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# Temporomandibular disorders in relation to craniofacial dimensions, head posture and bite force in children selected for orthodontic treatment

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SUMMARY The present study examined the associations between craniofacial dimensions, head posture, bite force, and symptoms and signs of temporomandibular disorders (TMD). The sample comprised 96 children (51F, 45M) aged 7–13 years, sequentially admitted for orthodontic treatment of malocclusions entailing health risks. Symptoms and signs of TMD were assessed by 37 variables describing the occurrence of headache and facial pain, clicking, jaw mobility, tenderness of muscles and joints, and the Helkimo Anamnestic and Dysfunction indices. Craniofacial dimensions (33 variables), and head and cervical posture (nine variables) were recorded from lateral cephalometric radiographs taken with the subject standing with the head in a standardized posture (mirror position). Dental arch widths were measured on plaster casts and bite force was measured at the first molars on each side by means of a pressure transducer. Associations were assessed by Spearman correlations and multiple stepwise logistic regression analyses.

The magnitudes of the significant associations were generally low to moderate. On average, temporomandibular joint (TMJ) dysfunction was seen in connection with a marked forward inclination of the upper cervical spine and an increased craniocervical angulation, but no firm conclusion could be made regarding any particular craniofacial morphology in children with symptoms and signs of TMJ dysfunction. Muscle tenderness was associated with a 'long face' type of craniofacial morphology and a lower bite force. Headache was associated with a larger maxillary length and increased maxillary prognathism. A high score on Helkimo's Clinical Dysfunction Index was associated with smaller values of a number of vertical, horizontal, and transversal linear craniofacial dimensions and a lower bite force.

## Introduction

The term 'temporomandibular disorders' (TMD) refers to symptoms and signs associated with pain and functional and structural disturbances of the masticatory system, especially the temporomandibular joints (TMJ) and the masticatory muscles. Textbooks and clinicians generally agree that the most important symptoms and signs of TMD are headache, tenderness in the masticatory muscles and the TMJ, reduced or impaired mobility of the mandible, and TMJ sounds (e.g. Bush and Dolwick, 1995). The general opinion is that the aetiology of TMD is multifactorial, with structures, function, occlusion, stress, trauma, and hypermobility as risk or contributing factors (Solberg *et al*., 1972; Egermark-Eriksson *et al*., 1981; Nilner and Lassing, 1981; Geissler, 1985; Ash, 1986; Bakke and Møller, 1992; Olsson and Lindqvist, 1992, 1995; Westling, 1992; Bakke, 1993; Sessle *et al*., 1995; Okeson, 1996; Henrikson, 1999).

The question of whether or not the occurrence of malocclusion traits are related to symptoms and signs of TMD has attracted considerable interest (for surveys see Reynders, 1990; Tallents

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*et al.*, 1991; Vanderas, 1993; Henrikson, 1999). Moreover, a number of studies have examined whether particular characteristics of craniofacial morphology could be observed in subjects with symptoms and signs of TMD (Dibbets *et al.*, 1985; Stringert and Worms, 1986; Huggare and Raustia, 1992; Keeling *et al.*, 1992; Brand *et al.*, 1995; Dibbets and van der Weele, 1996; Nebbe *et al.*, 1997, 1999a,b; Bosio *et al.*, 1998; Muto *et al.*, 1998). Most of these studies have focused on patients with symptoms and signs of TMJ dysfunction, assessed anamnestically, clinically by palpation or auscultation, or by radiographs or magnetic resonance imaging (MRI) scanning of the TMJs. Thus, Dibbets *et al.* (1985) in pre-orthodontic children with TMD found a shorter mandible, a lower posterior facial height, and a larger jaw angle and mandibular plane inclination. Brand *et al.* (1995) and Dibbets and van der Weele (1996) in adult TMD patients with disc displacement assessed by MRI, or evidenced by clicking, found sagittally shorter maxillary and mandibular lengths. Nebbe *et al.* (1997, 1999a,b) in adolescent pre-orthodontic patients with disc displacement assessed by MRI found a smaller posterior to anterior face height ratio. Muto *et al.* (1998) in adult pre-orthognathic Class III patients with disc displacement evidenced by clicking or restricted mouth opening reported a larger mandibular plane inclination, and Bosio *et al.* (1998) in adult TMD patients with disc displacement assessed by MRI found a somewhat retrognathic mandible.

The different and sometimes conflicting findings reported above may, to some extent, have been due to differences in the designs and methodologies used in the various studies. Moreover, many studies include only few symptoms and signs of TMD or few cephalometric variables. So far, no systematic screening has been made of the pattern of associations between the symptoms and signs of TMD, and traits of craniofacial morphology and posture.

The aim of the present study was to examine whether any consistent pattern of associations could be found between the occurrence of symptoms and signs of TMD, craniofacial dimensions, and head and cervical posture in a group of children selected for orthodontic treatment by screening the child population for malocclusions.

## Subjects

The sample comprised 96 children (51 girls and 45 boys) aged 7–13 years (Table 1), admitted for orthodontic treatment at three Municipal Dental Health Services in North Zealand, Denmark. The children were selected by the Danish procedure for screening the child population for malocclusions entailing health risks (Danish Ministry of Health, 1990; Solow, 1995; Appendices I and II) by the orthodontic specialist in charge at the clinic concerned. Most of the children were Caucasian, and none had craniofacial anomalies or systemic muscle or joint disorders. The sample was obtained from that reported by Sonnesen (1997) and Sonnesen *et al.* (1998) after exclusion of subjects with insufficient quality of cephalometric radiographs. The prevalences of malocclusion according to the Angle classification were 26 (27 per cent) Class I, 69 (72 per cent)

**Table 1** Distribution by sex, age and stage of eruption.

| | Age in years | | | | | | | Stage of eruption (DS)[1] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | 7 | 8 | 9 | 10 | 11 | 12 | 13 | DS1 | DS2 | DS3 | DS4 | Total |
| Girls | 4 | 10 | 8 | 6 | 9 | 5 | 9 | 4 | 16 | 22 | 9 | 51 |
| Boys | 4 | 4 | 10 | 5 | 3 | 6 | 13 | 4 | 16 | 16 | 9 | 45 |
| Total | 8 | 14 | 18 | 11 | 12 | 11 | 22 | 8 | 32 | 38 | 18 | 96 |

[1]Stage of eruption (DS) according to Björk *et al.* (1964): DS1: incisors erupting; DS2: incisors fully erupted; DS3: canines or premolars erupting; DS4: canines and premolars fully erupted.

