Original Article

A 20-Year Follow-up of Signs and Symptoms of Temporomandibular Disorders and Malocclusions in Subjects With and Without Orthodontic Treatment in Childhood

Inger Egermark, LDS, Odont Dr/PhD[a]; Tomas Magnusson, LDS, Odont Dr/PhD[b]; Gunnar E. Carlsson, LDS, Odont Dr/PhD, Dr Odont hc, FDSRCS[c]

Abstract: This investigation analyzes the influence of orthodontic treatment on signs and symptoms of temporomandibular disorders (TMDs) and different malocclusions during a 20-year period. Originally, 402 randomly selected 7-, 11-, and 15-year-old subjects were examined clinically and by means of a questionnaire for signs and symptoms of TMDs. The examination was repeated after five and ten years. After 20 years, 320 subjects (85% of the traced subjects) completed the questionnaire. The oldest age group, now 35 years of age, was invited to a clinical examination, and 100 subjects (81% of the traced subjects) were examined. The correlations between signs and symptoms of TMD and different malocclusions were mainly weak, although sometimes statistically significant. Lateral forced bite and unilateral crossbite were correlated with TMD signs and symptoms at the 10- and 20-year follow-ups ($r = 0.38$, $P < .05$ and $r = 0.34$, $P < .01$, respectively). Subjects with malocclusion over a long period of time tended to report more symptoms of TMD and to show a higher dysfunction index, compared with subjects with no malocclusion at all. There were no statistically significant differences in the prevalence of TMD signs and symptoms between subjects with or without previous experience of orthodontic treatment. This 20-year follow-up supports the opinion that no single occlusal factor is of major importance for the development of TMD, but a lateral forced bite between retruded contact position (RCP) and intercuspal position (ICP), as well as unilateral crossbite, may be a potential risk factor in this respect. Furthermore, subjects with a history of orthodontic treatment do not run a higher risk of developing TMD later in life, compared with subjects with no such experience. (*Angle Orthod* 2003;73:109–115.)

Key Words: Temporomandibular disorders, Malocclusion, Orthodontic treatment

INTRODUCTION

Epidemiological studies have shown that subjective symptoms and clinical signs of temporomandibular disorders (TMD) are commonly found both in children and adults.[1–6] It is generally agreed that such signs and symptoms are mostly mild in childhood and that they increase slightly with age up to adolescence, both in prevalence and severity.[7–10] Studies on the consequences of orthodontic treatment on TMD have shown that such treatment neither increases nor decreases the risk of developing TMD later in life.[5,6,11] But the results are not conclusive, and some recent studies have found less prevalent TMD signs and symptoms in subjects who have received orthodontic treatment, compared with orthodontically untreated subjects.[12–14]

During the last decades, several investigations have focused on morphological and functional malocclusions as well as signs and symptoms of TMD.[3,5,6,15,16] In other studies, efforts have been made to evaluate the possible etiological importance of occlusal factors for the development of TMD.[9,17–22] These studies indicate, in general, that occlusal factors are of minor etiological importance for pain and functional disorders in the masticatory system. But the role of occlusion in the etiology of TMD is still controversial.[23,24]

The objective of the present study was to evaluate whether previously received orthodontic treatment, as well as different morphological and functional malocclusions, had any consequences for the long-term development of signs and symptoms of TMD in 402 children and adolescents who have been followed longitudinally for a period of 20 years.

[a] Department of Orthodontics, Göteborg University, Göteborg, Sweden.

[b] The Institute for Postgraduate Dental Education, Jönköping, Sweden.

[c] Department of Prosthetic Dentistry/Dental Materials Science, Göteborg University, Göteborg, Sweden.

Corresponding author: Dr. Inger Egermark, Department of Orthodontics, Box 450, SE 405 30 Göteborg, Sweden.

Accepted: August 2002. Submitted: June 2002.

MATERIALS AND METHODS

Because a detailed description of the subjects included and the methods used has been presented recently,[25,26] only a brief summary is given here.

