Original Article

Malocclusion and Temporomandibular Disorder: A Comparison of Adolescents with Moderate to Severe Dysfunction with those without Signs and Symptoms of Temporomandibular Disorder and Their Further Development to 30 Years of Age

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Abstract: A total of 1018 subjects were examined at the age of 11 years, 791 were reexamined at 15 years, 456 at 19 years, and 337 at 30 years. Anamnestic and clinical recordings of temporomandibular disorder (TMD) were made. Morphology, including calculation of peer assessment rating (PAR) scores, was recorded. Previous history of orthodontic treatment was assessed. Muscular endurance was recorded. The subjects completed four psychological measures. The malocclusion prevalence, occlusal contacts, psychological factors, and muscular endurance in subjects with no recorded signs and symptoms of TMD were compared with those with the most severe dysfunction at 19 years of age. The further development of TMD to 30 years of age was followed. PAR scores were significantly higher in the subjects with the most severe dysfunction. Apart from crowding of teeth, no other significant differences were found between the groups with regard to separate malocclusions, tooth contact pattern, orthodontic treatment, or extractions. A greater proportion of subjects with low endurance were found in those with TMD. Significant associations between TMD and general health and psychological well-being as well as the personality dimension of neuroticism and self-esteem were found. During the period from 19 to 30 years, the prevalence of muscular signs and symptoms showed considerable reduction, whereas clicking showed a slight increase. Locking of the joint showed a decrease from 19 to 30 years. One-quarter of the TMD subjects showed complete recovery. Thus, orthodontic treatment seems to be neither a major preventive nor a significant cause of TMD. (*Angle Orthod* 2004;74:319–327.)

Key Words: Malocclusion; Orthodontic treatment; Temporomandibular disorders (TMD); Muscular endurance; Personality

INTRODUCTION

Previous findings in this cohort study

The prevalence of temporomandibular disorder (TMD) in a large sample of Welsh children at 11–12, 15, and 19 years of age has been presented earlier.[1–3] Many of these subjects were selected based on the presence of malocclusion. Nevertheless, the prevalence of TMD at all recordings during childhood and adolescence was similar or slightly lower than has been found in random samples of subjects of approximately the same age in whom malocclusion has not been used as a selection criterion.[4–15] The prevalence of clicking and locking clearly increased from 12 to 15 years, especially in girls, and continued to increase up to 19 years

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of age. Headache (weekly or daily) showed a more moderate increase.[2]

Previous reports of associations between malocclusion and TMD

In epidemiological and some postmortem studies, certain types of malocclusion have been more closely associated with the development of TMD than others. This seems to be especially true with regard to Angle class II, including large overjet, and class III malocclusions, crossbite and open bite.[1,5,13,16–24] These associations may be partly explained by the less-stable occlusion found in connection with such malocclusions. Another explanation could be the less-resistant muscles in malocclusions, often characterized by a steep mandibular plane angle.[25–30] Another proposed explanation concerns associations between class II malocclusion and head posture and clicking.[23]

Previous reports of associations between orthodontic treatment and TMD

With a few exceptions,[20,21,24] treatment of malocclusions has not been reported to have a great preventive influence on the development of signs and symptoms of TMD.[3,15,31–39] The study by Henriksson[24] specifically evaluated the effect of correction of Angle class II malocclusion.

Other factors associated with TMD

The etiology of TMD is usually claimed to be multifactorial. Factors predisposing to the development of TMD may be divided into systemic, psychological (personality, behavior), and structural (malocclusion and other types of occlusal discrepancies, joint laxity, and others) factors. Associations between psychological variables and dysfunction in children have been found.[1,5] Not least, structural and psychological factors can be expected to interact through the same areas in the central nervous system.

