The triangle bruxism, pain, and psychosocial factors

Manfredini, D.

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Chapter 2

RELATIONSHIP BETWEEN BRUXISM AND TEMPOROMANDIBULAR DISORDERS. A SYSTEMATIC REVIEW OF LITERATURE FROM 1998 TO 2008

Daniele Manfredini, Frank Lobbezoo

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Abstract

Objectives The present paper aims to systematically review the literature on the temporomandibular disorders (TMD)-bruxism 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 relationship 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.

Introduction

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

There is a considerable amount of literature suggesting that sleep and awake bruxism are two 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], while awake bruxism is characterized by a clenching-type activity and is associated with psychosocial factors and a number of psychopathological symptoms [11].

Due to their different characteristics, sleep and awake bruxism may have different consequences on the masticatory muscles and the temporomandibular joints. This issue is an under-reviewed aspect in the literature. Indeed, although bruxism 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 [15,16]. In particular, there is a need to clarify the possibly differential role of both types of bruxism in the etiology of TMD.

The issue is complicated by the difficulties to distinguish clinically between sleep and awake 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 only be detected unequivocally by means of polysomnographic recordings, the employ 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 (viz., questionnaires, interviews) approaches to bruxism diagnosis still remain incomplete, not allowing a distinction between the different types of this disorder, they are the easiest and most adopted methods to gather data in large-sample studies.

All these difficulties may have discouraged researchers to perform investigations to get deeper into the assessment of the bruxism-TMD relation, and the paucity of well-designed works led the authors of the last comprehensive review on this issue to conclude that there were not enough elements to support or refute the existence of a causal link between bruxism and TMD [15]. It should be interesting to assess whether knowledge on the TMD-bruxism relation is improved with respect to data available at the time of that review. Considering these premises, the present paper aims to systematically review the literature on the TMD-bruxism relationship over the last decade and, when possible, to discuss available information on the different types of bruxism.

Materials and methods

On May 26th, 2009, a systematic search in the National Library of Medicine's PubMed Database was performed to identify all peer-review papers in the English literature dealing with the bruxism-TMD relation according to the search strategy described below. The studies included for review were assessed independently by the two authors on the basis of a structured reading of articles approach which is also described in details 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 papers 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 its relation to dentition and mastication and the symptomatic effects in other areas which 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 papers on adult populations (+19 years) in the English language published later than 01/01/1998. The combination of the two MeSH terms, which alone yielded 11975 and 1932 citations, respectively, allowed identifying 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, viz., clinical studies on humans, assessing: 1. the relation between TMD symptoms and bruxism diagnosed clinically or by means of questionnaires/interviews; 2. the relation 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 duplication studies (i.e. studies presenting the same findings and/or conducted on the same populations), only one paper was included for further assessment.

After abstracts reading, 78 papers were excluded from further assessment, and the remaining 49 papers were retrieved in full text and assessed for possible admittance in the review. The full texts were assessed independently by the two authors and consensus was reached in all cases to include/exclude papers 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 papers were read carefully to search for other studies to be potentially included in the review.

Systematic assessment of papers

The methodological characteristics of the selected papers were assessed according to a format which enabled a structured summary of the articles in relation to four main issues, viz., 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, viz., longitudinal or cross-sectional-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, viz., a control group or a specific comparison subgroup within the patients' 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 authors' conclusions consistency with study findings. Also, the authors' main conclusions with regards 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 two authors, and in cases of divergent assessments with regards to the assignment of strengths and weaknesses, the element under discussion was deleted from the tables if consensus wasn't reached.

Results

After examination of the full-text articles, 33 papers were selected for inclusion in the review. From the reference lists of the included papers and PubMed-related 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 papers were added to the original list of papers, thus accounting for a total of 46 papers to be discussed in the review. Table 2.1 provides the list of papers excluded after reading the full texts, including the reason for exclusion.

According to the criteria adopted to make the diagnosis of bruxism, the papers 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.

Table 2.1. *Studies retrieved in full text and excluded from the review.*

Study' s first author and year	Reason for exclusion
Mundt, 2008 [19]	Same data presented in [20]
Johansson, 2008 [21]	Longitudinal study on bruxism and TMD prevalence
Park, 2008 [22]	Assessment of tooth grinding pattern
Rues, 2008 [23]	Activity of jaw muscles during different clenching levels
Leresche, 2007 [24]	Study on adolescents only
Pizolato, 2007 [25]	Maximal bite force in TMD and bruxism
Unell, 2006 [26]	Longitudinal study on bruxism and TMD prevalence, same data as [21]
Casanova- Rosado, 2006 [27]	Study also on adolescents (not possible to extract data of young adults)
Glaros, 2005 [28]	Same data presented in [29]
Johansson, 2004 [30]	Same data presented in [31] and as part of [32]
Carlsson, 2004 [33]	Same data presented as part of [34]
Johansson, 2003 [31]	Same data presented in [30] and as part of [32]
Carlsson, 2002 [35]	Same data presented in [34]
Molina, 2001 [36]	Description of oral jaw behaviors in TMD and bruxers
Amemori, 2001 [37]	Presentation of a device to measure bruxism
Egermark, 2001 [38]	Same data presented in [34]
Magnusson, 2000 [39]	Same data presented in [33] and as part of [34]
Molina, 2000 [40]	Features of TMD and bruxers vs. TMD and nonbruxers subjects
Gavish, 2000 [41]	Study on adolescents only
Kieser, 1998 [42]	Study on adolescents only

Summary of findings of questionnaire/self-report studies (Table 2.2)

Twenty-one studies which assessed the relation of TMD with bruxism as diagnosed by means of questionnaires or self-report assessments were identified. These studies' populations accounted for a total of 32116 subjects (15470 females, 14978 males, 1668 unspecified sex), of whom more than 93% (N=29934) 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.

The questionnaire/self-report bruxism diagnosis was combined with a similar approach to diagnose TMD in 4 papers, and only 9 out 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 papers and axis II in another one). A control group was included in 7/21 studies and, overall, a good quality of statistical design was warranted, with only 4 studies basing their conclusions on univariate

statistical analysis. Only one study was performed longitudinally, with four 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 20/21 studies [20,29,32,34,43-46,48-59], while one study did not retrieve any association [47]. In the majority of papers, association was found with myofascial pain or symptoms of muscle disorders, but many studies did not specify TMD symptoms. As a result from a couple of studies [45,46], myofascial pain patients 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.

Table 2.2. *Summary of findings from studies with a questionnaire or self-report based diagnosis of bruxism. Legends: F, females; M, males; a.r., age range; m.a., mean age; yrs, years; TMJ, temporomandibular joint; ID, internal derangement; ADDWoR, anterior disk displacement without reduction; MR, magnetic resonance; T1W, T1 weighted; T2W, T2 weighted; Q, questionnaire; JE, joint effusion; C.I., confidence interval; OR, odds ratio; MAP, myoarthropathy; NTC, nonfunctional teeth contact; TCH, teeth contacting habit; HADS, Hospital Anxiety and Depression Scale; CP, chronic pain; CA, clinical assessment; MO, mouth opening; CPI, chronic pain intensity; SR, self-report; GCPS, Graded Chronic Pain Scale; M, myogenous; A, arthrogenous; DD, disk displacement; AAOP, American Academy of Orofacial Pain; MFP, myofascial face pain; SCL-90R, Symptoms Checklist-90R; MP, myofascial pain; PDS, pain-dysfunction syndrome; GHQ, General Health Questionnaire; IBQ, Illness Behavior Questionnaire; SE, sensitivity; SP; specificity; CT, computerized tomography.*