Class II, and 1 (1 per cent) Class III cases. The study was approved by the Scientific-Ethical Committee for Copenhagen and Frederiksberg (Ref. no. 03–010/93).

*Methods*

The study was based on four types of examination: a functional examination performed by one of the authors (LS) prior to the orthodontic treatment, cephalometric radiographs, casts of the dental arches, and records of the maximal unilateral bite force.

*Functional examination*. The examination comprised an interview of the child and a clinical examination (Table 2).

The interview consisted of standardized questions relating to functional disorders (difficulties in jaw opening, biting and chewing) and pain (facial pain and headache) related to the masticatory system. The clinical examination comprised a registration of mandibular mobility, and an evaluation of the TMJs with regard to tenderness of the joint capsule and clicking or grating sounds. Mobility was measured in millimetres on maximal opening, lateral excursions and protrusion, taking due account of the overbite and overjet. Joint sounds were classified as clicking or grating sounds directly audible, audible by auscultation with a stethoscope, or noticeable as irregularities when palpated. Tenderness was assessed for the masticatory muscles (anterior and posterior temporal, superficial and deep masseter, lateral and medial pterygoid), and neck and shoulder muscles (sternocleidomastoid, occipital, trapezius). Tenderness in the muscles and the lateral and dorsal TMJ capsules was assessed on each side by unilateral palpation with firm pressure exerted by one or two fingers and by a gradation of the response. Only tenderness that triggered reflex blinking or flinching was recorded (e.g Bakke and Michler, 1991). The assessment of tenderness in the dorsal joint capsule was made by palpation through the meatus acusticus. A total of 61 TMD-variables were recorded. Of these, 54 related to bilateral items. In the analysis, each pair of bilateral variables was replaced by a single variable, which was recorded when one or both sides were affected.

Based on the TMD registrations some combined variables were constructed. The variable 'any muscles' was recorded when tenderness in any masticatory, shoulder, or neck muscle had been recorded. The children were also classified according to Helkimo's Anamnestic Index (Ai) and Clinical Dysfunction Index (Di), and assigned a score, 0, I, II for Ai, and 0, I, II, III for Di (Helkimo, 1974).

Thus, a total of 37 TMD variables were initially included in the analysis. Details concerning the TMD interview and the clinical examination have been previously reported (Sonnesen, 1997).

*Bite force*. In order to assess the strength of the mandibular elevator muscles, the maximal unilateral bite force was measured in all subjects.

The recordings were made at the first mandibular molars on each side by means of a pressure transducer (Flöystrand *et al*., 1982) during 1–2 seconds maximal clenching. The peak value of the bite force was measured four times on each side and was repeated in reverse order after a 2–3-minute interval. The bite force was determined as the average of the 16 measurements (Bakke *et al*., 1989)

*Cephalometric analysis*. The profile radiographs were taken with the teeth in occlusion and in the natural head posture (mirror position) as described by Siersbæk-Nielsen and Solow (1982). The radiographs were taken in a Dana Cephalix cephalostat with a film-to-focus distance of 180 cm and a film-to-median plane distance of 10 cm. No correction was made for the constant linear enlargement of 5.6 per cent. An aluminium wedge placed between the cassette and the patient's face, and a movable grid was used to increase the sharpness of the image. The reference points were marked and digitized directly on the radiographs (Figure 1), and 42 variables describing the craniofacial morphology and head posture were calculated (Table 3).

*Upper and lower dental arch widths*. The upper and lower dental arch widths were measured on the plaster casts. The measuring points were

**Table 2** Prevalence of subjective symptoms and clinical signs of TMD in 7- to 13-year-old Danish pre-orthodontic children ($n = 96$).

| Variables | | | | *n* | % |
|---|---|---|---|---|---|
| **Subjective symptoms** | | | | | |
| *Pain* | | | | | |
| T01 | Headache (weekly) | | | 25 | 26.0 |
| T02[2] | Facial pain (weekly) | | | 12 | 12.5 |
| *Jaw mobility problems* | | | | | |
| T03 | Difficulty in opening (burger/apple) | | | 7 | 7.3 |
| T04 | Locking of the jaw | | | 11 | 11.5 |
| T05[2] | Joint sounds (eating/talking) | | | 14 | 14.6 |
| *Chewing difficulty* | | | | | |
| T06[2] | Difficulty in biting off (apple/raw carrot) | | | 6 | 6.3 |
| T07[2] | Difficulty in chewing (tough meat) | | | 9 | 9.4 |
| **Clinical signs** | | | | | |
| *Clicking* | | | | | |
| T08[1] | Directly audible | | | 2 | 2.1 |
| T09 | Audible through stethoscope | | | 15 | 15.6 |
| T10 | Irregularities on palpation | | | 18 | 18.8 |
| *Crepitation* | | | | | |
| T11[1] | Directly audible | | | 0 | 0.0 |
| T12[1] | Audible through stethoscope | | | 0 | 0.0 |
| T13[1] | Irregularities on palpation | | | 0 | 0.0 |
| *Palpatory tenderness of muscles or joints* | | | | | |
| T14 | Anterior temporal | | | 38 | 39.6 |
| T15[2] | Posterior temporal | | | 5 | 5.2 |
| T16[2] | Temporal tendon on coronoid process | | | 15 | 15.6 |
| T17 | Superficial masseter | | | 35 | 36.5 |
| T18 | Profound masseter | | | 32 | 33.3 |
| T19[2] | Lateral pterygoid | | | 15 | 15.6 |
| T20[1] | Medial pterygoid, palpated intraorally | | | 3 | 3.1 |
| T21[2] | Medial pterygoid, palpated extraorally | | | 9 | 9.4 |
| T22[1] | Sternocleidomastoid | | | 4 | 4.2 |
| T23[2] | Back of neck | | | 36 | 37.5 |
| T24 | Shoulder muscles | | | 36 | 37.5 |
| T25 | Lateral joint capsule | | | 7 | 7.3 |
| T26[1] | Dorsal joint capsule | | | 1 | 1.0 |
| T27 | Any muscles | | | 67 | 69.8 |
| *Jaw mobility problems* | | | | | |
| T28[1] | Pain on jaw movement | | | 1 | 1.0 |
| T29[1] | Jaw locking or fixation | | | 0 | 0.0 |
| T30[1] | Maximal opening capacity < 30 mm | | | 0 | 0.0 |
| T31 | Irregular opening movement > 2 mm | | | 13 | 13.5 |
| T32 | Asymmetrical opening (maximal gape) > 2 mm | | | 6 | 6.3 |
| T33[1] | Maximal protrusion < 6 mm | | | 4 | 4.2 |
| T34 | Asymmetrical maximal protrusion < 2 mm | | | 18 | 18.8 |
| T35[1] | Maximal lateral movement < 6 mm | | | 0 | 0.0 |
| *Helkimo Indices (scores)* | | 0 | I | II | III |
| T36[2] | Ai (%) | 66 | 15 | 20 | – |
| T37 | Di (%) | 32 | 39 | 29 | 0 |

