European Journal of Orthodontics 26 (2004) 311–320
European Journal of Orthodontics vol. 26 no. 3

The prevalence of temporomandibular joint dysfunction in the mixed dentition

Virginie Tuerlings and Michel Limme
Department of Orthodontics, University Hospital, Liège, Belgium

SUMMARY A functional and articular examination was carried out of 136 children (70 boys, 66 girls) aged from 6 to 12 years (6 years 1 month to 12 years 9 months), all presenting with a malocclusion in the mixed dentition and who had not yet received orthodontic treatment. The aim of the study was to examine the prevalence of signs of temporomandibular joint dysfunction (TMD) in this population and to evaluate the possible relationship between certain 'individual' parameters and TMD signs.

The results showed an elevated prevalence of muscle tenderness, particularly in the lateral pterygoid muscle, which was found to be sensitive in 80.9 per cent of patients. Muscle tenderness had a tendency to increase with age and was greater on the right side. Temporomandibular joint sounds were present in 35.3 per cent of the subjects and more frequent in girls and in older children. Of the children who presented a mandibular deviation on maximal opening (19.8 per cent), 13.2 per cent had a predominance of opening deviation towards the left. Retruded contact position interferences were present in 57.4 per cent of the children and 72.1 per cent presented lateral and protrusive interferences. Assessment of the maximal amplitudes of mandibular movements did not reveal any limitations. These results indicate that few relationships exist between individual parameters and TMD signs.

Introduction

It has been suggested that orthodontic treatment causes temporomandibular joint dysfunction (TMD) (Ricketts, 1966; Roth, 1973). In spite of the abundance of publications concerning the effects of different orthodontic techniques on the temporomandibular joint (TMJ), the question remains unanswered. Two reviews of the literature examining the relationships between orthodontic treatment and TMD (Reynders, 1990; Luther, 1998), in addition to the studies of Henrikson and Nilner (2000) and Henrikson *et al.* (2000), show that orthodontic treatment plays but a weak role in the aggravation or initiation of TMD. On the contrary, longitudinal studies have shown a decrease in TMD signs in patients receiving orthodontic treatment (Dibbets *et al.*, 1985; Dibbets and Van der Weele, 1987, 1991, 1992; Egermark-Eriksson *et al.*, 1990; Sadowsky *et al.*, 1991; Årtun *et al.*, 1992; Egermark and Thilander, 1992; Hirata *et al.*, 1992; Olsson and Lindqvist, 1992, 1995; Egermark-Eriksson and Ronnerman, 1995; Henriksson *et al.*, 2000).

Functional disorders of the stomatognathic system may already be present in children in the primary dentition, but are often poorly diagnosed and can develop into TMD (Ingerslev, 1983; De Vis *et al.*, 1984; Bernal and Tsamsouris, 1986; Widmalm *et al.*, 1995a,b,c; Alamoudi *et al.*, 1998; Alamoudi, 2000). Few studies have examined the prevalence of TMD signs and symptoms in children in the mixed dentition before orthodontic treatment. Williamson (1977) found that 35 per cent of 6–16-year-old patients had at least one sign of TMD, while this prevalence was reported to be 75.2 per cent in the study of Olsson and Lindqvist (1992), where the average age was 12.8 years. Keeling *et al.* (1994) found that 10 per cent of 6–12-year-old patients presented TMJ sounds, and Sonnesen *et al.* (1998) reported that 30 per cent of 7–13-year-old children had a TMD sign. Thus, TMD prevalence rates vary from one investigation to another. They also vary in terms of their methodology and the different parameters evaluated (Deng *et al.*, 1995).

The aim of the present study was to evaluate the prevalence of TMD in an orthodontic population in the mixed dentition before treatment and to determine if a relationship exists between TMD signs and various occlusal and functional parameters.

Subjects and methods

A sample of 136 consecutive subjects aged from 6 to 12 years was selected by examination of patients requesting orthodontic evaluation at the Department of Orthodontics, University Hospital of Liège, Belgium. All patients were selected and examined by the same orthodontist (TV). All presented with Class I, II or III malocclusions (open bite, deep bite, overjet, anterior or lateral crossbite, crowding, dental or mandibular deviation, discrepancies of maxillary or mandibulary width) and required orthodontic treatment. The patients were selected based on the following criteria: in the mixed dentition without previous or current orthodontic treatment and absence of grinding on the primary teeth.

The average age of the patients was 108 ± 17.5 months. The sample comprised 70 boys (51.5 per cent) and 66 girls (48.5 per cent) (Table 1). A Class I malocclusion was present in 16 patients (11.8 per cent), a Class II in 111 (81.6 per cent) and a Class III in 9 (6.6 per cent).

Clinical and articular examination

Articular variables. For each patient, 'articular variables' (clinical signs of dysfunction), including tenderness on palpation of the TMJ and the masticatory muscles, the existence of a mandibular deviation on maximal opening, the presence of TMJ sounds (clicking and popping, heard with a stethoscope), and articular mobility (maximal opening, maximal right and left movements, maximal protrusion), were examined.

Palpations were carried out on the anterior, middle and posterior fibres of the temporalis, the coronoid process, the TMJ lateral and posterior aspects, the deep and superficial masseter (anterior part, body, gonial part), the styloid process, the anterior belly of the digastric muscle, and the medial and lateral pterygoid muscles.

As the investigation involved young patients, the examination commenced with a 'placebo test', which consisted of applying pressure to the patient's hand. They were then informed of the difference between 'to feel a pressure' and 'to have tenderness', and their understanding of this distinction was confirmed. Evaluation of the palpations was coded in the following manner: 0 = no tenderness, 1 = weak tenderness, 2 = moderate tenderness, 3 = great tenderness.

For the evaluation of mandibular deviations on maximal opening, an 'opening deviation' was defined as being an anomaly where the opening path deviates like a bayonet and then returns towards the midline. 'Opening deflection' was further defined as being an anomaly of the opening path where the mandible presents a deviation that persists on maximal opening.