First author and year	Population	Intervention	Comparison	Outcome	Conclusions	Strength	Weakness
Costa, 2008 [43]	42 consecutive patients with TMJ ID and pain (35F, 7M; a.r.18-63 yrs.)	42 joints RDC/TMD Calibrated examiners (non-specified procedures) Non-specified bruxism diagnosis Headache diagnosis (history and examination) MR (T1W and T2W) for ID and effusion Single radiologist Chi-square or	N=21 TMJ ID and headache N=21 TMJ ID without headache N=16 TMD- and headache-free (11F, 5M; a.r. 26-37 yrs.)	Bruxism in headache 71.4% ($p<0.0125$ vs. non-headache) Headache more frequent in patients with more severe TMJ ID and ADDWoR JE more prevalent in headache patients(16/21, $p<0.0125$ vs. non-headache)	Bruxing behavior risk factor for headaches in TMJ	Attempt to relate bruxing behavior with headache and TMJ pain RDC/TMD	Univariate analysis Incorrect use of terms (e.g., "headaches in TMJ") No information on calibration No information on bruxism assessment Unmatched groups (patients vs. controls) as for age and sex

		Fisher-exact test					
Osterberg, 2007 [44]	Two cohorts of 70-yrs. subjects (N=904; 481F, 425M) representative of the general population	Dental occlusion Q: 5 item TMD index Q: other health problems, among which bruxism Logistic regression analysis	Comparison of subjects with different TMD severity Only 1% high scores (3-5 points) in the 5-item TMD index	Sex differences for bruxism (20%F, 15%M, p <.01) Correlation between TMD index and bruxism (p<.001) Bruxism: 2.23 OR (95% C.I.:1.48-3.35) for severe TMD (more than two symptoms)	TMD symptoms associated with bruxism Uncertainty in self-reported bruxism, caution in interpretation of results	Multivariate analysis Attempt to create a TMD index Population representative sample	Self-report TMD diagnosis Single-item diagnosis of bruxism Very low prevalence of severe TMD (potential bias for regression analysis)
Chen, 2007 [45]	9 patients with MFP (6F, 3M: med.a. 35 yrs.; a.r. 18-67)	RDC/TMD 43 alerts/day (wrist vibrator) On alerts, subjects checked for their teeth contact 10-day protocol Q: stress assessment 100% statistical power Frequency of NTC (non-parametric test)	15 MAP-free controls (10F, 5M; med.a. 30 yrs.; a.r. 19-49)	MFP more NTC than controls (med. 34.9% vs. 8.9%, p<.001) NTC frequency not different between genders (med. F13.5%, M11.1%) FTC frequency (chewing or swallowing) similar in MFP and controls (med. 10.9% vs. 9.2%) MFP higher stress scores, not correlated with NTC frequency	MFP nearly 4 times more NTC during wake time and higher stress levels than controls NTC frequency not correlated with stress levels	RDC/TMD High number of alerts/day High statistical power (even if low sample size) "Longitudinal" design	Single question to assess frequency of teeth contact No information on other concurrent TMD diagnoses
Sato, 2006 [46]	508 patients with TMD from more than one week	RDC/TMD Q: TCH, VAS, HADS Logistic regression	TCH-TMD association analyzed on 229 CP patients (85.6%F; med.a. 32 yrs.) Improved vs. not-improved	TCH not different between improved and not-improved pat. TCH significant	TCH in about half of chronic TMD TCH potential risk factor for TMD pain	RDC/TMD Multivariate analysis Attempt to study the relation between	Single question to assess TCH Difficult interpretation of results Unclear

			with respect to pain levels of the first visit	factor for pain duration (OR 1.944)	prolongation	TMD and TCH	selection of samples and methods of comparison (improved vs. not-improved) Low number of alerts/day
Johansson, 2006 [32]	Two cohorts of 50 yrs. (N=12468) and 60 yrs.-old (N=6232) subjects representative of the general population (50.6%M, 49.4%F)	Q: 123 items on general and oral health CA in a randomly selected subgroup of 961 subjects (for purposes of Q validation as for number of remaining teeth and MO) Logistic regression	Comparison of subjects with and without TMD	TMD pain: 12.1%; MO difficulty: 11.1% Bruxism: 79.9% of TMD pain; 78.3% of MO difficulty Bruxism: highest odds ratio for TMD pain (OR=4.2) and MO difficulty (OR=2.0)	Association between bruxism and TMD signs and symptoms	Large population representative sample Multivariate analysis Clinical validation of self-report TMD items (data provided elsewhere)	Single-item diagnosis of bruxism Overestimation of results of bruxism-TMD association (OR are within 95% C.I.)
Van der Meulen, 2006 [47]	226 consecutive TMD patients (88.5%F; m.a.38.5±13.3; a.r. 13-76 yrs.): frequency cohort, FC 303 consecutive TMD patients (83.8%F; m.a.37.2±14.2; a.r. 14-83 yrs.): stressfulness cohort, SC	Q: 12 items for oral parafunctions (TMD experts to assess content validity) Occurrence (FC) or perceived stressfulness (SC) of parafunctions (same questions) 5-point ordinal scale to answer RDC/TMD axis II (CPI scores) Q: BRUX, BITE, SOFT scales; good internal consistency Logistic regression	No control group	No relationship between BRUX scale and CPI scores FC: negative relationship between BITE scale and CPI scores (p=.010) SC: positive relationship between SOFT scale and CPI scores (p=.013) Very small variance in CPI (up to 3.5%) explained by the oral parafunctions	Causal relation between bruxism and TMD, if existing, is small	Sample size Multivariate analysis Standardized TMD pain intensity assessment	Absence of control group
Camparis, 2006 [48]	100 consecutive patients (80F, 20M; m.a.	Standardized orofacial pain questionnaire	30 bruxers without orofacial pain (A) vs. 70	Sex differences between groups (F:	Clear differences between long-standing	RDC/TMD	Single self-report feature to select bruxers

	36.1±11.3 yrs.; a.r. 13-66) with sleep tooth grinding sounds (SR)	RDC/TMD Chi-square test for comparison between groups	bruxers with orofacial pain (B)	60% vs. 88.6%) Age differences not significant (33.0 vs. 37.5 yrs.) RDC/TMD axis I diagnoses: MP (0.0% vs. 95.7%), DD (10.0% vs. 22.8%), A (6.7% vs. 77.1% Differences between groups (p= .001) as for levels of depression and somatization	bruxism, with and without chronic facial pain Bruxers with CFP: bilateral pain, uncomfortable bite, stiffness in the morning (statistically different from bruxers without pain)		Univariate analysis not adjusted for confounders (ex: sex)
Kobs, 2005 [49]	307 population representatives subjects (140M, 167F; m.a. 35.4 yrs.; a.r. 20-54)	Abbreviated CA for TMD Unspecified "clenching" assessment (self-report) 299 subjects examined for clenching-muscle sensitivity to palpation relationship Chi-square test	Stomatognathic dysfunction (N=114) vs. no dysfunction (N=193)	Clenching: 81 yes vs. 218 no Bilateral muscle sensitivity: 53.1% of "clenchers"vs. 31.2% of "non-clenchers" (p=.001)	"Solid relationship" between "incidence of clenching" and muscle palpation findings	Population-representative sample	Univariate analysis Unspecified diagnosis of clenching Incorrect use of terms (e.g. "relationship"-"association"; "incidence"-"prevalence") Non-validated TMD diagnosis
Magnusson, 2005 [34]	320 subjects aged 7,11 or 15 years	20 years FU: incidence of TMD signs and symptoms Four observation points in time (4,5,10 years FU) on incomplete samples Q: TMD symptoms and putative risk	No "patients" control group	Fluctuation of symptoms and presence/absence of TMD Baseline reported tooth grinding at night predictor of TMJ clicking at 20-year FU (OR 2.2)	Significant correlations between reported bruxism and TMD symptoms Baseline report of tooth-grinding at night predictor of TMD treatment	Longitudinal design Long-term follow up Calibrated examiners Incidence of TMD Statistical design	Difficult interpretation of results (clinical examinations vs. self-report; signs vs. symptoms) Low rate treatment-needing TMD (potential clinical and

