

TMD in Relation to Malocclusion and Orthodontic Treatment

A Systematic Review

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ABSTRACT

Objective: The aim of this systematic literature review was to evaluate associations between different malocclusions, orthodontic treatment, and signs and symptoms of temporomandibular disorders (TMD).

Materials and Methods: This review was part of a project at the Swedish Council on Technology Assessment in Health Care focusing on malocclusion and orthodontic treatment from a health perspective. As a first step, the literature was searched in the Medline and Cochrane Library databases from 1966 to May 2003. A later update was made in January 2005. Human studies in English or in Scandinavian languages were included.

Results: Associations between certain malocclusions and TMD were found in some studies, whereas the majority of the reviewed articles failed to identify significant and clinically important associations. TMD could not be correlated to any specific type of malocclusion, and there was no support for the belief that orthodontic treatment may cause TMD. Obvious individual variations in signs and symptoms of TMD over time according to some longitudinal studies further emphasized the difficulty in establishing malocclusion as a significant risk factor for TMD. A considerable reduction in signs and symptoms of TMD between the teenage period and young adulthood has been shown in some recent longitudinal studies.

Conclusions: Associations between specific types of malocclusions and development of significant signs and symptoms of TMD could not be verified. There is still a need for longitudinal studies.

KEY WORDS: Malocclusion; Temporomandibular joint disorders; Craniomandibular disorders; Orthodontics

INTRODUCTION

Two main questions about temporomandibular disorders (TMD) in relation to malocclusion/orthodontic treatment seem to be of interest. The first concerns correlations between TMD and different kinds of functional or morphologic malocclusions. The other seeks to determine whether the severity and prevalence of TMD are influenced or even caused by orthodontic treatment.

The concept of TMD usually includes a wide variety of signs and symptoms, such as pain from the temporomandibular joints (TMJs) or jaw muscles, pain on mandibular movement, joint sounds, and locking/luxation of joints, as well as restricted mandibular movement. Often, TMD have been evaluated on the basis of variation in rather insignificant signs and symptoms, for instance, variation in muscle sites that are tender to palpation, without correlation to experienced problems.

The etiology of TMD is usually considered multifactorial. Untreated malocclusions, unstable occlusion, stress and other psychologic factors, trauma, individ-

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Accepted: August 2006. Submitted: April 2006.

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Table 1. Search Strategy

Medline 1966–2005 (January)				
Malocclusion	AND	Craniomandibular disorders	NOT	Case report
Orthodontics		Temporomandibular disorder		Abnormalities
Therapy		Temporomandibular joint disorders		Surgery
Occlusal adjustment		Temporomandibular joint dysfunction syndrome		Cleft palate
Dental occlusion		Headache		Craniofacial syndromes
		Facial pain		Myofunctional therapy
		Masticatory muscles		
<i>Limits</i>				
0–18 years				
Human				
Danish				
English				
Finnish				
Norwegian				
Swedish				

ual predisposition, and structural conditions have been suggested as possible etiologic factors. The view of the influence of occlusion on the development of TMD has varied from none to considerable. There are still controversies concerning canine protection, lack of non–working side interferences on lateral mandibular movements, and the importance of establishing an ideal occlusion via orthodontic treatment. Does any particular concept of ideal occlusion still represent an ideal with regard to oral function, or is it time to re-evaluate and modify the norm?

The aim of this systematic literature review was to answer the following question: Are signs and symptoms of TMD related to malocclusion or orthodontic treatment?

MATERIALS AND METHODS

Methods for the Literature Review

This review was part of a project at the Swedish Council on Technology Assessment in Health Care, which focused on malocclusions and orthodontic treatment from a health perspective. As a first step, the literature was searched in the Medline and Cochrane Library databases from 1966 to May 2003. A later update was made in January 2005. Key words such as “experimental,” “animal,” “letters,” “editorials,” and “short communications” were excluded. Studies of cleft lip and palate, craniofacial syndromes, and treatment with orthognathic surgery were not included. Human studies in Danish, English, Finnish, Norwegian, or Swedish were considered. The search strategy is presented in Table 1. A review team of three persons made the searches interactively, with support from an expert in informatics.

