Abstract

Bruxism and temporomandibular disorders

Objectives - The present paper aims to systematically review the literature on the temporomandibular disorders (TMD)-brux-ism relationship published from 1998 to 2008.

Study design - A systematic search in the National Library of Medicine's PubMed database was performed to identify all studies on humans assessing the relation- ship between TMD symptoms and bruxism diagnosed with any different approach. The selected articles were assessed independently by the 2 authors according to a structured reading of articles format (PICO).

Results - A total of 46 articles were included for discussion in the review and grouped into questionnaire/self-report (n = 21), clinical assessment (n = 7), experimental (n = 7), tooth wear (n = 5), polysomnographic (n = 4), or electromyographic (n = 2) studies. In several studies, the level of evidence was negatively influenced by a low level of specificity for the assessment of the bruxism-TMD relationship, because of the low prevalence of severe TMD patients in the studied samples and because of the use of self-report diagnosis of bruxism with some potential diagnostic bias.

Conclusions - Investigations based on self-report or clinical bruxism diagnosis showed a positive association with TMD pain, but they are characterized by some potential bias and confounders at the diagnostic level (e.g., pain as a criterion for bruxism diagnosis). Studies based on more quantitative and specific methods to diagnose bruxism showed much lower association with TMD symptoms. Anterior tooth wear was not found to be a major risk factor for TMD. Experimental sustained jaw clenching may provoke acute muscle tenderness, but it is not analogous to myogenous TMD pain, so such studies may not help clarify the clinical relationship between bruxism and TMD.

This article was originally published in: Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 109: e26-e50.

Emneord: Bruxism; temporomandibular disorders; review

Relationship between bruxism and temporomandibular disorders: a systematic review of literature from 1998 to 2008

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The study of bruxism is complicated by some taxonomic and diagnostic aspects that have prevented achieving an acceptable standardization of diagnosis until recent years. Indeed, a major concern for researchers approaching this phenomenon is the definition of bruxism itself, which is a term grouping different entities, namely, sleep and awake bruxism (1). The American Academy of Sleep Medicine defines bruxism as a stereotyped oral motor disorder characterized by sleeprelated grinding and/or clenching of the teeth (2), whereas the American Academy of Orofacial Pain extends the definition to the same movements that occur during wakefulness (3).

There is a considerable amount of literature suggesting that sleep and awake bruxism are 2 different disorders with a different etiopathogenesis (4-11). Sleep bruxism is characterized by both a grinding-type and a clenching-type activity and is associated with complex micro-arousal phenomena occurring during sleep, the pathophysiology of which is yet to be clarified (7,12-14), whereas awake bruxism is characterized by a clenching-type activity and is associated with psychosocial factors and a number of psychopathological symptoms (11). The 2 activities are likely to have different consequences on the masticatory muscles and the temporomandibular joints but, unfortunately, this issue is an under-reviewed aspect in the literature. Indeed, although bruxism

as a whole is commonly considered the most detrimental among all the parafunctional activities of the stomatognathic system and a major risk factor for temporomandibular disorders (TMD), there are still many unsolved issues concerning the actual causal relationship between the occurrence of TMD symptoms and bruxism, and little is known on the possibly different role of the different bruxism activities in the etiology of TMD (15). Bruxism has been called into cause as a risk factor for temporomandibular joint as well as masticatory muscle disorders, and it seems that uncertainties exist as to whether it is a potential cause of joint overload or muscle damage, or both (16).

The issue is complicated by the difficulties in diagnosing clinical bruxism, as well as by the unclear distinction between instrumentally detected bruxism on the one hand and clinically diagnosed or self-perceived bruxism on the other hand (17). Sleep bruxism (SB) as a pathophysiological entity can be detected unequivocally only by means of polysomnographic recordings, the use of which is limited by the high costs and the low number of adequately equipped sleep laboratories (18). Nonetheless, even though clinical or self-report (i.e., questionnaires, interviews) approaches to bruxism diagnosis still remain incomplete, they are the easiest and most adopted methods to gather data in large-sample studies.

The paucity of well-designed works led the authors of a comprehensive review on this issue published in 1997 to conclude that there were not enough elements to support or refute the existence of a causal link between bruxism and TMD, also because of the poor methodological quality of the studies (15). Since that time, many investigations were conducted and one would expect that the advent of evidence-based medicine concepts has helped researchers design better studies; thus, it should be interesting to assess whether knowledge on the TMD-bruxism relationship is improved with respect to data available at that time. Considering these premises, the present paper aims to systematically review the literature on the TMD-bruxism relationship published from January 1st, 1998 to December 31st, 2008 and to summarize it on the basis of the diagnostic criteria for bruxism.

Materials and Methods

On May 26, 2009, a systematic search in the National Library of Medicine's PubMed Database was performed to identify all peer-reviewed articles in the English literature dealing with the bruxism-TMD relationship according to the search strategy described in the following sections. The studies included for review were assessed independently by the 2 authors on the basis of a structured reading of articles approach, which is also described in detail in the following sections.

Search strategy and literature selection

A search with Medical Subjects Headings (MeSH) terms was first used, and the following terms were used to identify a list of potential articles to be included in the review:

- Temporomandibular joint disorders: A variety of conditions affecting the anatomic and functional characteristics of the temporomandibular joint. Factors contributing to the complexity of temporomandibular diseases are their relation to dentition and mastication and the symptomatic effects in other areas that account for referred pain to the joint and the difficulties in applying traditional diagnostic procedures to temporomandibular joint pathology where tissue is rarely obtained and x-rays are often inadequate or nonspecific. Common diseases are developmental abnormalities, trauma, subluxation, arthritis, and neoplasia. Year introduced: 1997 (Previous indexing: temporomandibular joint diseases 1982-1996).

- Bruxism: A disorder characterized by grinding and clenching of the teeth. Year introduced: 1965.

