DOI: 10.1111/j.1365-263X.2008.00965.x

Factors affecting masticatory performance of Japanese children

HASSAN OUEIS

Department of Pediatric Dentistry, University of Detroit Mercy, Detroit, MI, USA

International Journal of Paediatric Dentistry 2009; 19: 201–205

Aim. The aim of this study was to analyse occlusal parameters and body variables to examine the factors accounting for masticatory performance of Japanese children in relation to adults.

Methods. Sixty-six children and 24 adults chewed three pieces of a colour-changeable chewing gum, separately, for 30 s, 60 s, and 90 s. The colour change was measured at 30 s using L^* a^* b^* colour space system. Biting force, occlusal contact areas, and occlusal pressure were recorded by Dental Prescale. Number of strokes, and the height and weight of the subjects were included in the statistical analysis.

Results. Within each sample, Student's *t*-test revealed significant differences among a^* values at the three chewing times in which the value of a^* (indicator of red) increased as the length of chewing time increased ($P < 0.05$). Multiple regression analysis showed that the rate of mandibular movement in preschool children has a significant impact on masticatory performance ($P < 0.05$). In schoolchildren, the rate of mandibular movement, biting force, and body weight were significant factors ($P < 0.05$). In adults, occlusal contact area, biting force, and the rate of mandibular movement were the significant factors ($P < 0.05$).

Conclusion. Factors affecting masticatory performance differ according to the developmental stage of the individual.

Introduction

Chewing is one of the principal functions of the masticatory system. Food is prepared for swallowing by breaking it down into small portions. Chewing is considered a multifactorial process, which involves factors such as movement of the jaw[1,2] and tongue[3], occlusal contact area, and biting force[4,5]. Many of these factors undergo significant changes during growth. For example, the size of occlusal table changes from primary to mixed, then to permanent dentition. Malocclusion was reported to negatively affect the ability to break down food[6,7], and facial type was found to affect occlusal force[8,9]. In addition, pathological conditions such as caries, temporomandibular joint (TMJ), myofacial pain, and loss of postcanine teeth have significant effect on mastication[10,11].

A previous report showed that chewing in children is a learning experience, and a significant increase in biting force was observed after 3 months of masticatory training using a special type of a chewing gum[12]. Most of the previous reports on masticatory performance were conducted on adult samples with different oral conditions; limited information is available on masticatory performance in the paediatric population.

A new type of a colour-changeable chewing gum was introduced and considered to be applicable for evaluating masticatory performance[13]. The gum contains xylitol, colouring agents for red, yellow, and blue, fragrance, citric acid, and gum base. The initial colour of the gum is light green and turns into red when the citric acid is eluted from the gum by means of chewing. Matsubara *et al.* utilized the same chewing gum to measure the adaptability of masticatory function of children[14]. The aim of this study was to analyse a number of occlusal parameters and body variables to examine the factors accounting for masticatory performance in children and adults utilizing the newly developed chewing gum.

Correspondence to:
Dr Hassan Oueis, 2700 Martin Luther King Jr Blvd, Detroit, MI, 48208 USA. E-mail: oueishs@udmercy.edu

Materials and methods

Sample

This study was approved by the Human Subjects Committee of Tokyo Medical and Dental University. All subjects of the study had a full dentition (excluding third molar in some adult subjects) with normal class I occlusion (no more than 2–3 mm arch–teeth discrepancy) and no history of orthodontic treatment. All the subjects were free of any clinical signs of TMJ or stomatognathic dysfunctions at the time of the test.

Evaluating masticatory performance

The subjects were seated in an upright position and instructed to chew three pieces of the gum freely, separately, for 30 s, 60 s, and 90 s. One minute had been given to chew for the warm-up before the experiment. A brief interval, 2–3 min, was given during the testing to avoid any fatigue. The chewed gum was placed on a polyethylene sheet and flattened to 2 mm thick by pressing with a glass plate. The colour was measured after 30 s from the chewing by means of a spectrophotometer (Minolta CR-13, Minolta Co. Ltd, Tokyo, Japan). Color space system (L^* a^* b^* coordinates) recognized by the Commission Internationale de l'Eclairage[15] was used to evaluate colour changes. In this colour system, the coordinate a^* indicates the degree of red. Two examiners recorded the number of strokes at each chewing time, and the average was calculated.

