Acta Odontologica Scandinavica, 2005; 63: 99–109

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

A prospective investigation over two decades on signs and symptoms of temporomandibular disorders and associated variables. A final summary

TOMAS MAGNUSSON, INGER EGERMARK & GUNNAR E. CARLSSON

Department of Stomatognathic Physiology, The Institute for Postgraduate Dental Education, Jönköping, Sweden, Departments of Orthodontics and Prosthetic Dentistry/Dental Material Science, Göteborg University, Göteborg, Sweden

Abstract
The aim of this summary of a longitudinal investigation on temporomandibular disorders (TMD) was to present the prevalence figures of signs and symptoms of TMD and certain other examined variables, and the correlations between these variables, over a 20-year period. Originally, 402 randomly selected 7-, 11-, and 15-year-olds were examined clinically and by means of a questionnaire. The same examination procedure was repeated three times: after 4–5 years and after 10 and 20 years, respectively. Signs and symptoms of TMD were mainly mild, but common already in childhood. They increased up to young adulthood, after which they leveled out. Progression to severe pain and dysfunction was rare, and spontaneous recovery from more pronounced symptoms was also rare. Significant correlations between reported bruxism and TMD symptoms were found, and a baseline report of tooth-grinding was a predictor of TMD treatment during the 20 years covered by the investigation. Occlusal factors were only weakly associated with TMD signs and symptoms. However, a lateral forced bite between the retruded contact position (RCP) and the intercuspal contact position (ICP) and a unilateral crossbite deserve further consideration as possible local risk factors for development of TMD. In conclusion, a substantial fluctuation of TMD signs and symptoms was observed in this sample of Swedish subjects followed for 20 years from childhood to adult. The demand for TMD treatment was low at all examinations, while the estimated treatment need was larger. One-third of subjects who had some kind of orthodontic treatment did not run a higher risk of developing TMD later in life.

Key Words: *Bruxism, epidemiology, longitudinal study, orofacial pain, orthodontics*

Introduction

In the late 1970s, one of the present authors carried out a cross-sectional investigation of 3 age groups of children in respect of malocclusions and temporomandibular disorders (TMD). The results were published in five different papers [1–5] and became part of a doctoral thesis [6]. At the time, there were many unsolved issues in the field of TMD. For instance, opinions differed about the causes of TMD and on whether or not orthodontic treatment might be a risk factor for its development later in life. Little was known about other risk factors, nor about the need and demand for TMD treatment in the population. Attempts were made in a number of cross-sectional studies to shed light on these, and other, questions, but the results were contradictory and inconclusive. One possible answer to the unsolved questions might be longitudinal, prospective studies, which were practically non-existent at that time. We therefore decided to follow this cross-sectional sample of schoolchildren longitudinally over a long-term period – if possible until the participants had reached adulthood. The findings of these follow-ups have been published in different articles focusing on partly differing questions. Now when these investigations have come to an end, it is the aim of this paper to present a summary of the findings in one single article. More detailed descriptions can be found in the separate articles [7–21].

Material and methods

Subjects

The original sample comprised 136 seven-year-olds, 131 eleven-year-olds, and 135 fifteen-year-olds,

Correspondence: Tomas Magnusson, Department of Stomatognathic Physiology, Institute for Postgraduate Dental Education, Box 1030, SE-551 11 Jönköping, Sweden. Tel: +46 36 32 46 95. Fax: +46 36 32 46 01. E-mail: tomas.magnusson@lj.se

(Received 25 October 2004; accepted 11 January 2005)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.1080/00016350510019739

making a total of 402 children (194 girls and 208 boys), all from randomly selected classes of different schools in Varberg, a town with 40 000 inhabitants located in the southern part of Sweden. The subjects in the 4-year follow-up [7] were 120 randomly selected children from the 2 youngest age groups (participation rate 99%) who answered a questionnaire and were examined clinically. The 5-year follow-up included all 135 individuals in the oldest age group [8]. Reported data and clinical information could be collected from 121 and 119 participants, respectively (participation rates 88% and 90%).

After 10 years [13], the answers to questionnaires were collected and presented from 293 of the original 402 subjects (participation rate 73%). Another paper [14] dealt exclusively with the oldest age group, and entailed reported and clinical information from 103 and 84 subjects (participation rates 76% and 62%, respectively). A paper focusing on orthodontic treatment in childhood and TMD development analyzed the questionnaire data from all 3 age groups and clinical information from the oldest group after 10 years [12].

At the 20-year follow-up [15,16], the questionnaire response was obtained from 320 of the original sample of 402 subjects (participation rate 80%), and clinical data from 100 subjects in the oldest age group (participation rate 81%). The results and analyses of data collected during the 20-year follow-up have been presented [17–21].

Methods

Questionnaire. The questionnaire included questions about the presence of symptoms from the masticatory system, including headaches, or if the subject often felt stress, or was worried or depressed. Other questions dealt with oral parafunctions, previous trauma to the face, orthodontic treatment during childhood, experience of TMD treatment during the observation period, and present/current demand for any such treatment. Questions about oral parafunctions comprised tooth-clenching, tooth-grinding at night, and oral habits such as biting the nails, lip, cheek, and/or foreign objects. The variable bruxism was constructed by combining daytime tooth-clenching and/or tooth-grinding at night.

Clinical examination. The standardized clinical examination [6,22] comprised measurements of range of movement of the mandible, presence of deflection during mouth opening, registration of TMJ sounds, locking or luxation, pain on movement of the mandible, TMJ or muscle pain on palpation, number of teeth, number of occluding tooth pairs in maximal intercuspation, occlusal interferences and, finally, the degree of occlusal wear. All three authors who took part in the clinical examinations were well trained together and calibrated [23]. Calibration was repeated before each follow-up.

From five clinical parameters (mandibular mobility, TMJ function, pain on movement of the mandible, TMJ pain on palpation, and muscle pain on palpation), a clinical dysfunction index (Di), following Helkimo [24], was calculated. The maximal jaw opening, including vertical overbite, lateral excursions, and protrusion, was measured to the nearest millimeter with a ruler. Deflection of more than 2 mm on jaw opening was registered. TMJ sounds were recorded as grade 1 (palpable clicking when the TMJ was palpated laterally) and grade 2 (audible clicking or crepitations). TMJ and muscle tenderness was recorded if the subject described the palpation as painful or if it gave rise to a palpebral reflex. The TMJs were palpated for pain laterally and also posteriorly via the auditory meatus. The muscles palpated were the origin and the insertion of the temporal muscle, the lateral pterygoid muscle, the superficial portion of the masseter muscle, and the posterior belly of the digastric muscle. All muscles were palpated bilaterally.