Subjects

Originally, 402 randomly selected 7-, 11-, and 15-year-old subjects were examined by means of a questionnaire on TMD symptoms, headaches, and oral parafunctions and clinically regarding signs of TMD and occlusal factors. The results were published in a doctoral thesis.[1] The investigation was repeated after 5 and 10 years, using the same methods, and the results have been published earlier.[7,8,12,17,19,27,28] Twenty years after the first examination, an attempt was made to find the addresses of the original participants, who at that time had reached the ages of 27, 31, and 35 years, respectively. Three hundred seventy-eight individuals of the original group could be traced (94%). The traced subjects were all sent a questionnaire, and 320 (80% of the original sample, 85% of the traced subjects), 167 women and 153 men, completed and returned the questionnaire.

Subjects belonging to the oldest age group, originally 135 randomly selected 15-year-old individuals, now 35 years of age, were also invited to a clinical examination. Of the 124 individuals who could be traced, 114 completed and returned the questionnaire, and 100 (44 women and 56 men) were also subjected to a functional examination of the masticatory system (92% and 81% of the traced subjects, respectively).

Methods

The questionnaire focused on the presence of symptoms from the masticatory system such as temporomandibular joint (TMJ) clicking, difficulties in mouth opening, pain and tiredness in jaws, as well as headaches and oral parafunctions. At the 10-year follow-up, the subjects were also asked about previous orthodontic treatment (fixed appliances or more simple orthodontic treatment such as removable plates, headgear, etc). At the 20-year follow-up, information about previous orthodontic treatment performed in the oldest age group was obtained by scrutinizing the individual case records.

The standardized clinical examination[1,29] comprised measurements of the range of movement of the mandible, presence of deflection during mouth opening, registration of TMJ sounds, joint locking or luxation, pain on movement of the mandible, and TMJ or muscle pain on palpation. From these clinical parameters, a clinical dysfunction index according to Helkimo[30] was calculated.

The registration of morphological malocclusions, such as post- and prenormal occlusion, inverted incisors, cross- and scissors bite, deep bite, anterior or lateral open bite, was made according to the definitions given by Björk et al[31] The following findings were registered as functional malocclusions (occlusal interferences): unilateral contacts in retruded contatct postition; RCP (grade I/mild: reported by the patient, grade II/grave: visible to the naked eye), lateral forced bite ($\geq$0.5 mm) between RCP and intercuspal position; ICP, anterior forced bite ($\geq$1.5 mm) between RCP and ICP, and occlusal interferences on the nonworking side preventing contact on the working side during lateral excursion.

All three authors took part in the clinical examinations after calibration, which has been described earlier.[32] The calibration was repeated at each follow-up.

The 35-year-old subjects were also divided into two subgroups: (1) a no malocclusion long-term-group containing subjects for whom no morphological or functional malocclusions had been registered at the ages of 25 and 35 years ($n = 14$); and (2) a malocclusion long-term-group containing subjects who had at least two different malocclusions, morphological and/or functional, at the ages of 25 and 35 years ($n = 21$).

Statistical methods

The Wilcoxon matched pairs signed rank test and Fisher test were used for analysis of differences between variables. The correlation between variables was calculated by means of the Spearman (r_s) rank correlation test.[33] The following levels of significance have been used: $P > .05$ not significant, $.01 < P < .05$, $.001 < P < .01$, $P < .001$.

RESULTS

Previous orthodontic treatment

At the 20-year follow-up, a total of 102 individuals (32%) gave an affirmative answer that they had received some kind of orthodontic treatment in childhood. Of the respondents, 192 subjects (60%) stated that they had not received orthodontic treatment, but as many as 26 subjects (8%) did not remember whether they had received such treatment. The corresponding figures for the oldest group was 26%, 68%, and 6%, respectively. In this group, a scrutiny of the case records showed that 15% had received orthodontic treatment from specialists, and 10% had received treatment from general practitioners. Thus, the differences between reported and true values were small. Nevertheless, two orthodontically treated subjects did not remember that they had received such treatment, and three other subjects, not orthodontically treated according to the case records, reported such treatment. The prevalence figures of TMJ clicking, other subjective symptoms of TMD, headache, and subjective reports of bruxism at the 20-year follow-up in respect of whether the subjects had received previous orthodontic treatment are presented in Table 1. There were no statis-