The reference lists and abstracts of the papers were examined by at least two members of the evaluation

team. The full text of a paper was obtained if at least one of the reviewers thought that the paper addressed the issue in question. If obviously relevant literature was missing from the reference lists, further database searches were carried out using key words from known papers. Textbooks and reports from authorities as well as review papers could be used as background material, but not in the evaluation of systematic evidence.

All selected papers were read and evaluated independently by two persons according to a protocol that was previously designed by the whole group of eight reviewers. This protocol included evaluation of study design and study population, including presence of a control group; the variables used; the extent and character of dropouts; statistical analysis; and testing of validity and reliability. In the event of disagreement between the two reviewers, the article was discussed among the whole group to reach a consensus. If necessary, additional advice from, for instance, statisticians could be obtained. The evidence grade of the included studies was judged to be strong, moderately strong, or limited. It is important to note that “insufficient scientific knowledge” refers only to the question at hand and does not mean that other kinds of scientific knowledge are lacking.

The following criteria for inclusion of studies were used:

- Studies that addressed the questions of untreated malocclusions or orthodontic treatment in relation to signs and symptoms of TMD
- All kinds of clinical studies in humans, including qualitative research
- Papers written in English or Scandinavian languages
- Studies in children and adolescents; studies in adults were accepted when long-term follow-up of

Table 2. Excluded Papers

Reason for Exclusion	Reference No.
Incomplete results	(6)
Outcome measure not among inclusion criteria	(7), (8)
Not relevant for the question at hand	(9), (10), (11), (12), (13), (14), (15), (16), (17), (18), (19), (20), (21), (22)
Review	(23)
No or little original or relevant data	(24), (25)
Earlier, repeated, or later study	(26/27), (28/29), (30/28)
Selected subjects	(31), (32), (33)

treatment and untreated malocclusions had been performed

Recorded Variables

Subjects who were considered to suffer from TMD needed to have substantial problems in the TMJs or muscles verified by a clinical examination. Recording of clinical parameters alone, as, for instance, by use of an index, was not considered clinically relevant. Correlations between signs and symptoms of TMD and different kinds of malocclusions and tooth contact patterns were evaluated.

Setting the Evidence Grade

The papers were evaluated according to the following criteria, which are based on the criteria for assessing study quality from the Centre for Reviews and Disseminations in York, United Kingdom¹:

Strong evidence (A).

- Randomized controlled trial, prospective studies/ large study samples
- Well-defined and adequate control group
- Clearly defined and clinically relevant variables
- Low dropout rate
- Relevant statistical analysis

Moderately strong evidence (B).

- Prospective study, cohort, controlled clinical trial, or well-defined retrospective study with large study group
- Clearly defined and clinically relevant variables
- Low dropout rate
- Relevant statistical analysis

Limited evidence (C).

- Cross-sectional study
- Clinically inadequate result variables
- High dropout rate
- No control group of its own in the study
- Limited/no statistical analysis
- Addressing the issue in question only in part
- Qualitative studies were evaluated with respect to

validity, which includes credibility or trustworthiness. There should be harmony between the addressed issue and the applied method. Ethical value should be fulfilled, meaning that the conclusions should have a solid basis in the data. Principles of strategic sampling and saturation should be upheld. There should also be as few contradictions as possible. Reliability is reached when similar relationships between phenomena are emerging frequently from the data.^{2,3} The preconceptions of the researchers were considered as well.^{4,5}

Strong scientific support (evidence grade 1). Conclusion based on at least two studies with strong evidence (A). Studies with opposite conclusions may lower the evidence grade.

Moderately strong scientific support (evidence grade 2). Conclusion based on one study with strong evidence (A) and two with moderately strong evidence (B). Studies with opposite conclusions may lower the evidence grade.

Limited scientific support (evidence grade 3). Conclusion is based on at least two studies with moderately strong evidence (B). If studies contradicting the conclusion existed, the scientific basis was judged as insufficient or contradictory.

Insufficient scientific support. If studies fulfilling the evidence criteria are lacking, the scientific basis for the conclusion was considered insufficient.