The search was limited to articles on adult populations (+19 years) in the English language published later than January 1, 1998. The combination of the 2 MeSH terms, which alone yielded 11,975 and 1932 citations, respectively, allowed identification of 127 citations, the abstracts of which were read to select articles to be retrieved in full text.

The inclusion criteria for admittance in the systematic review were based on the type of study, namely, clinical studies on humans, assessing (1) the relationship between TMD symptoms and bruxism diagnosed clinically or by means of questionnaires/interviews; (2) the relationship between TMD symptoms and bruxism diagnosed by means of polysomnography (PSG) or electromyography (EMG); or (3) the effects of experimental clenching or grinding on the onset of TMD symptoms. In cases of duplicate studies (i.e., studies presenting the same findings and/or conducted on the same populations), only one article was included for further assessment.

After reading the abstracts, 78 articles were excluded from further assessment, and the remaining 49 articles were retrieved in full text and assessed for possible admittance in the review. The full texts were assessed independently by the 2 authors and consensus was reached in all cases to include/exclude articles from systematic assessment. Also, the PubMed search was expanded to the articles related to the selected ones and the reference lists of the full-text articles were read carefully to search for other studies to be potentially included in the review.

Systematic assessment of articles

The methodological characteristics of the selected articles were assessed according to a format that enabled a structured summary of the articles in relation to 4 main issues, namely, patients/problem/population, intervention, comparison, and outcome (PICO), for each of which specific questions were constructed. For each article, the study population ("P") was described in the light of the criteria for inclusion, the demographic features of the sample, and the sample size. The study design was described in the section reserved to questions on the study intervention ("I"), and information was gathered on all methodological features of

the study, namely, longitudinal or crosssectional observational design, type of experiment/intervention protocol, blindness of the examiners, assessment instruments, and statistical analysis. The comparison criterion ("C") assessed the presence of any comparison groups, namely, a control group or a specific comparison subgroup within the patient population. The study outcome ("O") was evaluated on the basis of the application of objective diagnostic criteria for bruxism as well as for TMD, calibration of operators/diagnosis, features of the described association (strength, dose/response, temporality, biological plausibility), and the consistency of the authors' conclusions with study findings. Also, the authors' main conclusions with regard to the bruxism-TMD association were reported.

All the above-described features of the included studies were put into tables, which also comprehend some critical considerations about the potential points of strength and weakness. All the studies were assessed separately by the 2 authors, and in cases of divergent assessments with regard to the assignment of strengths and weaknesses, the element under discussion was deleted from the tables if consensus was not reached.

Results

After examination of the full-text articles, 33 articles were selected for inclusion in the review. From the reference lists of the included articles and PubMedrelated articles, another 17 potentially relevant titles were identified and also retrieved as full texts. Four of them were subsequently excluded for not fulfilling the inclusion criteria, and 13 articles were added to the original list of articles, thus accounting for a total of 46 articles reviewed. Table 1 provides the list of articles excluded after reading the full texts, including the reason for exclusion.

According to the criteria adopted to make the diagnosis of bruxism, the articles included in the review were grouped into questionnaire/self-report (n = 21), clinical assessment (n = 7), experimental (n = 7), tooth wear (n = 5), polysomnographic (n = 4), or electromyographic (n = 2) studies.

Summary of findings of questionnaire/self-report studies

Twenty-one studies that assessed the relationship of TMD with bruxism as diagnosed by means of questionnaires or self-report assessments were identified (Table 2). These studies' populations accounted for a total of 32,116 subjects (15,470 females, 14,978 males, 1668 unspecified sex), of whom more than 93% (n = 29,934) were recruited among general population subjects. The remaining were patients with different TMD symptoms (n = 2082) or bruxers (n = 100). More than 50 % of the studies (n ≈ 11/21) based their diagnosis of bruxism on a single item, and diagnostic items were not specified in another 5 studies.

Table 1. Studies retrieved in full text and excluded from the review *(Study' s first author and year and reason for exclusion)*.

Mundt, 2008:	Same data presented in Mundt et al.
Johansson, 2008:	Longitudinal study on bruxism and TMD prevalence
Park, 2008:	Assessment of tooth-grinding pattern
Rues, 2008:	Activity of jaw muscles during different clenching levels
Leresche, 2007:	Study on adolescents only
Pizolato, 2007:	Maximal bite force in TMD and bruxism
Unell, 2006:	Longitudinal study on bruxism and TMD prevalence, same data as Johansson et al.
Casanova-Rosado, 2006:	Study also on adolescents (not possible to extract data of young adults)
Glaros, 2005:	Same data presented in Glaros et al.
Johansson, 2004:	Same data presented in Johansson et al.
Carlsson, 2004:	Same data presented as part of Magnusson et al.
Johansson, 2003:	Same data presented in Johansson et al.
Carlsson, 2002:	Same data presented in Magnusson et al.
Molina, 2001:	Description of oral jaw behaviors in TMD and bruxers
Amemori, 2001:	Presentation of a device to measure bruxism
Egermark, 2001:	Same data presented in Magnusson et al.
Magnusson, 2000:	Same data presented in Carlsson et al.
Molina, 2000:	Features of TMD and bruxers vs TMD and nonbruxer subjects
Gavish, 2000:	Study on adolescents only
Kieser, 1998:	Study on adolescents only

The questionnaire/self-report bruxism diagnosis was combined with a similar approach to diagnose TMD in 4 articles, and only 9 of 21 studies adopted the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) (60) to establish the presence of TMD symptoms (axis I diagnoses were adopted in 8 articles and axis II in another one). A control group was included in 7 of 21 studies and, overall, a good quality of statistical design was warranted, with only 4 studies basing their conclusions on univariate statistical analysis. Only 1 study was performed longitudinally, with 4 observation points over a 20-year span (34); all the others were cross-sectional studies assessing the TMD-bruxism association at a single observation point.