Measurement of occlusal parameters

Biting force, occlusal contact areas, and average and maximum occlusal pressures were obtained using the pressure-sensitive film method (Dental Prescale, Fujifilm Co. Ltd, Tokyo, Japan). Each subject was instructed to bite on the Dental Prescale in central occlusion as strongly as possible for 3 s. Type R film, which has the measurement range from 5 to 120 MPa (50H) was used. The procedure was repeated two times and the films were scanned using the Occluzer FPD-703 (GC International Co. Tokyo, Japan). The average of the two measurements was calculated. Body variables, including height and weight of the children at the time of the examination, were obtained.

Table 1. Sample characteristics.

Sample	Age (year)	No. of subjects	Male	Female
Preschool	4–6	24	12	12
School	9–11	42	22	20
Adult	24–36	24	12	12

Statistical analyses

Within each sample, the differences between a^* values at the three selected chewing times were evaluated using Student's t-test ($P < 0.05$). In multiple regression analysis, a^* values at 60 s and 90 s chewing times were used as the dependent variables, and the occlusal parameters and number of strokes at each corresponding chewing time were used as the independent variables. For preschool and school samples, body height and weight were also included in the analysis as independent variables. The selection of the independent variables was completed according to stepwise method. The data were analysed using the statistical software SPSS version 10.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Table 1 describes the sample of the study. Table 2 shows descriptive statistics of a^* values, number of strokes, occlusal parameters, and body variables of the samples. Figure 1 represents the changes of a^* values. According to Student's t-test, significant differences were found among

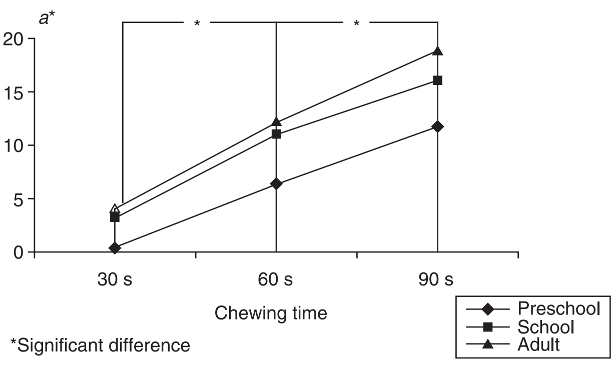

Fig. 1. a^* Values at the three chewing times.

Table 2. Descriptive statistics of *a values and the independent variables.**

Variable	*a** Value at 30 s	*a** Value at 60 s	*a** Value at 90 s	Strokes at 60 s	Strokes at 90 s	Contact area (mm)	Biting force (N)	Average pressure (MPa)	Maximum pressure (MPa)	Height (cm)	Weight (kg)
Sample											
Preschool											
Mean	0.4	6.4	11.5	87.6	134.9	8.8	385.1	44.5	111.1	110.4	19.3
SD	1.1	1.7	2.0	14.6	22.3	3.8	148.2	4.6	10.5	6.0	3.3
School											
Mean	3.1	11.0	16.0	114.4	169.5	13.1	604.0	47.4	118.0	139.0	35.3
SD	1.8	2.7	3.3	10.8	13.6	6.0	241.8	5.0	4.9	6.8	7.7
Adults											
Mean	4.1	12.2	18.9	120.0	177.0	24.0	905.7	39.5	105.3	–	–
SD	2.6	3.8	3.6	22.0	23.9	15.6	397.5	4.3	11.0	–	–

Table 3. Significant variables by regression analysis.

Sample	60 s Chewing	R^2	90 s Chewing	R^2
Preschool	Strokes	0.294	Strokes	0.224
School	Strokes	0.240	Weight	0.138
	Biting force	0.076	_	
Adults	Contact area	0.242	Biting force	0.256
			Strokes	0.198

*a** values at 30 s, 60 s, and 90 s in which the value of *a** (the degree of red) increased as the length of chewing time increased ($P < 0.05$). Table 3 shows the independent variables that were significantly selected by multiple regression analysis for each sample at 60 s and 90 s chewing times along with the R^2 values.

Discussion

This study evaluates the masticatory performance of subjects using the chewing gum colourimetric technique. The method has been practiced for the evaluation of masticatory performance and was found to be practical[13,16]. The chewing gum used in this study was developed as having more colour uniformity after chewing. Therefore, multiple-site measurement was not needed as previously suggested for other types of chewing gums[17]. At 30 s chewing time, however, the colour was not fully uniform in the preschool sample. Therefore, it was not included in the analysis. The results of *t*-test revealed significant differences in *a** values among the three chewing times in which the colour of the gum increased significantly when the length of the chewing time increased, which is the basis of the colourimetric method for the evaluation of mastication performance[16,17]. According to the results, the colour of the gum developed more as the subject performed better, because chewing is a multifactorial process, *a** value represents the final outcome of the mastication process.

