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Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion

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SUMMARY The present study reports the prevalence of the various traits of malocclusion, as well as the occurrence of associations between malocclusion, and symptoms and signs of temporomandibular disorders (TMD) in children selected for orthodontic treatment by the new Danish procedure for screening the child population for severe malocclusions entailing health risks.

The sample comprised 104 children (56 F, 48 M) aged 7–13. Malocclusion traits were recorded at the time of selection, symptoms and signs of TMD were recorded at recall. The most prevalent malocclusion traits were distal molar occlusion (Angle Class II; 72 per cent), crowding (57 per cent), extreme maxillary overjet (37 per cent) and deep bite (31 per cent). Agenesis or peg-shaped lateral teeth were observed in 14 per cent of the children. The most prevalent symptom of TMD was weekly headache (27 per cent); the most prevalent signs of TMD were tenderness in the anterior temporal, occipital, trapezius, and superficial and profound masseter muscles (39–34 per cent). Seven per cent of the children were referred for TMD treatment. The Danish TMD screening procedure was positive in 26 per cent, while 20 per cent had severe symptoms (AiII), and 30 per cent had moderate signs (DiII) according to Helkimo (1974). Symptoms and signs of TMD were significantly associated with distal molar occlusion, extreme maxillary overjet, open bite, unilateral crossbite, midline displacement, and errors of tooth formation. The analysis suggests that there is a higher risk of children with severe malocclusions developing TMD. Errors of tooth formation in the form of agenesis or peg-shaped lateral teeth showed the largest number of associations with symptoms and signs of TMD; these associations have not previously been reported in the literature.

Introduction

The relationship between malocclusion traits and symptoms and signs of temporomandibular disorders (TMD) has been extensively studied in the orthodontic literature (for survey, see e.g. Vanderas, 1993; McNamara *et al*., 1995), and TMD is now generally considered to be one of the health risks related to malocclusion (e.g. Brook and Shaw, 1989; Espeland *et al.*, 1992).

Symptoms and signs of TMD and their associations with malocclusion have been less extensively studied in children and adolescents. Olsson and Lindqvist (1992) found that patients in major need of orthodontic treatment had a greater occurrence of symptoms and signs of TMD than those in minor need of orthodontic treatment. Wadhwa *et al*. (1993) found a significant difference between subjects with and without malocclusion as regards Helkimo's Clinical Dysfunction Index, whereas there was no significant difference as regards Helkimo's Anamnestic Dysfunction Index (Helkimo, 1974). Tanne *et al*. (1993) found that the occurrence of symptoms

Table 1 (a) Distribution by sex, age and stage of dental eruption.

Sex	Age (years)							Stage of eruption				Total
	7	8	9	10	11	12	13	DS1	DS2	DS3	DS4	
Girl	5	11	9	6	9	6	10	5	17	24	10	56
Boy	5	4	11	6	3	6	13	4	18	17	9	48
Total	10	15	20	12	12	12	23	9	35	41	19	104

and signs of TMD was more frequent in patients with open bite, deep bite and crossbite than in those with other malocclusion traits. Williamson (1977) reported that 72 per cent of orthodontic patients with symptoms and signs of TMD had either deep bite or open bite.

In Denmark a new system for selecting children for orthodontic treatment has recently been implemented (Danish Ministry of Health, 1990). This system differs in principle from previous index methods and scoring systems by incorporating an assessment of the *health risks* related to each of the various traits of malocclusion. As a result of the introduction of this system, only children with more severe malocclusions are now being offered treatment. The prevalence of the various traits of malocclusion in this group of children will therefore differ from those of the population in general and could also differ from groups of children selected for orthodontic treatment according to other commonly used malocclusion indices and scoring systems. The prevalence of the various types of malocclusion in children selected by this method has not yet been described, nor is it known whether associations between malocclusions, and symptoms and signs of TMD in a group with these severe malocclusions differ from those observed in earlier investigations.

The aim of this study therefore was to report the occurrence of malocclusion traits and the prevalence of symptoms and signs of TMD in a group of children with severe malocclusions, and to describe the associations between malocclusions, and symptoms and signs of TMD in this group.

Subjects

The study was performed at three North Zealand (Denmark) Municipal Dental Health Services (Birkerød, Farum and Fredensborg-Humlebæk). All children selected for orthodontic treatment on the weekdays Monday, Tuesday, and Thursday in the period February to August 1994, were examined prior to orthodontic treatment. The children were selected for orthodontic treatment by the new Danish procedure for screening the child population for severe malocclusions entailing health risks (Danish Ministry of Health, 1990; Appendices I and II). In addition, children in earlier age classes with certain malocclusion traits had been referred for interceptive treatment by paediatric dentists in the Municipal Dental Health Services concerned.

The sample comprised 104 children (56 F, 48 M) aged 7–13 (Table 1a). Most of the children were Caucasian, and none of them had craniofacial anomalies or systemic muscle or joint disorders. Children with temporomandibular disorders (TMD) requiring treatment were later treated for this condition in the Municipal Dental Health Service. The study was approved by the Scientific-Ethical Committee for Copenhagen and Frederiksberg (Ref. no. 03-010/93).

Methods

The study was based on two types of data: existing information from patient dental records about malocclusion traits recorded when they were selected for orthodontic treatment by the orthodontist in charge at the clinic concerned; and the results from a functional examination

Table 1 (b) Prevalence (per cent) of malocclusion traits in 7–13-year-old children in the present study, in unselected reference groups, and in a reference group selected for orthodontic treatment.