In general, the findings are supportive of an association between self-reported/questionnaire-diagnosed bruxism and TMD symptoms, which were found to be associated in 20 of 21 studies (20,29,32,34,43-46,48-59), whereas 1 study did not retrieve any association (47). In most articles, association was found with myofascial pain or symptoms of muscle disorders, but many studies did not specify TMD symptoms. As a result from 2 studies (45,46), patients with myofascial pain seem to have more teeth contact than controls over a 24-hour period. The teeth-contacting habit may represent a risk factor for the prolongation of pain.

Summary of findings of clinical assessment studies

Seven studies were based on a clinical approach to bruxism diagnosis (Table 3). They accounted for a total of 1302 subjects (672 females, 236 males, 394 unspecified sex) and were based on TMD patient populations in 6 articles (62-67) and on the general population selected from among dental students in 1 article (61). The criteria for diagnosing bruxism were not homogeneous among studies and often biased by preconceived ideas on the bruxism–muscle pain association. Diagnosis was based on functional loading of the masticatory system, namely, bruxism diagnosed when fatigue or pain was elicited by static 30-second maximum clenching (2 studies) (61,62), a set of clinical criteria (1 study) (64), nonvalidated attempts to rate bruxism severity (2 studies) (65,67), patterns of wear on a stabilization splint (1 study) (66), or even on not well-specified protocols (1 study) (63). In less than 50 % ($n \approx 3/7$) of the studies (61,62,64) was the diagnosis of TMD based on standardized criteria, such as the RDC/TMD (60). A true control group was recruited in 4 articles (62-65) and the study population was split into 2 or more comparison subgroups in 3 studies (61,65,67) (in 1 article to be compared also with a control group (65)). A comparison group was lacking in 1 study (66). There were only 2 longitudinal studies (61,62), but their findings are tempered by the fact that the study of bruxism-TMD relationship was not the main focus of the investigation, and, in 1 study, by the absence of "true" treatment-needing patients with TMD (study performed in dental students (61)). In 4 studies, the adoption of univariate analysis (63-65) or unclear statistical procedures (67) limited the statistical power and the robustness of findings.

CLINICAL RELEVANCE

The issue of the bruxism-TMD relationship is one of the most controversial aspects of dental literature, mainly because of the uncertainties that characterize the acquisition of knowledge on the etiologic and diagnostic aspects of both disorders. The result of this review indicates that an improvement in the methodological quality is strongly encouraged for future research, possibly with the adoption of approaches focusing on the different types of bruxism and TMD. A review published in 1997 claimed that the relationship had several unclear aspects. The present systematic review covered articles published in the PubMed database over the past decade.

As for the outcomes, a positive association was found with myofascial pain in 4 studies (61,62,64,67), 2 of which also described an association with TMJ pain (64,67). An association with condylar bony changes was described in 1 article (63). In 2 additional articles, the results were unclear as for unequivocal support/rejection of the hypothesized association (65,66). In general, comparison of findings was not possible between any of the studies because of adoption of highly variable criteria for patient inclusion and study design.

Summary of findings of experimental studies

Seven studies attempted to relate experimental clenching (6 articles) (68-71,73,74) or grinding tasks (1 article) (72)with the onset of TMD-like symptoms (Table 4). They accounted for a total of 79 subjects (53males, 26 females), 23 of whom took part in 2 different protocols published in different articles (68,69). The age range of participants, who in all studies were healthy volunteers mainly selected from among dental students or university staff members, was limited, and the mean age of participants of the 7 studies was confined to between 23 and 28 years. The study samples were of small size (5 to 23 subjects/study). All of these factors limit the external validity of findings, which have to be interpreted with caution before extrapolation of data to the general population.

A standardized RDC/TMD assessment was used in only 2 studies /70,73), and in 2 studies (68,69), saline or glutamate injections were also performed as a noxious stimulus to provoke pain and to compare it with the effects of clenching. Five studies were single-session experiments (30 minutes of sustained clenching at 10 % of the maximum voluntary contraction force [MVCF] in 2 studies (68,69); 60 minutes of sustained clenching at 10 % MVCF in 1 study (71); 9 trials of 5 minutes of grinding at 50 % of the maximum voluntary occlusal force [MVOF] with a short rest between each trial in 1 study (72); and a combina-

Table 2. Summary of findings from studies with a questionnaire or self-report based diagnosis of bruxism.