The aims of the present study

There has been considerable fluctuation in the signs and symptoms of TMD in adolescents in this study as well as in other studies,[6,7,24,39,40] which reduces the possibility of finding clear associations between orthodontic treatment and TMD. Moreover, a sufficiently high level of severity of signs and symptoms has to be established to motivate treatment of TMD. This was the basis for the decision to create a group with reasonably severe dysfunction ($n = 62$), including subjects who may be expected to become future TMD patients. As a control, subjects who had been constantly free from TMD ($n = 72$) also were selected from the 456 subjects examined at 19 years of age.

The influence of malocclusion, the characteristics of occlusion, and articulatory movements as well as psychological factors and muscular endurance were studied comparing the individuals with clinically important levels of TMD with those constantly free from TMD. The comparison was made to verify or reject the view of a limited influence of malocclusions within a probably multifactorial etiology of TMD. The further development of TMD to 30 years of age was then studied to further evaluate the importance of orthodontic treatment to prevent TMD.

MATERIALS AND METHODS

Sampling

The selection methods have been described previously.[41] The selection was made with a view to forming groups of children large enough for study of the reasons and motivation for orthodontic treatment in both common malocclusions and malocclusions of special interest to orthodontists.[1,41] A total of 1018 children were finally selected for examination in 1981 at the age of 11 years. Of these, 791 subjects were available for reexamination in 1984 at the age of 15 years, 456 were successfully recalled in 1989 at the age of 19 years, and 337 of these subjects were reexamined at 30 years of age. The variables recorded in 1984, 1989, and 2000 were mainly the same and were defined identically. The following subjects were included in the comparison of moderate to severe vs no TMD at 19 years of age:

1. Subjects without signs and symptoms of TMD at 19 years of age who previously had not had TMD.
2. Subjects with the most severe TMD at 19 years of age:
   - Subjects with impaired joint function with recorded and reported clicking;
   - Subjects with severely impaired joint function, clicking, and locking.
   - Subjects with impaired joint and muscle function; a) plus tender muscles.
   - Subjects with severely impaired joint and muscle function; b) plus tender muscles.
   - Subjects with severely impaired muscle function; >3 tender sites and reported prevalent headache and/or fatigue.

Subjects in group 2 will be referred to as TMD subjects and those in group 1 as non-TMD subjects/individuals. In all examinations, the examiners were blinded to the TMD status of each case.

Clinical examination

The examination methods to record signs of TMD have been described previously.[1,42] In 1989, bite force was recorded for the first time and was used to calculate muscular endurance, which was defined as the time taken by the individual to bite with 50% of maximal bite force until pain or obvious discomfort arose.[3] The limit for reduced muscular endurance was set to 20 seconds or less.

TABLE 1. Repeat PAR Calculations in 15 Randomly Selected Cases (1 = First Calculation, 2 = Second Calculation, w = Weighted)

Case	PAR 1	wPAR 1	PAR 2	wPAR 2
1	10	34	13	34
2	7	15	8	16
3	3	9	3	9
4	9	20	11	22
5	4	7	4	7
6	11	14	11	14
7	3	8	5	10
8	11	26	11	26
9	7	14	7	14
10	9	13	8	12
11	16	31	16	31
12	11	11	11	11
13	5	6	5	6
14	14	24	14	24
15	6	16	6	16

Examination of casts

Peer assessment rating (PAR) index values were calculated on study casts according to Richmond et al.[43] This index gives a score representing the overall severity of malocclusion. Malocclusions were recorded on study casts according to the methods described by Björk et al.[44]

Anamnestic examination

The questions about dental conditions as well as those relevant to the social psychological assessment have been described earlier.[41] In 1989, anamnestic data were collected partly through questionnaires and partly through interviews.[3] All the questions were in the same document, and this allowed the examiner (in this case, one of the present authors who was not involved in the clinical examination) to review all the questions and resolve any misunderstandings. On this occasion, the interview also included questions concerning general health and general joint problems, back and shoulder pain, as well as jaw injuries.

Orthodontic treatment

Any previous history of orthodontic treatment was assessed by interview and with additional copies of orthodontic case notes obtained from the orthodontists responsible for the treatment.