Occlusal factors. When recording the number of occluding tooth pairs in the intercuspal contact position (ICP), only the main antagonist was counted; the maxilla was used as basis for the counting. The maximum number of pairs in a 32-tooth dentition was therefore 16. Occlusal interferences included unilateral contact in the retruded contact position (RCP), lateral deviation between RCP and ICP, large anterior-posterior distance RCP–ICP, and interferences on the non-working side [1,2]. Registration of morphological malocclusions was done according to the definitions given by Björk et al. [25]. Occlusal tooth wear was classified in accordance with a 5-point scale: 1 = no or slight wear, 2 = wear of enamel only, 3 = wear into the dentin in single spots, 4 = exposure of dentin in an area of more than 2 mm^2, 5 = wear of more than one-third of the clinical crown.

Need for treatment. Assessment of an individual need for TMD treatment was based on each subject's signs and symptoms, and was determined after discussion with the individual participant. As there are no specific criteria available, treatment need was assessed on the basis of clinical experience, a concept of a multifactorial etiology of TMD acknowledging that the causal processes are mainly unknown, and a rather conservative approach to treatment [22].

Statistical methods

A number of statistical methods have been used in the different analyses. Differences between the groups were tested with Fisher's permutation test for ordered variables [26] and by Fisher's exact test for dichotomous

variables. Sign tests and Wilcoxon's matched-pairs signed-rank test [27] was used for analysis of differences between the different examinations, and Pitman's non-parametric permutation test was used to test for sex differences [28]. Correlations between variables were calculated by means of Spearman's (*rs*) and Pearson's (*rp*) rank correlation tests [27]. Stepwise multiple regression analysis was also performed [28], and logistic regression was used for analyses of predictors of different variables recorded at the previous examination. The following levels of significance have been used in most of the papers: $p > 0.05$ N.S. (not significant); $*0.01 < p < 0.05$; $**0.001 < p < 0.01$; $***p < 0.001$.

Results

Subjective symptoms of TMD

As early as ages 7, 11, and 15 years, subjective symptoms of TMD were common, but in most cases of a mild character and mainly occurring occasionally. At the first follow-ups after 4 and 5 years, there was a statistically significant increase of subjects with one or more TMD symptoms in the youngest and oldest age groups [7,8]. To the 10-year follow-up, this increase had continued in all 3 age groups [13], and at that time, when the subjects were 17–25 years of age, approximately 10% reported that such symptoms occurred frequently, while another 33% said that they occurred only occasionally. It was also found that reported symptoms of TMD, including headaches, were in most cases significantly correlated to one another, but weak. Females reported significantly more TMD symptoms compared to males (*p*-values ranging between 0.05 and 0.001).

At the 20-year follow-up, no further increase of TMD symptoms had occurred in any age group, compared to the 10-year follow-up, and the prevalence of such symptoms was similar in all 3 age groups [16]. Now, at age 27–35 years, 13% reported frequent occurrence of TMD symptoms, and another 33% (exactly the same figure as 10 years earlier) reported occasional symptoms (Table I). There was a substantial fluctuation of all the individual symptoms, as well as of presence or absence of TMD symptoms during the observation period (Figure 1). Progression to severe pain and dysfunction of the masticatory system was rare. On the other hand, recovery from frequent symptoms to no symptoms was also rare (Figure 1).

In corroboration with the results at the 10-year follow-up, most of the TMD related symptoms, including headaches, were more commonly reported by women than by men. Once again, the different symptoms were found to be statistically significantly but mainly weakly correlated to each other as well as to tooth-clenching and tooth-grinding (*rs* values ranging between 0.11 and 0.53, *p*-values ranging between 0.05 and 0.001). The strongest correlations found were between jaw fatigue and tooth-clenching and tooth-grinding ($rs = 0.42$ and 0.53, respectively).

Table I. Prevalence in % of reported symptoms of temporomandibular disorder in the 402 subjects examined originally on 4 occasions during a 20-year period

	Age at examination			
Reported symptoms	7–15 years $n=402$	11–20 years $n=240$	17–25 years $n=293$	27–35 years $n=320$
1. TMJ sounds				
Frequent	0	5	8	8
Occasional	13	18	24	24
2. Jaw fatigue				
Frequent	0	0	2	4
Occasional	5	1	14	17
3. Difficulties in mouth opening				
Frequent	0	1	2	4
Occasional	6	6	7	11
4. Pain or fatigue in the jaws or face during chewing, for example of chewing gum				
Frequent	6	7	12	11
Occasional	47	50	51	45
5. One or more symptoms 1–3				
Frequent	0	6	10	13
Occasional	19	24	33	33

Predictors of TMD symptoms. The logistic regression procedure showed that 3 independent variables recorded at first examination were significant predictors for reported TMJ clicking 20 years later [18]. These variables were: tooth wear index (OR 4.3, $p = 0.014$), clinically recorded TMJ clicking (OR 3.3, $p < 0.0001$), and reported tooth-grinding at night (OR 2.2, $p = 0.023$). In a second logistic regression model, when reported TMD symptoms, excluding TMJ clicking, at the 20-year follow-up was the dependent variable, only reported TMJ clicking at the start turned out to be a significant predictor (OR 2.3, $p = 0.011$).

Clinical signs of TMD

Clinical signs of TMD were fairly common at baseline, but severe signs were uncommon. At the first clinical follow-ups after 4 and 5 years [7,8], the clinical dysfunction index used [24] had increased in the 2 youngest age groups but remained unchanged in the oldest. The oldest age group was clinically examined also after 10 and 20 years. The clinical dysfunction index remained unchanged up to the 10-year follow-up [14], and from 25 to 35 years of age [15] there was a statistically significant reduction of the index (Figure 2; $p < 0.001$). During the period covered by the investigation, the clinical dysfunction index fluctuated unpredictably.