Contradictory scientific support. When studies with equal evidence value but contradictory results exist, the scientific basis was considered contradictory and no conclusions can be drawn.

RESULTS

The search resulted in 58 papers. Twenty-eight papers^{6–33} were excluded because they did not contribute to the evidence regarding the question at hand and are listed in Table 2. Twenty-one papers^{34–54} were found to contribute limited evidence (Table 3). Nine papers^{55–63} were judged to give moderately strong evidence (Table 4).

The differences in TMD between those with and without malocclusion were small. Subjects with untreated crossbite, crowding of teeth/high PAR (Peer

Assessment Rating) index value (overall severity of malocclusion), or large overjet showed a higher prevalence of signs and symptoms of TMD.^{57,58,61,62} Associations between malocclusions and TMD varied over time in some longitudinal studies and sometimes even disappeared.^{55–58} Different kinds of malocclusions were correlated to TMD in the studies mentioned above. Other studies failed to identify significant associations between malocclusion and TMD.^{55,58,59,63} For that reason, no conclusions could be drawn about associations between specific types of malocclusion and TMD. Studies that followed patients to about 30 years of age showed a general reduction in signs and symptoms of TMD and an overall low prevalence at that age.^{58,59,62} The prevalence of clicking remained fairly unchanged, whereas prevalence of locking of the TMJ decreased. Especially when recordings related to muscle involvement such as tender muscles or reported muscle pain and headache were used, a considerable decrease was seen in prevalence during early adult life. Differences regarding TMD between those with and without malocclusion tended to diminish. Moreover, some studies that followed subjects from adolescence to adulthood observed large individual variations over time in prevalence of TMD.^{58,61,62}

In some studies that compared treated malocclusions with untreated controls, a slightly lower prevalence of TMD was found.^{56,61} Differences were small, and the findings referred to different types of malocclusions. In other studies, no difference was found between subjects with treated versus untreated malocclusions.^{58,63} The influence of different orthodontic treatment methods as well as differences between

treatment and no treatment tended to vanish over time.^{55,58}

DISCUSSION

The restrictions imposed by the authors concerning the number of databases and languages in searching the literature may have yielded fewer articles than would a more comprehensive search. However, the strength of the evidence in a systematic review is probably more dependent on the quality of the included studies than on the degree of comprehensiveness.⁶⁴ One of the major problems when interpreting associations between malocclusion and TMD is whether the recorded variables represent a severe enough condition to motivate patients to seek treatment for the functional problems. There seems to be a great disproportion between dysfunction that was recorded as “moderately severe” or “severe” and the estimated treatment need for TMD. The prevalence of moderately severe to severe TMD has been found to be about 20% to 30%, whereas the treatment need seems to be about 5%.^{50,61} A lot of indirect measures, such as muscle palpation and painless clicking/popping from the TMJs, are used to identify TMD. There are many doubts about whether this gives a proper representation of the condition. Signs and symptoms are often dealt with separately, often with greater emphasis on the recorded signs than on reported symptoms.

Another difficulty when evaluating associations between malocclusions and TMD is the previously mentioned individual fluctuation of signs and symptoms of

Table 3. Studies with Low Evidence Value

Study	Reason for Low Evidence Value
Dahl et al 1988 (34)	Reply rate not stated. Only TMD indices used.
Egermark-Eriksson 1982 (35)	Mainly associations between morphology and movement pattern.
Heikinheimo et al 1989 (36)	Small sample. Questions not validated.
Helm et al 1984 (37)	No control group.
Hirata et al 1992 (38)	Only baseline data for the control group, no follow-up. Large dropout.
Janson and Hasund 1981 (39)	Malocclusions in the control group not described.
Keeling et al 1995 (40)	Too young patients for the question at issue.
Kess et al 1991 (41)	Retrospective observation and control groups. Dental students as controls.
Lagerström et al 1998 (42)	No control group.
Milosevic and Samuels 2000 (43)	No control group.
Olsson and Lindqvist 1992 (44)	Young subjects. Control group not completely described.
Olsson and Lindqvist 1995 (45)	TMD index before and after orthodontic treatment. No controls.
Rodrigues-Garcia et al 1998 (46)	No control group.
Sadowsky and BeGole 1980 (47)	Large age span. Large dropout.
Sadowsky et al 1991 (48)	Dropout, fairly small sample, limited outcome measures.
Smith and Freer 1989 (49)	Small sample. Dropout rate 42%.
Sonnesen et al 1998 (50)	Small sample.
Sonnesen et al 2001 (51)	No control group.
Tanne et al 1993 (52)	No control group.
Tullberg et al 2001 (53)	Large dropout.
Wadhwa et al 1993 (54)	Population less representative. Uncertainties regarding statistical analysis.