[1]Variable not included in analysis of associations due to a prevalence less than 5 per cent.
[2]Variable with no significant association with morphology or posture.

defined as the mesial contact points of the first molars on the right and left side (Solow, 1966). The distance between the two points was measured by digital sliding callipers (Table 3). If the tooth was rotated or damaged on the mesial surface, the corresponding point on the distal

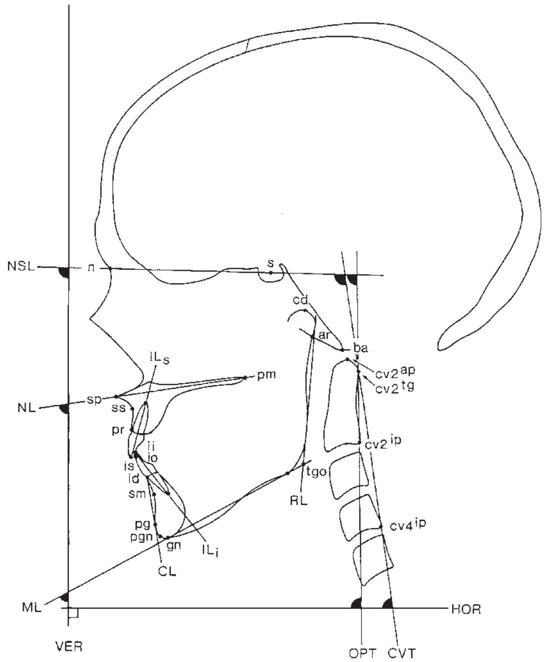


**Figure 1** Reference points and lines according to Solow and Tallgren (1976). io: projection of the incision inferius on a line through the incision superius and the distobuccal cusp of the upper first molar.

surface of the second premolar or the second primary molar was used.

*Reliability and calibration.* The reliability of the functional registration was determined by inter-observer examinations before, during, and after the data collection (Sonnesen *et al.*, 1998). Before the inter-observer examinations, LS was trained and calibrated with one of the other authors, MB, who is a stomatognathic physiologist. 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 reliability of the bite force measurements was determined on 23 randomly selected children in the same age group as the subjects in the study having dental treatment in the Department of Pedodontics, School of Dentistry, University of Copenhagen. These children underwent bite-force measurements 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 error (Dahlberg, 1940) of the individual measurements was $s(i)$ = 22.1 N.

**Table 3** Craniofacial morphology, head posture and bite force in 7- to 13-year-old Danish pre-orthodontic children ($n$ = 96).

| Variable | | Mean | SD |
|---|---|---|---|
| *Linear morphological variables (mm)* | | | |
| M01 | n–s | 69.08 | 3.06 |
| M02 | n–ba | 102.37 | 5.18 |
| M03 | n–ar | 91.80 | 4.66 |
| M04 | n–sp | 48.96 | 3.54 |
| M05 | n–gn | 109.94 | 7.00 |
| M06 | s–ba | 42.89 | 3.82 |
| M07 | s–ar | 33.24 | 3.07 |
| M08 | s–pm | 45.02 | 3.02 |
| M09 | s–tgo | 72.46 | 6.18 |
| M10 | sp–gn | 63.06 | 5.01 |
| M11 | ar–tgo | 42.79 | 4.28 |
| M12 | sp–pm | 51.64 | 3.13 |
| M13 | ss–pm | 47.12 | 2.78 |
| M14 | pgn–cd | 106.93 | 6.72 |
| M15 | pg–tgo | 72.51 | 4.94 |
| M16[1] | Overjet (is–io) | 5.72 | 2.64 |
| M17[1] | Overbite (ii–io) | 2.86 | 2.31 |
| M18[2] | Width 6+6 | 41.82 | 3.08 |
| M19[3] | Width 6–6 | 39.53 | 2.34 |
| *Angular morphological variables (degrees)* | | | |
| M20 | n–s–ba | 130.96 | 4.65 |
| M21 | n–s–ar | 123.84 | 4.60 |
| M22 | s–n–sp | 86.18 | 3.48 |
| M23 | s–n–ss | 80.69 | 3.39 |
| M24 | s–n–sm | 76.94 | 2.77 |
| M25 | s–n–pg | 77.60 | 3.02 |
| M26 | ss–n–sm | 3.76 | 2.12 |
| M27 | ss–n–pg | 3.09 | 2.68 |
| M28 | NSL/NL | 6.96 | 2.63 |
| M29 | NSL/ML | 32.43 | 5.64 |
| M30 | NL/ML | 25.48 | 5.38 |
| M31 | ML/RL | 125.08 | 6.64 |
| M32[1] | ILs/NL | 108.87 | 8.37 |
| M33 | ILi/ML | 95.10 | 6.74 |
| M34 | pr–n–ss | 2.07 | 1.13 |
| M35 | CL/ML | 72.01 | 4.70 |
| *Angular postural variables (degrees)* | | | |
| P01 | NSL/VER | 96.28 | 6.10 |
| P02 | NL/VER | 89.32 | 5.88 |
| P03 | NSL/OPT | 94.64 | 7.53 |
| P04 | NSL/CVT | 98.93 | 7.93 |
| P05 | NL/OPT | 87.68 | 7.64 |
| P06 | NL/CVT | 91.97 | 7.97 |
| P07 | OPT/HOR | 91.64 | 7.60 |
| P08 | CVT/HOR | 87.35 | 7.28 |
| P09 | OPT/CVT | 4.29 | 2.66 |
| *Bite force (N)* | | | |
| B01 | Bite force | 360.4 | 71.7 |

[1]N = 95; [2]N = 76; [3]N = 73.