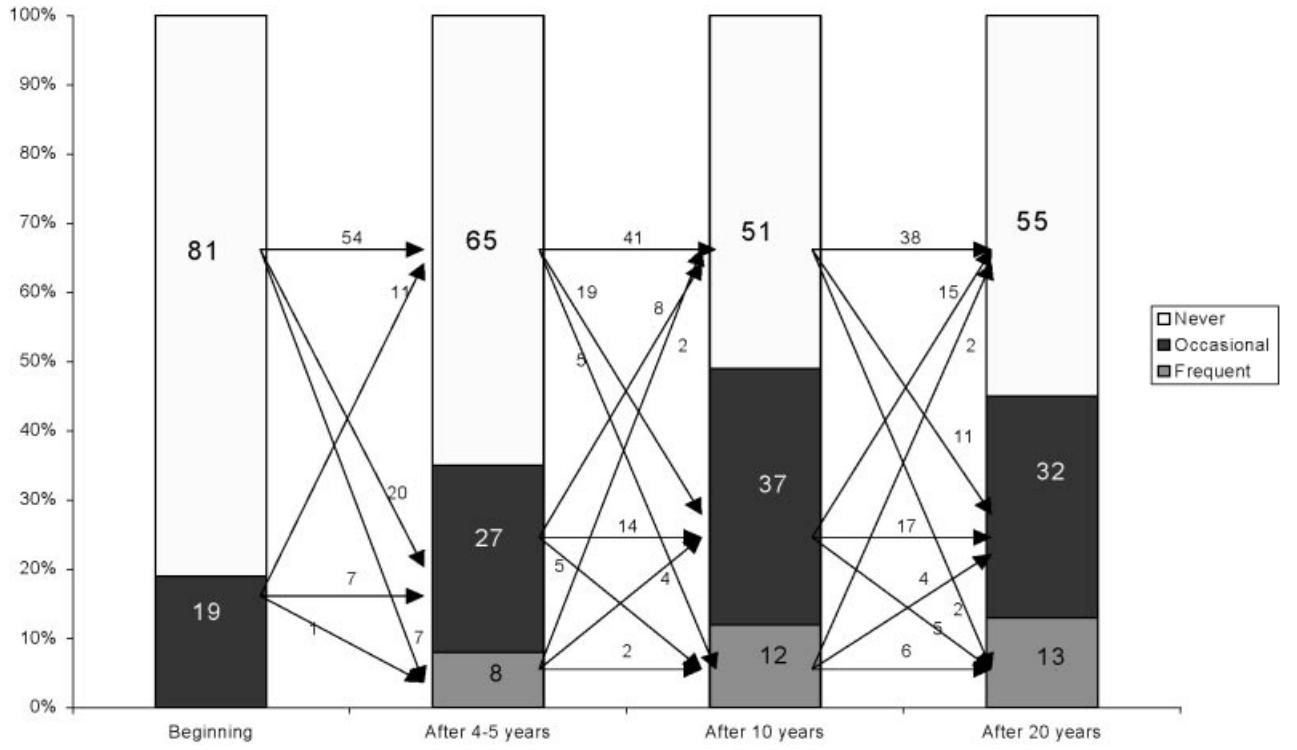

Figure 1. Variation (in %) in reported temporomandibular disorder symptoms on 4 occasions during a 20-year period.

At the first follow-ups after 4 and 5 years there was no difference between boys and girls in prevalence of clinical signs in the 2 youngest age groups [7]. However, at the age of 20 years [8], females were recorded to have impaired TMJ function more often than males ($p<0.05$), and at both the 10- and 20-year follow-ups [14,15], jaw muscles tender upon palpation and TMJ sounds were more common findings in women than in men (p-values ranging between <0.05 and <0.01).

A significant correlation between subjective symptoms of TMD and the clinical dysfunction index were found on all follow-up examinations; at the 20-year follow-up the *rs* value was 0.45 and the p value <0.001 [15].

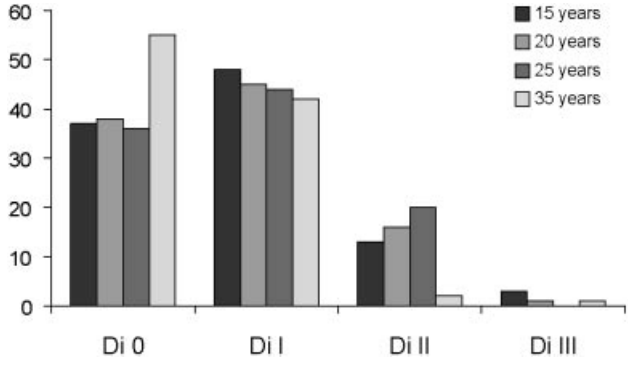

Figure 2. Distribution of the clinical dysfunction index, Di, on four occasions. (Reprinted from Magnusson T, Egermark I, Carlsson GE. A longitudinal epidemiologic study of signs and symptoms of temporomandibular disorders from 15 to 35 years of age. J Orofacial Pain 2000;14:310–9, by permission of Quintessence Publishing Co.).

The mean maximal jaw opening was 49 mm in the 7-year-old children, 53 mm in the 11-year-olds and 56 mm in the 15-year-olds [7]. At the follow-ups, the level of the maximal jaw opening remained constant in those 15 years old or older (mean 56 mm, range 43–74 mm at the age of 35). The adult men had a significantly larger mouth opening than women (57 and 54 mm, respectively). At the age of 15 years [8], the maximal jaw opening was negatively correlated to TMD symptoms as well as to the clinical dysfunction index ($rs=-0.22$ and -0.33, $p<0.05$ and <0.001, respectively), and at the age of 35 [15], this negative correlation to TMD symptoms remained ($rs=-0.26$, p-value <0.01). A reduced maximal opening of the mouth was twice as common among subjects with a TMD treatment need compared to those with no such need [11].

Predictors of TMD signs. Four different variables registered at baseline predicted clinical signs of dysfunction 20 years later [18]: deep bite (OR 12.5, $p=0.025$), clinically recorded TMJ clicking (OR 8.3, $p=0.002$), bruxism + other oral parafunctions (OR 7.7, $p=0.0031$), and bruxism (OR 5.3, $p=0.016$).

Occlusal factors

Functional malocclusions/occlusal interferences. Occlusal interferences were a common finding in all ages. At the

age of 7 years, 53% had one or more such interference, and this figure increased to 76% at the age of 20 years [9]. However, at the follow-up after 4 to 5 years only a few weak and inconsistent correlations were found between occlusal interferences and signs and symptoms of TMD. The only exception was lateral forced bite between RCP and ICP, which variable was positively correlated to TMJ sounds in all age groups ($rs = 0.24$–0.31, $p < 0.01$–0.001). This correlation persisted at the 20-year follow-up [20], when TMJ clicking was more than twice as common among subjects with a lateral forced bite ($rs = 0.31$, $p < 0.01$). When multiple regression analysis was performed, the explanatory effects of occlusal factors on signs and symptoms of TMD in a longitudinal aspect were very small.

At ages 25 and 35 years [20], a lateral forced bite between RCP and ICP was significantly correlated to subjective symptoms of TMD ($rs = 0.29$, $p < 0.05$ and $rs = 0.23$, $p < 0.05$, respectively). A great sagittal and vertical distance between RCP and ICP (> 0.5 mm) was more commonly recorded among those judged to be in need of TMD treatment compared to those without such a treatment need [11]. At the age of 25 years [14], non-working-side interferences during the first 3 mm of lateral excursion were significantly correlated to the presence of one or more subjective symptoms of TMD ($p < 0.05$, $rs = 0.23$), and non-working-side interferences from more than 3 mm to maximal lateral excursion were correlated to intermittent locking of the TMJs reported by 6 individuals ($p < 0.01$, $rs = 0.30$).

Morphological malocclusions. Some kind of morphological malocclusion was recorded in 51% of the 7-year-olds. This figure decreased to 38% at the age of 20 years [10]. In the oldest age group, the prevalence figures for the different malocclusions were fairly constant from the age of 15 to 35 years [20]. The only exception was subjects with crossbite, i.e. a statistically significant increase from 12% to 22% mostly due to eruption of 3rd molars.