Author	Population	Study design features	Comparison	Outcome	Conclusion	Strength	Weakness
Costa 2008	42	RDC/TMD Headache MR	Headache vs no headache	Bruxism in headache	Bruxism risk factor, headache	Relate bruxism to headache	Non-specified procedures
Osterberg 2007	2 cohortes: 904	Q TMD + health Dental Occlusion	Different TMD severity	Correlations TMD and bruxism	TMD symptoms associated with bruxism	Population sample representative	Self reported TMD
Chen 2007	9	Q stress RDC/TMD	15 MAP-free controls	Correlations in MFP patients	In MFP: more NTC when awake and higher stress levels	Statistical power 100%	Single question to assesst
Sato 2006	508	Q stress RDC/TMD	Pain improved/ not improved	TCH: no diff. in pain improvement	TCH in ½ of chronic TMD	RDC/TMD	Single question to assess TCH
Johansson 2006	2 cohortes: 12468 + 6232	Q in oral health	Patients with TMD vs without TMD	Bruxism: High odds ratio for TMD pain	Association: Bruxism and TMD symptoms	Large representative sample size	Single-item diagnosis of bruxism
Van der Meulen 2006	226 + 303	Q in oral parafunction	No control	No relation bruxism/CPI score	Causal relation between bruxism and TMD	Sample size	No control group
Camparis 2006	100	Q in orofacial pain, RDC/TMD	30 bruxers without orofacial pain vs 70 bruxers with	Sex diff. and differences in depression and somatization	Diff. longlasting brux. in patients with/without chronic facial pain	RDC/TMD	Single self-report feature to select bruxers
Kobs 2005	307	Selfreported clenching TMD	Stomatognathic dysfunction vs no dysfunction	Bilat. muscle sensivity larger in clenchers	Solid relationship: Clenching/muscle palpation finding	Population representative sample	Univariate analysis, unspec. clench diagnosis
Magnusson 2005	320	Q: TMD risk and symptoms TMD	No control	Fluctuation of TMD symp. presence/ absence	Correlation: Reported bruxism/ TMDsymp	Longitudinel design, TMD	Difficult interpretation of result
Ahlberg 2005	750	Q: work-related aspects Orofacial pain	Appr. 20% with orofacial pain, 80% without	Probability of current orofacial pain ass. with frequent bruxism	Association between perceived orofacial pain/self-reported bruxism	Multivariate analysis, RDC/TMD axis II in orofacial pain severity	Single quest. to assess brux. Concl. partly justified by design/ result
Mundt 2005	2963	TMJ Dental interview	Cases	Bruxers: more TMJ tendermess	Sign. ass.: bruxism and TMD signs	Large sample	
Glaros 2005	96	RDC/TMD	Compared groups	MP subj. more TC Correlation: Muscle tension and jaw pain	Parafunc.behaviors related with jaw pain level in TMD and control subj.	RDC/TMD Calibrated examiners	Demographic diff. Sample size
Gesch 2005	4290	Dental interview, Q: Frequency of grind/clench	No control	TMD symp. associated with parafunction	Frequent clenching sign. and clinically connected with subj. TMD symp	Large sample Calibration of examiners and interviewers	TMD symp: Low preval. Non-validated TMD diagnosis
Velly 2003	83	Q: Bruxism RDC/TMD	100 TMD-free patients	Clench/grind ass. with MFP, grind only not ass.	Clenching alone or with grinding contributes to MFP	RDC/TMD Multivariate analysis	Difficulty in discriminating clench/grind
Velly 2002	152	Q: Putative TMD factors RDC/TMD	100 subjects	Clenching/grinding related to intense pain w/high frequency	TMD strongly relates to clenching/ grinding and depression	RDC/TMD Cluster analysis	Unspecified method/question: clench/grind
Celic 2002	230, need of dental treatment	Q: Perceived symptoms Occl./ TMJ	Presence vs absence of signs and symp.	Awareness of parafunction: 15%	TMD symp. Weak ass.:	Assessment of occlusion and parafunction	Non-validated TMD diagnosis Sample size
Huang 2002	261	Q: Specific TMD risk RDC/TMD	195 controls	80% MP reported clenching. Clench= increased MP risk	Clench identified as risk of MP	RDC/TMD	Ass. Brux./TMD relationship not main study focus

Table 2: Continued ...

Author	Population	Study design features	Comparison	Outcome	Conclusion	Strength	Weakness
McFarlane	131	Q (postal) health GHQ	196 TMD-free controls	Grinding associated with Pain Dysfunction Syndrome pat.	PDS characteristics Headache, facial trauma, grinding, sleep probl., pain	Control goup Power analysis	Incorrect TMD nomenclature Info: diagnosis on TMD subgroups
Ciancaglini 2001	483	Q-based interview and Q-masticatory disturbances	No control	Assoc. of bruxism with several signs - and symptoms of mast. disturb.	Bruxism potentially harmful to masticatory system	Large sample Q: test-retest reliability	Absence of clinical conf. of TMD diagnosis.
Yamada 2001	94, need of ortognathic surgery	Q: parafunc. awareness TMJ disorder+ condyl.change	No control	Prevalence of bruxism higher in subj. w/condylar bone change	Selfreported bruxisme ass. w/ condylar change and DD	Assess brux./TMD relationship to morphology	Original idea not pursued Non-validated TMD diagnosis
Israel 1999	83 severe TMJ subj	Arthroscopic surgery, Parafunctional habits	No control	Osteoarthritis: 72% of joints with parafunction vs 55% without	Sign. relationship: Parafunc. activity/ TMJ osteoarthritis, not synovitis	Better insight into TMJ through arthroscopy	Non-validated TMD diagnosis as well as diagnosis of parafunction

tion of 3 different clenchingtype exercises in 1 study (74)) and 2 studies were based on multisession protocols (28 sessions over 6 weeks in 1 study (73); 5 sessions over 1 week in 1 study (70)). The maximum follow-up span was 3 days in 1 study (72), whereas the other 6 studies had either no follow-up or 1 single day of post-exercise observation. Six studies had no control or comparison groups, and in 1 study comparison was made between 2 different protocols of jaw clenching (70). Appropriate statistical analysis for repeated measures was applied in all articles.

The findings of the 7 different studies are hard to compare. In general, the effects of low levels of prolonged clenching (10 % MVCF for 30-60 minutes) provoked a short-lasting feeling of pain (findings from 6 studies), whereas grinding may cause a delayed-onset pain in the day following the exercise (findings from 1 study). In all studies, effects tended to disappear shortly after the exercises.

Summary of findings of tooth wear studies

Five studies were based on some sort of tooth wear analysis, which was suggested to be used as a proxy for bruxism diagnosis (Table 5). The total number of participants was 1103 (578 females, 357 males, 168 unspecified sex), of whom 646 were general population subjects recruited for a single study (76), and 457 were patients with TMD who took part in the other 4 studies (94 myofascial pain, 52 unilateral TMJ disk displacement, 73 TMJ osteoarthrosis, 238 unspecified TMD symptoms) (75,77-79).