The reliability of the cephalometric measurements was assessed by remeasurement of 26 lateral radiographs selected at random from the previously recorded radiographs. The reference points were removed from the films, marked and digitized again, and the differences between the two sets of recordings were calculated. Significant differences were found for a number of variables. The definitions of some reference points (cd, pgn, pg, and ii) were therefore further specified. All 96 radiographs were checked again for the location of these points, and corrected and re-recorded if necessary. After corrections, there were no significant differences between the two sets of recordings. The method errors ranged from 0.21 to 0.83 degrees or mm (Dahlberg, 1940) and the reliability coefficients from 0.97 to 1.00 (Houston, 1983).

The reliability of the dental arch width measurements was determined on 30 randomly selected sets of study casts from a collection of study casts at the Department of Orthodontics, School of Dentistry, University of Copenhagen, measured twice with an interval of 1 week. The analysis showed no significant differences between the two sets of recordings. The method errors were 0.13 and 0.17 mm (Dahlberg, 1940), and the reliability coefficients 1.00 and 0.99 (Houston, 1983).

*Statistical methods*. Associations between the occurrence of each of the symptoms and signs of TMD and the variables describing craniofacial morphology, head and cervical posture and bite force were assessed by Spearman rank order correlation coefficients, and differences in means were assessed by unpaired *t*-tests. In these analyses gender and age groups were pooled and TMD variables that occurred with a prevalence of less than 5 per cent were excluded.

Possible effects of gender, age, and dentitional stage were assessed by multiple logistic regression analysis with stepwise backwards elimination. In logistic regression analysis, the significance of the results depends not only on the sample size, but also the prevalence of the dependent variable, and on the number and sequence of independent variables. In the present study of about 100 subjects only TMD traits that occurred in more than 10 subjects were analysed, and only one morphological or postural variable was used as the independent variable together with gender, age, and dentitional stage in each logistic regression analysis. The multiple correlation coefficients ($R^2$) in the logistical regression analyses were calculated according to Nagelkerke (1991). The normality of the distributions was assessed by the parameters of skewness and kurtosis and by Shapiro–Wilks *W*-test. The results were considered to be significant at *P*-values below 0.05. The statistical analyses were performed by the SAS Statistical Programme Package (SAS Institute Inc., 1982, 1988). The complete listing of all tests has been reported by Sonnesen (1997).

## Results

There were no gender differences in the distributions of stage of dental eruption and age (Table 1). The prevalences of symptoms and signs of TMD are presented in Table 2. Assessed by Helkimo's anamnestic and clinical indices 35 per cent of the subjects had mild or severe symptoms (AiI and AiII), and 68 per cent had mild or moderate signs (DiI and DiII). These data have previously been discussed in detail (Sonnesen *et al*., 1998). Data for craniofacial morphology, head posture, and bite force are presented in Table 3. Most of these variables were normally distributed, although a few variables showed moderate deviations from normal distribution form (ar-tgo, overbite, NSL/CVT, NL/CVT). Among the associations between TMD and morphology or posture only one (Table 4: irregular opening versus s–ar) was found to be due to a common dependence on gender, age, or dentitional stage.

Twelve TMD variables that occurred with a prevalence of less than 5 per cent (Table 2) were not included in the analysis of associations, and 10 that showed no significant association with morphology or posture were not included in the tables (Tables 4–7). After this, 15 TMD variables remained. In the analysis of the associations, the main emphasis was placed on those that appeared in clusters, in order to avoid the effect of statistical type 1 errors. In the tables, the

**Table 4** Average significant differences in morphological (mm or degrees) variables between subjects with and without symptoms and signs of TMJ dysfunction.

| Morpho-logical variables | | T03 Difficulty in opening *n* = 7 | T10 Clicking, palpation *n* = 18 | T09 Clicking, stethoscope *n* = 15 | T04 Locking of the jaw *n* = 11 | T31 Irregular opening *n* = 13 | T32 Asymmetric opening *n* = 6 | T34 Asymmetric protrusion *n* = 18 | T25 Tenderness, joint capsule *n* = 7 |
|---|---|---|---|---|---|---|---|---|---|
| M07 | s–ar | . | . | . | . | 1.87*[2] | . | . | . |
| M12 | sp–pm | 2.49*[1] | . | . | 2.09* | . | . | . | . |
| M05 | n–gn | . | . | . | . | . | . | 3.61*[1] | . |
| M11 | ar–tgo | . | . | . | . | . | . | . | –3.63* |
| M22 | s–n–sp | . | 2.27* | 2.47* | . | . | . | . | . |
| M23 | s–n–ss | . | 1.74*[1] | . | . | . | . | . | . |
| M26 | ss–n–sm | . | 1.39* | . | . | . | –1.05***[1] | –1.18* | . |
| M27 | ss–n–pg | 2.17*[1] | 1.92** | . | . | . | . | . | . |
| M31 | ML/RL | . | –2.93* | –2.67*[1] | . | –4.42* | . | . | . |
| M34 | pr–n–ss | . | . | –0.72* | . | . | . | . | . |
| M35 | CL/ML | . | 4.18*** | . | . | . | . | . | . |
| M16 | Overjet | 2.06* | . | . | . | . | . | . | . |

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
[1]Spearman correlation not significant.
[2]The prevalence of irregular opening decreased with age. Variables with no significant differences have been deleted from the table.