Individual variables. 'Individual variables', consisting of 'functional' variables (including functional malocclusion, various parameters in relation to masticatory function, orofacial dysfunctions and parafunctions) and 'morphological' variables (morphological malocclusion), were also evaluated (Table 2). For example, this consisted of the functional masticatory angles of Planas that represent the direction of the displacement of the lower interincisor point with respect to the horizontal plane, on the left and right sides (Planas, 1992). That is, the child carries out a left and then a right lateral movement. According to that author, these angles are equal in bilateral mastication. On the contrary, if the angles are unequal, the side where the angle is the smallest is the preferential mastication side (Figure 1). For each patient, these angles were evaluated by observation of the displacement of the lower interincisor point with respect to the horizontal plane from four ranges of angulations: from 0 to 10, from 11 to 20, from 21 to 30, and from 31 to 40 degrees. Another example is the speech space, which represents the main component of the mandibular movement (horizontal or vertical) when the patient is speaking.

Table 1 Distribution of sex and age in 136 pre-orthodontic patients.

Age (years)	Girls (%)	Boys (%)	Total (%)
6	3 (2.2)	5 (3.7)	8 (5.8)
7	16 (11.7)	12 (8.8)	28 (20.6)
8	21 (15.4)	21 (15.4)	42 (30.9)
9	8 (5.8)	12 (8.8)	20 (14.7)
10	11 (8.1)	13 (9.6)	24 (17.6)
11	6 (4.4)	5 (3.7)	11 (8.1)
12	1 (0.7)	2 (1.5)	3 (2.2)
Total	66 (48.5)	70 (51.5)	136 (100)

Table 2 Individual variables.

'Functional' variables
Retruded contact position interferences
Lateral and protrusive interferences
Functional masticatory angles of Planas
Dental or mandibular midline displacement
Anomalies of transverse relationships
Type of breathing (oral, nasal or both)
Deep bite
Speech space
Lingual function and swallowing
Thumb or finger sucking
Parafunctions
'Morphological' variables
Molar and canine class
Overjet (mm)
Overbite (mm)
Upper and lower crowding (mm)
Intermolar width (16–26 and 36–46) = Pont's indices (mm)

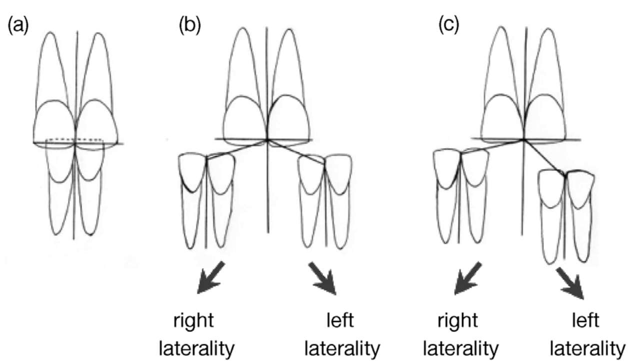

Figure 1 Functional masticatory angles of Planas. (a) Maximal intercuspal position, (b) equal angles, (c) unequal angles. In this example, the right side is the smallest and indicates the preferential mastication side.

Statistical analyses

The results were expressed as the mean and standard deviation for quantitative variables and as frequencies for categorical findings.

To compare means of several groups, one-way analysis of variance (ANOVA) was used. A Student's *t*-test was applied where two groups were to be compared. To determine proportions in different groups or to measure associations between two qualitative variables, the Chi-squared test for contingency tables was used. The association between two quantitative variables was evaluated with the correlation coefficient (r). Multiple regressions were utilized where relationships between one quantitative dependent variable and a group of independent variables were examined.

To obtain a graphical representation of the multivariate problem (articular and individual variables), the biplot method was utilized (Gabriel, 1971). This method permits a graphical visualization of both observations (i.e. subjects) and variables included in the study. Variables pointing in the same direction are positively correlated. Furthermore, the closer they are to each other, the greater their correlation with each other. If they point in diametrically opposed directions, they are negatively correlated. The absence of a relationship between variables corresponds to variables where vectors are more or less orthogonal. The length of the variable arrow represents the importance of this variable in the correlation structure. The biplot method also permits 'logical' clustering of the variables. All statistical analyses were carried with the SAS (SAS Institute, Cary, North Carolina, USA; version 6.12 for Windows) and S-PLUS (StatSoft Inc., version 2000) programs. The results were considered significant at the 5 per cent level.

Results

Muscular palpations

Table 3 shows that a tenderness score of 3 was predominant for the lateral pterygoid muscle, frequent for the coronoid and styloid process and the TMJ posterior aspect, and negligible, that is non-existent, for the anterior fibres of the temporalis muscle, the superficial masseter and the anterior belly of the digastric muscle. A score of 0 was more frequent for the posterior fibres of the temporalis muscle, the superficial masseter and the anterior belly of the digastric muscle. The other muscles showed mostly weak or moderate tenderness.

For each muscle, the global percentage of tenderness for the left and right sides was also calculated, in addition to the average tenderness score (weak, moderate or great, on a scale from 0 to 3) (Table 4).

The lateral pterygoid muscle presented the largest prevalence (80.9 per cent), followed by the coronoid process, the medial pterygoid muscle, the styloid process, and the TMJ posterior aspect. The deep masseter, the TMJ lateral aspect, the superficial masseter (gonial part) and the middle fibres of the temporalis muscle presented a low prevalence, whereas the anterior belly of the digastric muscle, the superficial masseter and the posterior fibres of the temporalis muscle showed a weak prevalence of muscular sensitivity. Based on the scale from 0 to 3, the average tenderness scores were mostly moderate or weak (ranging between 0.11 and 1.09), with

Table 3 Distribution of muscle tenderness as a function of score.