A standardized RDC/TMD diagnosis was provided in 4 of the 5 studies (75,77-79), and true control groups were recruited in 3 studies, accounting for a total of 264 subjects (75,77,79). In 2 studies, the study sample was split to compare 2 subgroups of subjects (bruxism was taken as the independent variable in the first article (78); TMD pain was taken as the independent variable in the other article (76)). Tooth wear was assessed on dental casts in 4 of the 5 studies (75,77-79), and clinically in 1 of the 5 studies (76). Examiners were calibrated in all studies, and blinded when necessary. Statistical analysis was always appropriate, thus suggesting a high-quality standard of these articles. Four studies were cross-sectional, with only 1 observation point in time (76-79), whereas 1 study was longitudinal over a 2-week span (75).

As for the outcomes, all studies but one found no association between anterior tooth wear and any of the studied TMD symptoms. Only 1 observational study (77), according to the authors, allowed identifying patterns of attrition, which may contribute to discriminate patients with different TMD with respect to TMD-free controls, but findings seem to be difficult to interpret in a clinical setting.

Summary of findings of polysomnography studies

Four studies assessed the association of TMD symptoms with sleep bruxism diagnosed by means of polysomnographic recordings (80-83); 2 of them came from the same group of researchers (Table 6) (80,81). In total, 184 subjects (124 females, 60 males) were involved in the studies, 30 of whom were patients with myofascial pain, 14 had unspecified TMD symptoms, 40 were self-reported tooth grinders, and 100 were self-reported sleep bruxers (of those bruxers, only 54 were confirmed by PSG and included for statistical analyses).

A standardized RDC/TMD diagnostic assessment was performed in 3 studies (80,81,83), and a control group was selected in 3 of the 4 studies, accounting for 76 subjects (42 TMD-free

Table 3. Summary of findings from studies with a clinically based diagnosis of bruxism.

Author	Population	Study design features	Comparison	Outcome	Conclusion	Strength	Weakness
Marklund 2008	308	Q, Loading test, RDC/TMD	No control	Grinding ass.w. myofac. symp.	Hypothesized positive rel. bruxism/ MP	Longitudinal design, large sample size	Non-validated bruxism diagnosis
Storm 2007	22	Q parafunction awareness, loading test	46 without TMD	Positive loading test, awareness of grind/clench	TMJ pain elicited with loading test, association: TMD/ parafunction	Longitudinal design, RDC/ TMD	Low sample size, high drop-out rate
Guler 2003	64	MR, VAS pain, bruxism	30 without bruxism/with TMJ, 60 MR	Higher prevalence of DD in study gr.	High prevalence of bone change in bruxers	Attempt to relate brux. with TMJ in MR	Univariate analysis. Unclear brux. criteria
Manfredini 2003	212	RDC/TMD	77 TMD-free	Prevalence of bruxism in diff. RDC/ TMD subgroups	Bruxism more ass. with muscle disorder than joint pathology and DD	Large sample RDC/TMD	Univariate analysis, single examiner
Molina 2003	394	Q Bruxism severity	109 with DAP	Severe bruxism	TMD/brux and DAP patients more impaired	Large sample	Univ. analysis, non-standard. TMD diagnosis
Chung 2000	26	Stabilization splint, VAS, bruxofacet-pattern	No control	Bruxofacets on 88% splints at 10 week	Sleep bruxism ass. with grinding more than clench	Attempt to analyze splints wear as proxy for bruxism	No control Small sample
Molina 1999	276	Q, Bruxism severity	No control	Prevalence of CMD increased with increased brux. severity	Higher prevalence of muscle and joint disorder in severe bruxers	Large sample	Non-standard. TMD diagnosis

Table 4. Summary of findings from experimental studies.

Author	Population	Study design features	Comparison	Outcome	Conclusion	Strength	Weakness
Torisu 2007	23	Induction of muscle fatigue EMG, VAS	No control	ES more inhibited after induced fatigue	Muscle fatigue and pain diff. effect on EMG and ES response	Attempt to discriminate: effect fatigue/ pain on EMG	No follow-up
Torisu 2006	23	Induction of muscle fatigue EMG, VAS	No control	Fatigue score higher in male Pain diff.	Gender diff. in devel. of chronic musc.skel.pain	Gender comparison	No follow-up
Glaros 2004	14	RDC/TMD to exclude TMD EMG, VAS	(n=7+7) EMG Decrease vs EMG Increase	Postsession worst pain > in Increase group	Parafunc. act. Increase pain	RDC/TMD Blind exam.	No follow-up Low sample size
Svensson 2001	11	Biteforce VAS pain Jaw opening	No control	Stronger ass.: EMG/fatigue than EMG/pain	Sustained clench involved in fatigue develop	Discrimination fatigue/pain	No follow-up Low sample size
Arima 1999	12	Voluntary grinding VAS, EMG	No control	Grinding-related change on affectory/pain dimension	45 min. grinding TMJ and MMS next day	Prolonged exp. grinding: 3 days	No control
Glaros 1998	5	VAS pain Blind exam.	No control	Increase VAS pain higher Pain relief in following 24h	Low-level parafunc. activity and pain relationship	RDC/TMD Blind exam.	No follow-up Small, non-representative sample
Plesch 1998	14	Bite force Diff exercises	No control	Imm. Post-exercise pain No decrease in PPT d2 vs d1	Post-exertional pain 24h only in females, unclear rel. w/chronic pain	Gender comparison 3 different exercises	No follow-up

ES=Exteroceptive Suppression, PPT=Pressure Pain Treshold

subjects from 2 studies (80,81); 34 non-SB in 1 study (82)). In 1 article (83), the study sample was split to compare bruxers with TMD pain to bruxers without TMD pain. Two studies based their findings on a single night of PSG recordings (81,83), whereas in 2 studies an additional preliminary adaptation night was part of the protocol (80,82). All studies adopted standardized criteria for SB diagnosis, even if inconsistencies in the criterion adopted to diagnose rhythmic masticatory muscles activity (RMMA) were present (EMG activity over 20 % of maximum voluntary contraction [MVC] was selected as the cut off in 3 studies (80,81,83); cut off was set at 10 % of MVC in 1 study (82)).