**Table 5** Average significant differences in postural (degrees) variables between subjects with and without symptoms and signs of TMJ dysfunction.

| Postural variables | | T03 Difficulty in opening *n* = 7 | T09 Clicking, stethoscope *n* = 15 | T04 Locking of the jaw *n* = 11 | T32 Asymmetric opening *n* = 6 |
|---|---|---|---|---|---|
| P03 | NSL/OPT | . | . | 5.20* | . |
| P04 | NSL/CVT | . | . | 5.47** | . |
| P05 | NL/OPT | . | . | 5.83* | 6.90* |
| P06 | NL/CVT | . | . | 6.10*** | 6.69* |
| P07 | OPT/HOR | . | –5.28* | –7.78*** | –6.46*[1] |
| P08 | CVT/HOR | –5.75* | –4.88* | –8.04*** | –6.24* |
| P09 | OPT/CVT | . | . | . | . |

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.
[1]Spearman correlation not significant.
Variables with no significant differences have been deleted from the table.

associations are represented by the statistically significant mean differences in the various morphological and postural variables between subjects with and without each trait of TMD. These associations were in most cases also statistically significant when assessed by the Spearman correlation coefficient, and, for TMD traits that occurred in more than 10 subjects, also when assessed by stepwise logistical regression analysis. The results from the Spearman correlation analyses and the logistical regression analyses are not shown in Tables 4–6. The significant Spearman correlation coefficients were generally low to moderate, the numerical values ranging from 0.21 to 0.37. The associations with the Ai and Di variables were assessed only by Spearman correlations and by stepwise logistical regression analysis.

The significant associations were grouped into four main categories of TMD variables, namely

(1) symptoms and signs of TMJ dysfunction;
(2) tenderness of the masticatory, neck, and shoulder muscles;
(3) headache;
(4) Helkimo's indices.

In the present study, *TMJ dysfunction* was represented by 19 variables (T03–T13, T28–T35). Ten of these occurred with a prevalence of 5 per cent or more, and eight of these showed significant cluster associations with morphology or posture (Tables 4 and 5). Children with clicking assessed by palpation or auscultation had, on average, almost 2.5 degrees larger maxillary prognathism (M22–M23), 1–2 degrees larger sagittal jaw relationship (M26–M27), 0.7 degrees smaller maxillary alveolar prognathism (M34), approximately 4 degrees larger mandibular alveolar prognathism (M35), and about 3 degrees smaller gonial angle (M31) than children without clicking. Moreover, children with clicking assessed by auscultation had a cervical posture (P07–P08) which was approximately 5 degrees more proclined. Children with locking of the jaw during opening had on average 5–6 degrees more extended craniocervical posture (P03–P06) and about 8 degrees more proclined cervical posture (P07–P08) than those without locking of the jaw. Children with asymmetrical opening movement had, on average, almost 7 degrees more extended craniocervical posture (P05–P06) and almost 6.5 degrees more proclined cervical posture (P07–P08) than those without asymmetrical opening movement. The strongest association was observed between locking of the jaw and cervical posture ($r_S = -0.37$, $R^2 = 0.26$).

Palpatory tenderness of muscles (Table 6) showed several clusters of significant associations. Children with tenderness of the masseter and

**Table 6** Average significant differences in morphological, postural, and bite force variables between subjects with and without tenderness of muscles or headache.

| | | T14 Anterior temporal *n* = 38 | T17 Superficial masseter *n* = 35 | T18 Profound masseter *n* = 32 | T24 Shoulder muscles *n* = 36 | T27 One or more muscles *n* = 67 | T01 Headache, weekly *n* = 25 |
|---|---|---|---|---|---|---|---|
| *Morphological variables (mm or degrees)* | | | | | | | |
| M12 | sp–pm | . | . | . | . | . | 2.17** |
| M13 | ss–pm | . | . | . | . | . | 1.46* |
| M09 | s–tgo | –2.96* | –2.96* | –2.75* | . | . | . |
| M11 | ar–tgo | –2.00* | –2.00* | . | . | . | . |
| M14 | pgn–cd | –3.76** | –3.12* | . | . | . | . |
| M19 | Width 6–6 | . | –1.36* | –1.31* | . | –1.35* | . |
| M20 | n–s–ba | . | . | . | 2.02* | . | . |
| M22 | s–n–sp | . | . | . | . | . | 1.64* |
| M24 | s–n–sm | . | . | . | –1.27* | –1.22* | . |
| M25 | s–n–pg | . | . | . | –1.53* | –1.58* | . |
| M29 | NSL/ML | . | . | . | 3.20** | 2.79* | . |
| M30 | NL/ML | . | . | . | 2.98** | . | . |
| M17 | Overbite | . | . | . | –1.00*[1] | . | . |
| *Postural variables (degrees)* | | | | | | | |
| P03 | NSL/OPT | . | . | . | . | 4.25* | . |
| P05 | NL/OPT | . | . | . | . | 3.46*[1] | . |
| P09 | OPT/CVT | . | . | . | . | –1.40* | . |
| *Bite force (N)* | | | | | | | |
| B01 | Bite force | –36.5* | –33.3* | . | . | . | . |

$^*P < 0.05$; $^{**}P < 0.01$.
[1]Spearman correlation not significant. Variables with no significant differences have been deleted from the table.

anterior temporal muscles had, on average, 2–3 mm shorter posterior face height (M09–M11), 3 mm shorter mandibular length (M14), and somewhat narrower lower dental arch width (M19) than those without tenderness of these muscles. Children with tenderness of the trapezius muscles had, on average, 2 degrees larger cranial base angle (M20), about 3 degrees larger mandibular inclination and vertical jaw relationship (M29–M30) and about 1.5 degrees smaller mandibular prognathism (M24–M25) than those without tenderness of these muscles. Children with tenderness of one or more masticatory, neck or shoulder muscles furthermore had on average about 4 degrees more extended craniocervical posture (P03, P05) than those without tenderness of any muscles, and about 1.5 mm smaller cervical lordosis (P09).

Children with muscle tenderness of the anterior temporal and the superficial masseter (Table 6) also had significantly lower bite force than those without tenderness of these muscles, and the bite force showed a significant negative correlation with the Helkimo Clinical Dysfunction Index (Table 7).

Children reporting weekly headache (Table 6) had about 2 mm larger maxillary length (M12–M13) and about 1.5 degrees larger maxillary prognathism (M22) than those without headache.