Malocclusion traits	Present study	Reference groups		
		Unselected		Selected
		1	2	3
Distal molar occlusion [Angle Class II]	72.1[4]	26.0	14.1	31.4
Mesial molar occlusion [Angle Class III]	1.9	3.9	4.2	7.6
Extreme maxillary overjet	36.5[4]	14.7	8.0	mm
Mandibular overjet	1.9	0.6	–	mm
Anterior crossbite	7.7[2]	–	11.1	–
Deep bite	30.8[1]	17.7	8.4	33.9
Open bite	3.8	2.1	3.6	8.5
Crossbite	22.1[2,3]	12.8	10.7	23.8
Scissors bite	2.9	8.5	2.0	5.0
Midline displacement	12.5	16.7	–	–
Crowding	56.7	42.0	26.3	–
Spacing	13.5	7.8	8.6	–
Agenesis or peg-shaped lateral incisors	13.5[1]	2.0[a]/5.9[b]	0.7[a]/6.1[b]	–

[1]Increase with age; $P < 0.05$ (Logistic regression analysis).
[2]Decrease with age; $P < 0.05$ (Logistic regression analysis).
[3]Decrease with dental stage; $P < 0.05$ (χ^2).
[4]More boys than girls; $P < 0.05$ (χ^2).
1. 11–18 years (Dental Stage DS4), $n = 1.258$, Denmark (Helm and Prydsö, 1979).
2. School children, $n = 5.459$, Sweden (Thilander and Myrberg, 1973).
3. 7–13 years (selected for orthodontic treatment), $n = 118$, Sweden (Olsson and Lindqvist, 1995).
[a]Peg-shaped lateral incisors.
[b]Agenesis.
mm: Reported in mm.
–: Not reported.

undertaken by one of the authors, LS, not more than 2 months after the selection and prior to orthodontic treatment.

Patient dental record information

The malocclusion traits and the stage of dental eruption of each child were diagnosed according to Björk *et al.* (1964) and classified as anomalies of sagittal molar occlusion: distal occlusion ≥ ½ cusp (unilateral, bilateral; Angle Class II), mesial occlusion ≥ ½ cusp (unilateral, bilateral; Angle Class III), sagittal incisor occlusion: extreme maxillary overjet ≥ 6 mm, mandibular overjet ≥ 0 mm, anterior crossbite (1–3 incisors occlude lingual to the lower incisors), vertical incisor occlusion: deep bite ≥ 5 mm, open bite ≥ 0 mm, transverse molar occlusion: posterior crossbite ≥ 1 cusp (unilateral, bilateral), scissors bite ≥ 1 cusp (unilateral, bilateral), midline displacement: ≥ 2 mm, space relationships: crowding ≥ 2 mm (anterior/R/L segment, upper/lower arch), spacing ≥ 2 mm (anterior/R/L segment, upper/lower arch), and errors of tooth formation: absent teeth (excluding third molars) or peg-shaped lateral incisors. The stages of eruption were classified as DS1: incisors erupting (early mixed dentition); DS2: incisors fully erupted (intermediate mixed dentition); DS3: canines or premolars erupting (late mixed dentition); and DS4: canines and premolars fully erupted (adolescent dentition).

Table 2 (a) Prevalence of symptoms (weekly) of TMD in 7–13-year-old children in the present study ($n = 104$)

	n	Per cent	Included in	
			Ai	Screening
Pain, total	39	37.5		
Headache, total	28	26.9[1,2]		x
Headache, total, according to parents	23	22.1		
Headache several times a week	16	15.4		
Headache several times a week according to parents	14	13.5		
Facial pain	13	12.5	x	x
Jaw mobility problems, total	26	25.0		
Difficulty in opening (burger/apple)	7	6.7	x	x
Locking of the jaw (when opening)	12	11.5	x	
Joint sounds (eating/talking)	15	14.4	x	x
Chewing difficulty, total	14	13.5		
Difficulty in biting off (apple/carrot)	7	6.7		
Difficulty in chewing (tough meat)	10	9.6	x	x
Bruxism	23	22.1[3]		

[1]Increase with age; $P < 0.05$ (Logistic regression analysis).
[2]Most in DS3; $P < 0.05$ (χ^2).
[3]Decrease with age; $P < 0.05$ (Logistic regression analysis).
Ai: Anamnestic Dysfunction Index (Helkimo, 1974).
Screening: TMD Screening (Bakke *et al*., 1990b).

Functional examination

The investigation comprised a dental history in the form of an interview of the child and its parents, and a clinical examination, which included a registration of erupted teeth, number of teeth in contact and bite force.

The interview consisted of questions relating to functional disorders (difficulty in jaw opening, biting, and chewing) and pain (headache and facial pain) related to the masticatory system (Table 2a). In addition, the parents were asked whether the child had been examined or treated for headache, about any medication given to the child, and whether the parents had noticed bruxism in the child. If the child had suffered from headaches, a more extensive headache case history was undertaken. The clinical examination (Table 2b) comprised a registration of mandibular mobility and an evaluation of the temporomandibular joints with regard to tenderness of the joint capsule and clicking or grating sounds. Mobility was measured in whole millimetres on opening, lateral excursions and protrusion, taking due account of the vertical and horizontal overjet. Joint sounds were classified as clicking or grating sounds, directly audible, audible through a stethoscope, or as irregularities when palpated. Tenderness was assessed for the masticatory muscles (anterior and posterior temporal, superficial and profound masseter, lateral, and medial pterygoid), and the neck and shoulder muscles (sternocleidomastoid, occipital, trapezius). Tenderness in the muscles and the temporomandibular joints was assessed on each side by unilateral palpation with firm pressure exerted by one or two fingers and by a graduation of the response. Only tenderness that triggered reflex blinking or flinching