TABLE 1. Percentage Distribution of Reported TMJ Clicking, Other Subjective Symptoms of TMD, Headache, and Bruxism in 27-, 31-, and 35-Year-Old Subjects (N = 320) According to Reports of Orthodontic Treatment

Variable	Orthodontic Treatment (n = 102)	No Orthodontic Treatment (n = 192)	Don't Know (n = 26)
Reported TMJ[a] clicking			
Sometimes	26	22	31
Often	6	9	8
Other subjective symptoms of TMD[b]			
Sometimes	17	27	15
Often	6	6	8
Headache			
Sometimes	17	26	35
Often	15	12	0
Bruxism			
Sometimes	30	36	23
Often	22	22	12

[a] TMJ indicates temporomandibular joint.
[b] TMD indicates temporomandibular disorder.

tically significant differences between the groups, but subjects who had no experience of orthodontic treatment tended to report more frequent headache, bruxism, and subjective symptoms of TMD (TMJ clicking excluded) compared with those who had received such treatment.

According to the case records, 17 subjects in the oldest age group had received orthodontic treatment (mostly fixed appliances) from specialists in orthodontics. Their attitude to the orthodontic treatment changed over time. They were more satisfied with the result of the orthodontic treatment at the age of 35 years, compared with 10 years earlier (Table 2). The 35-year-old subjects also answered some other questions about their orthodontic treatment. At the age of 35 years, none of those who had received orthodontic treatment regretted that they had undergone the treatment, and 80% should recommend someone in their previous situation to have orthodontic treatment performed. Six percent of all subjects in the oldest age group expressed a present demand for orthodontic treatment.

There was a tendency of less frequent TMD symptoms, headache, and bruxism in the corrective group in comparison with the interceptive and nontreatment groups (Table 3). But the differences were not statistically significant.

All the recorded signs and symptoms of TMD fluctuated considerably during the 20 years covered by this longitudinal investigation as reported previously.[25,26] This was also the case among those included in the corrective and interceptive orthodontic groups. About half of the subjects in each group did not report TMJ clicking or other subjective symptoms of TMD on any occasion, whereas one subject in each group reported one or more such symptoms at all four examinations during the 20-year period. In all other cases, there was a substantial fluctuation of symptoms during the examination period.

TABLE 2. Distribution of Answers at the 10- and 20-Year Follow-ups to Questions About Orthodontic Treatment Received from Specialists (n = 17)

Question	After 10 y	After 20 y
Did you find the treatment inconvenient?		
Yes	2	2
Sometimes	6	4
No	6	8
Don't know	3	3
Did you use your removable appliance regularly?		
Yes	7	8
Sometimes neglected	4	3
No	2	2
Don't know	4	4
Are you satisfied with the orthodontic treatment result?		
Yes, very satisfied	6	16
Yes, acceptable	5	—
It could be better	3	—
No, not at all	1	—
Don't know	2	1
Have your teeth relapsed since the treatment?		
Yes, very much	2	2
Yes, little	6	—
No	8	13
Don't know	1	2

TABLE 3. Percentage Distribution of Reported TMJ Clicking, Other Subjective Symptoms of TMD, Headache, Bruxism, and Recorded Clinical Dysfunction Index in 35-Year-Old Subjects (N = 114) Who Had Earlier Had Orthodontic Treatment Performed by Specialists (corrective group) and by General Practitioners (interceptive group) and Individuals Who Had Not Received any Orthodontic Treatment[a]

Variable	Corrective Group (n = 17)	Interceptive Group (n = 11)	No Orthodontic Treatment (n = 86)
Reported TMJ clicking			
Sometimes	18	18	24
Often	6	9	8
Other subjective symptoms of TMD			
Sometimes	18	9	29
Often	6	18	9
Headache			
Sometimes	24	27	26
Often	12	36	9
Bruxism			
Sometimes	35	18	36
Often	24	36	13
Clinical dysfunction index[b]			
None	56	55	52
Mild	44	36	45
Moderate/severe	0	9	3

[a] TMJ indicates temporomandibular joint; TMD, temporomandibular disorder.
[b] N = 100, and N in the three groups was 16, 11, and 73, respectively.