**Table 7** Correlations between morphological and bite-force (mm or N) variables and the Clinical Dysfunction Index (Di).

| Morphological variables | | T37 Di |
|---|---|---|
| M02 | n–ba | –0.26* |
| M06 | s–ba | –0.28** |
| M07 | s–ar | –0.27** |
| M08 | s–pm | –0.24* |
| M09 | s–tgo | –0.30** |
| M11 | ar–tgo | –0.26* |
| M05 | n–gn | –0.23* |
| M10 | sp–gn | –0.23* |
| M14 | pgn–cd | –0.27** |
| M15 | pg–tgo | –0.21* |
| M18 | Width 6+6 | –0.28* |
| M19 | Width 6–6 | –0.28* |
| B01 | Bite force | –0.27** |

*$P < 0.05$; **$P < 0.01$.
Variables with no significant correlations have been deleted from the table.

Children with a high score on Helkimo's Clinical Dysfunction Index (Table 7) had, on average, smaller values for a number of vertical, horizontal and transversal linear craniofacial dimensions (M2, M05–M11, M14–M15, M18–M19). Logistical regression analyses of each subcategory of these indices as well as multiple linear regression analyses of the scored indices showed that these associations were not due to the effect of gender, age or dental development. The Di index showed no significant associations with angular dimensions, and the Ai index showed no significant associations with any morphological or postural variables.

## Discussion

The present paper is exploratory in nature, and reports the results of systematic screening for associations between the occurrence of 16 TMD variables and 44 variables describing craniofacial morphology and head and cervical posture in a sample of 96 pre-orthodontic children with severe malocclusion. In order to reduce the effect of statistical type I errors, only those associations that occurred in clusters of related variables were considered in the interpretation of the findings. In the following, the associations with craniofacial morphology and with posture are considered separately.

### *Associations between TMD and craniofacial morphology*

Children with TMJ dysfunction as evidenced by clicking, assessed by palpation or auscultation, on average, showed a craniofacial morphology characterized by a set of traits that were consistent with a partly compensated large sagittal jaw relationship, namely a larger maxillary prognathism, a larger sagittal jaw relationship, and smaller maxillary and larger mandibular alveolar prognathism. Surprisingly, moreover, a smaller gonial angle was also found in these children. On the other hand, the occurrence of restricted mobility and tenderness in the TMJ showed only a few scattered associations with craniofacial morphology.

In previous studies that have examined the craniofacial morphology in subjects with symptoms and signs of TMJ dysfunction, no typical craniofacial morphology has emerged as representative for this condition. Dibbets *et al*. (1985), Nebbe *et al*. (1997, 1999a,b) and Muto *et al*. (1998) in pre-orthodontic children and adolescents found a morphology characterized by a larger mandibular plane inclination or a smaller posterior to anterior face height ratio. Brand *et al*. (1995) and Dibbets and van der Weele (1996) in adult TMD patients found a morphology characterized by sagittal maxillary and mandibular deficiency, and Keeling *et al*. (1992) in pre-orthodontic children, reported a craniofacial morphology characterized by a larger apical base discrepancy, i.e. a larger sagittal jaw relationship, in combination with a smaller mandibular plane inclination. The findings in the present study of average morphological features characterized by a larger sagittal jaw relationship and a smaller gonial angle are similar to those reported by Keeling *et al*. (1992). However, in view of the conflicting evidence in the literature, and from the low number of significant correlations observed in the present study and their low magnitude, it does not seem possible to draw any firm conclusions regarding the presence of any particular craniofacial morphology in children with symptoms or signs of TMJ dysfunction.

On the other hand, subjects with tenderness of the muscles, on average, showed a characteristic craniofacial morphology. Tenderness of the masticatory muscles was associated with a shorter posterior facial height and a shorter mandible, and tenderness of the shoulder muscles was seen in subjects with a larger cranial base angle, reduced mandibular prognathism, and larger mandibular inclination and vertical jaw relationship. Thus, overall, there was a tendency for the occurrence of muscle tenderness to be found in subjects with morphological features seen in the 'long face' type of craniofacial morphology. This relationship between tenderness of the masticatory muscles and facial form has not previously been reported.

Previous studies have found that low maximal mandibular elevator muscle activity or low bite force are associated with a vertical facial morphology (Møller, 1966; Ringqvist, 1973; Ingervall and Thilander, 1974; Schendel *et al*., 1976; Ingervall and Helkimo, 1978; Proffit *et al*., 1983; Bakke and Michler, 1991; Raadsheer *et al*., 1999). Moreover, weak mandibular elevator muscles or low maximal elevator activity are often seen in patients with symptoms and signs of TMD (Helkimo *et al*., 1975; Sheikholeslam *et al*., 1980; Møller *et al*., 1984; Naeije, 1988; Kroon and Naeije, 1992). The results of these investigations suggest that the occurrence in the present study of muscular tenderness in subjects with morphological traits that are consistent with a long-face craniofacial morphology, could be due to a functional overloading of weak mandibular elevator muscles. The findings in the present study of a lower maximal bite force in children with tenderness of the masseter and anterior temporal muscles, and with a higher Clinical Dysfunction Index support these considerations. An alternative explanation is that the tenderness may lead to a temporary hypofunction of the masticatory muscles and a resulting reduction of the bite force (Okeson, 1996). However, the relationship between tenderness and craniofacial morphology points to a long-term interaction between muscle force and craniofacial growth.

Headache was reported by 25 subjects. The craniofacial morphology of these was characterized by a larger average maxillary length, an increased maxillary prognathism, and also (Sonnesen *et al*., 1998) by a higher prevalence of unilateral posterior crossbite and unilateral distal occlusion. Interestingly, this specific combination of morphological characteristics has also been reported for children with prolonged dummy- and finger-sucking habits (Larsson, 1978, 1986).

### *Associations between TMD and posture*

A characteristic pattern of associations with posture was found for three signs of TMJ dysfunction, namely clicking assessed by auscultation with a stethoscope, the occurrence of locking of the jaw, and the occurrence of an asymmetric opening movement of the mandible. All three signs were associated with a marked forward inclination of the cervical column, and locking of the jaw was furthermore characterized by a marked increase in craniocervical angulation. No symptoms or signs were associated with craniovertical angulation.