Table 2 (b) Prevalence of signs of TMD in 7–13-year-old children in the present study (n = 104).

	n	Per cent	Included in	
			Di	Screening
Joint sounds				
Clicking, total	24	23.1		
Directly audible clicking	3	2.9	x	x
Irregularities on palpation	21	20.2	x	x
Clicking audible through stethoscope	17	16.3		x
Clicking directly audible or through stethoscope	17	16.3		
Crepitation	0	0	x	x
Palpatory tenderness of muscles or joints (unilateral or bilateral)				
All muscles examined	72	69.2		
Masticatory muscles, total	50	48.1		
Anterior temporal	41	39.4	x	x
Posterior temporal	7	6.7	x	
Insertion of temporal tendon on coronoid process	16	15.4	x	
Superficial masseter	37	35.6	x	x
Profound masseter	35	33.7	x	
Lateral pterygoid	16	15.4	x	
Medial pterygoid, palpated intraorally	3	2.9		
Medial pterygoid, palpated extraorally	9	8.7	x	
Neck and shoulder muscles, total	53	51.0		
Sternocleidomastoid	6	5.8		
Occipital	40	38.5		
Trapezius	40	38.5		
Joint capsule, total	8	7.1		
Lateral	7	6.7[1]	x	
Dorsal	1	1.0	x	
Jaw mobility problems				
Pain during jaw movements	1	1.0	x	
Jaw locking or fixation	0	0.0	x	
Reduced or irregular movements, total	36	34.6		
Maximal opening capacity < 30 mm	0	0	x	x
Irregular opening movement > 2 mm	14	13.5	x	
Asymmetrical opening movement > 2 mm	8	7.7	x	
Maximal protrusion < 6 mm	5	4.8	x	
Asymmetrical maximal protrusion < 2 mm	18	17.3		
Maximal lateral movement right/left < 6 mm	0	0	x	

[1]Decrease with age; $P < 0.05$ (Logistic regression analysis).
Di: Clinical Dysfunction Index (Helkimo, 1974).
Screening: TMD Screening (Bakke *et al*., 1990b).

(distinct/marked tenderness) was included (Møller *et al*., 1985; Bakke *et al*., 1990b; Bakke and Kjøller, 1993).

If a child had one or more subjective symptoms and one or more clinical signs, the screening result was classified as positive (Bakke *et al*., 1990b; Bakke and Kjøller, 1993). In addition to this, the children were classified according to Helkimo's indices Ai and Di (Helkimo, 1974). The TMD variables and the variables involved in the TMD screening and Helkimo's indices are shown in Tables 2a and 2b.

The number of teeth in contact in the ICP was assessed from the ability to hold a plastic strip,

0.05 mm thick and 6 mm wide (Hawe Transparent Strips No. 690, straight) between the teeth against a strong pull when the child's teeth were firmly closed (Bakke *et al*., 1990a).

In order to judge the strength of the elevator muscles of the mandible, the children's bite force was measured at the first mandibular molar of each side by a pressure transducer (Flöystrand *et al*., 1982; Bakke *et al.*, 1989). Nine children did not have their bite force measured, either because of large restorations or due to anxiety about the procedure. The peak value of the bite force was measured four times on each side (Model 204B-3, Newport). After a 2–3-minute pause, the measurements were repeated, but in reverse order. The bite force was determined as an average of the 16 measurements (Bakke *et al*., 1989, 1990a).

The children were also diagnosed according to the standardized classifications of facial pain and headache (International Headache Society, 1988; McNeill, 1993; Working Party of the Danish Association for Craniomandibular Disorders). The diagnoses were not included in the analyses, but were made with a view to possible referral for TMD treatment.

Calibration, inter-observer reliability, and method variation

Before the inter-observer examinations, LS was trained and calibrated with one of the other authors, MB, who had used these examination methods routinely. Three inter-observer examinations were then conducted between LS and MB: immediately prior to, during the collection, and after data collection had been completed. Each inter-observer examination was carried out within a period of 2 hours. These examinations comprised, respectively, 12, 12, and 11 adult patients, selected at random from the Department of Oral Diagnosis at the School of Dentistry, University of Copenhagen. All variables and indices in the inter-observer examinations showed good to perfect agreement between LS and MB, assessed by the kappa coefficient (Cohen, 1960).

The method variation of the bite force measurements was determined by LS on 23 randomly selected children, aged 7–14 years, who attended the School of Dentistry for routine dental treatment. These children underwent bite force measurement at intervals of 14 days, using the same method as in the study. There was no significant difference between the two sets of measurements, and the method variation of the individual measurement was $s(i) = 22.1$ N. This is in agreement with Bakke *et al*. (1992). The method variation of the recording of the number of teeth in contact, identical to the method employed in this study, has previously been reported by Bakke and Michler (1991) to be 10 per cent of the average number of teeth, assessed by double recordings at an interval of 1 week.

The method variation of recording of stages of eruption and malocclusion traits has been reported by Helm (1970). He found, from double recordings of the stage of eruption and malocclusion traits by two examiners, that the difference between the two recordings was small, and that there was no significant difference ($P < 0.05$) between them.

Statistical methods

For the discrete data, the effect of sex and stage of eruption was assessed by chi-square tests. The age effect was assessed by logistic regression analysis (Tables 1b, 2a,b, and 3). For bite force, number of erupted teeth and number of teeth in

Table 3 TMD Screening results and Helkimo's indices in 7–13-year-old children in the present study ($n = 104$).

		n	Per cent
Screening	Positive	27	26.0[1]
	Negative	77	74.0
Ai	Ai0	68	65.4
	AiI	15	14.4
	AiII	21	20.2
Di	Di0	35	33.7
	DiI	38	36.5
	DiII	31	29.8
	DiIII	0	0

Screening: TMD Screening (Bakke *et al*., 1990b).
Ai: Anamnestic Dysfunction Index (Helkimo, 1974).
Di: Clinical Dysfunction Index (Helkimo, 1974).
[1]Girls 34.0 per cent, boys 16.7 per cent; $P < 0.05$ (χ^2).