TABLE 4. Prevalence in Percent of Different Morphological and Functional Malocclusions on Three Occasions in 135 15-Year-Old Subjects, Some of Whom Were Followed for 20 Years

Type of Malocclusion	15 y[a]	25 y[b]	35 y[c]
Postnormal occlusion	17	20	12
Prenormal occlusion	3	1	2
Deep bite (overbite ≥ 5 mm)	11	13	11
Anterior open bite (overbite < 0 mm)	1	2	1
Lateral open bite	4	3	4
Crossbite	12	18	22
Bilateral	1	6	8
Unilateral	11	12	14
Scissors bite	2	3	3
Inversion of incisors	4	3	3
Extreme maxillary overjet (≥6 mm)	9	4	4
Nonworking side interferences	23	26	28
Lateral forced bite RCP[d]/ICP[e] (≥0.5 mm)	39	33	27
Anterior forced bite RCP/ICP (≥1.5 mm)	10	12	12
Unilateral contact in RCP	56	72	78

[a] N = 135.
[b] N = 83.
[c] N = 100.
[d] RCP = retruded contact position.
[e] ICP = intercuspal position.

Malocclusions

Among those examined clinically, no gender differences were found for the different malocclusions, and therefore the results are pooled for men and women (Table 4). The prevalence figures for the different malocclusions were fairly constant during the 20-year period, but the number of subjects with crossbite increased statistically significantly during the observation period (Table 4). At the age of 35 years, 10 of the 22 crossbites registered were laterally forced ≥0.5 mm between RCP and ICP. The registration of functional malocclusions fluctuated considerably, eg, registrations of a lateral slide ≥0.5 mm between RCP and ICP was registered in 52% of the subjects on some occasion but only in 13% was it registered on all examinations. At the age of 35 years, not less than 78% of the subjects reported a unilateral contact in RCP, and in 19%, this premature contact could be seen by the examiner with the naked eye (grave unilateral RCP interference).

Some of the malocclusions were weakly correlated to each other. For example, nonworking side interferences were positively correlated to lateral forced crossbite ($r = 0.33$, $P < .01$), and a lateral forced bite RCP/ICP was positively correlated both to unilateral crossbite and unilateral contact in RCP ($r = 0.38$, $P < .001$ and $r = 0.34$, $P < .01$, respectively).

Statistically significant correlation coefficients between signs and symptoms of TMD (including headache and bruxism) and different malocclusions were few and, in general, weak (Table 5). But both at the age of 25 and 35 years, the lateral forced bite between RCP and ICP was statistically significantly correlated to subjective symptoms of TMD ($r = 0.29$, $P < .05$ and $r = 0.23$, $P < .05$, respectively). At the age of 35 years, TMJ clicking was three times more common among those who had a unilateral crossbite 10 years earlier ($r = 0.35$, $P < .01$) and more than twice as common among those with a lateral forced bite at present ($r = 0.31$, $P < .01$). For the other correlations found, no conclusive pattern could be seen (Table 5).

The malocclusion long-term-group reported more frequent TMD symptoms and bruxism and had more severe clinical dysfunction than the no malocclusion long-term-group (Table 6). The differences, however, did not reach statistically significant levels.

Among the 35-year-old subjects, a total of six subjects had severe clinical signs of dysfunction and/or frequent

TABLE 5. Significant ($P<.05$) Spearman Rank Correlations (r_s) in 35-Year-Old Subjects Between Reported TMJ Clicking, Other Subjective Symptoms of TMD, Headache, Bruxism (N = 114), and Clinical Dysfunction Index (N = 100), Respectively, and Different Malocclusions at the First Examination and After 10 and 20 Years[a]