Table 4. Studies of Associations Between TMD and Malocclusions^a

Study	Study Design	Population	Age (y)	Variables	Result	Evidence
Dibbets and van der Weele 1987 (55)	Prospective, 10-y follow-up, CC	63 activator 72 Begg 55% female	MD	Reported TMD Joint palpation, radiographs	No difference before/after treatment. No difference between groups.	B
Egermark-Eriksson et al 1990 (56)	Cohort CS	238 questionnaires/examined 49% female	Examined at 7, 11, 15	Reported TMD DI	Weak associations treatment and TMD, malocclusion and TMD. Crossbite, open bite, Class II, and Class III more important.	B
Egermark and Thilander 1992 (57)	Cohort CS 10-yr follow-up of ref (15)	293 questionnaires 83 examined 55% female	17–25	Reported TMD DI	DI sign. Lower in treated patients at 25 yrs of age.	B
Egermark et al 2003 (58)	Follow-up of ref (15, 16) Cohort CS	320 questionnaires 100 examined 53% female	35	Reported TMD DI	No correlation between TMD and malocclusion.	B
Helm and Petersen 1989 (59)	Cohort CS, 20-y follow-up	232 malocclusions 48 no malocclusions 26 TMD 78% female	Mean 35.5	Clinical examination Questionnaire	No correlation between TMD and malocclusion.	B
Henriksson 1999 (60)	CC, 2-y follow-up	65 treated Class II 58 untreated Class II 60 normal occlusion 100% female	11–15	Clinical examination Reported TMD Occlusal contacts	Slightly higher prevalence of TMD signs in Class II subjects.	B
Henriksson et al 2000 (61)	As above	As above	As above	As above	More severe signs in untreated subjects.	B
Mohlin et al 2004 (62)	CC Prospective	62 grave TMD (at 19 y) 66% female 72 without TMD 61% female	11–19 30	Reported TMD Clinical examination Psychologic status Orthodontic recordings (casts)	Sign higher PAR score and crowding in TMD subjects. Sign more negative psychologic factors and less muscular endurance in TMD subjects.	B
Sadowsky and Polson 1984 (63)	Retrospective, ≥10 y follow-up Two-center CC	207 treated 60% female 214 untreated 61% female	Mean 29–39	Reported TMD Clinical examination	No difference between treated and untreated regarding TMD.	B

^a CS, case series; CC, case control; DI, Dysfunction Index (Helkimo); MD, missing data; TMD, temporomandibular disorders.

TMD when subjects are followed longitudinally.^{58,61,62} Prevalence as well as severity may vary between recordings made on different occasions.

The studies that evaluated the effects of orthodontic treatment on TMD gave heterogeneous results, with some studies finding small positive effects in treated subjects and others finding no differences or differences between groups that tended to diminish with age.^{55,56,61–63} None of the studies indicated that orthodontic treatment caused TMD.

In studies that included variables other than malocclusion, items such as psychologic health and muscular endurance showed associations with TMD that were at least as obvious as that between TMD and malocclusion.^{28,62} Muscle strength and muscle endurance have previously been associated with craniofacial morphology. Vertically growing faces are often

characterized by low muscle strength, whereas the opposite is true regarding subjects with parallel maxillary and mandibular planes.⁵¹ The etiologic importance of malocclusion on the development of TMD must be viewed with this in mind. Muscular resistance to overload may be more important than the presence of a certain malocclusion. It is interesting to note that deep bites tend to be more common among subjects without TMD.⁶²

CONCLUSIONS

- Associations between specific types of malocclusions and development of significant signs and symptoms of TMD could not be verified.
- There is still a need for longitudinal studies.
- Observations should be made before treatment as

well as by long-term observation of untreated and treated subjects.