Table 4 (a) Significant differences in the prevalence of symptoms and signs of TMD, positive screening result and Helkimo's indices between children with and without malocclusion traits (n = 104).

Symptoms and signs of TMD	N(TMD)	Malocclusion	N(MAL)	Prevalence of TMD trait in subjects with/without malocclusion trait				
				With		Without		
				n	%	*n*	%	*P*
Pain								
Headache several times a week	14	Unilateral distal molar occlusion	16	5	31.3	9	10.2	*
Headache several times a week	14	Unilateral crossbite	21	6	28.6	8	9.6	*
Palpatory tenderness of muscles or joints								
Tenderness of anterior temporal muscle	41	Agen./peg-shaped inc.	14	10	71.4	31	34.4	**
Tenderness of posterior temporal muscle	7	Agen./peg-shaped inc.	14	3	21.4	4	4.4	*
Tenderness of superficial masseter muscle	37	Agen./peg-shaped inc.	14	10	71.4	27	30.0	**
Tenderness of profound masseter muscle	35	Agen./peg-shaped inc.	14	9	64.3	26	28.9	**
Tenderness of lateral pterygoid muscle	16	Agen./peg-shaped inc.	14	6	42.9	10	11.1	**
Tenderness of occipital muscles	40	Extreme maxillary oj.	38	21	55.3	19	28.8	**
Tenderness of trapezius muscle	40	Open bite	4	4	100.0	36	36.0	*
Jaw mobility problems								
Subjective locking of jaw	12	Agen./peg-shaped inc.	14	5	35.7	7	7.8	**
Asymmetrical opening movement	8	Distal molar occlusion	75	3	4.0	5	17.2	*[1]
Asymmetrical opening movement	8	Extreme maxillary oj.	38	0	0.0	8	12.1	*[1]
Asymmetrical maximal protrusion	18	Midline displacement	13	6	46.2	12	13.2	**
Screening result and indices								
Positive screening result	27	Agen./peg-shaped inc.	14	8	57.1	19	21.1	**
AiI or AiII	36	Agen./peg-shaped inc.	14	9	64.3	27	30.0	*
DiI or DiII	69	Agen./peg-shaped inc.	14	13	92.9	56	62.2	*

N(TMD): Prevalence of TMD trait.
N(MAL): Prevalence of malocclusion trait.
*$P < 0.05$, **$P < 0.01$ (Fisher's exact test).
Agen./peg-shaped inc.: Agenesis or peg-shaped lateral incisors.
Screening: TMD Screening (Bakke *et al*., 1990b).
Ai: Anamnestic Dysfunction Index (Helkimo, 1974).
Di: Clinical Dysfunction Index (Helkimo, 1974).
[1]Negative association.

contact, the effects of age, sex, and stage of eruption were assessed by linear regression analyses. Differences in prevalence were assessed by Fisher's exact test (Table 4a). The agreement in the inter-observer examinations was assessed by the kappa coefficient and the method error of the bite force measurements was calculated by Dahlberg's formula (Dahlberg, 1940). The results were considered to be significant at *P*-values below 0.05. The statistical analyses were performed by the SAS Statistical Program Package (Proc MEANS, Proc FREQ, Proc GLM, Proc CATMOD) (SAS Institute Inc., 1982, 1988).

Results

The prevalences of the variables are reported in Tables 1b, 2a,b, and 3. All variables were tested for associations with gender, age and stage of dental development. The children had on average 24.5 erupted primary and permanent teeth, with an average of 11.8 teeth in contact; the teeth

in contact were distributed either bilaterally in the lateral regions only or in both the lateral and anterior regions. The number of erupted teeth increased with age, and the number of erupted teeth as well as the number of teeth in contact increased with the stage of eruption. No significant sex difference was found with regard to stage of eruption or age (Table 1a). The bite force (mean = 360.4 N, SD = 71.7 N) increased significantly with age, with increasing stage of eruption and with increasing number of teeth in contact. There was no significant difference in bite force between the sexes.

Prevalence of malocclusion traits

In the present study the most prevalent malocclusion traits (Table 1b) were distal molar occlusion (Angle Class II) (72 per cent), crowding (57 per cent), extreme maxillary overjet (37 per cent), and deep bite (31 per cent). Errors of tooth formation were observed in 14 per cent of the children: 11 children with agenesis of second premolars, two children with agenesis of a maxillary lateral incisor, and one child with two peg-shaped maxillary lateral incisors. There were significantly more boys than girls with distal molar occlusion and extreme maxillary overjet. The prevalences of unilateral crossbite and anterior crossbite significantly decreased with age, and the prevalence of unilateral crossbite decreased with stage of eruption. The prevalence of deep bite and errors of tooth formation increased with age.

Prevalence of symptoms and signs of TMD

The most prevalent *symptoms* of TMD (Table 2a) were the occurrence of weekly headache (27 per cent) and bruxism, verified by parents (22 per cent). The occurrence of weekly headache increased with age and there were significantly more children with weekly headache in DS3 than in the other stages of eruption. The occurrence of bruxism in children, according to the evidence of the parents, decreased with age.