Variable at 35 y of Age	First Examination at Age 15 y	After 10 y at Age 25 y	After 20 y at Age 35 y
TMJ clicking		Unilateral crossbite** ($r = 0.35$)	Lateral forced bite RCP/ICP** ($r = 0.31$)
Headache	Crossbite* ($r = 0.21$)	Frontal open bite* ($r = -0.23$)	Grave unilateral RCP interference* ($r = 0.20$)
	Postnormal occlusion** ($r = -0.29$)	Postnormal occlusion** ($r = -0.31$)	
		Unilateral RCP interference* ($r = 0.23$)	
Bruxism		Unilateral crossbite* ($r = 0.26$)	Deep bite* ($r = -0.24$)
Subjective symptoms of TMD, excluding clicking		Lateral forced bite RCP/ICP* ($r = 0.29$)	Lateral forced bite RCP/ICP* ($r = 0.23$)
Clinical dysfunction index		Grave unilateral RCP interference** ($r = 0.25$)	Lateral forced bite RCP/ICP** ($r = 0.26$)

[a] TMJ indicates temporomandibular joint; TMD, temporomandibular disorder.
* $.01 < P < .05$, ** $.001 < P < .01$.

TABLE 6. Prevalence Figures in Percent of Reported TMJ Clicking, Other Subjective Symptoms of TMD, Headache, Bruxism, and Recorded Clinical Dysfunction Index in 35-Year-Old Subjects Among Those Who Had at Least Two Different Malocclusions Both at the 10- and 20-Year Follow-ups (n = 21) and Among Those Who Had No Malocclusions Registered (n = 14)[a]

Variable	Malocclusion Long-Term-Group	No Malocclusion Long-Term-Group
Reported TMJ clicking		
Sometimes	24	7
Often	9	0
Other subjective symptoms of TMD		
Sometimes	19	21
Often	5	0
Headache		
Sometimes	38	36
Often	14	14
Bruxism		
Sometimes	24	22
Often	33	14
Clinical dysfunction index		
None	52	79
Mild	38	21
Moderate/severe	10	0

[a] TMJ indicates temporomandibular joint; TMD, temporomandibular disorder.

symptoms of TMD both at the 10- and 20-year follow-ups. Two of these subjects had no malocclusion, whereas four of them had a lateral forced bite between RCP and ICP and/or a unilateral crossbite. Seven subjects had no signs or symptoms of TMD at any of the two follow-up examinations. Two of them had no malocclusion, whereas five of them had either a postnormal occlusion or a deep bite. One of them also had nonworking side interferences.

DISCUSSION

When considering the length of this follow-up investigation, the loss of participants is extremely small. Furthermore, the subjects who were lost did not differ from those who participated with respect to gender or to any of the originally recorded signs or symptoms of TMD according to previous analysis.[25,26] All the clinical examinations followed the same methods and were performed by the same examiners. The questionnaires used have been the same from the first investigation to the last one performed 20 years later, with the exception of a few added questions. These circumstances have probably minimized the errors, but, as always, results from questionnaires, as well as from clinical examinations based mainly on semiobjective parameters, should be interpreted with caution.

No statistically significant differences could be found between the orthodontically treated and untreated subjects regarding subjective symptoms of TMD, including headaches, or reports of bruxism, although the figures were numerically higher among orthodontically untreated subjects, compared with those who had received such treatment. Also in the oldest age group, for which information about previous orthodontic treatment was gathered from the patients' case records, only small differences concerning symptoms of TMD could be found. Thus, in agreement with several previous investigations, the present findings support the opinion that subjects who have received orthodontic treatment do not run a higher risk of developing signs or symptoms of TMD later in life.[10,13,14,34] An alternative view on this issue is that the subjects who needed and received orthodontic treatment as children, had, as grown-ups, reached the same level regarding risk for developing TMD signs and symptoms as those who did not need such treatment. In Sweden, a free dental health system exists, whereby children receive orthodontic treatment when indicated. One frequent indication is occlusal disturbances. We can assume that children who had received orthodontic treatment had originally a worse occlusal situation, possibly with a less favorable prognosis regarding development of TMD.