		factors (among which bruxism) CA: 100 subjects of the oldest group Logistic regression and other statistical tests		Baseline bruxism predictor of clinical TMD dysfunction at 20-year FU (OR 5-3-7.7) Weak to moderate correlations between tooth clenching and grinding and TMD symptoms	during the observation period		statistical bias)
Ahlberg, 2005 [50]	750 subjects with irregular shift-work and 750 with regular work in a broadcasting company (46.3%F, 53.7%M; 41.9% aged> 45 yrs.)	Q: work-related aspects and health problems Self-assessed frequency of tooth grinding and clenching Perceived current orofacial pain severity (RDC/TMD axis II: GCPS) Logistic regression analysis	19.6% of the study sample with perceived orofacial pain vs. 80.4% without	No subjects with GCPS grade III or IV scores Frequent bruxism: 10.6% of study sample vs. 37.6% of subjects with GCPS grade II scores (p<.001) Probability of current orofacial pain positively associated with frequent bruxism (p<.001).	Association between perceived orofacial pain and self-reported bruxism	Multivariate analysis RDC/TMD axis II to rate perceived orofacial pain severity	Single question to assess bruxism Absence of severely disabled orofacial pain subjects Conclusions justified only in part by the study design and results
Mundt, 2005 [20]	2963 subjects from a population based survey (1493F, 1470M; a.r. 35-74)	Assessment of TMJ or jaw muscle pain Assessment of occlusal support Dental interview with a question on bruxism Chi-square and logistic regression models	Cases (subjects with jaw muscle and/or TMJ pain) vs. controls	Bruxers: more TMJ tenderness (F: 26.1% vs. 39.4%, p=.003; M: 28.7% vs. 44.0%, p=.026) Female bruxers: more muscle tenderness (25.2% vs. 35.1%, p=.001) Logistic regression confirmed associations: muscle tenderness in	Significant associations between bruxism and TMD signs in females and males	Large sample Study of specific TMD "signs" (they are actually symptoms)	Bruxism-TMD relation not the main focus Low prevalence (5-10%) of TMD signs (potential statistical bias) Single question to assess bruxism OR of significant variables within the 95% C.I. (potential

				F (OR 1.7), TMJ tenderness in F (OR 2.0) and M (OR 1.9)			example of statistical but not clinical significance)
Glaros, 2005 [29]	96 subjects recruited at a TMD clinic or in the general population	RDC/TMD Two calibrated examiners Pagers to be filled out at each alert by a wrist vibrator (every 120 ± 20 min) Pagers: pain and stress VAS, yes/no question on teeth contacts Linear regression to predict jaw pain	MP (N=24) vs. MP+A (N=21) vs. DD (N=24) vs. no TMD (N=27) m.a: 35.4-44.9 yrs.; F: 60.7%-87.0% of the samples	MP+A highest scores of intensity in teeth contacts MP subjects higher levels of teeth contact intensity vs. DD and controls Correlation between muscle tension and jaw pain	Parafunctional behaviors related with jaw pain levels in subjects with TMD and controls	RDC/TMD Calibration of examiners	Demographic differences between groups Small sample size to perform a logistic regression (no a priori power analysis) Arbitrary variables on pagers Low numbers of alerts/day Unclear definition of parafunctions
Gesch, 2005 [51]	4290 representative randomly selected subjects from the general population (original sample: N=7008) (2181F, 2109M; a.r. 20-79 yrs.) Equal distribution per each five-year age strata	Dental interview: TMD signs and symptoms (AAOP questions) Q: frequency of parafunctions (clenching and grinding) Calibration of interviewers and dental examiners (occlusion) Blinded operators Logistic regression analysis	No control group Low frequency of positive endorsements to TMD-related items (10.7%)	Univariate analysis: "TMD symptoms" associated with parafunctions ($p<0.01$) Multivariate analysis: frequent clenching 3.4 OR, wear facets 0.7 OR for TMD symptoms	"Frequent clenching" significantly and clinically connected with subjective TMD symptoms	Large sample Combination of occlusal variables and parafunctions in the logit model Calibration of the examiners and interviewers Multivariate analysis	Very low prevalence of subjects with TMD symptoms (statistical bias) Non-validated diagnosis of TMD and bruxism OR of significant variables within the 95% C.I. (potential example of statistical but not clinical significance)
Velly, 2003 [52]	83 MFP patients from more than six months (81%F, med.a. 35 yrs., a.r.19-59)	RDC/TMD SCL-90R Q: bruxism (no clenching-grinding; clenching only; grinding only; clenching-	100 TMD-free selected among outpatients at a dental clinic (64%F, significantly different from cases)	Clenching-only (OR 2.50) or clenching–grinding (OR 6.79) positively associated with chronic MFP in the	Clenching alone or combined with grinding, contributing factors to chronic MFP	RDC/TMD Multivariate analysis	Difficulties in discriminating between clenching and grinding by self-report assessment alone

		grinding) Logistic regression		univariate and in the logistic regression Grinding-only not associated with MFP			Unmatched samples as for sex
Velly, 2002 [53]	152 TMD patients (derived from tables; unspecified demographic features)	RDC/TMD Q: putative factors related to TMD Single examiner Cluster analysis and logistic regression	100 subjects (data derived from tables; unspecified demographic features; 17 subjects with TMJ click and no pain)	Four clusters of patients Clenching plus grinding related to recurrent pain with short duration and low frequency (cluster 1, 7% of sample, OR 7.8) Clenching plus grinding related to intense pain with high frequency (cluster 3, 43% of sample, OR 4.7)	Generalized TMD groups ("dysfunctionals") strongly related to clenching-grinding and depression	RDC/TMD Cluster analysis	Single examiner Unclear demographic features of the sample and recruitment of controls Unspecified method/question to assess clenching/grinding
Celic, 2002 [54]	230 M needing for dental treatment (m.a. 21.3±2.1 yrs.; a.r. 19-28)	CA: occlusion, TMJ and masticatory muscles Q: perceived severity of symptoms and other health problems (awareness of parafunctions) Interobserver reliability test on 10 randomly selected subjects Logistic regression analysis	Presence vs. absence of specific clinical signs and symptoms	Awareness of parafunctions: 15% of sample Awareness of parafunctional habits (teeth grinding and teeth clenching) largest influence on the odds of clinical signs of TMD (3.6-6.7 OR for TMJ pain, 4.2-7.0 for muscle pain)	Clinical TMD signs and symptoms weak association with awareness of parafunctional habits and with some occlusal parameters Caution to not overestimate findings in the clinical setting	Combined assessment of the role of occlusion and parafunctions Multivariate analysis	Non-validated TMD diagnosis Non-representative sample "TMD" subjects might not be real patients Single item to "diagnose" parafunctions
Huang, 2002 [55]	261 patients seeking for TMD treatment (Clinic	RDC/TMD Q: specific risk factors for TMD	195 Controls 97 MP 20 A	About 80% of MP (with or without A) reported clenching along with	Clenching identified as a risk factor for subjects with MP and	RDC/TMD Criteria for patients/controls selection	Clenching "diagnosis" was based on a single question