Muscles	Tenderness score							
	0 (%)		1 (%)		2 (%)		3 (%)	
	Right	Left	Right	Left	Right	Left	Right	Left
Anterior fibres of the temporalis muscle	73.5	82.4	20.6	11.8	5.1	5.1	0.7	0.7
Middle fibres of the temporalis muscle	80.1	83.1	12.5	11.8	5.1	3.7	2.2	1.5
Posterior fibres of the temporalis muscle	89.0	89.0	5.9	5.9	2.9	2.2	2.2	2.9
TMJ lateral aspect	71.3	79.4	18.4	11.8	6.6	7.4	3.7	1.5
TMJ posterior aspect	47.1	69.9	28.7	15.4	12.5	8.1	11.8	6.6
Deep masseter	69.1	72.1	18.4	14	5.9	5.9	6.6	8.1
Superficial masseter (anterior part, body)	88.2	90.4	10.3	8.1	1.5	1.5	0	0
Superficial masseter (gonial part)	77.9	85.3	16.9	10.3	4.4	4.4	0.7	0
Styloid process	46.3	55.1	19.9	15.4	18.4	16.2	15.4	13.2
Anterior belly of the digastric muscle	86.8	86.8	8.1	8.1	5.1	5.1	0	0
Medial pterygoid muscle	47.1	65.4	27.2	15.4	16.2	11.0	9.6	8.1
Lateral pterygoid muscle	19.1	19.1	19.1	16.9	16.2	25.0	45.6	39.0
Coronoid process	40.4	43.4	27.2	19.9	16.2	21.3	16.2	15.4

TMJ, temporomandibular joint.
0 = no tenderness; 1 = weak tenderness; 2 = moderate tenderness; 3 = great tenderness.

Table 4 Percentage of tenderness on the left and right sides (average score from 0 to 3).

Muscle	Tenderness score			
	Right side		Left side	
	Frequency (%)	Mean ± SD	Frequency (%)	Mean ± SD
Anterior fibres of the temporalis muscle	26.5	0.33 ± 0.61	17.6	0.24 ± 0.58
Middle fibres of the temporalis muscle	19.1	0.29 ± 0.67	16.9	0.23 ± 0.59
Posterior fibres of the temporalis muscle	11.0	0.18 ± 0.59	11.0	0.19 ± 0.61
TMJ lateral aspect	28.7	0.43 ± 0.78	20.6	0.31 ± 0.67
TMJ posterior aspect	52.9	0.89 ± 1.03	30.1	0.51 ± 0.90
Deep masseter	30.9	0.50 ± 0.88	27.9	0.50 ± 0.93
Superficial masseter (anterior part, body)	11.8	0.13 ± 0.38	9.6	0.11 ± 0.36
Superficial masseter (gonial part)	22.1	0.28 ± 0.58	14.7	0.19 ± 0.49
Styloid process	53.7	1.03 ± 1.13	40.9	0.88 ± 1.11
Anterior belly of the digastric muscle	13.2	0.18 ± 0.50	13.2	0.18 ± 0.50
Medial pterygoid muscle	52.9	0.88 ± 1.00	34.6	0.62 ± 0.97
Lateral pterygoid muscle	80.9	1.88 ± 1.19	80.9	1.84 ± 1.14
Coronoid process	59.6	1.08 ± 1.10	56.6	1.09 ± 1.13

TMJ, temporomandibular joint; SD, standard deviation.
0 = no tenderness; 1 = weak tenderness; 2 = moderate tenderness; 3 = great tenderness.

the exception of the lateral pterygoid muscle, which had the highest score (1.88 and 1.84 for the right and left sides, respectively). When accounting for age, sex and laterality, the tenderness score was highest on the right side ($P < 0.001$) and muscle tenderness had a tendency to increase with age. No differences were found between boys and girls, except for the medial pterygoid muscle on the left side, which was more sensitive in girls. The relationships between the different muscle tenderness scores using the biplot method are shown in Figure 2.

The muscular correlations were numerous, complex and more or less strong. Two muscular groups could be clearly discerned on the biplot. One group consisted of the coronoid process (right and left): CORP_R and CORP_L; the TMJ posterior aspect (right and left): TMJ PA_R and TMJ PA_L; the medial pterygoid muscle (right and left): MEDPTE_R and MEDPTE_L; the styloid process (right and left): STYL_R and STYL_L; the lateral pterygoid muscle (right and left): LATPTE_R and LATPTE_L. The second group consisted of the anterior fibres of the temporalis muscle (right and left): MTANT_R and MTANT_L; the middle fibres of the temporalis muscle (right and left): MTMID_R and MTMID_L; the posterior fibres of the temporalis muscle (right and left): MTPOST_R and MTPOST_L; the TMJ lateral aspect (right and left): TMJLAT_R and TMJLAT_L; the deep masseter (right and left): DMAS_R and DMAS_L; the superficial masseter (anterior part, body) (right and left): SUPMAS_R and SUPMAS_L; the superficial masseter (gonial part) (right and left): SMASGO_R and SMASGO_L; the anterior belly of the digastric muscle (right and left): ANTDIG_R and ANTDIG_L.

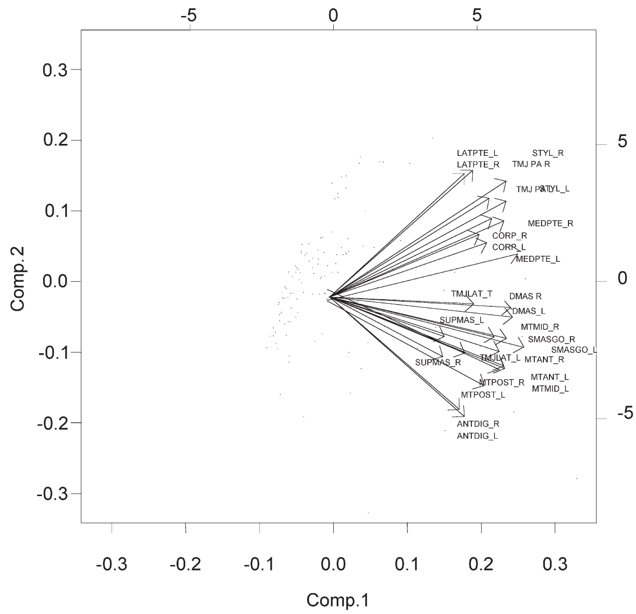

Figure 2 Biplot of muscular tenderness (0–3 for all muscles). The variables (muscles) are shown by the arrows, where the length of the arrow represents the importance of this variable in the correlation. Variables pointing in the same direction are positively correlated and the closer they are to each other, the greater the correlation. In this figure, two groups of arrows pointing in two different directions can be distinguished, revealing complex correlations between the different muscles studied.