The present results also support the opinion that correlations between TMD and different kinds of malocclusions are nonexistent or weak also in the long-term perspective of 20 years. We, however, cannot totally neglect the importance of occlusal factors in the complex and controversial concept of TMD etiology because weak, but still significant, associations were found between long-term development of TMD and some malocclusions. Especially, lateral forced bite between RCP and ICP, as well as unilateral crossbite, should be considered in this context. The possible etiological importance of these occlusal factors for the development of TMD in the present group has been stressed previously[17,19] and corroborates recently published results by others.[22,35–37] The finding that four of six subjects with severe clinical signs and/or frequent subjective symptoms of TMD at both the 10- and 20-year follow-ups had a lateral forced bite between RCP and ICP and/or a unilateral crossbite supports the findings by Mohlin et al,[35] who found that crossbite was more common in TMD patients compared with controls.

The increase of nonworking side interferences from 15 to 20 years of age is logical because third molars often erupt during this period, and these teeth contribute to most nonworking side interferences. The increase of crossbite is probably also attributable to the eruption of the third molars, resulting in a lack of space in the lateral segments with a possible development of a crossbite.

The answers to questions about previously received orthodontic treatment are interesting. It is obvious that a majority was satisfied with the results of the treatment both in a 10- and a 20-year perspective. It is, however, also obvious that in the longer perspective, perhaps because of a fading memory or a more mature judgment, the opinion about the treatment result is even more positive. For instance, minor

relapses after orthodontic treatment are forgotten in a long-term perspective. At the 10-year follow-up, half of the subjects reported no relapse of the orthodontic treatment, a figure that had increased to 87% at the 20-year follow-up. The reports of large relapses were the same at the 10- and 20-year follow-ups (13%). In spite of this, all were very satisfied with the result of the orthodontic treatment at the last follow-up. Many of the 35-year-old subjects said that they experienced the present period of their lives, with respect to family and work, as much calmer compared with their situation 10 years earlier. This may also have influenced their judgment about, and acceptance of, the treatment result.

CONCLUSIONS

The present investigation seems to warrant the following conclusions:

- Subjects who previously have received orthodontic treatment are in general very pleased with the treatment result, especially in a long-term perspective.
- Subjects who have received orthodontic treatment in childhood do not run an increased risk of developing signs or symptoms of TMD later in life.
- Correlations between signs and symptoms of TMD and different kinds of malocclusion are in general nonexistent or weak, but a lateral forced bite between RCP and ICP, as well as unilateral crossbite, might be of importance in some individuals.

ACKNOWLEDGMENT

This investigation was supported by grants from the Research Council, County of Halland, Sweden and the Swedish Dental Society.