Correlations between morphological malocclusions and signs and symptoms of TMD were weak and inconsistent [10]. In a long-term perspective, crossbite, anterior open bite, post-, and prenormal occlusion had some association with the development of TMD, but the only morphological malocclusion with a fairly substantial explanatory value in the regression analysis was crossbite that predisposed to TMJ pain. TMJ-related problems were more than twice as frequent in subjects recorded as having crossbite both at baseline and at the follow-up examination after 4 to 5 years compared to those with no malocclusion. At the age of 35 years [20], TMJ clicking was three times more common among those who had a unilateral crossbite 10 years earlier ($rs = 0.35$, $p < 0.01$).

Oral parafunctions

Reports of both occasional and frequent tooth-clenching and tooth-grinding gradually increased during the 20-year period in all 3 age groups. At the last examination, both frequent tooth-clenching in the daytime and frequent nocturnal tooth-grinding were reported by 16% of the participants, and more than half (55%) were aware of some kind of occlusal parafunction frequently or occasionally [16]. Weak to moderate correlations were found between both tooth-clenching and tooth-grinding and all the separate TMD symptoms, including headache [15,16].

In contrast to the increase of occlusal parafunctions, the prevalence of nail-biting and other biting habits decreased with increasing age, but at the 20-year follow-up, when the subjects were 27 to 35 years of age, as many as 14% reported that they frequently performed such habits.

Tooth wear

At the 4- to 5-year follow-ups, there was a minor but significant increase of tooth wear in all 3 age groups and in all 4 dental regions [9]. The wear seemed to slow down between 20 and 25 years [14], when the increase was statistically significant only in the canine region ($p < 0.001$). At the age of 25 years, the occlusal wear index was statistically significantly correlated to reported tooth-grinding and/or tooth-clenching ($p < 0.01$, $rs = 0.39$), as well as to TMJ pain on palpation ($p < 0.05$, $rs = 0.23$) and reports of difficulties in mouth opening ($p < 0.05$, $rs = 0.26$).

During the age period 25 to 35 years [15], the increase in wear was still minor but statistically significant for incisors (from a mean of 2.9 to 3.1 on the 5-point scale; $p < 0.001$) and for canines (from 2.8 to 2.9; $p < 0.05$). Men had statistically significantly more tooth wear in all dental regions compared to women (p-values ranging between 0.01 and 0.001).

Predictors of tooth wear. Logistic regression analyses at the 20-year follow-up [19] revealed 3 predictors for anterior tooth wear (wear on incisors and canines). The 3 variables at first examination that predicted tooth wear 20 years later were postnormal occlusion, anterior tooth wear and premolar tooth wear, postnormal occlusion being the strongest (OR 7.3, 3.4 and 4.1, respectively, p-values: 0.0011, 0.019, and 0.019, respectively). Of the variables recorded at the 20-year follow-up, non-working-side interferences turned out as a negative predictor for anterior tooth wear (OR 0.26, $p = 0.030$), indicating that those with non-working-side interferences had an almost 4 times reduced risk of exhibiting severe tooth wear.

Need and demand for TMD treatment. At the age of 20 years, 27% of the examined subjects were judged to be

in need of some kind of functional treatment [11]. The corresponding figure at the age of 25 years [14] was fairly much the same (25%), but considerably lower (11%) at the age of 35 years [17]. At the age of 20 years, the treatment need was greater among women compared to men by a ratio of 2 : 1. This gender difference had levelled out 5 years later, and at the age of 35 years fewer women than men were judged to have a treatment need, the ratio now being the reverse, i.e. 1 : 2. On all three occasions the treatment interventions suggested were minor and in most cases not time-consuming (besides counseling and education, jaw exercises, interocclusal appliances, and occlusal adjustment).

On all occasions, the expressed demand for TMD treatment was much less than the estimated treatment need. At the 10-year follow-up, when the participants were 17 to 25 years of age, 2% (all women) expressed a treatment demand [13]. Ten years later [16], at ages 27–35 years, this figure had increased to 4% (all men).

At the 10-year follow-up, 7% of the participants stated that they had received some kind of TMD treatment [13]. This figure increased to 12% at the 20-year follow-up [16]. On both occasions, more women than men had received treatment, the ratio being approximately 2 : 1. In the oldest age group, 35 years of age at the last examination, 18% had an experience of TMD treatment during the 20-year observation period, and in this age group there was no sex difference [17]. The most common treatment was interocclusal appliances, but jaw exercises and occlusal adjustment, as well as combinations of these options, had also been used. A vast majority of those who had been treated reported a positive treatment effect, i.e. 83% and 85%, respectively [16,17].

Predictors of demand for TMD treatment. At 15, 25, and 35 years of age [21], tooth-grinding at night was reported statistically significantly more often by those who had received TMD treatment during the 20-year period compared to the others (p-values ranging between 0.004 and 0.0001). When logistic regression analyses were performed, tooth-grinding at night fell out as a predictor for TMD treatment during the coming 20 years at 15, 25, and 35 years of age (OR 5.3, 4.9, and 50.0, respectively; p-values: 0.0038, 0.0097, and <0.0001, respectively). This indicates that those who reported tooth-grinding at baseline or at the 10-year follow-up had an approximately 5 times greater likelihood of demanding TMD treatment up to the age of 35 years, and there was a 50 times greater chance that those who reported this parafunction at the age of 35 years had been treated for TMD. The positive predictive value of this variable reported at baseline was low (36%), however, while the negative predictive value was 90%. This indicates a high probability of not demanding TMD treatment when not reporting this parafunction at the age of 15 years.

Orthodontics and TMD

At both the 10- and 20-year follow-ups, one-third of the subjects (34% and 32%, respectively) reported that they had had some kind of orthodontic treatment in childhood [12,20]. At the 10-year follow-up, those who had not experienced such treatment reported statistically significantly more pronounced symptoms and had more clinical signs of TMD compared to those who had received orthodontic treatment. At the 20-year follow-up, this difference persisted, but it did not reach statistically significant levels.

After 10 years, 12% of the orthodontically treated subjects in the oldest age group reported that they had experienced the treatment to be inconvenient all the time and 35% inconvenient sometimes. Thirteen percent reported a significant relapse and 26% some relapse. Thirty-five percent were very satisfied with the result of the treatment. Ten years later, at the 20-year follow-up, the subjects were more pleased with the treatment. As many as 94% were now very satisfied with the result of the treatment. None regretted that they had undergone the treatment, and 80% would recommend someone in their previous situation to have the treatment. Still, 12% remembered the treatment to be inconvenient all the time, but those who considered it inconvenient sometimes had been reduced to 24%. Only 12% reported a relapse, but all judged it to be significant. At both the 10- and 20-year follow-up, 6% expressed a present demand for orthodontic treatment.

Discussion

The present series of papers presents a number of data during a 20-year follow-up period focusing mainly on different TMD-related variables. When performing longitudinal studies covering such a long time period, loss of participants and data is inevitable. However, the participation rate must be considered exceptional and is probably one of the highest response rates reported for long-term epidemiological studies of TMD. When taking into account the explainable losses, reported and clinical information was available from 92% and 85% of the original sample, respectively, at the 20-year follow-up. The subjects examined were considered representative of Swedish individuals, and the longitudinal design made the sample suitable for descriptive epidemiology. The dropouts did not differ significantly from the remaining subjects with respect to gender or to any of the originally recorded signs and symptoms of TMD according to statistical analysis. However, loss of participants always entails a risk of skewed results, and they must therefore be interpreted with some caution.