Several factors, such as occlusal contact area[1] and biting force[5], were found to have significant impact on chewing performance in adults. In the present work, the pressure-sensitive film method was employed to measure occlusal parameters. The method has been considered reliable[18,19]. In this method, biting force indicates force (in N) applied to the total occlusal imprint (average pressure multiplied by area). Average occlusal pressure indicates the average pressure (in MPa) for the total occlusal imprint. Maximum occlusal pressure indicates the maximum pressure (in MPa) for the occlusal imprint measured in units of 0.0625 mm^2. In this study, regression analysis revealed significant factors that accounted for higher *a** value (better masticatory performance) within each sample. In preschool children, the number of strokes was the only significant variable that enhanced the red colour of the gum (better performance). The finding suggests that mandibular rhythm is an important factor in distinguishing better chewers among preschool children. Similar observations were reported, but for subjects with complete dentures, or missing postcanine teeth, the deterioration in masticatory efficiency was compensated for by performing more strokes[20,21].

There are very few reports on factors that may contribute to the masticatory performance in preschool children. Gaviao *et al.*[7] examined the influence of body weight and height on masticatory performance of children with primary dentition, and found no significant relationship, which agrees with the finding of this study. They also found that children with class II and III malocclusion had lower masticatory performance. The subjects of this study, however, had normal occlusion.

For schoolchildren, at 60 s chewing time the number of strokes was the most important parameter for better performance as selected first by the regression analysis. The second parameter was biting force. After 90 s, body weight was selected as a significant variable. Julien *et al.*[4] reported similar observation on girls in which biting force and body weight explained some variation of the masticatory performance. The effect of body weight on masticatory performance may be related to the increase in the muscle mass[4], which in turn affects the biting force as Van Spronsen *et al.* reported that the cross-sectional area of the masseter muscle and maximal biting force are significantly positively correlated[22].

The findings of this study on biting force and body weight show that the significant effect of these two factors on mastication is established during the mixed dentition stage, whereas they have no significant impact at primary dentition stage.

In the adult sample, occlusal contact area was the significant factor that differentiates subjects at 60 s chewing time. Many previous studies reported that occlusal contact area is an important factor for better chewing performance[4,5,23,24]. Occlusal contact area determines the area available for shearing the food during each cycle[4]. At 90 s chewing time, different factors account for better performance. Biting force and number of strokes were selected as the significant variables. The 90 s chewing time is considered a relatively long time; therefore, it is reasonable to assume that the subject with stronger biting force who has the ability to perform more strokes would show more efficient chewing. Fontijn-Tekamp *et al.* reported that nearly half of the variation in chewing efficiency of adult subjects was explained by biting force[25].

In this study, the regression analysis showed that average and maximum occlusal pressures had no significant effect on chewing performance in children or adults. These two parameters describe the relationship between pressure and occlusal contact area; with larger contact area, occlusal pressure will be reduced. The average and maximum pressures were decreased in adults, which is due to the increase in occlusal contact areas.

In conclusion, number of strokes significantly affects chewing performance of children. Biting force and body weight have significant effects on chewing performance in schoolchildren. In adults, occlusal area, biting force, and rate of mandibular rhythm accounted for better chewing performance.

What this paper adds

- Rates of mandibular rhythm, biting force, and body weight have significant effect on chewing performance in children.
- Occlusal area and biting force affect chewing performance of adults.

Why this paper is important to paediatric dentists

- It is important to paediatric dentists to monitor the developmental changes of masticatory changes of developing children.
- Paediatric dentists have an essential role to identify factors that affect chewing performance in children.

Acknowledgement

The author would like to thank Dr Yoshiaki Ono, Department of Orofacial Development and Function, Division of Oral Health Science, Graduate School, Tokyo Medical and Dental University, for his assistance with this study.

References

1 Wilding J, Lewin A. The determination of optimal human jaw movements based on their association with chewing performance. *Arch Oral Biol* 1994; **39**: 333–343.
2 Lucas W, Luke A, Voon C, Chew L, Ow R. Food breakdown patterns produced by human subjects possessing artificial and natural teeth. *J Oral Rehabil* 1986; **13**: 205–214.
3 Prinz F, Lucas W. 'The first bite of the cherry': intra-oral manipulation prior to the first bite in humans. *J Oral Rehabil* 2001; **28**: 614–617.