	Cases) 1016 age- and sex-matched subjects from a health cooperative, of which 121 were Community Cases and 210 (randomly selected) Community Controls	(clenching) MP, A, MP+A groups Exclusion of subjects with missing data or without MP or A Logistic regression analysis	157 MP + A	other risk factors (vs. 55%A 49% controls) Clenching associated with an increased risk of MP (OR 4.8) and MP+A (OR 3.3) (p<.01)	MP+A	Multivariate analysis	Assessment of bruxism-TMD relation not the main focus of the investigation Significant OR values within 95% C.I.
McFarlane, 2001 [56]	131 consecutive PDS patients (111F, 20M; med.a. 36 yrs.; a.r. 18-65)	Q (postal): demographic and health-related questions (one question on tooth grinding) GHQ, IBQ A priori sample size calculation (power analysis with recruited patients: 93% to detect a 2.5 OR) Logistic regression analysis	196 sex- and age-matched TMD-free controls consecutively selected at a clinic for conservative care	Univariate analysis: diurnal (OR 2.6), nocturnal (OR 2.5) and combined diurnal/nocturnal (OR 6.0) grinding associated with PDS. Logistic regression: five variables independently associated with PDS (among which teeth grinding during the day and/or night)	PDS patients characterized by frequent headaches, history of facial trauma, teeth grinding, sleep problems, pain elsewhere in the body and high levels of psychological distress	Control group Power analysis Several exposures (risk factors)	Incorrect use of TMD-related nomenclature Absence of information on TMD diagnostic subgroups Discussion mainly based on univariate analysis Single question to assess bruxism Test-retest reliability of the postal questionnaire not assessed
Ciancaglini, 2001 [57]	483 subjects at general population level (300F, 183M; m.a. 44.9±14.8 yrs.; a.r. 18-75)	Questionnaire-based interviews Standardization of interviewing dentists Q: masticatory disturbances (Helkimo Index) Single question for bruxism Test-retest reliability of questionnaire on 40 random subjects Multiple	No control group Bruxism taken as independent variable (152 bruxers vs. 331 non-bruxers)	Univariate analysis: association of bruxism with several signs and symptoms of masticatory disturbances Logistic regression: TMJ sounds (OR=1.64) and difficulty in closing the mouth (OR=2.84) associated with bruxism Bruxism: SE	Bruxism potentially harmful to the masticatory system Bruxism likely to have a direct relation with TMD and play an etiologic role	Large sample Statistical analysis Assessment of questionnaire's test-retest reliability	Single question to assess bruxism Absence of clinical confirmation of TMD diagnosis Low SE/SP values justify only in part the conclusions

		logistic regression		43.5-53.5%, SP 73.3-74.5% for the presence of craniofacial pain and difficulty in closing the mouth			
Yamada, 2001 [58]	94 F with TMJ disorders in need of orthognathic surgery (details on age are missing)	CA: TMJ disorders Q: awareness of parafunctional habits CT: TMJ disorders and condylar bony changes Patients divided into 6 craniofacial morphology groups Chi-square test	No control group 67 patients were not aware of bruxism/clenching habits	Bruxers: 85.2% TMJ sounds, 44.4% TMJ pain, 44.4% difficulty in mouth-opening, 74.1% (20/27) of bruxers condylar bony change Prevalence of bruxism higher in subjects with condylar bony change than in those without Association between bruxism and DDWoR No data with respect to different craniofacial morphologies	SR bruxism associated with condylar bony change and DD in orthognathic surgery patients with TMJ disorders	Attempt to assess the bruxism-TMD relation in patients with different craniofacial morphology	Original idea not pursued (few bruxers) Unclear data on patients' age Non-validated TMD diagnosis No information on calibration of the operators Univariate analysis
Israel, 1999 [59]	83 patients with severe TMJ pathology non-respondent to conservative management (70F, 13M; m.a. 35 yrs.)	Arthroscopic surgery on 124 joints: osteoarthritis, synovitis, adhesions, internal derangement "Detailed" history of parafunctional activities Chi-square test	No control group	Parafunctional activities influenced the status of 66% joints Osteoarthritis: 72% of joints with parafunctions vs. 55% without (p=.056) Absence of association between parafunctions and synovitis and adhesions	Significant relationship between parafunctional masticatory activity and TMJ osteoarthritis, but not with synovitis	Attempt to get a better "insight" into the TMJ by means of arthroscopy	Univariate analysis Use of the term "relationship" instead of "association" in the conclusion section Non-validated diagnosis of TMD Unspecified diagnosis of parafunctions

Summary of findings of clinical assessment studies (Table 2.3)

Seven studies were based on a clinical approach to bruxism diagnosis. They accounted for a total of 1302 subjects (672 females, 236 males, 394 unspecified sex) and were based on TMD patients' populations in six papers [62-67] and on the general population selected from among dental students in one paper [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 either on functional loading of the masticatory system, viz. bruxism diagnosed when fatigue or pain were elicited by static 30 sec maximum clenching (2 studies) [61,62], a set of clinical criteria (1 study) [64], non-validated 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]. Only in less than 50% (N=3/7) of the studies [61,62,64], the diagnosis of TMD was based on standardized criteria, such as the RDC/TMD [60]. A true control group was recruited in 4 papers [62-65] and the study population was split into two or more comparison subgroups in 3 studies [61,65,67] (in one paper to be compared also with a control group [65]). Any comparison group was lacking in one 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 one paper, by the absence of "true", treatment-needing TMD patients (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.

As for the outcomes, a positive association was found with myofascial pain in 4 studies [61,62,64,67], two of which also described an association with TMJ pain [64,67]. An association with condylar bony changes was described in one paper [63]. In two additional papers, 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 due to adoption of highly variable criteria for patient inclusion and study design.

Table 2.3. *Summary of findings from studies with a clinically-based diagnosis of bruxism. Legends (not included in previous tables): FU, follow up; MVC, maximum voluntary clenching; PD, proton density; DDwR, disk displacement with reduction; DDwoR, disk displacement without reduction; DAP, disk-attachment pain; CMI, craniomandibular index; VAS, visual analogic scale; CMD, craniomandibular disorders; MPDS, myofascial pain dysfunction syndrome.*

First author and year	Population	Intervention	Comparison	Outcome	Conclusions	Strength	Weakness
Marklund, 2008 [61]	308 dental students followed up for one year (196F, 112M; m.a. 23 yrs., a.r. 18-48)	Q: TMD symptoms and awareness of parafunctions Standardized CA by two expert examiners Loading test (MVC for 30s) to provoke fatigue and pain RDC/TMD diagnosis of MP Chi-square analysis (presence/absence of symptoms) Logistic regression	No "patients" control group Three partially overlapping cohorts: no signs and symptoms during the one-year interval (N=140); reports of jaw muscle signs or symptoms during the interval (N=196); RDC/TMD MP diagnosis at baseline or at FU (N=56)	Grinding associated with myofascial symptoms (p=.001) and MP RDC/TMD diagnosis (p=0.04) at baseline and 1 year Reported clenching habits increased from 38% at baseline to 48% at 1 year Clenching associated with myofascial symptoms and the MP RDC/TMD diagnosis at baseline and 1 year (p<.001)	Hypothesis of a positive relationship between awareness of bruxism and MP not rejected TMD signs and symptoms only in a minor proportion of subjects with awareness of bruxism	Longitudinal design RDC/TMD Large sample size Assessment of RDC/TMD MP incidence	Non-validated bruxism diagnosis Assessment of bruxism-TMD relation not the main focus Absence of "true" treatment-needing TMD patients
Storm, 2007 [62]	22 F with SR TMD pain lasting from 1 year (collected from participants to a previous study)	Longitudinal FU of a group of participants to a previous study Single blind and trained examiner RDC/TMD Q: parafunctions awareness Loading test (MVC for 30s) to provoke fatigue and pain Chi-square, parametric and non-parametric test	46 F without TMD	Positive loading test: 45% cases vs. 15% controls (p=.007). TMJ pain in 26% of cases (p=.002) Awareness of clenching: 6.60 OR for inclusion among "cases" (p=.002) Awareness of grinding: 1.35 OR for inclusion among "cases" (p=.60)	Muscle and TMJ pain elicited with loading test as a discriminator between cases and controls Association between parafunctions and TMD	Longitudinal design RDC/TMD	Low sample size High drop-out rate with respect to the original study (no conclusions on longitudinal relation between TMD and risk factors) Non-validated bruxism diagnosis All females Assessment of bruxism-TMD relation not the main focus
Guler, 2003 [63]	64 patients with bruxing	1.5 T MR (128 joints) – T1, T2,	30 patients without	Higher prevalence of	High prevalence of	Attempt to related	Univariate