Reproducibility

Study design and reproducibility of recordings have been discussed in previous papers.[1,41] The accuracy of determination of PAR scores was evaluated by repeat measurements of 15 cases. The results are shown in Table 1.

Psychological assessment

The psychological component of the survey was developed by psychologists and executed by experienced interviewers (details previously reported in Kenealy et al[45]). The relevant data were collected through questionnaires and interviews.

Psychological measures

The following measures were completed by subjects before the clinical examination:

The Life Events Inventory.[46] This 55-item questionnaire provides a measure of the relative severity of psychosocial stressors. The questionnaire is a revised version of the Holmes and Rahe[47] Schedule of Recent Experiences (SRE). It is a standardized measure of the amount of stress that has been present in a person's immediate environment during the past year.

General Health Questionnaire (GHQ-30).[48] This scale is a well-validated, self-administered measure for detecting nonpsychotic psychiatric disorder in people in community and medical settings. It is constructed to identify cases but is also used to measure the degree of disorder. Lower scores give an indication of psychological well-being; higher scores reflect psychological distress, with a recommended cutoff threshold score of five or greater indicating cases that merit psychological intervention.[49]

Eysenck Personality Inventory—Neuroticism (EPIN). This scale is used to assess the personality dimension of neurotic anxiety. Neuroticism scores generally correlate with clinical neurosis. The EPI[50] is a well-validated measure of personality, used extensively in research that led to the development of Eysenck's Theory of Personality.[51]

Rosenberg Self-Esteem (RSE) Scale. This 10-item scale is a one-dimensional index of self-esteem or perceived self-worth. Devised by Rosenberg[52] while working with adolescents and published in 1965 (reprinted 1989), it is widely used in research to assess self-esteem. Self-esteem is typically seen as a personal resource that may moderate the effects of threatening events or conditions such as disfigurement or incapacitating injuries. The RSE scale measures the self-acceptance aspect of self-esteem.

Statistical methods

Differences in PAR score (weighted and unweighted) in subjects with and without TMD were analyzed by use of the *t*-test. Sex differences and differences between the examinations in 1984 and 1989 regarding categorical variables were tested using chi-square tests. Cross tables were tested by Fisher's exact test (testing differences between percentages). TMD and non-TMD subjects were, with regard to psychological data, compared by use of analysis of variance. A logistic regression analysis was also performed to provide a better control of confounding factors. Because of the sample size, the analysis was performed in three steps. A preliminary analysis was conducted with tests in pairs, where factors showing tendency to or significant associations with TMD were included initially in a logistic regression. Clearly insignificant factors were excluded in a first step, and, finally, a second logistic regression analysis was performed. The following variables were included in the analyses: weighted and unweighted PAR; Angle class I, II, or III; large overjet (≥6 mm); deep bite; open bite; scissors bite; unilateral crossbite (more than one pair of teeth); bilateral crossbite (more than one pair of teeth); previous orthodontic treatment; previous orthodontic extractions; nonworking side interferences; cuspid protection; stress (Life Event Inventory), psychological well-being (GHQ-30); neuroticism (EPIN); self-esteem (RSE); and muscular endurance.

RESULTS

Separating signs and symptoms involving the TM joint from those in muscles turned out to be difficult because, at 19 years of age, only a very small proportion (13%) had TMD that could be attributed to muscles only. Muscle involvement alone or combined with impaired joint function was found in 55% of the TMD subjects. Sixty-two subjects, 41 women and 21 men, were found to have signs and symptoms of TMD, according to the definitions. Seventy-two individuals, 44 women and 28 men, had not shown signs and symptoms of TMD at the examinations at 11, 15, and 19 years of age.