Symptoms and signs of TMD, to a certain extent, overlap symptoms and signs of cervical spine disorders, and clinical observations of a forward head posture in subjects with TMD have been reported in the literature (Perry, 1956). In more recent studies, a forward head posture (FHP) has been defined as a small value of the angle between a horizontal line and a line from the tragus or the corner of the eye to the spinal process of CV7, assessed clinically or measured on lateral photographs. Studies of FHP have so far reported conflicting results. Kritsineli and Shim (1992) found FHP related to the occurrence of TMJ clicking in children in the early mixed dentition, but Hackney *et al*. (1993) in adult TMD patients, found no association between FHP and internal derangement of the TMJ. Watson and Trott (1993) in female adults found FHP related to the occurrence of headache, and Lee *et al*. (1995) found FHP in adult TMD patients with tenderness of the masticatory muscles. This lack of consistency in the findings may to some extent be due to the fact that skin surface measurements of posture do not reflect the actual postural relationship between the bony components of the head and neck (Johnson, 1998). The findings of the present study in pre-orthodontic children nevertheless confirm the clinical observations of a relationship between symptoms and signs of TMJ dysfunction, and the posture of the head and neck. On average, children with clicking and reduced mobility of the TMJs had a marked forward inclination of the upper cervical spine and an increased craniocervical angle. Various explanatory models for this relationship have been proposed, but so far no studies have documented whether the symptoms and signs of TMD dysfunction are the results or the causes of the forward cervical inclination, or whether both are triggered by other factors.

## Conclusions

The present study showed that symptoms and signs of TMD were related to craniofacial morphology and head posture in pre-orthodontic children. On average, TMJ dysfunction was seen in connection with a marked forward inclination of the upper cervical spine and an increased craniocervical angulation, but no firm conclusion could be made regarding any particular craniofacial morphology in children with symptoms and signs of TMJ dysfunction. Muscle tenderness was associated with a 'long face' type of craniofacial morphology and a lower bite force. Headache was associated with a larger maxillary length and increased maxillary prognathism. A high score on Helkimo's Clinical Dysfunction Index was associated with smaller values of a number of vertical, horizontal, and transversal linear craniofacial dimensions and a lower bite force. The magnitudes of most of the observed associations were generally low to moderate. Thus, they would hardly seem to be of direct clinical predictive value. On the other hand, the associations provide an insight into possible aetiological factors, and may therefore be of importance for a better understanding of the occurrence of symptoms and signs related to TMD in orthodontic patients, and for planning of future research into these problems.

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## References


Ash M M 1986 Current concepts in the aetiology, diagnosis and treatment of TMJ and muscle dysfunction. Journal of Oral Rehabilitation 13: 1–20

Bakke M 1993 Mandibular elevator muscles: physiology, action, and effect of dental occlusion. Scandinavian Journal of Dental Research 101: 314–331

Bakke M, Michler L 1991 Temporalis and masseter muscles activity in patients with anterior open bite and craniomandibular disorders. Scandinavian Journal of Dental Research 99: 219–128

Bakke M, Møller E 1992 Craniomandibular disorders and masticatory muscle function. Scandinavian Journal of Dental Research 100: 32–38

Bakke M, Michler L, Han K, Møller E 1989 Clinical significance of isometric bite force versus electrical activity in temporal and masseter muscles. Scandinavian Journal of Dental Research 97: 339–351

Björk A, Krebs Å, Solow B 1964 A method for epidemiological registration of malocclusion. Acta Odontologica Scandinavica 22: 27–41

Bosio J A, Burch J G, Tallents R H, Wade D B, Beck F M 1998 Lateral cephalometric analysis of asymptomatic volunteers and symptomatic patients with and without bilateral temporomandibular joint disc displacement. American Journal of Orthodontics and Dentofacial Orthopedics 114: 248–255

Brand J W, Nielson K J, Tallents R H, Nanda R S, Currier G F, Owen W L 1995 Lateral cephalometric analysis of skeletal patterns in patients with and without internal derangement of the temporomandibular joint. American Journal of Orthodontics and Dentofacial Orthopedics 107: 121–128

Bush F M, Dolwick M F 1995 The temporo-mandibular joint and related orofacial disorders. J B Lippincott Company, Philadelphia

Cohen J 1960 A coefficient of agreement for nominal scales. Educational and Psychological Measurement 20: 37–46

Dahlberg G 1940 Statistical methods for medical and biological students. Interscience Publications, New York

Danish Ministry of Health Order No. 338 1990 Bekendtgørelse om kommunal tandpleje. Schultz Grafisk A/S. Copenhagen

Dibbets J M H, van der Weele L TH 1996 Signs and symptoms of temporomandibular disorders (TMD) and craniofacial form. American Journal of Orthodontics and Dentofacial Orthopedics 110: 73–78

Dibbets J M H, van der Weele L TH, Boering G 1985 Craniofacial morphology and temporomandibular joint dysfunction in children. In: Carlson D S, McNamara J A, Ribbens K A (eds) Developmental aspects of temporomandibular joint disorders. Monograph No. 16, Craniofacial Growth Series. Center for Human Growth and Development, University of Michigan, Ann Arbor, pp. 279–298

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

Flöystrand F, Kleven E, Öilo G 1982 A novel miniature bite force recorder and its clinical application. Acta Odontologica Scandinavica 40: 209–214

Geissler P R 1985 An investigation of the stress factor in the mandibular dysfunction syndrome. Journal of Dentistry 13: 283–287

Hackney J, Bade D, Clawson A 1993 Relationship between forward head posture and diagnosed internal derangement of the temporomandibular joint. Journal of Orofacial Pain 7: 386–390

Helkimo E 1974 Studies on function and dysfunction of the masticatory system. II. Index for anamnestic and clinical dysfunction and occlusal state. Journal of Oral Rehabilitation 2: 397–406

Helkimo E, Carlsson G E, Carmeli Y 1975 Bite force in patients with functional disturbances of the masticatory system. Journal of Oral Rehabilitation 2: 397–406

Henrikson T 1999 Temporomandibular disorders and mandibular function in relation to Class II malocclusion and orthodontic treatment. Swedish Dental Journal 23, Suppl. 134: 1–144

Houston W J B 1983 The analysis of errors in orthodontic measurements. American Journal of Orthodontics 83: 382–390

Huggare J Å, Raustia A M 1992 Head posture and cervicovertebral and craniofacial morphology in patients with craniomandibular dysfunction. Journal of Craniomandibular Practice 10: 173–177

Ingervall B, Helkimo E 1978 Masticatory muscle force and facial morphology in man. Archives of Oral Biology 23: 203–206