	behavior and clinically diagnosed TMJ ID (52F, 12M; m.a. 29 yrs.; a.r. 13-63)	PD scans - disk position and degenerative disorders VAS pain rating Clinical diagnosis of bruxism (criteria not specified) Chi-square	bruxism but with TMJ ID (26F, 4M; m.a. 26 yrs.; a.r. 14-50) 60 MR	unilateral and bilateral DD was significant in the study group (p<.05) Condylar bony changes: 55% vs. 38% of DDwR; 86% vs. 24% of DDwoR joints	condylar bony changes in patients with bruxing behaviour	bruxism with TMJ status as diagnosed by MR	analysis Unclear criteria to assess bruxism Absence of a group of subjects without TMJ internal derangement
Manfredini, 2003 [64]	212 TMD patients (144 F, 68M; m.a. 34.7)	RDC/TMD Set of clinical criteria for bruxism (blind examiner with respect to TMD) Cross-sectional study Chi-square test	77 age- and sex-matched TMD-free subjects (52F, 25M; m.a. 33.6)	Bruxism: 58% vs. 44.1% (p<.05) Prevalence of bruxism in the different RDC/TMD subgroups between 38.5%-87.5% Strong associations with MP alone (p<.05) or combined with other diagnoses (p<.01)	Bruxism more strongly associated muscle disorders than with DD and joint pathologies Association independent from other concurrent RDC/TMD	Large sample RDC/TMD Control group Set of clinical criteria adopted to validate PSG Blind examiner	Univariate analysis Single examiner to assess bruxism
Molina, 2003 [65]	394 TMD patients with bruxing behavior	Q + CA: TMD and DAP Rating of bruxism severity (15-item list) Prevalence of bruxism severity in the three groups Pairwise comparisons	109 with DAP vs. 285 TMD-bruxers without DAP vs. 104 nonTMD patients	Severe bruxism: 46.7% of patients with TMD-DAP vs. 40.3% TMD-nonDAP vs. 0% control group	TMD/bruxing and DAP patients more impaired by their functional disorders when compared to a group of TMD/bruxing and nonDAP patients and to controls	Large sample	Univariate analysis Non-standardized diagnoses and nomenclature of TMD Non-validated classification of bruxism severity Unclear interpretation of results as for TMD-bruxism relationship No correspondence between study's aims and conclusions as for bruxism-TMD relation

Chung, 2000 [66]	26 patients with TMD signs and symptoms (22F, 4M; a.r. 16-54)	Stabilization splint (nighttime) Examinations at 1,3,6,10 weeks FU CMI and VAS at baseline and week 10 Analysis of patterns of bruxofacets T-test (comparison patients with different bruxofacets patterns)	No control group	Bruxofacets on 88% splints at 10 week (54% after one week) No patients with unilateral or protrusive pattern (comparison between small lateral and bilateral patterns) VAS, CMI: all subjects improved independently by bruxofacets patterns	Nocturnal bruxism mainly in the form of grinding rather than clenching No conclusions on bruxism-TMD relation	Attempt to analyze splints wear as a proxy for bruxism CMI Longitudinal study	Absence of a control group Small sample No sex comparison
Molina, 1999 [67]	276 patients with "CMD" referred to a specialist clinic (236F, 40M; m.a. 34.8 yrs., a.r. 12-73)	Q + CA for CMD Rating of bruxism severity (15-item list) Prevalence of different bruxism severity in patients with CMD	No control group 65/276 CMD patients were classified as "non-bruxers"	CMD patients: 36.2% mild bruxism, 23.9% moderate, 16.3% severe Prevalence of CMD symptoms increased with presence and severity of bruxism Severe bruxers: highest prevalence of capsulitis (97.7%), retrodiscal pain (84.4%), headache (80%), MPDS (77.7%)	Higher prevalence of specific muscle and joint disorders in severe bruxers when compared to mild and moderate bruxers, and to the CMD non-bruxing group	Attempt to assess a dose-response relationship Large sample	Non-standardized diagnoses of TMD Non-validated classification of bruxism severity Unclear statistical procedures

Summary of findings of experimental studies (Table 2.4)

Seven studies attempted to relate experimental clenching (6 papers) [68-71,73,74] or grinding tasks (1 paper) [72] with the onset of TMD-like symptoms. They accounted for a total of 79 subjects (53 males, 26 females), 23 of whom took part to two different protocols published in different papers [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 seven studies was confined between 23

and 28 years. The study samples were of small size (5 to 23 subjects/study). All 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 only in 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 min of sustained clenching at 10% of the maximum voluntary contraction force [MVCF] in 2 studies [68,69]; 60 min of sustained clenching at 10% MVCF in 1 study [71]; 9 trials of 5 min of grinding at 50% of the maximum voluntary occlusal force [MVOF] with a short rest between each trial in 1 study [72]; and a combination of three different clenching-type exercises in 1 study [74]) and two studies were based on multi-session 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 three days in one study [72], while the other six studies had either no follow-up or one single day of post-exercise observation. Six studies had no control or comparison groups, and in one study comparison was made between two different protocols of jaw clenching [70]. Appropriate statistical analysis for repeated measures was applied in all papers.

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

Table 2.4. *Summary of findings from experimental studies. Legends (not included in previous tables): MVCF, maximum voluntary contraction force; ES; exteroceptive suppression; ANOVA, analysis of variance; MVC, maximum voluntary contraction; PPT, pressure pain threshold; MPQ, Multidimensional Pain Questionnaire; PDT, pain detection threshold; MVOF, maximum voluntary occlusal force; Mi, maximum intercuspidation; MVBF, maximum voluntary bite force.*

First author and year	Population	Intervention	Comparison	Outcome	Conclusions	Strength	Weakness
Torisu, 2007 [68]	23 healthy volunteers (11F, m.a.25.5±1.0 yrs.; 12M, m.a.23.5±0.9	Two randomized sessions per patient Induction of muscle fatigue	No comparison group	ES response more inhibited in masseter and temporalis after clenching-induced fatigue	Combination of muscle fatigue (clenching task) and pain (injection of	Testing of additional effects of fatigue-related and injection-related	No follow up

	yrs.)	(10% MVCF for 30 min) plus, after ten minutes, injection of glutamate or isotonic saline (painful stimuli) into the left masseter Four evaluation points for EMG activity: baseline, after the tooth-clenching, after painful stimuli, 60 min after the tooth clenching Repeated VAS scores for fatigue sensation, fatigue-related pain, headache plus ES assessment Four electrodes (left and right masseter and anterior temporalis) ANOVA for repeated measures		Increased resting EMG activity of jaw-closing muscles after the clenching task Injection of painful stimuli: lower inhibition of ES response and higher increase in resting EMG activity of jaw-closing muscles	saline or glutamate) different effect on ES response and resting EMG activity Potential clinical interaction between muscle fatigue and nociceptive regulation	pain Attempts to discriminate between the effects of fatigue and those of pain on EMG activity and nociceptive pathways	
Torisu, 2006 [69]	23 healthy volunteers (11F, m.a.25.5±1.0 yrs.; 12M, m.a.23.5±0.9 yrs.)	Two randomized sessions per patient Induction of muscle fatigue (10% MVCF for 30 min) plus, after ten minutes, injection of glutamate or isotonic saline (painful stimuli) into the left masseter Four evaluation points for EMG activity: baseline, after the tooth-clenching, after painful stimuli, 60 min after the	No comparison group	Effects of sustained low-level clenching: fatigue sensation, fatigue-related muscle pain and headache-like symptoms in both genders Fatigue VAS scores higher in males Increases in resting EMG activity higher in females than in males in the masseter muscles Painful stimuli: additional pain responses different	Gender differences in the neuromuscular system as a potential contributor to a greater female susceptibility to develop chronic musculoskeletal pain problems	Testing of additional effects of fatigue-related and injection-related pain Gender comparison Much details to discriminate fatigue sensation from fatigue-related pain	No follow-up Inferences on chronic musculoskeletal pain not in line with the study's aim