The most prevalent clinical *signs* of TMD (Table 2b) were tenderness in the anterior temporal muscle (39 per cent), in the occipital and trapezius muscles (39 per cent), and in the superficial (36 per cent) and profound masseter (34 per cent), as well as clicking assessed by palpation (20 per cent). The only clinical sign that showed a significant correlation with age was lateral tenderness of the joint capsule, which decreased with age.

TMD screening (Table 3) was positive in 26 per cent of the children. There was no significant difference with regard to age and stage of eruption, but significantly more girls than boys (34 per cent girls and 17 per cent boys) had a positive screening result.

Classified according to Helkimo's indices (Table 3), 80 per cent of the children had no or mild subjective symptoms (Ai0, AiI), while 20 per cent had severe symptoms (AiII). Seventy per cent had no or mild clinical signs (Di0, DiI), 30 per cent had moderate clinical signs (DiII), but none of the children had severe clinical signs (DiIII). There was no significant difference in Ai and Di with regard to age, sex, or stage of eruption.

Fourteen per cent of the children had a diagnosis related to the masticatory muscles or the temporomandibular joints. In 7 per cent of the children the condition was so severe that they were referred for TMD treatment.

Associations between malocclusion traits and symptoms and signs of TMD

Symptoms and signs of TMD (Table 4a) were significantly associated with six malocclusion traits (distal molar occlusion, extreme maxillary overjet, open bite, unilateral crossbite, midline displacement, and errors of tooth formation).

Headache several times a week occurred more frequently in children with unilateral distal molar occlusion and unilateral crossbite. There were no associations between joint sounds and malocclusion traits, but tenderness in the neck muscles occurred more frequently in children with extreme maxillary overjet, and tenderness in the shoulder muscles occurred more frequently in children with anterior open bite. Furthermore, tenderness of the masticatory muscles occurred more frequently in children with errors of tooth formation.

Table 4 (b) Significant differences in bite force and number of erupted teeth in children with and without malocclusion traits.

Variable	N(TMD)	Malocclusion	N(MAL)	With trait		Without trait		*P*
				Mean	SD	Mean	SD	
Bite force	95	Unilateral crossbite	16	318.3	55.8	368.9	71.8	**
Erupted teeth	104	Unilateral crossbite	21	23.4	1.5	24.7	2.3	**
Erupted teeth	104	Midline displacemnt	13	22.8	1.8	24.7	2.2	**
Erupted teeth	104	Anterior crossbite	8	23.5	1.1	24.6	2.3	*

N(TMD): prevalence of TMD trait.
N(MAL): prevalence of malocclusion trait.
*$P < 0.05$, **$P < 0.01$ (unpaired *t*-test).

Locking of the jaw occurred more frequently in children with errors of tooth formation. Asymmetrical opening movement occurred less frequently in Class II children (distal molar occlusion and extreme maxillary overjet) and lateral displacement during maximal protrusion occurred more frequently in children with midline displacement. The maximum mean bite force (Table 4b) was signicantly lower in children with unilateral crossbite, and there were significantly fewer erupted teeth in children with unilateral crossbite, midline displacement, and anterior crossbite.

A positive screening result and Helkimo's symptoms (AiI or AiII) and signs (DiI or DiII) occurred more frequently in children with errors of tooth formation. Thus, the malocclusion trait that showed the largest number of associations with symptoms and signs of TMD was errors of tooth formation in the form of agenesis and peg-shaped teeth.

Discussion

This study addresses a problem not previously investigated, namely the occurrence of malocclusion traits and the prevalence of symptoms and signs of TMD in a group of children with severe malocclusions, and the presence of associations between malocclusions, and symptoms and signs of TMD in this group of children.

In the following comparison of the results in the present study with other studies, a distinction will be made between unselected and selected reference groups. The selected reference groups are persons selected for orthodontic treatment, but prior to the start of treatment. The unselected reference groups represent the population in general.

As regards the comparability of the material with other studies, the children had on average 24.5 erupted primary and permanent teeth, with an average of 11.8 teeth in contact. These findings, as well as the average bite force, were in agreement with findings in unselected children at the same age (Bakke *et al.*, 1990a). The high prevalence of malocclusion traits thus did not have any effect on the average number of erupted teeth or number of teeth in contact.

Regarding the validity of the TMD interview, it is uncertain how early children can participate in an interview study of the present type. Nilner and Lassing (1981) judged 7 years of age to be the minimum for a reliable TMD interview, and other authors (Kirveskari *et al.*, 1986; Bakke *et al.*, 1990b) stated that even children up to 10 years of age may be difficult to interview. Another factor of uncertainty is that children can be so co-operative that false positive responses are obtained (Nilner and Lassing, 1981; Nilner, 1985). In order to improve the validity of the present study a parent interview was conducted independently of the patient interview for some anamnestic items. The only disagreement between patient and parent answers was that in some cases, the parents had not been aware of

the child's headaches. This supports the validity of the interview responses from the children.

To facilitate comparison with other studies the clinical examination was performed by standard methods (Helkimo, 1974; Møller *et al*., 1985; Bakke *et al*., 1990b; Bakke and Kjøller, 1993), and an established national screening procedure (Bakke *et al*., 1990b; Bakke and Kjøller, 1993) as well as frequently used international indices (Helkimo, 1974), were employed. Nevertheless, such comparisons must be made with caution. Kopp and Wenneberg (1983) found that inter-observer variability was unacceptably high. On the other hand, Carlsson *et al*. (1980) found that inter-observer consistency between experienced observers was sufficient to allow comparisons between different studies performed by the same technique. In the present study all the variables and the two indices in the three inter-observer examinations showed an agreement that was generally better than reported in previous inter-observer studies (Carlsson *et al*., 1980; Kopp and Wenneberg, 1983; Dworkin *et al*., 1988, 1990; Lobbezoo-Scholte *et al*., 1994; de Wijer *et al*., 1995).