Analysis of the average tenderness scores between the two groups revealed an average tenderness score significantly greater for muscles in the first group compared with the second group (10.7 ± 7.6 versus 4.3 ± 6.3; $P < 0.001$).

Opening path

The results show that 19.9 per cent of the subjects had a mandibular deviation on maximal opening, with a predominance of deviations towards the left: 13.2 per cent of the children presented an opening deviation towards the left, 3.7 per cent an opening deflection towards the left, and only 2.9 per cent an opening deviation towards the right. No patient presented an opening deflection towards the right.

Articular sounds

In this sample, 25.7 per cent of the children had popping sounds and 9.6 per cent had clicking sounds (i.e. 35.3 per cent of the total). These sounds increased with age and were more frequent in girls.

Articular mobility

The average values of maximal oral amplitudes are shown in Table 5. No patient presented limitations of mandibular movement in the three levels of space.

Functional and morphological variables

Retruded contact position interferences were found in 57.4 per cent and lateral and protrusive interferences in 72.1 per cent. A greater percentage of patients possessed a left functional masticatory angle of Planas from 0 to 10 degrees and a right functional masticatory angle of Planas from 11 to 20 degrees (37.5 and 22.1 per cent, respectively; Table 6), indicating, according to that author, a left preferential masticatory side. On average, the patients showed a slight distocclusion (–2 ± 1.8 mm), an average overjet of 4.5 ± 3 mm and an average overbite of 3.1 ± 2.5 mm.

Table 5 Maximal amplitudes of mandibular movements.

	Mean ± standard deviation
Maximal opening (mm)	48.8 ± 5.2
Maximal right laterality (mm)	10.0 ± 2.2
Maximal left laterality (mm)	10.4 ± 2.2
Maximal protrusion (mm)	9.07 ± 1.9

Table 6 Functional masticatory angles of Planas.

Functional masticatory angles of Planas (degrees)	Right (%)	Left (%)
0–10	30 (22.1)	51 (37.5)
11–20	51 (37.5)	44 (32.4)
21–30	30 (22.1)	24 (17.6)
31–40	25 (18.4)	17 (12.5)

Relationships between articular variables

The relationships between articular variables, taking into account age and sex, are shown in Figure 3. There was a weak dependence between tenderness of the two muscular groups determined previously (arrows M1 and M2) with the other articular variables, in addition to sex and age. The maximal amplitudes of mandibular movements presented a negative correlation with muscular tenderness, revealing that increased muscular tenderness was associated with small amplitudes. Age was identified as a major factor in muscle tenderness compared with the other variables, with the exception of TMJ sounds (noises), which increased with age. TMJ sounds were positively correlated with mandibular deviations on maximal opening (DMAXOP) and with the amplitudes of the maximal opening (A_MAXOP) and maximal propulsion (A_MAXPR). Amplitudes of the right and left lateralities (A_LRMAX and A_LLMAX) were highly correlated with each other, as well as with the amplitude of maximal propulsion. Mandibular deviations on maximal opening and sex, represented by the two small arrows, were of weak significance in the correlations.

Correlations between articular and individual variables

The correlations between articular and individual variables were few and mostly weak (Figure 4) with the

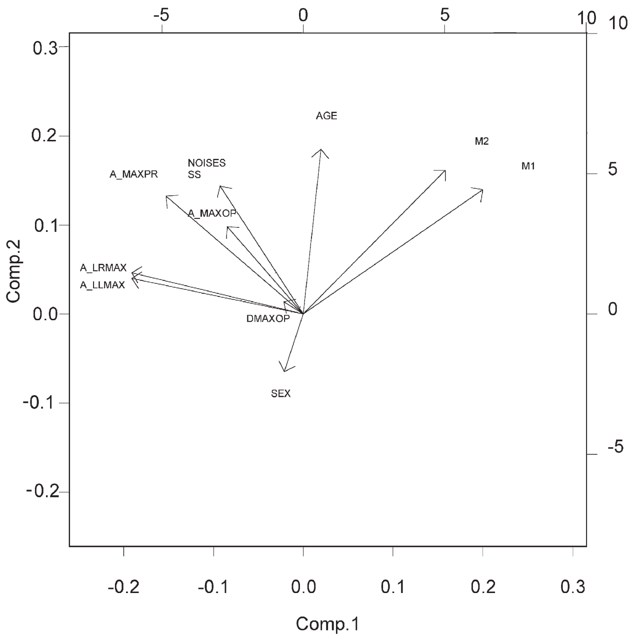

Figure 3 Biplot of articular variables. The direction of the arrows representing the articular variables indicates a weak dependence between muscle tenderness (M1 and M2) and the other articular variables, in addition to sex and age. Age mostly plays a role in muscle tenderness and sounds, whereas sex and the deviations of the mandible on maximal opening, represented by the very small arrows, play a weak role in the correlations.

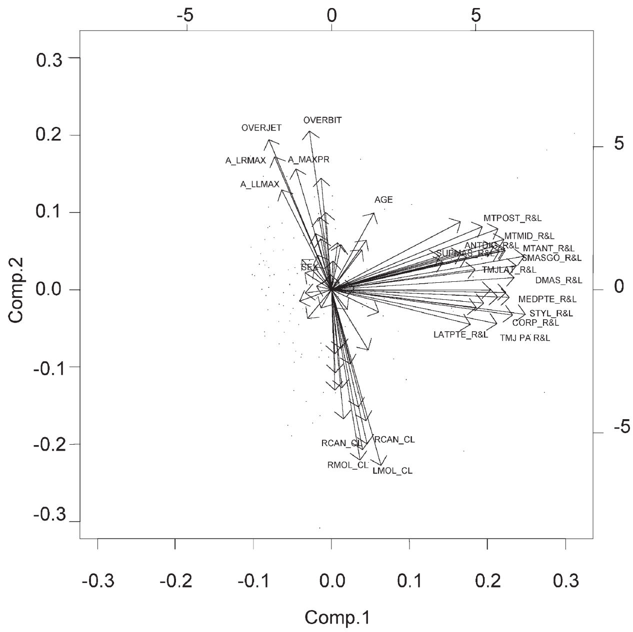

Figure 4 Biplot of articular and individual variables. The main correlations (the largest arrows) are represented by the amplitudes of the right and left lateralities and of the propulsion that presents a negative correlation with the left and right molar and canine classifications, and a positive correlation with overjet. Muscular tenderness is weakly associated with the other variables. The other individual variables are represented by the smallest arrows and are of lesser significance in the correlations.

three large axes, of different directions, defining each other. These are mainly represented by the amplitudes of the right and left lateralities and of the maximal protrusion (A_RLMAX, A_LLMAX and MAXPR) that presented a negative correlation with the right and left molar and canine classifications (RMOL_CL, LMOL_CL, RCAN_CL, LCAN_CL) (i.e. patients with a Class II malocclusion had larger values for these amplitudes) and a positive correlation with overjet. In addition, overjet and overbite also presented a negative correlation with the right and left molar and canine classifications. The third cluster was represented by sensitivities of the two muscular groups, where the orthogonal direction with the two other axes indicated less dependence between muscular tenderness and other variables.