		tooth clenching Repeated VAS scores for fatigue sensation, fatigue-related pain, headache, plus pain drawings Four electrodes (left and right masseter and anterior temporalis) ANOVA for repeated measures		between sexes			
Glaros, 2004 [70]	14 healthy subjects (8M, 6F; a.r. 21-35)	RDC/TMD to exclude TMD EMG activity of bilateral masseter and temporalis muscles (biofeedback exercises) Increase: EMG activity ≥10μV Decrease: EMG activity ≤2μV Daily (5/week) 20 min sessions VAS pain scores ANOVA for repeated measures	Decrease (N=7) vs. Increase (N=7) group	End of training: RDC/TMD MP in 2 subjects of the increase group Immediate post session worst pain higher for the Increase group No differences in EMG activity between subjects developing MP and those who did not	Parafunctional activities increase pain and can lead to a TMD diagnosis	RDC/TMD Four muscles EMG training Blind examiners	Low sample size No follow up Conclusions are justified only in part by the study's findings No sex comparison
Svensson, 2001 [71]	11 TMD-free M (a.r. 23-27)	Sustained clenching at 10% MVC for 60 min Bite force transducer (molars) VAS pain levels and EMG activity at four jaw closing muscles every 5 min PPT at four jaw closing muscles (bilateral masseter and	No control group	During task: fatigue (11/11 subjects); pain, maximum 2.7±2.8 cm (7/11); PPT unchanged; decreased frequency of EMG activity After task: decreased jaw opening and MVC Following day: 5/11 slight TMJ soreness (no	Sustained, low-intensity clenching likely involved causally in the development of fatigue Short-lasting pain sensation in some individuals (other factors needed for long-lasting pain)	Low levels of sustained clenching Suggestion to discriminate fatigue from pain	No follow up Low sample size All males

		anterior temporalis) Pre- and post-test jaw opening (mm) and MVC ANOVA for repeated measures		pain) Stronger associations between measures of EMG activity and fatigue than pain			
Arima, 1999 [72]	12 healthy M (m.a. 26.0 ± 2.0 yrs.; a.r. 28-42)	9 repeated 5-min tooth grinding trials (1 min rest between each) VAS, MPQ, PDT before experiments, after all 9 trials, during the 3 following days Measurement of EMG activity and MVOF during all trials Experimental grinding: excursion from MI to right canine-canine position and back to MI every 2 seconds for 5 min (1 trial) EMG activity > 50% MVOF ANOVA for repeated measures	No control group	After the 9 trials: 7/12 subjects bilateral pain (muscles and TMJ), 2/12 unilateral pain in the masseter; 3/12 unilateral pain in the left masseter and temporalis Second day: 7/12 subjects localized TMJ pain (nr. to decrease the following days) MPQ: grinding-related changes on sensory and affective pain dimensions VAS scores: higher immediately after the grinding exercise (only soreness higher on the first post-exercise day)	45 min grinding activity: marginal and self-limiting TMJ and masticatory muscles symptoms in the day following the exercise	First study on prolonged experimental grinding 3-day follow up	No sex comparison and control group
Glaros, 1998 [73]	5 healthy university students (2F, 3 M; a.r. 23-29 years old)	6 weeks protocol (three phases: decrease, 2w, 10sess- increase, 2w, 8sess- decrease, 2w, 10sess) 17 min sessions VAS: pain presence RDC/TMD and MPQ at baseline and after each training week	No control groups	Protocol completed by 3/5 subjects (stop by arthralgia in 1 case and by MP + A in 1 case) DDR at the end of the study in 1 case VAS pain levels higher during increase phase Pain relief within 24 hrs following	Low-level parafunctional activity-pain relationship in some subjects	RDC/TMD Four muscles EMG training Blind examiners	Small and non-representative sample No follow-up

		Blind examiners Four muscles EMG biofeedback (masseter and temporalis) Relaxation ≤2.0μV; clenching ≥ 10.0μV ANOVA for repeated measures		increase training High variability of EMG activity levels during increase training Poor correspondence between EMG values and pain			
Plesh, 1998 [74]	14 healthy subjects (7 M, 7 F; m.a. 25±3 yrs.)	Intra-oral 1 cm diameter bite force transducer Three types of exercises (5 min recovery between each): intermittent exercise at 100% MVBF for 8 s on, 4 s off to pain intolerance; ramp exercise (10% MVBF gradually up to 100%); sustained biting at 100% MVBF to pain intolerance Sustained biting exercise repeated also in the second day Pre- and post-exercise pain levels (VAS) and pain-free mouth opening (mm). PPT before each exercise ANOVA for repeated measures	No control group	Immediately post-exercises pain: M~30 mm; F~40 mm No pain on opening on the first day before or after exercise for any subject F only: reduction of the pain-free jaw opening and an increase in pain levels after the endurance exercise on the second day No decreases in PPT scores on second day vs. first day	Post-exercise pain 24 h later only in F, interpreted as true gender difference Unclear mechanisms for such pain, and no apparent relation with chronic pain pathology	Gender compariso n Three different exercises	No follow up No blindness of operators

Summary of findings of tooth wear studies (Table 2.5)

Five studies were based on some sort of tooth wear analysis, which was suggested to be used as a proxy for bruxism diagnosis. 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 TMD patients taking part to the other four 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 4/5 studies [75,77-79], and true control groups were recruited in 3 studies, accounting for a total of 264 subjects [75,77,79]. In two studies, the study sample was split to compare two subgroups of subjects (bruxism was taken as the independent variable in the first paper [78]; TMD pain was taken as the independent variable in the other paper [76]). Tooth wear was assessed on dental casts in 4/5 studies [75,77-79], and clinically in 1/5 papers [76]. Examiners were calibrated in all studies, and blinded when necessary. Statistical analysis was always appropriate, thus suggesting a high quality standard of these papers. Four studies were cross-sectional, with only one observation point in time [76-79], while one study was longitudinal over a two-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 one 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 hard to be interpreted in a clinical setting.