Twenty years is a long period of time, and during this period much new knowledge has been acquired concerning TMD. One of many reflections of the

development that has occurred in this field is the change in the name of the different functional disorders covered by the TMD umbrella. A common labeling 20 years ago was mandibular dysfunction, a term used in our first 3 papers. In the 1990s, the term craniomandibular disorders (CMD) came into use. Finally, today there is almost consensus on use of the term temporomandibular disorders (TMD). The current definition is that TMD is a collective term embracing a number of clinical problems that involve the masticatory musculature, the TMJ and associated structures, or both [29].

In the 1970s, there were many unsolved issues in the field of TMD, e.g. etiology, local and general risk factors, treatment need and demand, just to mention a few. We believed that one way of shedding light on these questions might be through longitudinal investigations. Our initial optimism did not last long. Already, when presenting the results of the 5-year follow-up [8], we wrote that the search for simple correlations was a Sisyphus task. This feeling has been strengthened further during the course of our investigations. However, some conclusions can be drawn from our results.

One conclusion is that TMD symptoms are common from childhood to adulthood. This is in line with previous epidemiological results [30]. Another obvious and important conclusion is that there is a substantial fluctuation of TMD symptoms over time. This corroborates the findings in other longitudinal studies, most of them performed during the past decade [31–46]. Another important finding is that progression to severe pain and dysfunction of the masticatory system was rare. On the other hand, spontaneous recovery from more pronounced symptoms was also rare. The latter finding contradicts the opinion put forward that TMD is remitting and self-limiting [29,47].

It is well established that in clinical series of TMD patients, women predominate. This sex difference has often been discussed, but it remains largely unexplained [48]. In contrast to many older epidemiological investigations, several recent studies [39,49–52], as well as the present one, have found more frequent and severe symptoms and signs of TMD in women than in men. This can partly but not completely explain the overrepresentation of women in clinical materials. Another contributing factor to this gender difference might be that women have a greater sensitivity to pain than men. This has been shown in experiments both in animals and in humans [53,54].

At both the 10- and 20-year follow-ups, correlations between the different TMD symptoms were found. Also many of the clinical variables of TMD were significantly correlated to one another. This clearly illustrates that patients who exhibit one symptom or sign of TMD are likely to have other such symptoms or signs. This underlines the fact that TMD patients are often not only multisymptomatic but also likely to exhibit more than one clinical sign of TMD.

The correlations found between reported TMD symptoms and tooth-clenching and tooth-grinding is interesting. Reports of bruxism at baseline were also a predictor for the presence of clinical signs 20 years later. Associations between oral parafunctions and TMD symptoms and signs have been reported in several studies [49,52,55,56]. This indicates that such parafunctions cannot be ruled out as possible etiological factors in the development of TMD. Another striking finding was that reported tooth-grinding at night, both at baseline and at the follow-up examinations, was a predictor of demand for TMD treatment [21]. This finding also supports the concept of a positive relationship between nocturnal bruxism and TMD. The impact of this variable was evident in all the regression models tested. Most of all, the negative predictive value at baseline was 90%, indicating a high probability of not demanding TMD treatment later in life when not reporting this parafunction in adolescence. However, the associations found do not tell us whether the parafunction is the cause or the consequence of pain/dysfunction. It has also been observed that patients with TMD signs and symptoms often report that they know they brux their teeth, because their previous dentists informed them of such habits, even if the evidence was uncertain [57]. Parafunctional habits are still regarded as important causative factors in TMD by most clinicians, but their role is confusing, and there is no strong scientific evidence of a close relationship between bruxism and TMD [58,59].

The finding that clinically recorded TMJ clicking at first examination predicted reported clicking 20 years later indicates that this symptom may persist for a long period of time in many subjects, but in most cases TMJ clicking fluctuates considerably over time [16] and rarely develops into locking [16,60]. We have previously emphasized that TMJ sounds per se are no indication for treatment, and that it can be questioned whether clicking without pain should be seen as a symptom or sign of TMD [15]. However, reported TMJ clicking at start was the only significant predictor for the presence of other TMD symptoms 20 years later [18] and reported joint sounds at the 20-year follow-up were also correlated to the presence of other TMD symptoms [15]. Furthermore, clinically recorded clicking at baseline was one of the predictors for the development of clinical signs 20 years later [18]. Because of this, such sounds can indicate a risk of having other TMD symptoms, or later of developing symptoms and signs of TMD, justifying an extended patient history and functional examination.

In the present investigation, the clinical dysfunction index increased from the age of 7 to 15 years and leveled out up to 25 years. This finding is in agreement with other studies [61]. The reduction registered from 25 to 35 years of age, however, differs from cross-sectional epidemiological investigation, where a further increase of clinical signs with increasing age has been reported [62]. The decrease in the present material is

remarkable and difficult to fully explain. One possible explanation is actually a decrease due to spontaneous regression. Many of the 35-year-old subjects said that they experienced the present period of their lives as much calmer with respect to family and work compared with their situation 10 years previously. Another possibility is that the decrease is due to the TMD treatment performed in nearly one-fifth of the subjects during the period covered by the investigation. A third explanation, one that cannot be excluded, is that the examiners' evaluation of the semi-objective clinical signs of TMD had changed over time.

The figures found for maximal mouth opening, as well as the sex difference, corroborate the findings by Agerberg [61] and support his finding that the maximal opening capacity of the mouth is reached in the early teens and then remains stable in adulthood. The finding that reduced maximal mouth opening was twice as common among those judged to be in need of TMD treatment [11], and the negative correlation between this clinical parameter and the presence of TMD symptoms both in adolescents [8] and adults [15] is interesting. Maximal jaw opening capacity is one of the few purely objective clinical parameters in functional examination of the masticatory system [61]. Our findings support the notion that intra-individual change in maximal mouth opening is a valid parameter reflecting the functional status in the masticatory system. Even a moderate reduction, on an individual basis, should be noted, as this may indicate a need for intervention.

The etiologic importance of occlusal factors in the development of TMD is still a topic of great controversy. In the present investigation, both occlusal interferences and morphological malocclusions were very common in all age groups. Several correlations were found between occlusal factors and both signs and symptoms of TMD. In most cases, however, the correlations were weak and inconsistent. This finding is in agreement with findings in recent research in this field [63–65]. It has been stated that the lack of an association between occlusal interferences and signs of TMD is due to the omnipresence of such interferences, and that inadequate and invalid study designs may have led to false-negative results [66]. The consistent finding in our studies of a correlation between a lateral forced bite between RCP/ICP and subjective symptoms of TMD, as well as the finding of a larger sagittal and vertical distance RCP/ICP in subjects in need of TMD treatment, is interesting. It suggests that the presence of such interferences should be considered in the treatment planning of subjects with TMD.