- d. The differentiation of patients into control and study groups is a constant problem.
- e. A proper observation period appears to be from the late teenage years to young adulthood (age about 30 years).
- f. Individual variations in TMD over time must be controlled in the study design.
- g. The main focus in the observations should be on TMD signs and symptoms of such a magnitude that treatment of TMD seems likely to be demanded.

REFERENCES

1. Deeks J, Glanville J, Sheldon T. *Undertaking Systematic Reviews of Research on Effectiveness, CRD Guidance for those Carrying Out or Commissioning Reviews*. York: NHS Centre for Reviews and Dissemination; 1996. CRD Report Number 4.
2. Larsson S. On quality criteria in qualitative studies. In Starin B, Svensson PG, eds. *Qualitative Methods in Practice and Theory*. Lund, Sweden: Studentlitteratur; 1994.
3. Lincoln YS, Guba EG. *Naturalistic Enquiry*. London: Sage Publications; 1985.
4. Malterud K. Qualitative research: standards, challenges, and guidelines. *The Lancet*. 2001;11:483–488.
5. Strauss A, Corbin J. *Grounded Theory in Practice*. Thousand Oaks, Calif: Sage Publications; 1997.
6. Barone A, Sbordone L, Ramaglia L. Craniomandibular disorders and orthodontic treatment need in children. *J Oral Rehabil*. 1997;24:2–7.
7. Carlton KL, Nanda RS. Prospective study of posttreatment changes in the temporomandibular joint. *Am J Orthod Dentofacial Orthop*. 2002;122:486–490.
8. Williamson EH. Temporomandibular dysfunction in pretreatment adolescent patients. *Am J Orthod*. 1977;72:429–433.
9. De Boever AL, Keeling SD, Hilsenbeck S, Van Sickels JE, Bays RA, Rugh JD. Signs of temporomandibular disorders in patients with horizontal mandibular deficiency. *J Orofac Pain*. 1996;10:21–27.
10. Deng Y, Fu MK. Occlusal contact changes before and after orthodontic treatment of a group of child and adolescent patients with TMJ disturbance. *Aust Orthod J*. 1995;13:231–237.
11. Hesse KL, Årtun J, Joondeph DR, Kennedy DB. Changes in condylar position and occlusion associated with maxillary expansion for correction of functional unilateral posterior crossbite. *Am J Orthod Dentofacial Orthop*. 1997;111:410–418.
12. Imai T, Okamoto T, Kaneko T, Umeda K, Yamamoto T, Nakamura S. Long-term follow-up of clinical symptoms in TMD patients who underwent occlusal reconstruction by orthodontic treatment. *Eur J Orthod*. 2000;22:61–67.
13. Jones S. Temporomandibular disorders and non-ideal occlusal schemes, report of a survey of 156 patients. *J Dent Assoc S Afr*. 1994;49:470–471.
14. Kasrovi PM, Meyer M, Nelson GD. Occlusion: an orthodontic perspective. *J Calif Dent Assoc*. 2000;28:780–790.
15. Kirveskari P, Jämsä T, Alanen P. Occlusal adjustment and the incidence of demand for temporomandibular disorder treatment. *J Prosthet Dent*. 1998;79:433–438.
16. Le Bell Y, Lehtinen R, Peltomäki T, Peltola J. Function of masticatory system after surgical-orthodontic correction of maxillomandibular discrepancies. *Proc Finn Dent Soc*. 1993;89:101–107.