Table 2.5. *Summary of findings from studies with bruxism diagnosis based on tooth wear. Legends (not included in previous tables): TW, tooth wear; MP; myofascial pain; OST, osteoarthritis; ANCOVA, analysis of covariance; MANOVA, multiple analysis of variance.*

First author and year	Population	Intervention	Comparison	Outcome	Conclusions	Strength	Weakness
Janal, 2007 [75]	51 F with MP (m.a. 34.5 ± 11.0 yrs)	Changes in TW over two weeks (blind examination of dental casts) Diary booklet each night (SCL-90 R, life stressors, daily	12 matched control F	(Dis)Appearance of similar proportion of old/new features appeared over 2 weeks (index WT creation)	Failure to show more tooth grinding in MP than control subjects Failure to support a model of MP maintenance by	"Longitudinal" tooth wear analysis Blind examiner RDC/TMD	No sex comparison No information on other concurrent TMD diagnoses

		stressors, self-report bruxism, spontaneous and widespread pain severity) RDC/TMD diagnosis of MP (good inter-examiner reliability) Control of diet influence on TW T-test for continuous variables and correlation test		Greater WT index in controls than MFP patients (1.34 vs. 1.23) Higher TW levels associated with lower reports of pain o muscle palpation Tooth grinding related to palpation pain reports only in those with unilateral pain	tooth grinding (no information on clenching or on the role of grinding in pain initiation)	Control for dietary factors	Indirect assessment of grinding
Schierz, 2007 [76]	646 population representative subjects (341F, 305M; a.r. 35-44 yrs)	Outcome variable: SR TMD pain (RDC/TMD question or Helkimo Index) Exposure variable: anterior TW on a four-point ordinal scale Three calibrated dentists (ICC=0.89) Chi-square plus logistic regression to control for age and sex	TMD pain (N=31) vs. non-TMD subjects (N=615)	No trend between increased TW and risk of TMD pain (OR 1.0-1.11)	Exclusion of a clinically relevant increased risk for TMD from anterior TW	Calibration of tooth wear analysis Control for age and sex	Self-report TMD diagnosis Non-homogeneity of samples sizes (potential for statistical bias)
Seligman, 2006 [77]	52 patients with unilateral TMJ DD (m.a. 32.2±9.6 yrs; a.r.: 17–63) 73 patients with TMJ OST (m.a. 40.7±13.2 yrs; a.r. 21–72) 43 patients with MP only (m.a.	Retrospective recruitment on the basis of RDC/TMD diagnoses No group overlap of diagnoses Dental casts (attrition severity) Attrition rate: attrition severity/years of age	132 asymptomatic controls (m.a. 37.3±15.4 yrs; a.r. 20–78)	Model for the asymptomatic controls vs. all the TMD patients: SE 74%, SP 86.4% Prediction of osteoarthrosis: SE 89.2%, SP 67.4% DD: SE 53.8% to 71.2% Nearly	Suggestion for a peculiar attrition pattern in MP Anterior attrition as a differentiating factor in the intracapsular models vs. with the asymptomatic controls Asymptomatics: low anterior attrition	Statistical model Control for age in the evaluation of attrition RDC/TMD Blind examiner	Difficult interpretation of results Absence of patients with multiple diagnoses (most frequent clinical condition)

	30.5±8.6 yrs; a.r. 13–54)	Single blind examiner Comparison of the severity and rates of dental attrition Classification tree method		perfect models on the attrition characteristics of MP patients	severity and some mediotrusive wear		
Pergamalian, 2003 [78]	84 consecutive TMD patients (84%F, 16%M; m.a.29.1±8.1 yrs)	RDC/TMD TW on dental casts Calibration of two examiners Q: bruxism presence/frequency (4 questions, 4 items each) ANCOVA, MANOVA, Pearson's correlation test	Bruxism as independent variable No bruxism (N=10), occasional bruxism (N=27), frequent bruxism (N=40) Exclusion of 7 subjects (inconsistencies of Q answers)	Bruxism not associated with the amount of TW (p=.477) Number of painful joint sites different across bruxism classifications (p<.05), painful muscle sites not different (p=.52) Painful joint sites: higher for no bruxism, no different between occasional and frequent bruxism	TW modestly correlated with age No association between TMD and TW No indication for bruxism as a TW accelerator in TMD Bruxism not associated with higher levels of muscle pain severity. Inverse relationship between bruxism and TMJ pain	RDC/TMD Statistical design Attempt to clarify relationship between bruxism and tooth wear Calibrated examiners	No TMD-free control group Few patients per group (potential bias for statistical analysis)
John, 2002 [79]	154 consecutive TMD patients (115F, m.a. 32.8±14.8 yrs, a.r. 13-76; 39M, m.a. 28.7±9.8 yrs; a.r. 13-58)	Patients grouped under the collective term TMD TW index on dental casts (single blinded examiner) Good intra- and inter-rater reliability Logistic regression	120 TMD-free patients in need for prosthodontic treatment (76F, m.a. 30.9±13.7 yrs, a.r. 16-75; 44M, m.a. 30.0±11.1 yrs, a.r. 17-64)	TW related to age in both groups Controls more TW (index severity > 2.5) than TMD patients (51.7% vs. 37.6%) Odds of TMD: 24% decrease for each additional unit of the mean TW score	Incisal TW not associated with TMD Exclusion of a clinically relevant increased risk for TMD from incisal TW	Multivariate analysis Blind and calibrated examiner	Unspecified TMD diagnosis No identification of TMD subgroups

Summary of findings of PSG studies (Table 2.6)

Four studies assessed the association of TMD symptoms with sleep bruxism diagnosed by means of polysomnographic recordings [80-83]; two of them came from the same group of researchers [80,81]. In total, 184 subjects (124 females, 60 males) were involved in the studies, 30 of whom were myofascial pain patients, 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 three studies [80,81,83], and a control group was selected in 3/4 studies, accounting for 76 subjects (42 TMD-free subjects from two studies [80,81]; 34 non-SB in one study [82]). In one paper [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], while in two 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 three studies [80,81,83]; cut-off was set at 10% of MVC in one study [82]).

The results are difficult to interpret, since 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 one paper [80], no association was detected in another paper [81], and a negative association, viz., subjects with pain exhibited less episodes of RMMA/hr with respect to subjects without pain, was described in two studies [82,83].

Table 2.6. *Summary of findings from studies with a PSG-based diagnosis of bruxism. Legends (not included in previous tables): MVC, maximum voluntary contraction; RMMA, rhythmic masticatory muscle activity; SB, sleep bruxism.*

First author and year	Population	Intervention	Comparison	Outcome	Conclusions	Strength	Weakness
Rossetti, 2008 [80]	30 MFP patients (24F, 6M; m.a.26.6±5 yrs.; a.r. 19-39) without sleep disorders and other TMD	Q + CA for MFP diagnosis Single examiner RDC/TMD	30 healthy controls (24F, 6M; m.a. 26.0±4.5 yrs.; a.r 20-42)	No association between SB and report of worst pain in the morning	RMMA during sleep associated with MFP and risk factor (although small) for MFP	Calibrated examiners Control group Standardiz	Only one night of PSG recordings Single question to assess

	symptoms	assessment TMD index PSG for 2 consecutive nights (one for adaptation) Calibration of EMG amplification Recordings of episodes of EMG activity >20% of MVC Additional question (one week later) to assess daytime clenching Parametric and non-parametric statistical test		(p=.76) SB: 63.3% of MFP patients vs. 33.3% of the controls (p=.04) No differences between MFP and controls as for sleep variables Association between SR daytime clenching and MFP; no association with report of worst pain in the morning or VAS levels in the evening	Daytime clenching potential risk factor for MFP	ed definition of SB events/diagnosis	clenching No adjustment for sex
Rossetti, 2008 [81]	14 TMD patients (8F, 6M; m.a. 27.1±7.4 yrs.; a.r. 17-40) without sleep disorders	VAS scores at rest RDC/TMD muscle and joint palpation Single-night PSG Calibration of EMG amplification Recordings of episodes of EMG activity >20% of MVC Parametric and non-parametric statistical test	12 non-TMD subjects (6F, 6M; m.a. 27.4±5.2 yrs.; a.r. 22-40)	No association between bruxism and TMD (p=.976), neither between bruxism and pain on palpation (p=1.000) No differences between groups for sleep variables No difference between RMMA in bruxers with and without pain on palpation (p>.05)	SB neither associated with general TMD nor pain on palpation Pain only in some SB individuals	RDC/TMD Control group Standardized definition of SB events/diagnosis	Single-night PSG with no adaptation Heterogeneous sample of TMD patients No adjustment for sex
Romprè, 2007 [82]	100 SB (60%F; m.a. 26.5±0.6 yrs.) without TMD as a primary	PSG for 2 consecutive nights (one for adaptation)	43 non-bruxers controls (68%M; m.a. 24.5±0.9	Excluded "bruxers" more complain of clenching,	SB-RDC: high level of discrimination between SB and controls	Standardized PSG-SB criteria Large sample	Non-standardized TMD diagnosis Only one