The results are difficult to interpret, as some inconsistencies of findings were present even between the studies performed by the same group of researchers. In summary, RMMA was found to be associated with myofascial pain (MP) in 1 article (80), no association was detected in another article (81), and a negative association, namely, subjects with pain exhibited fewer episodes of RMMA per hour with respect to subjects without pain, was described in 2 studies (82,83).

Summary of findings of electromyography studies

Two studies used a portable EMG recorder to assess the relationship between nocturnal masticatory muscle activity (NMMA) and the onset of TMD symptoms (Table 7). Both studies were performed in a home environment and accounted for a total of 111 subjects, of whom 103 were healthy volunteers (51 females, 52 males) (85) and 8 were females with RDC/TMD-diagnosed myofascial pain (84). Data are available on 97 subjects. Both studies had no control group and used a singlechannel EMG recorder on the right masseter, thus presenting strong limits to their external validity. One study was a longitudinal trial of 8 recording weeks over a 20-week span, with half (4 of 8) patients completing the entire recording period (84), and 1 study was based on 6 consecutive nights of recordings (85). Some inconsistencies were noticed as for diagnosis of NMMA events because of the adoption of different detection thresholds (10 % MVC versus 20 % MVC).

Results from the 2 studies suggest that an association may be hypothesized between NMMA and click sounds, whereas no relationship was found between NMMA and muscle pain.

Discussion

The issues of bruxism etiology, diagnosis, and treatmentare intriguing aspects in the medical literature (86-88), and recent years have been also characterized by an increasing interest in the consequences of this disorder on the teeth (89) and on dental implants (90), as well as on the different stomatognathic structures (91). The past decade has also provided some noteworthy attempts to get deeper into the issue of a possible bruxism-TMD relationship, which has been discussed in the present systematic review.

From a methodological viewpoint, the present review was based on a structured reading of articles, which helped in gathering relevant data from each article by answering clinical questions put into a PICO format. Such a frame, which is the acronym for questions formulated in terms of patients/problem/population, intervention, comparison, and outcome, has been recently gaining interest as a valuable tool to assist researchers propagating and clinicians practicing evidence-based medicine (92-94). In cases of arguments for which a meta-analysis of literature data is not possible, as in the present review, such an approach may

Table 5. Summary of findings from studies with bruxism diagnosis based on tooth wear (TW).

Author	Population	Study design features	Comparison	Outcome	Conclusion	Strength	Weakness
Janal 2007	51	Change in TW, diary, RDC/TMD	12 matched controls	TW over 2 weeks, TW index higher in controls than MFP patients	Failure to show more grinding. Failure to support model	Longitudinal TW analysis RDC/TMD	Indirect assessment of grinding
Schierz 2007	646	TMD pain Anterior TW	TMD subjects=31, non-TMD=615	No trend between increased TW and TMD pain	Anterior TW excluded as a clinical relevant risk for TMD	Calibration of TW analysis. Control for sex and age	Self-reported TMD, non-homogeneity in sample size
Seligman 2006	52 + 73 + 43	RDC/TMD	132 asymp. subjects	Model for TW characteristics of MP patients	Suggest TW pattern in MP. Ant. TW differentiating factor	Stat. model Control age in eval. of TW RDC/TMD	Difficult interpretation of result
Pergamalian 2003	84	RDC/TMD	Bruxism as indep. variable	Bruxism not ass. with TW	TW modestly correlated to age. No ass.: TMD and TW	RDC/TMD Attempt to clarfy rel.: TW and bruxism	No TMD-free group
John 2002	154	TW index	120 TMD-free subjects	TW related to age. Controls more TW than TMD patients	Incisal TW not ass. with TMD	Multivariate analysis. Blinded examiner	Unspecified TMD diagnosis

be useful to avoid bias in the interpretation of study results and to impede narrative speculations, thus keeping the review within the boundaries of evidence-based medicine. As for the literature selection, criteria for inclusion were based only on the type of study, so as to gather as much data as possible on the argument, the last comprehensive review of which dated to more than a decade ago (15), and which was partially rediscussed in a recent article (16). The adoption of wide inclusion criteria led to the selection of studies focusing on other issues, thus having a very low specificity for the bruxism-TMD relationship, the findings on which could be considered ancillary results that in some articles were not discussed exhaustively. Moreover, such a comprehensive systematic approach to literature selection showed some problems of redundancy, because in some occasions the same data appeared to be discussed in more than a single article, forcing us to exclude all duplicate studies from the review. In general, the level of evidence coming from the reviewed studies was less than optimal. Some cohort studies on general population samples were selected, but even though they are ranked IIB in the hierarchy of evidence, their level of specificity for the bruxism-TMD relationship was low, owing to the low prevalence of severe TMD patients in the studied samples and owing to the use of self-report diagnosis of bruxism. Most articles were either casecontrol studies (IIIB) or case series (IV). The 46 identified articles involved researchers from several countries, more than 35,000 subjects were recruited for the studies' populations, and some interesting findings did emerge.

Nearly half of the selected studies were based on self-report/questionnaire-diagnosed bruxism, which is the most suitable approach to gather large-sample data for epidemiological reasons, but is also poorly specific and tempers the external validity of results. In general, strong support for an association between bruxism and TMD came from studies with a self-report or clinical bruxism diagnosis, but many of the studies adopting other diagnostic approaches failed to confirm such an association. A recent narrative review hypothesized that self-report diagnosis of bruxism is probably suitable to detect conscious clenching-like activity during wakefulness, which may be associated with tenderness or fatigue in the jaw muscles, whereas other comprehensive approaches, such as tooth wear analysis or sleep laboratory recordings, are mainly indicated to detect grindinglike activities, the effects of which may be different with respect to

Table 6. Summary of findings from studies with a PolySomnoGraphic-based diagnosis of bruxism.