17. McNamara JA Jr, Seligman DA, Okeson JP. Occlusion, orthodontic treatment, and temporomandibular disorders: a review. *J Orofac Pain*. 1995;9:73–90.
18. Pocock PR, Mamandras AH, Bellamy N. Evaluation of an anamnestic questionnaire as an instrument for investigating potential relationships between orthodontic therapy and temporomandibular disorders. *Am J Orthod Dentofacial Orthop*. 1992;102:239–243.
19. Roth RH. Temporomandibular pain-dysfunction and occlusal relationships. *Angle Orthod*. 1973;43:136–153.
20. Scott BA, Clark GM, Hatch JP, van Sickels J, Rugh JD. Comparing prospective and retrospective evaluations of temporomandibular disorders after orthognathic surgery. *J Am Dent Assoc*. 1997;128:999–1003.
21. Vallon D. Studies of occlusal adjustment therapy in patients with craniomandibular disorders. *Swed Dent J Suppl*. 1997;124:1–65.
22. Dibbets JM, van der Weele LT. Extraction, orthodontic treatment, and craniomandibular dysfunction. *Am J Orthod Dentofacial Orthop*. 1991;99:210–219.
23. Dibbets JM, Carlson DS. Implications of temporomandibular disorders for facial growth and orthodontic treatment. *Semin Orthod*. 1995;1:258–272.
24. Egermark I, Blomqvist JE, Cromvik U, Isaksson S. Temporomandibular dysfunction in patients treated with orthodontics in combination with orthognathic surgery. *Eur J Orthod*. 2000;22:537–544.
25. Karjalainen M, Le Bell Y, Jämsä T, Karjalainen S. Prevention of temporomandibular disorder-related signs and symptoms in orthodontically treated adolescents. A 3-year follow-up of a prospective randomized trial. *Acta Odontol Scand*. 1997;55:319–324.
26. Henriksson T, Nilner M, Kurol J. Symptoms and signs of temporomandibular disorders before, during and after orthodontic treatment. *Swed Dent J*. 1999;23:193–207.
27. Henriksson T, Nilner M. Temporomandibular disorders and the need of stomatognathic treatment in orthodontically treated and untreated girls. *Eur J Orthod*. 2000;22:283–292.
28. Mohlin B, Pilley JR, Shaw WC. A survey of craniomandibular disorders in 1000 12-year olds. Study design and baseline data in a follow-up study. *Eur J Orthod*. 1991;13:111–123.
29. 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.
30. 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.
31. de Boer M, Steenks MH. Functional unilateral posterior crossbite. Orthodontic and functional aspects. *J Oral Rehabil*. 1997;4:614–623.
32. Marrant DG, Taylor GS. The prevalence of temporomandibular disorder in patients referred for orthodontic assessment. *Br J Orthod*. 1996;23:261–265.
33. Nassif NJ. Perceived malocclusion and other teeth-associated signs and symptoms in temporomandibular disorders. *Compend Contin Educ Dent*. 2001;22:577–585; quiz 586.
34. Dahl BL, Krogstad BS, Øgaard B, Eckersberg T. Signs and symptoms of craniomandibular disorders in two groups of 19-year-old individuals, one treated orthodontically and the other not. *Acta Odontol Scand*. 1988;46:89–93.