Discussion

While the clinical examinations of the patients were carried out by the same person, it is difficult to achieve total objectivity, especially for muscular palpations, which involve a ‘subjective’ reply from the patient. As the present study concerned children in the mixed dentition, which is the transitional period between complete primary dentition (before the age of 6 years) and permanent dentition (after the age of 12 years), only children from 6 to 12 years of age were included. In general, the minimum age for valid responses is 7 years (Nilner and Lassing, 1981). However, in the present study, patients aged 6 years were sufficiently co-operative. Furthermore, the reliability of responses was verified using a placebo test, in order to eliminate children from providing aleatory responses, and to clearly distinguish between feeling pressure and the various levels of tenderness.

In this study, 80.9 per cent of the children presented tenderness in the lateral pterygoid muscle, for which the average score was also highest (1.88 ± 1.19 on a scale from 0 to 3). While predominance of sensitivity of palpation of the lateral pterygoid muscle has been reported (Williamson, 1977; Olsson and Lindqvist, 1992), a greater prevalence was found in the present investigation (19 and 24.9 per cent, respectively). Williamson (1977) stated that this is due to the fact that this muscle is the most active during anterior or lateral function of the mandible. The prevalence of muscular sensitivities was quite high in the present study, but with the exception of the lateral pterygoid muscle, most of the sensitivities were moderate or weak, and none of the patients complained about these spontaneously. A high prevalence of muscular sensitivity in the mixed compared with permanent dentition has been reported (Nilner, 1981; Nilner and Kopp, 1983; Kirveskari *et al.*, 1986; Pahkala and Laine, 1991). TMD signs are generally slight or moderate (Egermark-Eriksson *et al.*, 1981, 1987; Vanderas, 1988b; Okeson, 1989; Mohlin *et al.*, 1991; Magnusson *et al.*, 1993; Morrant and Taylor, 1996), and few children complain about such problems (Okeson, 1989).

In the present study, and that of Olsson and Lindqvist (1992), muscle tenderness was found to be greater on the right side. This could be related to the patients’ masticatory habits, to individual adaptation capacities to different malocclusions, or to parafunctional activity leading to overloading of the masticatory muscles. The greater prevalence of right-sided tenderness is probably related to the lower value observed for the left functional masticatory angles of Planas, indicating a left masticatory preference, and leading to an overload of right-sided muscles.

Correlations between sex and the left lateral pterygoid muscle (of which girls presented greater tenderness) were observed, and the global tenderness score increased with age. On the other hand, Keeling *et al.* (1994), in an investigation of children aged 6–12 years before orthodontic treatment, did not find any correlation with sex or age for muscular sensitivities.

Several studies carried out in older children have shown that the incidence of signs and symptoms increases with age (Egermark-Eriksson *et al.*, 1981, 1987, 1990; Magnusson *et al.*, 1985, 1993; Kirsveskari *et al.*, 1986;

Jämsa *et al.*, 1988; Pahkala and Laine, 1991; Motegi *et al.*, 1992; Deng *et al.*, 1995) and that their severity increases with age (Egermark-Eriksson *et al.*, 1981, 1987, 1990; Nilner, 1981; Magnusson *et al.*, 1985; Barone *et al.*, 1997). The fact that the youngest children possessed only minor TMD signs and symptoms is related to the remarkable adaptation capacity of their masticatory systems and orofacial musculature (Grosfeld and Czarnecka, 1977; Morawa *et al.*, 1985). The majority of researchers do not report any difference between signs and symptoms in terms of sex (Grosfeld and Czarnecka, 1977).

In this study, popping sounds were present in 25.7 per cent and clicking sounds in 9.6 per cent (i.e. 35.3 per cent of the total). TMJ sounds were significantly more frequent in older children, which is in agreement with the observations that the frequency of clicking increases with age (Egermark-Eriksson *et al.*, 1981, 1983; Nilner and Lassing, 1981; Nilner, 1985; Morrant and Taylor, 1996; Kieser and Groeneveld, 1998; Stockstill *et al.*, 1998; Akeel and Al-Jasser, 1999) and with the development of the dentition (Deng *et al.*, 1995). The girls presented more sounds compared with the boys.

Sex differences (i.e. greater frequency of clicking in girls) have been reported by Egermark-Eriksson *et al.* (1981, 1983), Egermark-Eriksson and Ingervall (1982), Vanderas (1988b, 1989), Heikinheimo *et al.* (1990), Pahkala and Laine (1991), but not by Kirveskari *et al.* (1986), Vanderas (1992a) and Morrant and Taylor (1996). This difference could be related to hormonal changes during the pubertal peak, which is more precocious in girls (Keeling *et al.*, 1994).