	complaint	Sleep variables and SB episodes scored according to standardized criteria (blind examiner) Q: SR pain intensity and other factors Chi-square, non-parametric test and cluster analysis	yrs.) Some subjects excluded after the second PSG night (no SB confirmation/ absence) Comparison performed on 54 SB vs. 34 non-SB subjects	painful jaw upon awakening and muscle fatigue than included SB (OR 3.9-4.9) Pain of excluded "bruxers" higher than that of included SB (p=0.06)	Pain frequently reported among SB with low frequencies of jaw muscle contractions	PSG study Presence of control group	night of PSG recordings Sex-unmatched groups
Camparis, 2006 [83]	40 consecutive patients with SR tooth grinding (32F, 8M; m.a. 36.1±11.3 yrs.)	Preliminary interview RDC/TMD PSG to confirm SB (Single night) Recordings of episodes of EMG activity >20% of MVC RDC/TMD questionnaire items for axis I and II Univariate and non-parametric test	20 bruxers with TMD (Group A) vs. 20 bruxers without TMD (Group B)	Group A: myofascial pain (100.0%), disc displacement (10.0%) and arthralgia (85.0%) Difference between groups A and B for non-specific physical symptoms (p=.001) and mandibular impairment (p=.001); no differences for depression SB episodes/h: 20% more for subjects without pain (8.0 vs. 6.2)	Inconclusive evidence for the association between facial pain and SB	Standardized PSG-SB criteria RDC/TMD (axis I and II)	Single-night PSG with no adaptation No adjustment for sex Unclear aims with respect to conclusions

Summary of findings of EMG studies (Table 2.7)

Two studies used a portable EMG recorder to assess the relation between nocturnal masticatory muscle activity (NMMA) and the onset of TMD symptoms. 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 single-channel 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 (4/8) patients completing the entire recording period [84], and one study was based on six consecutive nights of recordings [85]. Some inconsistencies were noticed as for NMMA events diagnosis due to the adoption of different detection thresholds (10% MVC vs. 20% MVC).

Results from the two studies suggest that an association may be hypothesized between NMMA and click sounds, while no relation was found between NMMA and muscle pain.

Table 2.7. *Summary of findings from studies with an EMG-based diagnosis of bruxism. Legend (not included in other tables): NMMA=nocturnal masticatory muscles activity.*

First author and year	Population	Intervention	Comparison	Outcome	Conclusions	Strength	Weakness
Van Selms, 2008 [84]	8 F with MP (RDC/TMD) and SB (history and intra-oral inspection); a.r. 23-43 yrs. Selection (volunteers) among 120 consecutive patients	20 weeks (7 baseline + 13 occlusal splint therapy) Q: daily levels of pain, stress and daytime parafunctions Nocturnal EMG (W1,3,5,7,9,11,15,20) Single-channel right masseter ambulatory device NMMA events (10% MVC) Multivariate statistical analysis	No control group	4 subjects completed the study (20-30% of the registrations failed) No association between changes in MP and NMMA Only in one patient week association between evening jaw muscle pain and daytime clenching activity	Changes in chronic MMP more related to changes in stress than to those in parafunctional activities	Validated TMD diagnosis Long-term study Home environment	Single-channel EMG
Baba, 2005 [85]	103 consecutive healthy subjects (51 F, 23.7±2.6 yrs.; 52 M, 24.7± 2.0 yrs.) recruited among university	6 nights (no analysis on first night) Q: TMD-related symptoms and	No control group	Data on 93 subjects Average muscle activity duration for subjects with	Association between masseter muscle activity and click sounds	Sample size Calibrated diagnoses Home environme	Single-channel EMG No RDC/TMD

	students	awareness of bruxing behavior CA: jaw function and TMD symptoms (calibrated operators) Nocturnal EMG Single-channel right masseter ambulatory device NMMA events (20% MVC) Multivariate statistical analysis		joint sounds higher than that of sub. without sounds		nt per 6 nights	

Discussion

The issues of bruxism etiology, diagnosis, and treatment are 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], on dental implants [90], as well as on the different stomatognathic structures [91]. The last decade has also provided some noteworthy attempts to get deeper into the issue of a possible bruxism-TMD relation, which has been discussed in the present systematic review.

From a methodological viewpoint, the present review was based on a structured reading of papers, which helped gathering relevant data from each paper by answering to 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 be useful to avoid bias in the interpretation of studies' results and to impede narrative speculations, thus allowing 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, in order to gather as much data as possible on the argument, the last comprehensive review on which dated back to over a decade ago [15], and which was partially re-discussed in a recent paper [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 relation, the findings on which could be considered ancillary results that in some papers were not discussed exhaustively. Moreover, such a comprehensive systematic approach to literature selection showed some problems of redundancy, since in some occasions the same data appeared to be discussed in more than a single paper, forcing us to exclude all duplication 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 despite they are ranked IIB in the hierarchy of evidence, their level of specificity for the bruxism-TMD relation was low, due to low prevalence of severe TMD patients in the studied samples and due to the use of self-report diagnosis of bruxism. The majority of papers were either case-control studies (IIIB) or case series (IV). The forty-six identified papers involved researchers from several countries, over 35000 subjects were recruited for the studies' populations, and some interesting findings did emerge.

Nearly half of the selected studies were based on a 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, while other comprehensive approaches, such as tooth wear analysis or sleep laboratory recordings, are mainly indicated to detect grinding-like activities, the effects of which may be different with respect to those of clenching [95]. Actually, a systematic appraisal of the literature did not allow rejecting/confirming such speculation, due to the very low number of papers attempting to discriminate between the two different oral motor behaviors, viz., clenching and grinding activities. Thus, one of the

aims of the review, viz., 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 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 the majority of papers based on a clinical diagnosis of bruxism, with 5 out of 7 papers 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, viz. elicited by static 30 sec 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 myofascial pain patients [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 papers. Besides, in some papers, 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 polysomnographic or electromyographic recordings, as well as on experimental studies aimed directly to get deeper into the knowledge of bruxism-TMD relation 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 the majority of cases. Thus, they provided a consistent amount of evidence that anterior tooth wear cannot be considered a risk factor for TMD, while more complex patterns of wear may be worthy to be re-discussed before being considered 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, viz., functional vs. non-functional vs. dietary/metabolic or others, may not always have been taken into account properly. Also, importantly, temporal considerations, viz., 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 two-week time span, supported the absence of a positive association with myofascial pain [75].

Findings from papers 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 two investigations performed with an electromyographic 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 which were able to monitor the EMG activity of a single muscle, viz., 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 muscles activity in patients with pain is generally lower with respect to subjects without pain [96,97] cannot be fully supported by this review, since some inconsistencies among the papers included in this review as for the association of RMMA and sleep bruxism have been shown, viz., bruxers showed an increased RMMA in one study [80] and a decreased NMMA in two 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 papers 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 papers, viz., 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.

Conclusions

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

- It was not possible to discuss data on the relation between specific TMD signs and symptoms and the different bruxism-related motor activities, viz. clenching and grinding, due to the very low level of specificity which characterized the majority of investigations.
- Works 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).
- 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 researches, possibly with the adoption of approaches focusing on the different types of bruxism and TMD.

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