Ingervall B, Thilander B 1974 Relation between facial morphology and activity of the masticatory muscles. Journal of Oral Rehabilitation 1: 131–147

Johnson G M 1998 The correlation between surface measurement of head and neck posture and the anatomic position of the upper cervical vertebrae. Spine 23: 921–927

Keeling S D, Cabassa S R, Bates R E, Ossi A R, King G J 1992 Temporomandibular disorders and craniofacial morphology in children with Class II malocclusion. Journal of Dental Research 71: 19 (Abstract)

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

Kroon G W, Naeije 1992 Electromyographic evidence of local muscle fatigue in subgroup of patients with myogenous craniomandibular disorders. Archives of Oral Biology 37: 215–218

Larsson E 1978 Dummy- and finger-sucking habits with special attention to their significance for facial growth and occlusion. 7. The effect of earlier dummy- and finger-sucking habit in 16-year-old children compared with children without earlier sucking habit. Swedish Dental Journal 1: 23–33

Larsson E 1986 Effect of dummy-sucking on prevalence of posterior cross-bite in the permanent dentition. Swedish Dental Journal 10: 97–101

Lee W-Y, Okeson J P, Lindroth J 1995 The relationship between forward head posture and temporomandibular disorders. Journal of Orofacial Pain 9: 161–167

Møller E 1966 The chewing apparatus. An electromyographic study of the action of the muscles of mastication and its correlation to facial morphology. Acta Physiologic Scandinavica 1: Supplementum

Møller E, Sheikholeslam A, Lous I 1984 Response of elevator activity during mastication to treatment of functional disorders. Scandinavian Journal of Dental Research 92: 64–83

Muto T *et al.* 1998 Relationship between disc displacement and morphologic features of skeletal Class III malocclusion. International Journal of Adult Orthodontics and Orthognathic Surgery 13: 143–151

Naeije M 1988 Muscle physiology relevant in craniomandibular disorders. Journal of Craniomandibular Disorders and Facial Oral Pain 2: 153–157

Nagelkerke N J D 1991 A note on a general definition of the coefficient of determination. Biometrika 78: 691–692

Nebbe B, Major P W, Prasad N G, Grace M, Kamelchuck L S 1997 TMJ internal derangement and adolescent craniofacial morphology: a pilot study. Angle Orthodontist 67: 407–414

Nebbe B, Major P W, Prasad N G 1999a Female adolescent facial pattern associated with TMJ disc displacement and reduction in disc length: Part I. American Journal of Orthodontics and Dentofacial Orthopedics 116: 168–176

Nebbe B, Major P W, Prasad N G 1999b Male adolescent facial pattern associated with TMJ disc displacement and reduction in disc length: Part II. American Journal of Orthodontics and Dentofacial Orthopedics 116: 301–307

Nilner M, Lassing S 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 1996 Orofacial pain guidelines for assesssment, diagnosis, and management. Quintessence, Chicago

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: 202–214

Perry H T Jr 1956 Facial, cranial and cervical pain associated with dysfunction of the occlusion and articulations of the teeth. Angle Orthodontist 26: 121–128

Proffit W R, Fields H W, Nixon W L 1983 Occlusal forces in normal- and long-face adults. Journal of Dental Research 62: 566–571

Raadsheer M C, Van Eijden T M G J, Van Ginkel F C, Prahl-Andersen B 1999 Contribution of jaw muscle size and craniofacial morphology to human bite force magnitude. Journal of Dental Research 78: 31–42

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

Ringqvist M 1973 Isometric bite force and its relation to dimensions of the facial skeleton. Acta Odontologica Scandinavica 31: 35–42

SAS Institute Inc. 1982 SAS user's guide: basics. SAS Institute Inc., Cary

SAS Institude Inc. 1988 SAS/STAT™ user's guide, Release 6.03 Edition. SAS Institude Inc., Cary

Schendel S A, Eisenfeld J, Bell W H, Epker B N, Mischelevich D J 1976 The long face syndrome: vertical maxillary excess. American Journal of Orthodontics 70: 398–408

Sessle B V, Bryant P W, Dionne R A (eds) 1995 Temporomandibular disorders and related pain conditions. Progress in Pain Research, Vol. 4. IASP Press, Seattle

Sheikholeslam A, Møller E, Lous I 1980 Pain, tenderness and strength of human mandibular elevators. Scandinavian Journal of Dental Research 88: 60–66

Siersbæk-Nielsen S, Solow B 1982 Intra- and interexaminer variability in head posture recorded by dental auxiliaries. American Journal of Orthodontics 82: 50–57

Solberg W K, Flint R T, Brantner J P 1972 Temporomandibular joint and dysfunction: a clinical study of emotional and occlusal components. Journal of Prosthetic Dentistry 28: 412–422

Solow B 1966 The pattern of craniofacial associations. Acta Odontologica Scandinavica 24: Suppl. 46

Solow B 1995 Guest editorial: orthodontic screening and third party financing. European Journal of Orthodontics 17: 79–83

Solow S, Tallgren 1976 Head posture and craniofacial morphology. American Journal of Physical Anthropology 44: 417–435

Sonnesen L 1997 Ansigtsmorfologi og kæbefunktion [Craniofacial morphology and temporomandibular disorders. With an English summary]. Thesis, University of Copenhagen, Denmark, pp. 1–112

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

Stringert H G, Worms F W 1986 Variations in skeletal and dental patterns in patients with structural and functional alterations of the temporomandibular joint: a preliminary report. American Journal of Orthodontics 89: 285–297

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 1993 Relationship between malocclusion and craniomandibular dysfunction in children and adolescents: a review. Pediatric Dentistry 15: 317–322

Watson D H, Trott P H 1993 Cervical headache: an investigation of natural head posture and upper cervical flexor muscle performance. Cephalalgia 13: 272–284

Westling L 1992 Temporomandibular joint dysfunction and systemic joint laxity. Swedish Dental Journal, 13, Suppl. 81: 272–284

**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 treatment | Extreme deep bite |
| | Pronounced anterior crossbite or reverse overjet |
| | Pronounced crowding |
| 3. Traumatic dental injuries | Extreme overjet, particularly when the 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 | |
| 1. 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 1; Solow, 1995.