Malocclusion and TMD

Unweighted as well as weighted PAR values turned out to be about 50% higher in the subjects with the most severe dysfunction at 19 years of age than in those without signs and symptoms of TMD at all examinations (Table 2). The difference in PAR scores between TMD and non-TMD subjects was statistically significant for all individuals ($P < .01$) as well as for women ($P < .01$) and men ($P < .05$) separately. The corresponding difference in weighted PAR scores was also statistically significant for all individuals ($P < .01$) as well as for women ($P < .01$) separately but not for men. Also, crowding was more prevalent in TMD subjects ($P < .01$) and in women with TMD ($P < .001$). Crowding was predominantly found in the frontal segments. Both these findings were confirmed in the logistic regressions with PAR and crowding left in the final regression model.

Nonworking side interferences showed a higher prevalence in TMD men than in non-TMD men. This showed a tendency to correlation in the last regression step. Otherwise, differences between TMD and non-TMD subjects were not statistically significant. No significant difference in prevalence of cuspid guidance when comparing TMD and non-TMD subjects was found (Table 2).

The distribution of Angle classes differed very little between the groups in the sagittal occlusion (Table 2). Sex differences in the distribution of different malocclusions were found only in Angle class III malocclusion, with prevalence in the two groups of only 1% for women compared with 14% for men.

TABLE 2. PAR Scores, Occlusal Contact Pattern on Laterotrusion, Crowding, and Sagittal Occlusion in Subjects With ($n = 62$) and Without ($n = 72$) TMD. Mean Values in Percent. Range and Numerical Values Within Parentheses (* $P < .05$, ** $P < .01$, *** $P < .001$)

	All Subjects (134)	
No TMD subjects, PAR (72)	5.5	(0–15)
TMD subjects, PAR (62)	7.9***	(0–17)
No TMD subjects, wPAR (72)	10.5	(0–34)
TMD subjects, wPAR (62)	15.3**	(0–37)
No TMD subjects, cuspid guidance (72)	51.4	(37)
TMD subjects, cuspid guidance (62)	38.7	(24)
No TMD subjects, nonworking side interferences (72)	11.1	(8)
TMD subjects, nonworking side interferences (62)	21.0	(13)
No TMD subjects, crowding (72)	20.8	(15)
TMD subjects, crowding (62)	45.2**	(28)
No TMD subjects, Angle class I (72)	54.2	(39)
TMD subjects, Angle class I (62)	59.7	(37)
No TMD subjects, Angle class II (72)	40.3	(29)
TMD subjects, Angle class II (62)	33.9	(21)
No TMD subjects, Angle class III (72)	5.6	(4)
TMD subjects, Angle class III (62)	6.5	(4)
No TMD subjects, large overjet (72)	6.9	(5)
TMD subjects, large overjet (62)	9.7	(6)

The prevalence of deep bite was half as common among the TMD subjects as among the non-TMD individuals. Open bites showed a similar distribution, although the number of those cases was limited. None of these differences were statistically significant. Also, bilateral crossbite showed a tendency to be more common in TMD subjects, but again the number of subjects in each group was low (Table 3).

Orthodontic treatment and TMD

By 19 years of age, 46% of the men and 56% of the women stated that they had received orthodontic treatment and that, in most of these cases, extractions had been involved. Appliances had been worn by 43% of the men and 51% of the women. The distribution of different appliances among these subjects was such that 44% of the men and 39% of the women had had removable appliance/fixed appliance combinations. Treatment with removable appliances was received by 42% of the men and 47% of the women. Pure fixed appliance prescriptions were in the minority and involved 14% of the men and 13% of the women. The proportion of orthodontically treated subjects did not differ much between the TMD and non-TMD subjects (Table 3). Also, no greater differences could be noted between fixed, most often combined with removable, or removable appliances when comparing those with and without TMD. The prevalence of orthodontic extractions was similar in the two groups. There were no obvious sex differences in this con-

TABLE 3. Vertical and Transversal Malocclusions, Orthodontic Treatment and Muscular Endurance in Subjects With ($n = 62$) and Without ($n = 72$) TMD. Mean Values in Percent. Numerical Values Within Parentheses (* $P < .05$, ** $P < .01$, *** $P < .001$)