Prevalence of malocclusion traits

As would have been expected, the occurrence of malocclusion traits in the present study and in the Swedish reference group selected for orthodontic treatment (Olsson and Lindqvist, 1995) was much higher than in unselected reference groups (Thilander and Myrberg, 1973; Helm and Prydsö, 1979). Furthermore, the occurrence of distal molar occlusion (72 per cent) was more than twice as frequent in this study as in the Swedish study of children selected for orthodontic treatment (31 per cent; Olsson and Lindqvist, 1995). On the other hand, the occurrence of deep bite and crossbite were similar in these two groups. Space conditions had not been recorded in the Swedish reference group. Differences in the occurrence of malocclusion traits between children selected for orthodontic treatment and unselected children may be of relevance in assessment of results from studies of the association between malocclusion, and symptoms and signs of TMD, since children with a higher occurrence of malocclusion traits might exhibit a higher occurrence of symptoms and signs of TMD. The large difference in the occurrence of distal molar occlusion between the two groups of children selected for orthodontic treatment might conceivably further influence such associations.

A number of age- and maturity-related associations in the occurrence of malocclusion traits were observed. These may be considered as reflecting the professional rationale for selecting the various types of malocclusion for treatment. In addition to the systematic screening of children to be offered orthodontic treatment, unilateral crossbite and anterior crossbite are normally referred for treatment in the early mixed dentition, whereas most other malocclusions are selected for treatment in the late mixed dentition. Similarly, some cases of agenesis are often diagnosed at a relatively late stage of development of the dentition. Thus, the negative association of unilateral crossbite with bite force and number of erupted teeth, and between anterior crossbite and number of erupted teeth is probably due to the effect of age and stage of eruption, since bite force and the number of erupted teeth increased with age and stage of eruption, while the occurrence of unilateral crossbite and anterior crossbite decreased with age and stage of eruption.

Prevalence of symptoms and signs of TMD

The occurrence of symptoms and signs of TMD in this study with a high prevalence of severe malocclusion might be expected to be larger than in studies of unselected groups (Table 5a). In this study, the occurrence of headache and tenderness in the anterior temporal and superficial masseter muscles was indeed more frequent than in the unselected reference groups (Egermark-Eriksson *et al*., 1981; Nilner and Lassing, 1981; Heikenheimo *et al*., 1989; Bakke *et al*., 1990b). Furthermore, there were more frequent positive screening results in this study than in the unselected reference group (Bakke *et al*., 1990b). Also, in the present study the occurrence of tenderness in the anterior temporal and superficial masseter muscles was more frequent than

Table 5 (a) Prevalence (per cent) of symptoms and signs of TMD in 7–13-year-old children in present study and in four unselected (1–4) and two selected (5–6) reference groups.

Symptoms and signs	Present study	Reference groups*					
		Unselected				Selected	
		1	2	3	4	5	6
Symptoms							
Pain (weekly)							
Headache	26.9	9.8	14.0	–	4.2	–	–
Facial pain	12.5	0.5	–	6.0[b]	13.3[c]	–	–
Jaw mobility and chewing difficulty (weekly)							
Joint sounds	14.4	4.5	13.0[a]	0.0[b]	19.2[c]	–	–
Difficulty in opening	6.7	0.4	5.0[a]	0.0[b]	1.8[c]	–	–
Chewing difficulty	10.6	0.5	3.0[a]	–	7.2[c]	–	–
Signs							
Joint sounds (directly audible or through stethoscope)							
Clicking	16.3	14.3	8.0	11.0	–	–	19.0[d]
Crepitation	0	2.8	0.0	0.0	–	–	–
Palpatory tenderness of muscles or joints (unilateral or bilateral)							
Anterior temporal muscle	39.4	3.2	27.0	5.0	–	3.9	5.5
Posterior temporal muscle	6.7	–	7.0	–	–	–	
Insertion of temporal tendon on coronoid process	15.4	–	23.0	21.0	–	23.3	–
Superficial masseter muscle	35.6	2.2	26.0	20.0	–	10.0	8.8
Lateral pterygoid muscle	15.4	–	18.0	25.0	–	23.4	19.0
Medial pterygoid muscle, palpated externally	8.7	–	23.0	–	–	–	10.8[e]
Lateral capsule tenderness	6.7	–	31.0	5.0	–	12.1	–
Dorsal capsule tenderness	1.0	–	22.0	2.0	–	23.1	–
Jaw mobility problems							
Maximal opening capacity < 30 mm	0	0	0	1.0	–	–	–
Asymmetrical opening movement > 2 mm	7.7	–	20.0	6.0	–	–	–
Asymmetrical maximal protrusion > 2 mm	17.3	–	26.0	–	–	–	–
Positive screenings result	26.0	5.2	–	–	–	–	–

Selected: selected for orthodontic treatment.
*Only symptoms and signs that are reported in the reference groups are included in this table.
1. 9–10 years, n = 553; 12–13 years, n = 544 (average), Denmark (Bakke *et al*., 1990b).
2. 7–14 years, n = 440, Sweden (Nilner and Lassing, 1981).
3. 11 years, n = 131, Sweden (Egermark-Eriksson *et al*., 1981).
4. 12 years, n = 167, Finland (Heikinheimo *et al*., 1989).
5. 7–13 years, n = 142, Sweden (Olsson and Lindqvist, 1992).
6. 6–16 years, n = 304, USA (Williamson, 1977).
–, Not reported.
[a]Criteria of occurrence: 'currently'.
[b]Criteria of occurrence: 'frequent'.
[c]Criteria of occurrence: unspecified.
[d]Directly audible or by palpation.
[e]Palpated intra-orally.