Author	Population	Study design features	Comparison	Outcome	Conclusion	Strength	Weakness
Rosetti 2008	30 MFP	Q + CA for MFP diagnosis PSG 2 nights EMG 20% MVC	30 healthy controls	No ass.: SB and worst pain in the morning. No diff in sleep	RMMA during sleep ass. with MFP. Daytime clench: MFP risk	Control group Calibrated examiner Standard. SB	PSG recording only 1 night (1 night adaptation)
Rosetti 2008	14 TMD	VAS, RDC/TMD 1 night PSG, EMG 20% MVC	12 non-TMD subjects	No ass.: SB and TMD, no diff in sleep	SB not associated w/TMD nor pain	RDC/TMD Control Group Standard. SB	1 night PSG No adaptation
Rompré 2007	100 Sleep Bruxism	PSG 2 nights Q: SR Pain intensity	43 non-bruxers Subj. excluded Due to no SB	Excl. bruxers more complain on clench/pain	Pain frequently report. in SB with low jaw activity	Standard PSG Large sample Control group	Non-standard RDC/TMD 1 night PSG
Camparis 2006	40 (20 with, 20 without TMD)	RDC/TMD PSG confirm SB EMG 20% MVC	20 (of 40)	SB periods/h: 20% more in subj w/no pain	Inconclusive evidence for ass.: Facial pain/SB	Standard PSG RDC/TMD	1 PSG night No adaptation

SB=Sleep Bruxism, MVC=Maximum Voluntary Contraction, RMMA=Rythmic Masticatory Activity, SR=Self Reported

Table 7. Summary of findings from studies with an EMG-based diagnosis of bruxism.

Author	Population	Study design features	Comparison	Outcome	Conclusion	Strength	Weakness
Van Selms 2008	8	20 weeks, Q Nocturnal EMG NMMA events	No control	No ass.: Changes in MP and MMA at night	Chronic MMP more related to stress than para-functional activ.	Longterm study at home	Single channel EMG
Baba 2005	103	6 nights, Q Nocturnal EMG	No control	Muscle activity higher in subj. w/ joint sound	Ass.: Masseter muscle activity and click sound	Sample size Home environment	Single channel EMG

MMA/MMP = masticatory muscle activity/pain

those of clenching (95). Actually, a systematic appraisal of the literature did not allow rejecting/confirming such speculation, owing to the very low number of articles attempting to discriminate between the 2 different oral motor behaviors, namely, clenching and grinding activities. Thus, a potentially interesting issue to be addressed in the review, that is, to discuss available information by focusing on the different types of bruxism, could not be pursued. The level of evidence of results coming from studies on self-report bruxism was generally low. More than half of the studies adopting such a diagnostic approach, based bruxism diagnosis on a single item in a questionnaire, and in most cases the assessment of bruxism-TMD relationship was not the main focus of the investigation. Moreover, most data came from epidemiological studies on general population subjects, and the study populations were characterized by a low rate of patients who were in need for TMD treatment or presented severe TMD symptoms. Such a limitation affected also the only longitudinal report on this issue, 34 thus representing a potential bias for statistical analysis and also preventing the collection of useful data for the clinical setting. Thus, caution has to be recommended in the interpretation of the results. The existence of a positive association between TMD and bruxism seems to be supported also by most articles, based on a clinical diagnosis of bruxism, with 5 of 7 articles reporting an association of bruxism with TMD, and myofascial pain in particular. Nevertheless, it should be noticed that in almost all studies, the patients needed to refer muscle pain in the morning or pain needed to be provoked with functional loading of the masticatory system, that is, elicited by static 30 seconds of maximum clenching, as a criterion to diagnose bruxism. Such an approach is a potential diagnostic bias and may have increased the level of significance of the bruxism-myofascial pain association, as in the case of a study reporting an over 70 % prevalence of bruxism in patients with myofascial pain (64). Some interesting protocols for the clinical assessment of bruxism were proposed by some authors (e.g., rating of bruxism severity, bruxism indexes), but validation was not provided, and calibration of the operators was also missing in some articles. In some articles, differences in the clinical approaches to the diagnosis of bruxism, which were almost totally based on anamnesis and interview, were minimal with respect to a self-report or questionnaire-based diagnosis. Both approaches were at risk of being influenced by the patients' and clinicians' beliefs about the causes of pain or fatigue within the masticatory muscles. This last observation seems to be suggested by the fact that the highest levels of association were found in studies with both bruxism and TMD self-report diagnoses, which were also those with the lowest level of specificity.

In general, a higher level of specificity characterized studies adopting other approaches to the diagnosis of bruxism. With no exceptions, all studies based on tooth wear assessment, on PSG or EMG recordings, and on experimental studies aimed directly to get deeper into the knowledge of bruxism-TMD relationship as the main focus of the investigation.

With the exception of one single study, which depicted peculiar patterns of attrition for patients with different TMD signs and symptoms (77), studies on tooth wear failed to prove an association between anterior attrition and TMD pain. Studies on tooth wear analysis were generally of high quality, adopting standardized and calibrated assessments for both tooth wear and TMD in most cases. Thus, they provided a consistent amount of evidence that anterior tooth wear cannot be considered a risk factor for TMD, whereas more complex patterns of wear may be worthy to be rediscussed before being considered as markers for specific TMD subgroups. The choice to adopt tooth wear as a proxy for bruxism was a potential bias, because the different causes of wear, namely, functional versus nonfunctional versus dietary/metabolic or others, may not always have been taken into account properly. Also, importantly, temporal considerations, namely, the presence of ongoing or past causes of tooth wear, are hard to make. Nevertheless, the only longitudinal study on tooth wear analysis, a high-quality case series performed over a 2-week time span, supported the absence of a positive association with myofascial pain (75). Findings from articles on EMG or PSG recordings were not conclusive, and results are not consistent with each other. Investigations adopting these approaches shared their diagnostic target on sleep bruxism, but the level of specificity was high only for PSG studies, thanks to the adoption of validated criteria for the diagnosis of sleep bruxism. The only 2 investigations performed with an EMG recording in a home environment provided inconclusive data (84,85) and, despite the well-designed longitudinal protocols, must be considered no more than sources of documentation to be deepened with future researches. In particular, the EMG recorders used in both studies were single-channel devices that were able to monitor the EMG activity of a single muscle, i.e., the right masseter muscle, thus not being suitable to gather information on more complex patterns of muscle contraction. As for the PSG studies, literature suggestions that the level of nocturnal masticatory muscle activity in patients with pain is generally lower with respect to subjects without pain (96,97) cannot be fully supported by this review, because some inconsistencies among the articles included in this review as for the association of RMMA and sleep bruxism have been shown, namely, bruxers showed an increased RMMA in one study (80) and a decreased NMMA in 2 studies (82,83). Such findings supported the view that many challenges have yet to be won before a full comprehension of phenomena related to the presence of pain in some bruxers can be achieved.