Concerning the prevalence of clicking, the results of this study are similar to those of Williamson (1977), who found that 7.2 per cent of 6–16-year-old pre-orthodontic patients had TMJ clicking, and Keeling *et al.* (1994), who reported a prevalence of 8.9 per cent in subjects aged from 6 to 12 years. Twenty per cent of these patients presented ‘sounds’ other than clicking. Contrary to the results of this study, the latter authors did not find an association between TMJ sounds and age and sex. In 7–13-year-old children, Sonnesen *et al.* (1998) found a greater prevalence of TMJ clicking (16 per cent) than that observed in the present study. Contrary to adults, clicking in children can occur without there being a dislocation of a disc, as the result of a compression of articular fluids at the time of condyle translation, which results in pressure and produces an audible clicking and a palpable shift in the mandible coincident with the sound (Razook *et al.*, 1989). TMJ sounds may originate from changes in articular surfaces (synovial membranes/cavitational phenomena) (Nilner, 1981; Razook *et al.*, 1989), deviations of the forms of articular components (Nilner, 1981; Razook *et al.*, 1989), loose bodies inside the joint space (Razook *et al.*, 1989; Stockstill *et al.*, 1998), in addition to a lack of muscle co-ordination (Perry, 1973; Nilner and Lassing, 1981; Nilner, 1983). Another causal factor for articular sounds may be a transitory incompatibility of the disc contour relative to the fossa and condyle contour originating from differential growth rates and calcification. All of these mechanisms can therefore explain the increased prevalence of the TMJ sounds found in this study. Certain authors do not necessarily consider them as a ‘problem’, but mostly as a ‘risk factor’ (Tallents *et al.*, 1991).

The results of the present study show that 19.9 per cent of subjects presented a deviation of the mandible on maximal opening, with a predominance of deviations towards the left, which has been observed by other authors (Grosfeld and Czarnecka, 1977; Nilner and Lassing, 1981; Nilner, 1983; Vanderas, 1988b, 1989, 1992b; Mohlin *et al.*, 1991). This can be considered as an adaptation of the mandible in the presence of interferences leading to asymmetric muscular activity. No statistically significant relationship with age and sex for mandibular deviations was found on maximal opening.

Comparison of articular variables showed a negative correlation between maximal amplitudes of mandibular movements and muscle tenderness, indicating that greater muscle tenderness is associated with smaller amplitudes. The amplitudes of the right and left movements correlated with the amplitude of the protrusion. The amplitudes of maximal opening and maximal protrusion were positively correlated with the presence of sounds, indicating that sounds have a tendency to be more frequent when the amplitudes of maximal opening and maximal protrusion increase. This is compatible with the mechanisms mentioned earlier concerning the origin of TMJ sounds in children, and above all with the compression of articular fluids during the translation of the condyle. Sounds also presented a positive correlation with the existence of mandibular deviation on maximal opening, which could be associated with a lack of muscle co-ordination mentioned earlier concerning the origin of TMJ sounds in children. The amplitude of the left maximal movement presented a negative yet weak correlation with tenderness in the right pterygoid muscle; a lower value of the left functional masticatory angles of Planas was also observed in these patients and results in a left-sided mastication preference.

Correlations between articular and individual variables were relatively few in number and most of them were weak. They were mainly linked with the amplitudes of the right and left movements and of the maximal propulsion, which revealed a negative correlation with the left and right molar and canine classifications (i.e. patients with a Class II malocclusion had greater values for these amplitudes). Keeling *et al.* (1994), in a study of children aged from 6 to 12 years who did not receive orthodontic treatment, observed that the prevalence of TMJ sounds was not associated with molar relationship, which is similar to the results in the present study.

In contrast, Sonnesen *et al.* (1998) found a statistically significant relationship between TMD signs and symptoms and six forms of malocclusion: distal molar occlusion, extreme maxillary overjet, anterior open bite, unilateral crossbite, midline displacement and errors of tooth formation. They did not, however, find any association between TMJ sounds and different forms of malocclusion. Those authors suggested that children with severe malocclusions present a greater risk of developing TMD. In investigations carried out on children in the mixed and permanent dentition, the role of malocclusions in TMD is controversial. Certain studies have not found any association between occlusal factors and TMD (Grosfeld and Czarnecka, 1977; De Boever and Van der Berghe, 1987; Egermark-Eriksson *et al.*, 1987; Barone *et al.*, 1997), whereas others have reported correlations (Grosfeld and Czarnecka, 1977; Egermark-Eriksson, 1982; Egermark-Eriksson *et al.*, 1983, 1990; Lieberman *et al.*, 1985; Nilner, 1985; Riolo *et al.*, 1987; Jämsa *et al.*, 1988; Heikinheimo *et al.*, 1990; Pahkala and Laine, 1991; Kritsineli and Shim, 1992; Motegi *et al.*, 1992; Henrikson *et al.*, 1997). However, the correlations in the present study were weak, and it is probable that malocclusion should be viewed as a contributing, rather than a causal, factor in TMD (Egermark-Eriksson, 1982; Vanderas, 1988a).

Conclusion

Except for the relationship between maximal amplitudes of the lateralities and propulsion with the right and left dental Classes and overjet, this study did not provide evidence of a statistically significant correlation between articular and individual variables. In particular, no significant correlation was found between malocclusions and clinical signs of dysfunction. However, the children already presented an increased prevalence of TMD signs associated with a form of malocclusion and of numerous interferences. Young children were examined, who possess a great capacity for adaptation of the masticatory system. It is, therefore, important to identify these clinical signs of dysfunction before orthodontic treatment is carried out.

Address for correspondence

Virginie Tuerlings
39 Rue de l'Industrie
7170 Manage
Belgium

Acknowledgements

We extend sincere thanks to the patients in the Department of Orthodontics at the University Hospital of Liège, to our colleague Dr Y. Gilon for his assistance and to Professor A. Albert and Ms L. Seidel for their statistical guidance.