Table 5 (b) Distribution (per cent) of Helkimo's indices in 7–13-year-old children in the present study and in two unselected (1,2) and two selected (3,4) reference groups.

Indices	Present study	Reference groups			
		Unselected		Selected	
		1	2	3	4
Ai0	65	–	–	–	85
AiI	14	–	–	–	15
AiII	20	–	–	–	0
Di0	34	54	41	25	20
DiI	37	37	33	23	51
DiII	30	8	24	33	29
DiIII	0	1	2	19	0

Selected: selected for orthodontic treatment.
1. 7, 11, and 15 years (average) $n = 402$, Sweden (Egermark-Eriksson *et al*., 1981).
2. 10–16 years, $n = 156$, Finland, (Könönen *et al*., 1987).
3. 7–20 years, $n = 245$, Sweden (Olsson and Lindqvist, 1992).
4. 13–25 years, $n = 41$, North India (Wadhwa *et al*., 1993).
–, Not reported.

in the selected reference groups (Williamson, 1977; Olsson and Lindqvist, 1992), while the prevalence of clicking in the temporomandibular joint was approximately the same in this study as in the selected and unselected reference groups. The differences between this study and the unselected reference groups in the occurrence of symptoms and signs of TMD supports the existence of an association between malocclusion traits, and symptoms and signs of TMD. These differences are suggested to be due to the selection procedure for children to be offered orthodontic treatment in this study. Thus, there seems to be a higher risk of children with severe malocclusion developing TMD.

As regards the Helkimo Indices (Table 5b), in this study, as well as in the two malocclusion reference groups (Olsson and Lindqvist, 1992; Wadhwa *et al*., 1993) there were somewhat more children who had clinical signs (DiI or DiII or DiIII) than in the unselected reference groups (Egermark-Eriksson *et al*., 1981; Könönen *et al*., 1987). However, in this study there were somewhat fewer children who had clinical signs (DiI or DiII, or DiIII) than in the selected reference groups. A contributory factor for this difference could be a higher mean age in those studies, since Di increased with age.

In view of the more frequent occurrence of symptoms and signs of TMD in the present study than in unselected groups, one would also expect more children to have been referred for TMD treatment. While in adults the need for TMD treatment in unselected groups varies from about 5 to 27 per cent (Wänman and Agerberg, 1986; Magnusson *et al*., 1991; Bakke and Kjøller, 1993), the need for TMD treatment in unselected groups of children is generally considered to be much less than 5 per cent (Okeson, 1989; Bakke *et al*., 1990b; Mintz, 1993). In the present study, 7 per cent of the children were referred for TMD treatment which, as expected, was somewhat more than in unselected groups. This suggests the existence of a somewhat higher risk of children with severe malocclusions needing referral for TMD treatment.

Associations between malocclusion traits and symptoms and signs of TMD

Earlier studies of associations between malocclusion traits and symptoms and signs of TMD in children and adolescents in unselected reference groups are presented in Table 6. Ten of the 12 studies showed significant associations between malocclusion traits, and symptoms and signs of TMD (Egermark-Eriksson *et al*., 1983, 1990; Brandt, 1985; Lieberman *et al*., 1985; Riolo *et al*., 1987; Gunn *et al*., 1988; Jämsä *et al*., 1988; Lous *et al*., 1989; Kritsineli and Shim, 1992; Keeling *et al*., 1994), while two of the studies did not find any such association (Nesbitt *et al*., 1985; de Boever and van den Berghe, 1987). The studies of Brandt (1985) and Riolo *et al.* (1987), based on the same large sample of about 1300 children, showed a comprehensive set of associations. Symptoms and signs of TMD were associated with the occurrence of distal molar occlusion, extreme maxillary overjet, deep bite, open bite, mandibular overjet, and crossbite.

For children selected for orthodontic treatment only a few studies have described associations

Table 6 Survey of studies of associations between malocclusion traits and symptoms and signs of TMD in children and adolescents in 12 unselected groups.

Malocclusion traits	Symptoms/signs	Associations			Not reported/investigated
		Positive	Negative	No	
Distal molar occlusion	Symptoms	(2),6,7,9	1	4,10	3,5,8,11,12
	Signs	2,6,7	–	1,3,12,10	4,5,8,9,11
Mesial molar occlusion	Symptoms	–	–	1,4,7,10	2,3,5,6,8,9,11,12
	Signs	–	–	1,3,7,10,12	2,4,5,6,8,9,11
Extreme maxillary overjet	Symptoms	9	–	1,2,4,6,7,10	3,5,8,11,12
	Signs	2,6,8,10,11	–	1,7,12	3,4,5,9
Mandibular overjet	Symptoms	6	–	2,4	1,3,5,7,8,9,10,11,12
	Signs	2	–	6,12	1,3,4,5,7,8,9,10,11
Deep bite	Symptoms	9	10	1,2,6,7	3,4,5,8,11,12
	Signs	3,11	6,2	1,5,8,10,12	4,7,9
Open bite	Symptoms	–	–	1,2,6,10	3,4,5,7,8,9,11,12
	Signs	2,3,6,11	–	1,5,8,10,12	4,7,9
Crossbite	Symptoms	10	–	1,2,4,6	3,5,7,8,9,11,12
	Signs	1,2,6,10,11	–	3,5,8	4,7,9,12
Scissors bite	Symptoms	–	–	1,4,10	2,3,5,6,7,8,9,11,12
	Signs	–	10	1,8	2,3,4,5,6,7,9,11,12