Finally, a good level of consistency could be detected among findings from studies on experimental clenching/grinding. There is evidence that low levels of prolonged clenching may provoke acute muscle tenderness, which is generally short lasting and decreases rapidly after the exercise. Interestingly, a couple of recent articles have attempted discriminating pain from the sensation of fatigue (68,69), which is a compelling need for future studies. The methodological quality and design of experimental studies was

high, even though a couple of major shortcomings could be identified for almost all the reviewed experimental articles, namely, the absence of follow-up and the selection of unrepresentative samples of healthy subjects in the third decade of life. Thus, it can be suggested that future investigations need to be performed to clarify the issue, even if the best available evidence seems to suggest that mechanisms other than sustained clenching may be needed to provoke chronic pain.

On the basis of this review, an improvement in the methodological quality of the studies seems to be a compelling need in the future, thus suggesting that some shortcomings that were pointed out in the review published in 1997 were still present in the bruxism-TMD literature. Strong efforts are needed to achieve a better standardization of bruxism diagnosis, possibly by means of dedicated multichannel EMG recorders that allow discriminating between the different bruxism activities. Indeed, it is likely that inconsistencies of literature findings depend on the large interindividual variability of muscle activity patterns that probably characterize the studies' populations. Also, the adoption of concurrent standardized diagnosis for TMD, with focus on reliable recordings of specific signs and symptoms is recommended to improve specificity in the assessment of the complex bruxism-TMD relationship.

Conclusions

The issue of the bruxism-TMD relationship is one of the most controversial aspects of dental literature, mainly because of the uncertainties that characterize the acquisition of knowledge on the etiologic and diagnostic aspects of both disorders. The comprehensive review on the issue published in 1997 claimed that the relationship had several unclear aspects and that most criteria that were needed to confirm a causal relationship between the 2 disorders could not be satisfied.15 The present systematic review covered articles published in the PubMed database over the past decade, and the following suggestions can be drawn:

- It was not possible to discuss data on the relationship be-tween specific TMD signs and symptoms and the different bruxism-related motor activities, namely, clenching and grinding, because of the very low level of specificity that characterized most investigations.

- Works on self-report or clinical bruxism diagnosis showed a positive association with TMD pain, but they were characterized by some potential bias and confounders at the diagnostic level (e.g., pain as a criterion for bruxism diagnosis).

- Anterior tooth wear is not a major risk factor for TMD.

- Experimental, sustained jaw clenching may provoke acute muscle tenderness, but it is not likely to be the main initiating factor for the onset of chronic pain.

- Improvement in the methodological quality is strongly encouraged for future research, possibly with the adoption of approaches focusing on the different types of bruxism and TMD.

Abstract (Dansk)

Relationen mellem bruksisme og temporomandibulær dysfunktioner: en systematisk oversigt over litteraturen fra 1998 til 2008

Mål - Et systematisk review af forholdet i publiceret litteratur mellem temporomandibular dysfunktioner (TMD) - bruksisme fra 1998 til 2008.

Studiedesign - En systematisk gennemgang af National Library of Medicine's PubMed database blev gennemført med henblik på at identificere alle in vivo-studier for at vurdere forholdet mellem TMD symptomer og bruksisme diagnoseret ud fra forskellige fremgangsmåder. De udvalgte publikationer blev vurderet uafhængigt af 2 forfattere i overensstemmelse med en struktureret læsning af artikel formatet (PICO).

Resultater - Totalt blev 46 publikationer inkluderet i diskussionen i dette review. De 46 publikationer blev grupperet i spørgeskema/selvrapportering (n = 21), klinisk vurdering (n = 7), eksperimentelle (n = 7), tandslid (n= 5), polysomnografiske (n= 4), eller elektromyografiske (n= 2) studier. I flere studier var evidensniveauet negativt påvirket af det lave specificitetsniveau ved vurderingen af forholdet mellem bruksisme og TMD på grund af den lave prævalens af alvorligt ramte TMD patienter i stikprøvestørrelserne og på grund af diagnosticering ved selvrapportering, som giver en risiko for diagnostisk skævvridning.

Konklusioner - Undersøgelser baseret på selvrapportering eller en klinisk bruksismediagnose viste en positiv korrelation med TMD smerte, men disse undersøgelser er karakteriseret af en mulig skævhed på diagnostisk niveau (fx smerte som kriterium for bruksismediagnose). Studier baseret på mere kvantitative og specifikke metoder til at diagnosticere bruksisme viste mindre korrelation med TMD symptomer. Anteriort tandslid var ikke en stor risiko faktor for TMD. Eksperimentel vedvarende tandpres kan fremkalde akut muskelømhed, men ømheden er ikke analog med myogen TMD smerte, således vil disse studier ikke hjælpe med at afklare det kliniske forhold mellem bruksisme og TMD.

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