, from 3 to 14 years of age (Figure 2). This finding is in agreement with Sonnesen *et al.* (2001b). Although the maximum bite force exceeded 1000 N in some individuals, the mean bite force of 12–17-year-old Japanese children ranged from 500 to 600 N.

Table 5 confirms that normal occlusion is positively correlated with bite force. In general, it has been reported that conditions such as dental caries and/or symptoms of temporomandibular dysfunction can directly influence bite force (Shi, 1989; Sonnesen *et al.*, 2001a). The present study confirms the existence of a relationship between the presence of malocclusion and reduced bite force (Figure 3). Inoue (1980) and Hanihara *et al.* (1981) proposed that the reduced jaw bone size in the modern Japanese population, resulting in the increased prevalence of dental crowding, was a direct consequence of changes in eating behaviour during the last three decades. Beecher and Corruccini (1981), on the basis of animal studies, also support the relationship between modern diet and the increased prevalence of malocclusion. Human morphological variations are affected both by the personal gene pool and environmental factors. In addition to these environmental factors, genetics has been identified as playing an important role in the determination of tooth size (Hunter, 1959; Mizoguchi, 1977). Based on experimental data, Nakano *et al.* (1997) also reported that the determination of tooth size was affected by nutritional factors in the foetal stage. This

Table 3 Distribution of occlusion in subjects (percentage). For criteria, see Inoue and Suzuki (1971).

Group	Age (years)	Normal occlusion		Malocclusion		Maxillary protrusion		Anterior crossbite		Crowding		Open bite	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
A	3–5	77.8	70.3	22.2	29.7	11.1	5.4	11.1	8.1	0.0	8.1	0.0	8.1
B	6–8	44.2	43.1	55.8	56.9	17.3	13.1	12.8	12.7	25.2	29.2	0.4	1.9
C	9–11	39.5	40.1	60.5	59.9	18.5	14.0	8.7	11.3	33.0	33.9	0.4	0.4
D	12–14	42.6	38.6	57.4	61.4	20.0	19.1	11.8	13.9	25.4	24.9	0.2	2.8
E	15–17	32.3	29.9	67.7	70.1	14.5	18.1	14.9	11.2	34.2	39.0	3.0	1.5

Table 4 Frequency of pathogenic factors of malocclusion (percentage).

Group	Age (years)	Skeletal		Functional		Discrepancy		Habitual		Others	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
A	3–5	5.6	2.7	19.4	13.5	47.2	70.3	2.8	8.1	0.0	0.0
B	6–8	12.4	13.8	24.8	20.8	61.9	62.3	0.9	0.4	0.4	0.0
C	9–11	9.4	8.6	21.4	17.5	65.2	65.0	0.4	0.4	0.0	0.8
D	12–14	12.5	10.4	18.1	22.6	67.6	72.0	0.2	0.2	0.0	0.2
E	15–17	16.7	11.8	16.0	19.3	66.5	69.5	0.7	0.3	0.0	0.0

Table 5 Pearson's correlation coefficient between bite force and occlusion in 1502 males and females with a malocclusion.

	Bite force	Normal occlusion	Maxillary protrusion	Anterior crossbite	Crowding	Open bite	Skeletal	Discrepancy
Bite force	1.000	**	ns	**	ns	**	**	**
Normal occlusion	0.152	1.000	**	**	**	**	**	**
Maxillary protrusion	–0.027	–0.361	1.000	**	**	*	ns	**
Anterior crossbite	–0.106	–0.293	–0.182	1.000	**	*	**	**
Crowding	–0.031	–0.497	–0.309	–0.250	1.000	**	**	**
Open bite	–0.084	–0.103	–0.064	–0.052	–0.088	1.000	**	ns
Skeletal	–0.080	–0.262	–0.012	0.675	–0.224	0.070	1.000	**
Discrepancy	–0.130	–0.628	0.174	0.149	0.416	0.014	0.125	1.000

Skeletal, skeletal factor, one pathogenic factor of malocclusion; discrepancy, tooth to denture base discrepancy, one pathogenic factor of malocclusion.
*$P < 0.05$; **$P < 0.01$; ns: not significant.

supports the findings of Suzuki (1993), who indicated that the increasing tooth size in Japanese children was due to an increased consumption of protein and fat in the modern diet.

It has also been proposed that the development and growth of the masticatory apparatus may be affected by the eating behaviour of children, through infancy to puberty, and the consequent associated morphological changes (Inoue, 1980; Hanihara *et al.*, 1981; Kuragano *et al.*, 1983). In the infant, Inoue *et al.* (1995) and Sakashita *et al.* (1996, 1998) reported that the manner in which a child was nursed, i.e. mother's milk or bottle feeding, could be a decisive factor for having a healthy or weak function and structure of the maxillofacial complex. Their findings were based on electromyographic observation from newborns and children, and measurements of the dental arch from casts. The masseter muscle function in nursery school children was shown to be at a higher level in the breast-feeding group when compared directly with bottle feeding. A number of animal studies have demonstrated a reduced condylar head, masseter muscle and craniofacial structure in mice given a soft or liquid diet (Barber *et al.*, 1963; Beecher and Corruccini, 1981; Kiliaridis *et al.*, 1985; Ito *et al.*, 1988; Kiliaridis, 1989; Kuroe and Ito, 1990; Kuroe, 1991). Furthermore, Shozushima *et al.* (1996) reported a reduction in the density of trabecular alveolar bone in subjects who had a lower bite force.

The present study offers support only to the existence of a link between reduced masticatory function as a consequence of certain malocclusion traits (Figure 3). It is apparent that the mean bite force in the group without any discrepancy was significantly greater than those with a discrepancy, over the age of 9 years. This difference in bite force would indicate that the influence of any discrepancy became apparent during the eruption and establishment of the permanent dentition.

Conclusions

1. The use of a previously designed occlusal force gauge to record bite force in children from the age of 3 to 17 years has been shown to be reliable.
2. Bite force increases with age from 3 to 14 years, in both males and females.
3. The presence of certain malocclusion traits adversely influences bite force.

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