1. Egermark-Eriksson *et al*. (1983).
2. Brandt (1985).
(2) Only significant in left side.
3. Lieberman *et al*. (1985).
4. Nesbitt *et al*. (1985).
5. de Boever and van den Berghe (1987).
6. Riolo *et al*. (1987).
7. Gunn *et al*. (1988).
8. Jämsä *et al*. (1988).
9. Lous *et al*. (1989).
10. Egermark-Eriksson *et al*. (1990).
11. Kritsineli and Shim (1992).
12. Keeling *et al*. (1994).
–, Not reported.

between malocclusion traits and symptoms and signs of TMD. Tanne *et al.* (1993) in 232 orthodontic patients and 73 cleft lip and palate patients, aged 4–29 years, found that symptoms and signs of TMD were associated with the occurrence of open bite, deep bite, and crossbite. Williamson (1977) in 304 orthodontic patients, aged 6–16 years, found that symptoms and signs of TMD were associated with the occurrence of open bite and deep bite.

In the present study, symptoms and signs of TMD were associated with the occurrence of distal molar occlusion, extreme maxillary overjet, open bite, crossbite, midline displacement, and errors of tooth formation. This comprehensive set of associations is in agreement with those found in the two studies based on the large sample of about 1300 unselected children (Brandt, 1985; Riolo *et al*., 1987), apart from the associations with deep bite and mandibular overjet. This suggests that for the documentation of the high occurrence of significant associations between malocclusion traits, and symptoms and signs of TMD, the present study, based on a relatively small sample of 104 children with a high occurrence of severe malocclusion traits, is as effective as studies based on large samples of unselected children with average occurrence of malocclusion.

The conflicting evidence regarding the presence of associations between malocclusion and symptoms and signs of TMD thus is probably due to differences in methodological factors such as the nature and size of the samples, and the degree of detail used in the recording of malocclusion, and symptoms and signs of TMD in the various studies. The findings in the present study of a large set of associations between specific traits of malocclusion and specific symptoms and signs of TMD are in agreement with and supplement detailed studies of large samples. In the current discussion of procedures for selection of children for orthodontic treatment, this supports the validity of including a TMD-related component in health risk based procedures for selection of children for orthodontic treatment.

Errors of tooth formation in the form of agenesis and peg-shaped lateral teeth showed the largest number of associations with symptoms and signs of TMD. This has not previously been reported in the literature. Associations between agenesis and craniofacial morphology have been described earlier (Wisth *et al.*, 1974; Roald *et al.*, 1982; Sarnäs and Rune, 1983; Nodal *et al.*, 1994) and agenesis often occurs together with other anomalies of the dentition (Hoffmeister, 1985; Bjerklin *et al.*, 1992; Peck *et al.*, 1993). Further research seems required to explain the associations between agenesis, and symptoms and signs of TMD observed in the present study.

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Appendix I: Health risks related to malocclusion

Risk	Malocclusion
I Risk of damage to the teeth and surrounding tissue	
1. Caries	Rarely justifies orthodontic treatment
2. Periodontal lesions	Extreme deep bite
	Pronounced anterior crossbite or reverse overjet
	Pronounced crowding
3. Traumatic dental injuries	Extreme overjet, particularly when the teeth are not protected by the lips
4. Extreme wear of the teeth	Forced bite
	Deep bite with retroclined upper incisors
5. Root resorption of the upper incisors	Unerupted ectopic upper canines
II Risk of functional disorders	
1. Craniomandibular disorders	Forced bite (forwards, backwards, laterally)
	Lack of occlusal stability
2. Chewing and/or incising difficulties	Pronounced anterior or lateral open bite
	Pronounced reverse overjet
	Locking of the bite due to extensive lingual or buccal crossbite
	Pronounced anterior crossbite
3. Speech disorders	Rarely justify orthodontic treatment
III Risk of psychosocial stress	
Teasing, harassment, low self-esteem	Facial deformities, cleft lip
	Extreme overjet
	Reverse overjet
	Pronounced crowding, particularly of the upper incisors and canines
	Pronounced spacing of the upper incisors
IV Risk of late sequelae	
1. Forward migration of the upper incisors	Extreme overjet with lip trap
2. Late development of extreme deep bite	
	Extreme jaw growth in connection with lack of incisal contact
3. Asymmetric facial development	Pronounced lateral lingual or buccal crossbite with forced bite

From Solow (1995).

Appendix II: Orthodontic treatment indications

Malocclusion	Risk code
Unerupted ectopic teeth, particularly upper canines	I.5
Certain cases of agenesis, particularly of upper incisors	III
Extreme overjet, particularly when the incisors are not protected by the lips	I.3, III, IV.1
Pronounced reverse overjet or anterior crossbite with forced bite or locking of the bite	I.2, II.1, II.2, III
Extreme deep bite, particularly with biting of the gingiva or retroclined upper incisors in conjunction with unfavourable jaw growth	I.2, I.4, II.1, IV.2
Pronounced open bite	II.2
Comprehensive lateral lingual or buccal crossbite with forced bite or locking of the bite	I.4, II.1, II.2, IV.3
Pronounced crowding, particularly of the maxillary incisors and canines	I.2, III
Pronounced spacing of upper incisors, particularly in cases of agenesis of upper incisors	III
Combinations of malocclusions, which are not as serious considered individually, but whose severity in combination corresponds to the above-mentioned	I, II, III, IV
Malocclusions related to facial malformations	III

Malocclusions that should be treated due to health risk. The list is arranged according to type of malocclusion (anomalies of dentition, occlusion, spacing), not according to 'severity'. The Risk codes refer to the classification in Appendix I (Solow, 1995).