Of the different morphological malocclusions, the presence of crossbite seems to be a risk factor for TMD. Prolonged presence of crossbite predisposed to TMJ pain, and 4 out of 6 subjects with severe clinical signs and/or frequent subjective symptoms of TMD both at the 10- and 20-year follow-ups [20] had a lateral forced bite RCP/ICP and/or a unilateral crossbite. A recent study also reported that crossbite was more common in adolescents with compared to controls without TMD signs and symptoms [67].

A deep bite at baseline was one of the risk factors found for the development of clinical signs of TMD 20 years later with an odds ratio of 12.5. The clinical relevance of this finding is questionable, however, since only a few subjects had this malocclusion, and they did not turn out to have any increased risk of developing subjective symptoms of TMD.

The degree of tooth wear increased slowly with increasing age, but still at the age of 35 years pronounced wear was a rare finding. This finding is in line with the opinion that rapid wear is uncommon. In most individual cases, it is sufficient to follow the wear longitudinally, preferably with study casts. If, in single cases, significant continuing wear is observed, causes such as dental erosion should be considered. If bruxism is an evident cause, an interocclusal appliance can be recommended to protect the teeth from further excessive wear [22]. The negative correlation found between wear and non-working-side interferences indicates that such interferences may protect the front teeth from extensive wear by preventing the anterior teeth from contact during function.

At 20 and 25 years of age, approximately one-fourth of the subjects were judged to need TMD treatment. This is in agreement with figures presented by others [68–70]. At the age of 35 years, the estimated treatment need had decreased to 11%. This corresponds well with the parallel decrease of clinical signs of dysfunction discussed above, and is probably a reflection of a calmer period in life expressed by many of the participants. It might also be a consequence of the TMD treatment that had been performed during the time period covered by the investigation. A change in the examiners' evaluations over the years is still another possibility that cannot be excluded.

A comparatively large number of subjects had received some kind of TMD treatment during the 20-year period, figures higher than those presented in other investigations [37,71,72]. One plausible explanation might be that the present sample had been regularly questioned about symptoms and been examined for signs of TMD, leading to an increased awareness of their presence and knowledge that treatment options were available. The figure indicates an incidence of 1% new TMD cases per year, which is lower than the 2% to 3% suggested in a review on epidemiology of orofacial pain [73].

The treatment proposed was in most cases simple and not time-consuming. In only 4% of the 20-year-old subjects was the treatment judged to be more extensive, a figure in good agreement with that reported by others [74].

Among those who had received TMD treatment (usually interocclusal appliances, sometimes in combination with jaw exercises and occlusal adjustment), 85% stated that the treatment had had a positive effect

on their symptoms [17]. This is in accordance with numerous reports of a favorable outcome of simple, not time-consuming and mostly reversible, TMD treatment [22,29].

Corroborating previous investigations [75,76], the demand for treatment was very low in all ages covered by this investigation. At 35 years of age, only 3 out of 114 subjects expressed an active demand for treatment. One explanation might be the previous treatment performed in 18% of the group.

It has been claimed that previously orthodontically treated patients run a higher risk of developing TMD [77]. From the analyses of TMD signs and symptoms among those who had received orthodontic treatment in the present material, compared to those who had not, it is obvious that this treatment does not lead to a higher risk of developing TMD later in life. This finding is also in line with other recent investigations [45,78–82].

At both the 10- and 20-year follow-ups, patients were satisfied with the result of the orthodontic treatment. An interesting observation, however, was that opinions about the treatment result were even more positive in the longer perspective of 20 years compared to 10 years. Negative recollections thus seemed to fade away and left, in the long term, a mainly positive memory of the treatment in most subjects.

Conclusions

This article summarizes a number of studies of TMD-related variables in a relatively large sample followed for 20 years from childhood to adult age. The study was not originally planned for etiological analyses, and therefore the associations found between possible causal factors and TMD signs and symptoms must be interpreted with caution. Acknowledging these limitations, the results warrant the following conclusions:

- Signs and symptoms of TMD were common already in childhood, but they were mainly of a mild character. Prevalence increased up to young adulthood after which a minor reduction occurred.
- Both signs and symptoms of TMD fluctuated, and progression to severe pain and dysfunction was rare.
- The gender difference in signs and symptoms was small in childhood, but from late adolescence women reported more symptoms and exhibited more clinical signs than men did.
- There were significant correlations between reported bruxism and TMD symptoms. Baseline report of tooth-grinding at night was a predictor of TMD treatment during the observation period.
- Occlusal interferences were numerous at all examinations. They were only weakly associated with TMD signs and symptoms. However, a lateral forced bite between RCP and ICP, as well as unilateral crossbite, showed significant correlations with TMD signs and symptoms indicating that they deserve further consideration.
- The demand for TMD treatment was low at all examinations, while the estimated treatment need was greater. Since 18% of the subjects in the oldest age group had received some kind of TMD treatment during the 20-year period, the incidence of new TMD cases per year was approximately 1%.
- Those who had received orthodontic treatment were in general satisfied with the treatment result, and the recollection became more positive with time.
- Orthodontic treatment does not imply a risk of development of TMD later in life.

References

[1] Egermark-Eriksson I, Carlsson GE, Ingervall B. Prevalence of mandibular dysfunction and orofacial parafunction in 7-, and 15-year-old Swedish children. Eur J Orthod 1981;3:163–72.

[2] Egermark-Eriksson I. Malocclusion and some functional recordings of the masticatory system in Swedish schoolchildren. Swed Dent J 1982;6:9–20.

[3] Egermark-Eriksson I. Prevalence of headache in Swedish schoolchildren. A questionnaire survey. Acta Paediatr Scand 1982;71:135–40.

[4] Egermark-Eriksson I, Ingervall B. Anomalies of occlusion predisposing to occlusal interference in children. Angle Orthod 1982;52:293–9.

[5] Egermark-Eriksson I, Ingervall B, Carlsson GE. The dependence of mandibular dysfunction in children on functional and morphologic malocclusion. Am J Orthod 1983;83:187–94.

[6] Egermark-Eriksson I. Mandibular dysfunction in children and in individuals with dual bite [Thesis]. Swed Dent J Suppl 10 1982;10:1–45.

[7] Magnusson T, Egermark-Eriksson I, Carlsson GE. Four-year longitudinal study of mandibular dysfunction in children. Community Dent Oral Epidemiol 1985;13:117–20.

[8] Magnusson T, Egermark-Eriksson I, Carlsson GE. Five-year longitudinal study of signs and symptoms of mandibular dysfunction in adolescents. J Craniomandib Pract 1986;4: 338–44.

[9] Egermark-Eriksson I, Carlsson GE, Magnusson T. A long-term epidemiologic study of the relationship between occlusal factors and mandibular dysfunction in children and adolescents. J Dent Res 1987;66:67–71.