	All Subjects (134)	
No TMD subjects, deep bite (72)	13.9	(10)
TMD subjects, deep bite (62)	6.5	(4)
No TMD subjects, open bite (72)	8.3	(6)
TMD subjects, open bite (62)	1.6	(2)
No TMD subjects, bilateral crossbite (72)	2.8	(2)
TMD subjects, bilateral crossbite (62)	9.7	(6)
No TMD subjects, unilateral crossbite (72)	9.7	(7)
TMD subjects, unilateral crossbite (62)	14.5	(9)
No TMD subjects, fixed and fixed/removable appliance (72)	29.2	(21)
TMD subjects, fixed and fixed/removable appliance (62)	33.9	(21)
No TMD subjects, removable appliance (72)	23.6	(17)
TMD subjects, removable appliance (62)	25.8	(16)
No TMD subjects, orthodontic treatment (72)	52.8	(38)
TMD subjects, orthodontic treatment (62)	54.8	(34)
No TMD subjects, orthodontic extractions (72)	54.2	(39)
TMD subjects, orthodontic extractions (62)	53.2	(33)
No TMD subjects, reduced muscular endurance (64)	6.3	(4)
TMD subjects, reduced muscular endurance (55)	30.9***	(17)

text. None of the differences with regard to orthodontic treatment and extractions turned out to be statistically significant.

Muscular endurance and TMD

A comparison of muscular endurance revealed a greater proportion of subjects with low endurance among those with TMD ($P < .001$) (Table 3). The difference between TMD and non-TMD subjects was obvious only in the women ($P < .01$), whereas altogether only one man showed a much reduced endurance (less than 20 seconds). Recording of endurance could not be performed in eight subjects without TMD (six women and two men) and seven individuals with TMD (five women and two men) because of biting difficulties caused by damaged or painful teeth. The influence of muscular endurance was also indicated, with this factor being included in the last regression model.

Psychological factors and TMD

Stress (the Life Events Inventory). There was no significant effect of TMD group on stress levels experienced during the previous year. Subjects with moderately impaired TMJ and muscle function reported the highest mean levels of stress present in their immediate environment, and non-TMD men reported the lowest mean levels of stress experienced during the previous year.

Psychological well-being (General Health Questionnaire—GHQ-30). There was a significant correlation between the TMD group and general health and psychological well-being (Table 4). Individuals with severely impaired muscle function had the highest mean scores, and 71.4% ($n = 5$) of the subjects in this group had scores above the cutoff threshold, indicating significant psychological distress. Subjects with moderately impaired TMJ and muscle function had the next highest mean scores, and 60% ($n = 6$) of this group reported scores that indicated significant psychological distress.

Personality (neuroticism—EPIN). There was a significant association between TMD group and the personality dimension of neuroticism. Subjects with severely impaired muscle function reported the highest mean levels of neurotic anxiety. The mean levels in this group were significantly higher than in all other groups, with the exception of those with moderately impaired TMJ and muscle function (Table 4)

Self-esteem RSE scale. There was a significant correlation between TMD group and self-esteem. Mean scores in Table 4 have been reversed from the original scoring to a positive direction, with high scores indicating higher self-

TABLE 4. Mean Levels of Psychological Health (GHQ-30), Neuroticism (Eysenck Personality Inventory—Neuroticism—EPIN), and Self-esteem (Rosenberg Self-Esteem Scale—RSE) by TMD and non-TMD Groups