REFERENCES

1. Egermark-Eriksson I. Mandibular dysfunction in children and individuals with dual bite [thesis]. *Swed Dent J.* 1982;10(suppl):1–45.
2. Mohlin B. *Need and Demand for Orthodontic Treatment with Special Reference to Mandibular Dysfunction. A Study in Men and Women* [thesis]. Göteborg, Sweden: Faculty of Odontology, University of Göteborg; 1982.
3. Nydell A, Helkimo M, Koch G. Craniomandibular disorders in children. A critical review of the literature. *Swed Dent J.* 1994; 18:191–205.
4. Carlsson GE, LeResche L. Epidemiology of temporomandibular disorders. In: Sessle BJ, Bryant PS, Dionne RA, eds. *Temporomandibular Disorders and Related Pain Conditions. Progress in Pain Research and Management.* Seattle, Wash: IASP Press; 1995:211–226.
5. Luther F. Orthodontics and the temporomandibular joint: where are we now? Part 1. *Angle Orthod.* 1998;68:295–304.
6. Luther F. Orthodontics and the temporomandibular joint: where are we now? Part 2. *Angle Orthod.* 1998;68:305–318.
7. Magnusson T, Egermark-Eriksson I, Carlsson GE. Five-year longitudinal study of signs and symptons of mandibular dysfunction. *J Craniomandib Pract.* 1986;4:338–344.
8. Magnusson T, Carlsson GE, Egermark I. Changes in subjective symptoms of craniomandibular disorders in children and adolescents during a 10-year period. *J Orofac Pain.* 1993;7:76–82.
9. Wänman A. Craniomandibular disorders in adolescents [thesis]. *Swed Dent J.* 1987;44(suppl):1–61.
10. Pilley JR, Mohlin B, Shaw WC, Kingdon A. A survey of craniomandibular disordes in 500 19-year-olds. *Eur J Orthod.* 1997; 19:57–70.
11. McNamara JA, Seligman D, Okeson JA. Occlusion, orthodontic treatment, and temporomandibular disorders: a review. *J Orofac Pain.* 1995;9:73–90.
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. Ohlsson M, Lindquist B. Mandibular function before and after orthodontic treatment. *Eur J Orthod.* 1995;17:205–214.
14. Henrikson T. Temporomandibular disorders and mandibular function in relation to Class II malocclusion and orthodontic treatment. A controlled, prospective and longitudinal study [thesis]. *Swed Dent J.* 1999;134(suppl):1–62.
15. 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;14:152–161.
16. 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;27:367–379.
17. 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.
18. Kirveskari P, Alanen P, Jämsä T. Association between craniomandibular disorders and occlusal interferences. *J Prosthet Dent.* 1989;61:66–69.
19. Egermark-Eriksson I, Carlsson GE, Magnusson T, Thilander B. A longitudinal study on malocclusion in relation to signs and symptoms of craniomandibular disorders in children and adolescents. *Eur J Orthod.* 1990;12:399–407.
20. Heikinheimo K, Salmi K, Myllärniemi S, Kirveskari P. A longitudinal study of occlusal interferences and signs of craniomandibular disorder at the age of 12 and 15 years. *Eur J Orthod.* 1990;12:190–197.
21. Carlsson GE, De Boever JA. Epidemiology. In: Zarb GA, Carlsson GE, Sessle BJ, Mohl ND, eds. *Temporomandibular Joint and Masticatory Muscle Disorders.* Copenhagen: Munksgaard; 1994: 159–170.
22. Pullinger AG, Seligman DA. Quantification and validation of predictive values of occlusal variables in temporomandibular disorders using a multifactorial analysis. *J Prosthet Dent.* 2000;83:66–75.
23. Kirverskari P, Jamsa T, Alanen P. Occlusal adjustment and the incidence of demand for temporomandibular disorder treatment. *J Prosthet Dent.* 1998;79:433–438.
24. Greene CS. The etiology of temporomandibular disorders: implications for treatment. *J Orofac Pain.* 2001;15:93–105.
25. 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;14:310–319.
26. 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;59:40–48.
27. Magnusson T, Egermark-Eriksson I, Carlsson GE. Four-year longitudinal study of mandibular dysfunction in children. *Community Dent Oral Epidemiol.* 1985;13:117–120.

28. Magnusson T, Carlsson GE, Egermark I. Changes in clinical signs of craniomandibular disorders from the age of 15 to 25 years. *J Orofac Pain.* 1994;8:207–215.
29. Carlsson GE, Magnusson T. *Management of Temporomandibular Disorders in the General Practice.* Chicago: Quintessence; 1999: 68–77.
30. Helkimo M. *Studies on Function and Dysfunction of the Masticatory System* [dissertation]. Göteborg, Sweden: University of Göteborg; 1974.
31. Björk A, Krebs AA, Solow B. A method for epidemiological registration of malocclusion. *Acta Odontol Scand.* 1964;22:27–41.
32. Carlsson GE, Egermark-Eriksson I, Magnusson T. Intra- and interobserver variation in functional examination of the masticatory system. *Swed Dent J.* 1980;4:187–194.
33. Siegel S. *Nonparametric Statistics.* New York, NY: McGraw-Hill; 1956:75–83; 203–213.
34. 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;22:177–186.
35. Mohlin B, Derweduwen K, Pilley R, Kingdom A, Shaw WC, Kenealy P. Malocclusion and TMD. A comparison of subjects with moderate to severe dysfunction with those without signs and symptoms of TMD followed from 11 to 19 years of age. *J Orthod.* In press.
36. Olson M, Lindqvist B. Occlusal interferences in orthodontic patients before and after treatment and in subjects with minor orthodontic treatment need. *Eur J Orthod.* In press.
37. Thilander B, Guillermo R, Pena L, De Mayorga C. Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development. *Angle Orthod.* 2002;72:146–154.