[10] Egermark-Eriksson I, Carlsson GE, Magnusson T, Thilander B. A longitudinal study on malocclusion in relation to signs and symptoms of cranio-mandibular disorders in children and adolescents. Eur J Orthod 1990;12:399–407.

[11] Magnusson T, Carlsson GE, Egermark-Eriksson I. An evaluation of the need and demand for treatment of craniomandibular disorders in a young Swedish population. J Craniomandib Disord 1991;5:57–63.

[12] Egermark I, Thilander B. Craniomandibular disorders with special reference to orthodontic treatment: an evaluation from childhood to adulthood. Am J Orthod Dentofacial Orthop 1992;101:28–34.

[13] Magnusson T, Carlsson GE, Egermark I. Changes in subjective symptoms of craniomandibular disorders in children and adolescents during a 10-year period. J Orofacial Pain 1993; 7:76–82.

[14] Magnusson T, Carlsson GE, Egermark I. Changes in clinical signs of craniomandibular disorders from the age of 15 to 25 years. J Orofacial Pain 1994;8:207–15.
[15] Magnusson T, Egermark I, Carlsson GE. A longitudinal epidemiologic study of signs and symptoms of temporomandibular disorders from 15 to 35 years of age. J Orofac Pain 2000;14:310–9.
[16] Egermark I, Carlsson GE, Magnusson T. A 20-year longitudinal study of subjective symptoms of temporomandibular disorders from childhood to adulthood. Acta Odontol Scand 2001;59:40–8.
[17] Magnusson T, Egermark I, Carlsson GE. Treatment received, treatment demand, and treatment need for temporomandibular disorders in 35-year-old subjects. J Craniomandib Pract 2002;20:11–17.
[18] Carlsson GE, Egermark I, Magnusson T. Predictors of signs and symptoms of temporomandibular disorders: a 20-year follow-up study from childhood to adulthood. Acta Odontol Scand 2002;60:180–5.
[19] Carlsson GE, Egermark I, Magnusson T. Predictors of bruxism, other oral parafunctions, and tooth wear over a 20-year follow-up period. J Orofac Pain 2003;17:50–7.
[20] Egermark I, Magnusson T, Carlsson GE. A 20-year follow-up of signs and symptoms of temporomandibular disorders and malocclusions in subjects with and without orthodontic treatment in childhood. Angle Orthod 2003;73: 109–15.
[21] Carlsson GE, Magnusson T, Egermark I. Prediction of demand for treatment of temporomandibular disorders based on a 20-year follow-up study. J Oral Rehabil 2004;31:511–7.
[22] Carlsson GE, Magnusson T. Management of temporomandibular disorders in the general dental practice. Chicago: Quintessence; 1999.
[23] Carlsson GE, Egermark-Eriksson I, Magnusson T. Intra- and inter-observer variation in functional examination of the masticatory system. Swed Dent J 1980;4:187–94.
[24] Helkimo M. Studies on function and dysfunction of the masticatory system. II. Index for anamnestic and clinical dysfunction and occlusal state. Swed Dent J 1974;67:101–21.
[25] Björk A, Krebs AA, Solow B. A method for epidemiological registration of malocclusion. Acta Odontol Scand 1964;22: 27–41.
[26] Good P. Permutation tests. A practical guide to resampling methods for testing hypotheses. New York: Springer; 2000. pp 36–7.
[27] Siegel D. Non-parametric statistics for the behavioral sciences. New York: McGraw Hill; 1956.
[28] Bradley JV. Distribution-free statistical tests. Englewood Cliffs, NJ: Prentice Hall; 1968.
[29] Okeson JP. Orofacial pain: guidelines for assessement, diagnosis and management. Carol Stream: Quintessence; 1996.
[30] Carlsson GE. Epidemiology and treatment need for temporomandibular disorders. J Orofac Pain 1999;13:232–7.
[31] De Boever JA, van den Berghe L. Longitudinal study of functional conditions in the masticatory system in Flemish children. Community Dent Oral Epidemiol 1987;15:100–3.
[32] Wänman A, Agerberg G. Recurrent headaches and craniomandibular disorders in adolescents. A longitudinal study. J Craniomandib Disord Facial Oral Pain 1987;4:229–36.
[33] Heikinheimo K, Salmi K, Myllarniemi S, Kirveskari P. Symptoms of craniomandibular disorders in a sample of Finnish adolescents at the age of 12 and 15 years. Eur J Orthod 1989;11:325–31.
[34] Österberg T, Carlsson GE, Wedel A, Johansson U. A cross-sectional and longitudinal study of craniomandibular dysfunction in an elderly population. J Craniomandib Disord Facial Oral Pain 1992;6:237–45.
[35] Pilley JR, Mohlin B, Shaw WC, Kingdon A. A survey of craniomandibular disorders in 800 15-year-olds. A follow-up study of children with malocclusion. Eur J Orthod 1992;14: 152–61.
[36] Könönen M, Nyström M. A longitudinal study of craniomandibular disorders in Finnish adolescents. J Orofac Pain 1993;7:329–36.
[37] Kampe T, Hannerz H, Ström P. Ten-year follow-up study of signs and symptoms of craniomandibular disorders in adults with intact and restored dentitions. J Oral Rehabil 1996;23: 416–23.
[38] Onizava K, Yoshida H. Longitudinal changes of symptoms of temporomandibular disorders in Japanese young adults. J Orofac Pain 1996;10:151–6.
[39] Wänman A. Longitudinal course of symptoms of craniomandibular disorders in men and women. Acta Odontol Scand 1996;54:337–42.
[40] Kuttila M, Kuttila S, Niemi PM, Alanen P, Le Bell Y. Fluctuation of treatment need for temporomandibular disorders and age, gender, stress, and diagnostic subgroup. Acta Odontol Scand 1997;55:350–5.
[41] Alanen P, Kuttila M, Le Bell Y. Fluctuation of temporomandibular disorders in accordance with two classifications: the Helkimo dysfunction index and treatment need grouping. Acta Odontol Scand 1997;55:14–7.
[42] Kitai N, Takada K, Yasuda Y, Verdonck A, Carels C. Pain and other cardinal TMJ dysfunction symptoms: a longitudinal survey of Japanese female adolescents. J Oral Rehabil 1997; 24;741–8.
[43] Kuttila M, Niemi PM, Kuttila S, Alanen P, Le Bell Y. TMD treatment need in relation to age, gender, stress, and diagnostic subgroup. J Orofac Pain 1998;12:67–74.
[44] Pahkala RH, Laine-Alava MT. Do early signs of orofacial dysfunction and occlusal variables predict development of TMD in adolescents? J Oral Rehabil 2002;29:737–43.
[45] Henriksson T, Nilner M. Temporomandibular disorders, occlusion and orthodontic treatment. J Orthod 2003;30: 129–37.
[46] Rammelsberg P, Le Reche L, Dworkin S, Mancl L. Longitudinal outcome of temporomandibular disorders: a 5-year epidemiologic study of muscle disorders defined by research diagnostic criteria for temporomandibular disorders. J Orofac Pain 2003;17:9–20.
[47] Dworkin SF, Huggins KH, Le Resche L, von Korff M, Howard J, Truelove E, et al. Epidemiology of signs and symptoms of temporomandibular disorders: clinical signs in cases and controls. J Am Dent Assoc 1990;120:273–81.
[48] Dao TT, LeResche L. Gender differences in pain. J Orofac Pain 2000;14:169–84.
[49] Conti PC, Ferreira PM, Pegoraro LF, Conti JV, Salvador MC. A cross-sectional study of prevalence and etiology of signs and symptoms of temporomandibular disorders in high school and university students. J Orofac Pain 1996;10: 254–62.
[50] List T, Wahlund K, Wenneberg B, Dworkin SF. TMD in children and adolescents: prevalence of pain, gender differences, and perceived treatment need. J Orofac Pain 1999;13:9–20.
[51] Nordström G, Eriksson S. Longitudinal changes in craniomandibular dysfunction in an elderly population in northern Sweden. Acta Odontol Scand 1994;52:271–9.
[52] Johansson A, Unell L, Carlsson GE, Söderfeldt B, Halling A. Gender differences in symptoms related to temporomandibular disorders in a population of 50-year-old subjects. J Orofac Pain 2003;17:29–35.
[53] Sternberg W. Animal models of sex differences in pain and analgesia. J Musculoskeletal Pain 1998;6:36–40.
[54] Berkley KJ. Sex differences in pain. Behav Brain Sci 1997;20:371–80.
[55] Abdel-Hakim AM, Alsalem A, Khan N. Stomatognathic dysfunctional symptoms in Saudi Arabian adolescents. J Oral Rehabil 1996;23:655–61.