References

Akeel R, Al-Jasser N 1999 Temporomandibular disorders in Saudi females seeking orthodontic treatment. Journal of Oral Rehabilitation 26: 757–762

Alamoudi N 2000 The correlation between occlusal characteristics and temporomandibular dysfunction in Saudi Arabian children. Journal of Clinical Pediatric Dentistry 24: 229–236

Alamoudi N, Farsi N, Salako N O, Feteih R 1998 Temporomandibular disorders among school children. Journal of Clinical Pediatric Dentistry 22: 323–328

Årtun J, Hollender L G, Truelove E L 1992 Relationship between orthodontic treatment, condylar position, and internal derangement in the temporomandibular joint. American Journal of Orthodontics and Dentofacial Orthopedics 101: 48–53

Barone A, Sbordone L, Ramaglia L 1997 Craniomandibular disorders and orthodontic treatment need in children. Journal of Oral Rehabilitation 24: 2–7

Bernal M, Tsamsouris A 1986 Signs and symptoms of temporomandibular joint dysfunction in 3 to 5 year old children. Journal of Pedodontics 10: 127–140

De Boever J A, Van den Berghe L 1987 Longitudinal study of functional conditions in the masticatory system in Flemish children. Community Dentistry and Oral Epidemiology 15: 100–103

De Vis H, De Boever J A, Van Cauwenberghe P 1984 Epidemiologic survey of functional conditions of the masticatory system in Belgian children aged 3–6 years. Community Dentistry and Oral Epidemiology 12: 203–207

Deng Y M, Fu M K, Hägg U 1995 Prevalence of temporomandibular joint dysfunction (TMJD) in Chinese children and adolescents. A cross-sectional epidemiological study. European Journal of Orthodontics 17: 305–309

Dibbets J M H, Van der Weele L Th 1987 Orthodontic treatment in relation to symptoms attributed to dysfunction of the temporomandibular joint. A 10-year report of the University of Groningen study. American Journal of Orthodontics and Dentofacial Orthopedics 91: 193–199

Dibbets J M H, Van der Weele L Th 1991 Extraction, orthodontic treatment and craniomandibular dysfunction. American Journal of Orthodontics and Dentofacial Orthopedics 99: 210–219

Dibbets J M H, Van der Weele L Th 1992 Long-term effects of orthodontic treatment, including extraction, on signs and symptoms attributed to CMD. European Journal of Orthodontics 14: 16–20

Dibbets J M H, Van der Weele L Th, Uildriks A K 1985 Symptoms of TMJ dysfunction: indicators of growth patterns? Journal of Pedodontics 9: 265–284

Egermark-Eriksson I, Thilander B 1992 Craniomandibular disorders with special reference to orthodontic treatment: an evaluation from childhood to adulthood. American Journal of Orthodontics and Dentofacial Orthopedics 101: 28–34

Egermark-Eriksson I 1982 Mandibular dysfunction in children and individuals with dual bite. Tandlakartidningen 74: 118–121

Egermark-Eriksson I, Ingervall B 1982 Anomalies of occlusion predisposing to occlusal interference in children. Angle Orthodontist 52: 293–299

Egermark-Eriksson I, Ronnerman A 1995 Temporomandibular disorders in the active phase of orthodontic treatment. Journal of Oral Rehabilitation 22: 613–618

Egermark-Eriksson I, Ingervall B, Carlsson G E 1981 Prevalence of mandibular dysfunction and orofacial parafunction in 7-, 11- and 15-year-old Swedish children. European Journal of Orthodontics 3: 163–172

Egermark-Eriksson I, Ingervall B, Carlsson G E 1983 The dependence of mandibular dysfunction in children on functional and morphologic malocclusion. American Journal of Orthodontics 83: 187–194

Egermark-Eriksson I, Carlsson G E, Magnusson T 1987 A long-term epidemiologic study of the relationship between occlusal factors and mandibular dysfunction in children and adolescents. Journal of Dental Research 66: 67–71

Egermark-Eriksson I, Carlsson G E, Magnusson T, Thilander B 1990 A longitudinal study on malocclusion in relation to signs and symptoms of craniomandibular disorders in children and adolescents. European Journal of Orthodontics 12: 399–407

Gabriel K R 1971 The biplot graphical display of matrices with application to principal component analysis. Biometrika 58: 456–467

Grosfeld O, Czarnecka B 1977 Musculo-articular disorders of the stomatognathic system in school children examined according to clinical criteria. Journal of Oral Rehabilitation 4: 193–200

Heikinheimo K, Salmi K, Myllärniemi S, Kirveskari P 1990 A longitudinal study of occlusal interferences and signs of craniomandibular disorder at the ages of 12 and 15 years. European Journal of Orthodontics 12: 190–197

Henrikson T, Nilner M 2000 Temporomandibular disorders and the need for stomatognathic treatment in orthodontically treated and untreated girls. European Journal of Orthodontics 22: 283–292

Henrikson T, Ekberg E C, Nilner M 1997 Symptoms and signs of temporomandibular disorders in girls with normal occlusion and Class II malocclusion. Acta Odontologica Scandinavica 55: 229–235

Henrikson T, Nilner M, Kurol J 2000 Signs of temporomandibular disorders in girls receiving orthodontic treatment. A prospective and longitudinal comparison with untreated Class II malocclusions and normal occlusion subjects. European Journal of Orthodontics 22: 271–281

Hirata R H, Helf M W, Hernandez B, King G J 1992 Longitudinal study of signs of temporomandibular disorders (TMD) in orthodontically treated and nontreated groups. American Journal of Orthodontics and Dentofacial Orthopedics 101: 35–40

Ingerslev H 1983 Functional disturbances of the masticatory system in school children. Journal of Dentistry for Children 50: 445–454

Jämsä T, Kirveskari P, Alanen P 1988 Malocclusion and its association with clinical signs of craniomandibular disorder in 5-, 10- and 15-year old children in Finland. Proceedings of the Finnish Dental Society 84: 235–240

Keeling S D, McGorray S, Wheeler T T, King G J 1994 Risk factors associated with temporomandibular joint sounds in children 6 to 12 years of age. American Journal of Orthodontics and Dentofacial Orthopedics 105: 279–287

Kieser J A, Groeneveld H T 1998 Relationship between juvenile bruxing and craniomandibular dysfunction. Journal of Oral Rehabilitation 25: 662–665

Kirveskari P, Alanen P, Jämsä T 1986 Functional state of the stomatognathic system in 5, 10 and 15 year old children in southwestern Finland. Proceedings of the Finnish Dental Society 82: 3–8

Kritsineli M, Shim Y S 1992 Malocclusion body posture and temporomandibular disorder in children with primary and mixed dentition. Journal of Clinical Pediatric Dentistry 16: 86–93

Lieberman M A, Gazit E, Fuchs C, Lilos P 1985 Mandibular dysfunction in 10–18 year old school children as related to morphological malocclusion. Journal of Oral Rehabilitation 12: 209–214

Luther F 1998 Orthodontics and the temporomandibular joint: where are we now? Part 1. Orthodontic treatment and temporomandibular disorders. Angle Orthodontist 68: 295–304