	GHQ-30			EPIN			RSE		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
Non-TMD females	41	3.7	4.8	40	11.5	4.3	42	28.9	4.0
Non-TMD males	24	2.5	4.5	22	9.1	4.4	24	32.8	4.9
Moderately impaired TMJ function	10	2.1	2.1	9	9.7	4.4	10	33.0	4.5
Severely impaired TMJ function	15	5.5	6.0	14	9.6	3.8	15	31.3	4.3
Moderately impaired TMJ and muscle function	10	7.7	7.5	8	14.4	3.9	10	29.3	4.3
Severely impaired TMJ and muscle function	13	4.3	4.9	14	12.9	5.3	14	30.5	2.1
Severely impaired muscle function	7	8.6	9.2	7	17.3	3.4	7	29.4	4.3
Total	120	4.2	5.5	114	11.4	4.7	122	30.5	4.4
ANOVA	$P < .05$			$P < .001$			$P < .01$		
Groups	1–5, 1–7, 2–5, 2–7, 3–5, 3–7			1–2, 1–7, 2–5, 2–6, 2–7, 3–5, 3–7, 4–5, 4–7, 6–7			1–2, 1–3, 1–4, 2–5, 3–5		

esteem. Non-TMD women had the lowest mean self-esteem scores, followed by those with moderately impaired TMJ and muscle function and those with severely impaired muscle function (Table 4).

The influence of psychological factors was partly confirmed by inclusion in the final step of regression, indicating a tendency to association with TMD. This was also found regarding recently experienced stress (Life Events Inventory, LEI).

Further development to 30 years of age

Movement capacity in the 30-year-olds was in most cases within expected normal values. Only five subjects showed an opening capacity of slightly less than 40 mm.

When the groups who were healthy with respect to TMD or had obvious signs and symptoms of TMD were studied from 19 to 30 years of age, we found that 26% of former TMD subjects showed complete recovery and that another 44% showed reduced severity of TMD (in many cases not allowing them to belong to the TMD group).

The prevalence of clinically recorded TM joint clicking showed minor changes from 19 to 30 years of age. Audible clicking (with or without a stethoscope) in the right joint changed from 19% to 18% in this period. In the left joint, this prevalence changed from 22% at 19 years to 17% at 30 years of age. The subjects' reported frequent clicking indicated a slight increase in prevalence. In women, reported clicking increased from 17% to 20% and in men, from 9% to 14%. Only two subjects with crepitation and none with locking were found in the clinical examination. The reported prevalence of locking showed a reduction as well. In women, this prevalence changed from 15% to 9% and in men, from 10% to 9%. Recorded deviation on opening showed an approximately 50% reduced prevalence from 19 to 30 years of age.

The tenderness to palpation of the masticatory muscles showed reduction in prevalence from 30% to 60% in different muscles. Reported tiredness in jaw muscles showed a corresponding reduction in prevalence, whereas reported prevalent headache showed minor changes between 19 and 30 years. Reported prevalence of tiredness on hard chewing dropped from 37% to 25% in women and from 28% to 20% in men.

The statements of the subjects during the clinical examination revealed that seven subjects (2.2%) felt pain in the right joint on opening the mouth and eight individuals (2.4%) felt pain in the left joint during the same kind of movement. Only some subjects felt pain during other kinds of movements.

DISCUSSION

Study population

The sample attrition during the course of the study can be explained in part by the limited time available for recall and reexamination.[3,40] It was considered important to use the same examiners throughout the study to reduce variations in the recordings due to disagreement between observers. The overall conclusion from the analysis of differences between the longitudinal group, ie, the subjects observed at 19 years of age and the subjects lost to follow-up, is that there is no significant systematic difference between the groups, although some small differences exist between some variables.[40]

Functional occlusion and TMD

Most types of occlusal interferences actually showed a lower prevalence than has been reported in other studies.[12,13,53] This seems somewhat surprising considering that the selection was based on the presence of malocclusion in the present study. When comparing TMD and non-TMD subjects in the present study, there was only a tendency to a difference in prevalence of nonworking side interferences. The observation that nonworking side interferences do not appear to have a major influence on the development of signs and symptoms of TMD is in agreement with the results of previous studies.[7,12,13,16,42,54,55] Any major beneficial influence on mandibular function by cuspid guidance in laterotrusive movements could not be confirmed, contrary to what has been claimed by some authors.[56,57,58]

Malocclusion and TMD

Studies on associations between TMD and malocclusion/orthodontic treatment have often been based on a broad range of signs and symptoms of TMD. In addition, these signs and symptoms fluctuate considerably when individuals are followed longitudinally.[6,7,24,38,40] However, the need for treatment of TMD in children and adolescents is at a level of only 2–4% in a population.[23,24] It, therefore, seems more appropriate to focus only on individuals with clinically relevant TMD problems. Thus, this study focuses on a comparison between those with the most severe signs and symptoms and those without such problems up to 19 years of age.