4 Julien K, Buschang P, Throckmorton G, Dechow P. Normal masticatory performance in young adults and children. *Arch Oral Biol* 1996; **41**: 69–75.
5 Hatch P, Shinkai S, Sakai S, Rugh D, Paunovich D. Determinants of masticatory performance in dentate adults. *Arch Oral Biol* 2001; **46**: 641–648.
6 English D, Buschang H, Throckmorton S. Does malocclusion affect masticatory performance. *Angle Orthod* 2002; **72**: 21–27.
7 Gaviao B, Raymundo G, Sobrinho C. Masticatory efficiency in children with primary dentition. *Pediatr Dent* 2001; **23**: 499–505.
8 Proffit W, Fields H, Nixon W. Occlusal forces in normal and long-face adults. *J Dent Res* 1983; **62**: 566–570.
9 Proffit W, Fields H. Occlusal forces in normal and long-face. *J Dent Res* 1983; **62**: 571–574.
10 Kumai T. Differences in chewing patterns between involved and opposite sides in patients with unilateral temporomandibular joint and myofascial pain-dysfunction. *Arch Oral Biol* 1993; **38**: 467–478.
11 Van der Bilt A, Olthoff W, Bosman F, Oosterhaven S. Chewing performance before and after rehabilitation of postcanine teeth in man. *J Dent Res* 1994; **73**: 1677–1683.
12 Ono Y, Lin F, Iijima H, Miwa Z, Shibata M. Masticatory training with chewing gum on young children. *Kokubyo Gakkai Zasshi* (English Abstract) 1992; **59**: 512–517.
13 Hirano K, Takahashi Y, Hirano S, Hayakawa I, Seki T. A study on measurement of masticatory ability using a color-changeable chewing gum with a new coloring reaction. *J Jpn Prosthodont Soc* (English Abstract) 2002; **46**: 103–109.
14 Matsubara T, Ono Y, Takagi Y. A study on developmental changes of masticatory function in children. *J Med Dent Sci* 2006; **53**: 141–148.
15 Commission Internationale de 1'Eclairage. *Colorimetry*, 2nd edn. Publication CIE no. 15.2. Vienna: Central Bureau of the CIE, 1986.
16 Matsui Y, Ohno K, Michi K, Hata H, Yamagata K, Ohtsuka S. The evaluation of masticatory function with low adhesive color-developing chewing gum. *J Oral Rehabil* 1996; **23**: 251–256.
17 Hayakawa I, Watanabe I, Hirano S, Nagao M, Seki T. A simple method for evaluating masticatory performance using a color-changeable chewing gum. *Int J Prosthodont* 1998; **11**: 173–176.
18 Matsui Y, Ohno K, Michi K, Suzuki Y, Yamagata G. A computerized method for evaluating balance of occlusal load. *J Oral Rehabil* 1996; **23**: 530–535.
19 Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area and average bite pressure. *J Dent Res* 1999; **78**: 1336–1344.
20 Gunne HS. Masticatory efficiency and dental state. A comparison between two methods. *Acta Odontol Scand* 1985; **43**: 139–146.
21 Van der Bilt A, Olthoff LW, Bosman F, Oosterhaven S. The effect of missing postcanine teeth on chewing performance in man. *Arch Oral Biol* 1993; **38**: 423–429.
22 Van Spronsen H, Weijs W, Prahl-Andersen B, Valk J, Van Ginkel F. Comparison of jaw muscle bite-force cross-sections obtained by means of magnetic resonance imaging and high resolution CT-scanning. *J Dent Res* 1989; **68**: 1756–1770.
23 Owens S, Buschang P, Throckmorton G, Palmer L, English J. Masticatory performance and areas of occlusal contact and near contact in subjects with normal occlusion and malocclusion. *Am J Orthod Dentofacial Orthop* 2002; **121**: 602–609.
24 Wilding RJ. The association between chewing efficiency and occlusal contact area in man. *Arch Oral Biol* 1993; **38**: 589–596.
25 Fontijn-Tekamp F, Slagter A, Van Der Bilt A, *et al*. Biting and chewing in overdentures, full dentures, and natural dentitions. *J Dent Res* 2000; **79**: 1519–1524.