[56] Widmalm SE, Christiansen RL, Gunn SM. Oral parafunctions as temporomandibular disorder risk factors in children. J Craniomandib Pract 1995;13:242–6.

[57] Marbach JJ, Raphael KG, Dohrenwend BP, Lennon MC. The validity of tooth-grinding measures: etiology of pain dysfunction syndrome revisited. J Am Dent Assoc 1990;120: 327–33.

[58] Storey AT. Unresolved issues and controversies. In: Zarb GA, Carlsson GE, Sessle BJ, Mohl ND, editors. Temporomandibular joint and masticatory muscle disorders. Copenhagen: Munksgaard; 1994. pp 584–615.

[59] Lobbezoo F, Lavigne GJ. Do bruxism and temporomandibular disorders have a cause–effect relationship? J Orofac Pain 1997; 11:15–23.

[60] Könönen M, Waltimo A, Nyström M. Does clicking in adolescence lead to painful temporomandibular clicking? Lancet 1996;347:1080–1.

[61] Agerberg G. On mandibular dysfunction and mobility [Thesis]. Umeå, Sweden: University of Umeå; 1974.

[62] Salonen L, Hellden L, Carlsson GE. Prevalence of signs and symptoms of dysfunction in the masticatory system: an epidemiological study in an adult Swedish population. J Craniomandib Disord 1999;4:241–50.

[63] Celic R, Jerolimov V, Panduric J. A study of the influence of occlusal factors and parafunctional habits on the prevalence of signs and symptoms of TMD. Int J Prosthodont 2002; 15:43–8.

[64] McNamara JA Jr, Seligman DA, Okeson JP. Occlusion, orthodontic treatment and temporomandibular disorders: a review. J Orofac Pain 1995;9:73–90.

[65] De Boever JA, Carlsson GE, Klineberg IJ. Need for occlusal therapy and prosthodontic treatment in the management of temporomandibular disorders. Part I. Occlusal interferences and occlusal adjustment. J Oral Rehabil 2000;27:367–79.

[66] Kirveskari P, Alanen P, Jämsä T. Association between craniomandibular disorders and occlusal interferences. J Prosthet Dent 1989;62:66–9.

[67] Mohlin BO, Derweduwen K, Pilley R, Kingdon A, Shaw WC, Kenealy P. Malocclusion and temporomandibular disorders: 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. Angle Orthod 2004;74:319–27.

[68] Posselt U. The temporomandibular joint syndrome and occlusion. J Prosthet Dent 1971;25:432–8.

[69] Hansson T, Nilner M. A study of the occurrence of symptoms of disorders of the temporomandibular joint masticatory musculature and related structures. J Oral Rehabil 1975;2: 313–24.

[70] Tervonen T, Knuuttila M. Prevalence of signs and symptoms of mandibular dysfunction among adults aged 25, 35, 50 and 65 years in Ostrobothnia, Finland. J Oral Rehabil 1988;15: 455–63.

[71] Schiffman EL, Fricton JR, Haley DP, Shapiro BL. The prevalence and treatment needs of subjects with temporomandibular disorders. J Am Dens Assoc 1990;120:295–303.

[72] Wänman A, Wigren L. Need and demand for dental treatment. A comparison between an evaluation based on an epidemiological study of 35-, 50-, and 65-year-olds and performed dental treatment of matched age groups. Acta Odontol Scand 1995;53:318–24.

[73] LeReche L. Epidemiology of orofacial pain. In: Lund JP, Lavigne GL, Dubner R, Sessle BJ, editors. Orofacial pain. From basic science to clinical management. Chicago: Quintessence; 2001. pp 15–25.

[74] Solberg WK, Woo MW, Houston JB. Prevalence of mandibular dysfunction in young adults. J Am Dent Assoc 1979;98:25–34.

[75] Agerberg G, Carlsson GE. Functional disorders of the masticatory system. I: Distribution of symptoms according to age and sex as judged from investigation from questionnaire. Acta Odontol Scand 1972;30:597–613.

[76] Heloe B, Heloe LA. Frequency and distribution of myofascial pain-dysfunction syndrome in a population of 25-year-olds. Community Dent Oral Epidemiol 1979;7:357–60.

[77] Franks AS. The dental health of patients presenting with temporomandibular joint dysfunction. Br J Oral Surg 1967; 5:157–66.

[78] Olsson M, Lindqvist B. Mandibular function before and after orthodontic treatment. Eur J Orthod 1995;17:205–14.

[79] Olsson M, Lindqvist B. Occlusal interferences in orthodontic patients before and after treatment and in subjects with minor orthodontic treatment need. Eur J Orthod 2002;24: 677–87.

[80] Pilley JR, Mohlin B, Shaw WC, Kingdon A. A survey of craniomandibular disorders in 500 19-year-olds. Eur J Orthod 1997;19:57–70.

[81] Lagerström L, Egermark I, Carlsson GE. Signs and symptoms of temporomandibular disorders in 19-year-old individuals who have undergone orthodontic treatment. Swed Dent J 1998;22:177–86.

[82] Egermark I, Carlsson GE, Magnusson T. A prospective long-term study of signs and symptoms of temporomandibular disorders in patients who received orthodontic treatment in childhood. Angle Orthod 2005;75:in press.