A belief has arisen that orthodontic treatment frequently causes TMD. Successful legal action has been based on this belief, for which there is only anecdotal evidence. When studies of the causal effects of orthodontic treatment on the development of TMD are reviewed, there seems to be no support for such an opinion.[2,3,31–39] These TMD studies indicate that patients who had received orthodontic treatment were slightly less severely affected by TMD than those people who had not been orthodontic patients. Some studies[20,21,24] have even shown a significant reduction in prevalence of TMD by orthodontic treatment. The present study supports the view that orthodontic treatment in general has a fairly limited influence on the development of signs and symptoms of TMD. A negative influence could not be traced despite the fact that a large proportion of orthodontic patients had discontinued treatment and that a fairly small proportion were treated with fixed appliances, which might indicate less control of treatment outcome. Treatment with or without extractions did not change the picture much.

When interpreting the effects of orthodontic treatment on function, it is important to consider the average development of signs and symptoms in adolescents. The prevalence of TMD, and especially dysfunction of the TM joint, increases between 12 and 15 years of age.[2,3] These changes are more evident in girls than in boys. The effects of orthodontic treatment in this context may be confused with normal changes with age. These events probably do not coincide with any dramatic changes of the occlusion in this period but are probably explained by hormonal changes influencing the connective tissue and are also associated to a general hypermobility.[59]

TMD and non-TMD subjects differed with regard to the two malocclusion variables, PAR scores and crowding. These differences were greater for women than for men. Long-term follow-up studies by Egermark et al[39] did not confirm these observations but mainly found associations (fairly weak) between TMD and lateral forced bite in agreement with other studies in adults.[16,42] In the present study, only a few subjects were found to have lateral forced bite. The nature of the influence of high PAR scores and crowding can only be speculated about. Mohlin and Thilander[16] and Mohlin[42] found significant associations between the need for orthodontic treatment, the need for oral rehabilitation, the number of rotated teeth, the low educational level on one side, and TMD on the other. There might have been differences in the selection of orthodontic patients with regard to educational level and social class and general health situation. As previously mentioned, tooth contact pattern did not differ much between TMD and non-TMD subjects. In some studies, large overjet has shown associations with TM joint disk displacement.[17,23,24,59] One proposed explanation of this relates to the more extended head posture in Angle Class II cases.[23] The reported effect of orthodontic treatment on TMJ clicking and locking varies between studies. Henriksson[24] found a clear improvement, whereas in the present material,[3] no such effect was found at 15 and 19 years of age. Differences in age at treatment and quality of treatment might be possible explanations of the difference. Previously found associations between TMD and Angle Class III and open-bite malocclusion[16,42] could not be confirmed in the present study. Prevalence of these malocclusions in the present sample was very low, not allowing any conclusions to be drawn. The tendency for association found with bilateral crossbite in the TMD subjects confirms earlier observations made on TMD patients[16,60] and might be associated to sagittal discrepancies in jaw position.

Associations between malocclusion and TMD may be interpreted in several different ways. One way concerns the tooth contact pattern in, for instance, laterotrusive movements, as well as occlusal stability.[12] In the present study, any influence on TMD by the contact pattern on the working and nonworking sides could only be traced as very moderate, with numerical differences showing a slightly higher prevalence of nonworking side interferences and a slightly lower prevalence of cuspid guidance in the TMD subjects.

Muscular endurance and psychological factors

Another interpretation concerns associations between malocclusion/craniofacial configuration and the strength and, indirectly, the resistance to overload of the masticatory muscles. A low muscular endurance shows significant associations to TMD.