35. Egermark-Eriksson I. Malocclusion and some functional recordings of the masticatory system in Swedish schoolchildren. *Swed Dent J*. 1982;6:9–20.
36. Heikinheimo K, Salmi K, Myllärniemi S, Kirveskari P. Symptoms of craniomandibular disorder in a sample of Finnish adolescents at the ages of 12 and 15 years. *Eur J Orthod*. 1989;11:325–331.
37. Helm S, Kreiborg S, Solow B. Malocclusion at adolescence related to self-reported tooth loss and functional disorders in adulthood. *Am J Orthod*. 1984;85:393–400.
38. Hirata RH, Heft MW, Hernandez B, King GJ. Longitudinal study of signs of temporomandibular disorders (TMD) in orthodontically treated and nontreated groups. *Am J Orthod Dentofacial Orthop*. 1992;101:35–40.
39. Janson M, Hasund A. Functional problems in orthodontic patients out of retention. *Eur J Orthod*. 1981;3:173–179.
40. Keeling SD, Garvan CW, King GJ, Wheeler TT, McGorray S. Temporomandibular disorders after early Class II treatment with bionators and headgears: results from a randomised controlled trial. *Semin Orthod*. 1995;1:149–164.
41. Kess K, Bakopulos K, Witt E. TMJ function with and without orthodontic treatment. *Eur J Orthod*. 1991;13:192–196.
42. 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.
43. Milosevic A, Samuels RH. The post-orthodontic prevalence of temporomandibular disorder and functional occlusion contacts in surgical and non-surgical cases. *J Oral Rehabil*. 2000;27:142–149.
44. Olsson M, Lindqvist B. Mandibular function before orthodontic treatment. *Eur J Orthod*. 1992;14:302–309.
45. Olsson M, Lindqvist B. Mandibular function before and after orthodontic treatment. *Eur J Orthod*. 1995;17:205–214.
46. Rodrigues-Garcia RC, Sakai S, Rugh JD, Hatch JP, Tiner BD, van Sickels JE, et al. Effects of major Class II occlusal corrections on temporomandibular signs and symptoms. *J Orofac Pain*. 1998;12:185–192.
47. Sadowsky C, BeGole EA. Long-term status of temporomandibular joint function and functional occlusion after orthodontic treatment. *Am J Orthod*. 1980;78:201–212.
48. Sadowsky C, Theisen TA, Sakols EI. Orthodontic treatment and temporomandibular joint sounds—a longitudinal study. *Am J Orthod Dentofacial Orthop*. 1991;99:441–447.
49. Smith A, Freer TJ. Post-orthodontic occlusal function. *Aust Dent J*. 1989;34:301–309.
50. Sonnesen L, Bakke M, Solow B. Malocclusion traits and symptoms and signs of temporomandibular disorders in children with severe malocclusion. *Eur J Orthod*. 1998;20:543–559.
51. Sonnesen L, Bakke M, Solow B. Temporomandibular disorders in relation to craniofacial dimensions, head posture and bite force in children selected for orthodontic treatment. *Eur J Orthod*. 2001;23:179–192.
52. Tanne K, Tanaka E, Sakuda M. Association between malocclusion and temporomandibular disorders in orthodontic patients before treatment. *J Orofac Pain*. 1993;7:156–162.
53. Tullberg M, Tsarapatsani P, Huggare J, Kopp S. Long-term follow-up of early treatment of unilateral forced posterior cross-bite with regard to temporomandibular disorders and associated symptoms. *Acta Odontol Scand*. 2001;59:280–284.
54. Wadhwa L, Utreja A, Tewari A. A study of clinical signs and symptoms of temporomandibular dysfunction in subjects with normal occlusion, untreated, and treated malocclusions. *Am J Orthod Dentofacial Orthop*. 1993;103:54–61.
55. Dibbets JM, van der Weele LT. Orthodontic treatment in relation to symptoms attributed to dysfunction of the temporomandibular joint. A 10-year report of the University of Groningen study. *Am J Orthod Dentofacial Orthop*. 1987;91:193–199.
56. 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.
57. 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.
58. 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;73:109–115.
59. Helm S, Petersen PE. Mandibular dysfunction in adulthood in relation to morphologic malocclusion at adolescence. *Acta Odontol Scand*. 1989;47:307–314.
60. Henriksson T. Temporomandibular disorders and mandibular function in relation to Class II malocclusion and orthodontic treatment. A controlled, prospective and longitudinal study. *Swed Dent J Suppl*. 1999;134:1–144.
61. Henriksson T, Nilner M, Kurol J. Signs of temporomandibular disorders in girls receiving orthodontic treatment. A prospective and longitudinal comparison with untreated Class II malocclusions and normal occlusion subjects. *Eur J Orthod*. 2000;22:271–281.
62. Mohlin B, Derweduwen K, Pilley R, Kingdon A, Shaw WC, Kenealy P. Malocclusion and temporomandibular disorder: A comparison of adolescents with moderate to severe dysfunction with those without signs and symptoms of temporomandibular disorders and their further development to 30 years of age. *Angle Orthod*. 2004;74:319–327.
63. Sadowsky C, Polson AM. Temporomandibular disorders and functional occlusion after orthodontic treatment: result of two long-term studies. *Am J Orthod*. 1984;86:386–390.
64. Egger M, Jüni P, Bartlett C, Hohenstein F, Sterne J. How important are comprehensive literature searches and the assessment of trial quality in systematic reviews. *Health Technol Assess*. 2003;7(1):1–76.