Magnusson T, Egermark-Eriksson I, Carlsson G E 1985 Four-year longitudinal study of mandibular dysfunction in children. Community Dentistry and Oral Epidemiology 13: 117–120

Magnusson T, Egermark-Eriksson I, Carlsson G E 1993 Changes in subjective symptoms of craniomandibular disorders in children and adolescents during a 10-year period. Journal of Orofacial Pain 7: 76–81

Mohlin B, Pilley J R, Shaw W C 1991 A survey of craniomandibular disorders in 1000 12-year-olds. Study design and baseline data in a follow-up study. European Journal of Orthodontics 13: 111–123

Morawa A P, Loos P J, Easton J W 1985 Temporomandibular joint dysfunction in children and adolescents: incidence, diagnosis and treatment. Quintessence International 11: 771–777

Morrant D G, Taylor G S 1996 The prevalence of temporomandibular disorder in patients referred for orthodontic assessment. British Journal of Orthodontics 23: 261–265

Motegi E, Miyazaki H, Ogura I, Konishi H, Sebata M 1992 An orthodontic study of temporomandibular joint disorders. Part 1: Epidemiological research in Japanese 6–18 year olds. Angle Orthodontist 62: 249–256

Nilner M 1981 Prevalence of functional disturbances and diseases of the stomatognathic system in 15–18 year olds. Swedish Dental Journal 5: 189–197

Nilner M 1983 Relationships between oral parafunctions and functional disturbances and diseases of the stomatognathic system among children aged 7–14 years. Acta Odontologica Scandinavica 41: 167–172

Nilner M 1985 Functional disturbances and diseases in the stomatognathic system among 7- to 18-year-olds. Journal of Craniomandibular Practice 3: 358–367

Nilner M, Kopp S 1983 Distribution by age and sex of functional disturbances and diseases of the stomatognathic system in 7–18 year olds. Swedish Dental Journal 7: 191–198

Nilner M, Lassing S A 1981 Prevalence of functional disturbances and diseases of the stomatognathic system in 7–14 year olds. Swedish Dental Journal 5: 173–187

Okeson J P 1989 Temporomandibular disorders in children. Pediatric Dentistry 11: 325–329

Olsson M, Lindqvist B 1992 Mandibular function before orthodontic treatment. European Journal of Orthodontics 14: 61–68

Olsson M, Lindqvist B 1995 Mandibular function before and after orthodontic treatment. European Journal of Orthodontics 17: 205–214

Pahkala R, Laine T 1991 Variation in function of the masticatory system in 1008 rural children. Journal of Clinical Pediatric Dentistry 16: 25–30

Perry Jr H T 1973 Adolescent temporomandibular dysfunction. American Journal of Orthodontics 63: 517–525

Planas P 1992 La réhabilitation neuro-occlusale. Masson, Paris, pp. 19–22

Razook S J, Gotcher Jr J E, Bays R A 1989 Temporomandibular joint noises in infants: review of the literature and report of cases. Oral Surgery, Oral Medicine, Oral Pathology 67: 658–664

Reynders R M 1990 Orthodontics and temporomandibular disorders: a review of the literature (1966–1988). American Journal of Orthodontics and Dentofacial Orthopedics 97: 463–471

Ricketts R M 1966 Clinical implications of the temporomandibular joint. American Journal of Orthodontics 52: 416–439

Riolo M L, Brandt D, TenHave T R 1987 Associations between occlusal characteristics and signs and symptoms of TMJ dysfunction in children and young adults. American Journal of Orthodontics and Dentofacial Orthopedics 92: 467–477

Roth R H 1973 Temporomandibular pain-dysfunction and occlusal relationships. Angle Orthodontist 43: 136–153

Sadowsky C, Theisen T A, Sakols E I 1991 Orthodontic treatment and temporomandibular joint sounds. A longitudinal study. American Journal of Orthodontics and Dentofacial Orthopedics 99: 441–447

Sonnesen L, Bakke M, Solow B 1998 Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion. European Journal of Orthodontics 20: 543–559

Stockstill J W, Bowley J F, Dunning D, Spalding P, Stafford K, Erickson L 1998 Prevalence of temporomandibular disorders (TMD) in children based on physical signs. Journal of Dentistry for Children 65: 459–467

Tallents R H, Catania J, Sommers E 1991 Temporomandibular joint findings in pediatric populations and young adults: a critical review. Angle Orthodontist 61: 7–16

Vanderas A P 1988a An epidemiologic approach to the etiologic factors of craniomandibular dysfunction in children and adolescents: the host–agent model. Journal of Craniomandibular Practice 6: 172–178

Vanderas A P 1988b Part I: Calm group. Prevalence of craniomandibular dysfunction in white children with different emotional states. Journal of Dentistry for Children 55: 441–448

Vanderas A P 1989 Prevalence of craniomandibular dysfunction in white children with different emotional states. Part II. Not-calm group. Journal of Dentistry for Children 56: 348–352

Vanderas A P 1992a Prevalence of craniomandibular dysfunction in white children with different emotional states. Part III. A comparative study. Journal of Dentistry for Children 59: 23–27

Vanderas A P 1992b Mandibular movements and their relationship to age and body height in children with or without clinical signs of craniomandibular dysfunction: Part IV. A comparative study. Journal of Dentistry for Children 59: 338–341

Widmalm S E, Christiansen R L, Gunn S M, Hawley L M 1995a Prevalence of signs and symptoms of craniomandibular disorders and oral parafunction in 4–6-year-old African-American and Caucasian children. Journal of Oral Rehabilitation 22: 87–93

Widmalm S E, Gunn S M, Christiansen R L, Hawley L M 1995b Association between CMD signs and symptoms, oral parafunctions, race and sex in 4–6-year-old African-American and Caucasian children. Journal of Oral Rehabilitation 22: 95–100

Widmalm S E, Gunn S M, Christiansen R L 1995c Race and gender as TMD risk factors in children. Journal of Craniomandibular Practice 13: 163–166

Williamson E H 1977 Temporomandibular dysfunction in pretreatment adolescent patients. American Journal of Orthodontics 72: 429–433