An interesting observation was made regarding prevalence of deep bite, which turned out to be higher in subjects without TMD, thus giving some support to this view on influence by the strength of the masticatory muscles. Similar observations have been made in younger individuals.[61] Deep bite is probably more common in cases with anterior growth rotation, and this kind of craniofacial morphology has been associated with a greater muscular strength.[25] The much stronger associations between TMD and endurance found in women is difficult to explain. More women than men showed tender muscles when clinically examined and also more prevalently reported muscle pain and fatigue. Still, the difference in the number of women and men who complained about pain while biting hard seems far greater than can be explained by the difference in prevalence of muscle tenderness. Differences in muscle volume or in expression of pain between men and women may also partly explain this. In association with this, it might be that women reach maximal bite force more easily, whereas men may hesitate to use their full capacity, with periodontal receptors signaling overload.[62] This might mean that men use less than 50% of their maximal bite force in general, and cause vs effect in this context is difficult to explain.

Psychological factors as well as the state of general health have previously been mentioned as predisposing factors to TMD.[5,16,63–66] Significant associations between psychological variables and TMD were found in the present sample of children when they were examined at the age of 11 years.[1] At that age, the variables correlated to TMD were anxiety and neurotic personality as well as reported nail biting. The poorest levels of psychological health and the highest levels of neurotic anxiety were found in the subjects with severely impaired muscle function. The number of subjects in the TMD subgroups was small. The complexity of etiology to TMD is illustrated by the finding that non-TMD women had the lowest levels of self-esteem. Still, at 19 years of age, psychological health together with muscular endurance seems to be at least as strongly correlated to TMD as was malocclusion.

Development of TMD in young adults

There are only a few studies available that have followed signs and symptoms of TMD from adolescence into adult age. The observations of a considerable fluctuation of TMD also seem to exist in the age span of 20–30 years. This observation also has been made in other studies covering approximately the same age.[39,67,68] The fact that about a quarter of the subjects with the most severe TMD at 19 years of age showed complete recovery and that an additional large proportion showed reduced severity illustrates the difficulty of predicting development of TMD in an individual. This certainly makes decisions to correct malocclusions in order to prevent TMD difficult to motivate. Prevalence of clicking seems to remain fairly constant between 19 and 30 years of age. Recorded clicking showed a minor decrease in prevalence, whereas reported clicking showed a slight increase. Also, in the study by Magnusson et al,[68] the prevalence of clicking changed very little from 20 to 35 years of age. In both samples, the prevalence of locking was constantly low or even decreasing. This supports the view that clicking did not necessarily develop into locking, which is in agreement with the findings of Könönen et al.[69] Development of TMD signs and symptoms in muscles also shows a similarity between this study and the study by Magnusson et al.[68] In both samples, there is a reduction in the number of tender muscles on palpation and also a reduced prevalence of muscle tiredness when chewing hard. In both samples, the prevalence of frequent headache showed fairly small changes. Recorded headache could have causes other than overload of masticatory muscles.

CONCLUSIONS

This study comparing subjects without signs and symptoms of TMD with those with the most severe dysfunction revealed significantly higher levels of PAR scores in the TMD subjects. Crowding of teeth was the only separate malocclusion trait showing significant correlation to TMD. Neither prevalence of functional malocclusions nor orthodontic treatment or orthodontic extractions differed significantly between TMD and non-TMD subjects. A low muscular endurance was more commonly found in the female TMD subjects. Whether muscle function greatly influences craniofacial and occlusal development or is secondary to malocclusions is difficult to state. The importance of psychological factors confirms earlier observations. Judged by these findings, it is difficult to regard orthodontic treatment as a major preventive of TMD. On the other hand, there seems to be no support for assumptions that orthodontic treatment often causes TMD. This is further supported by the findings of a much reduced prevalence and severity of TMD from 19 to 30 years of age as well as the inconsistency in signs and symptoms of TMD throughout the observation period.

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