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REVIEW ARTICLE

Sleep and awake bruxism in adults and its relationship with temporomandibular disorders: A systematic review from 2003 to 2014

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ABSTRACT

Objective: In order to establish a relationship between bruxism and temporomandibular disorders (TMDs), a systematic review was performed.

Materials and methods: A systematic research was performed based on PubMed, Cochrane Library, Medline, Embase, BIREME, Lilacs and Scielo data bases, between 2003 and 2014 including all languages. Descriptive clinical cases were identified. Two independent authors selected the articles. PICO format was used to analyse the studies and the Newcastle-Ottawa Scale (NOS) was used to verify the quality of the evidence.

Results: Thirty-nine studies ($n = 39$) were analysed in this review. According to bruxism diagnosis, articles were grouped as follows: polysomnographic diagnosis (PSG) ($n = 7$), clinical diagnosis ($n = 11$) and survey/self-report ($n = 21$). Thirty-three articles ($n = 33$) established a positive relation between bruxism and TMD and six ($n = 6$) did not. Quality of evidence was low to moderate. In general, the most part of the studies showed shortcomings on their design with bias risk, and also had a low sensitivity on bruxism diagnosis.

Conclusions: The evidence based on PSG was not as conclusive as the studies that used surveys and clinical exam to diagnosis bruxism, when bruxism was related to TMD. Sleep bruxism could be associated with myofascial pain, arthralgia and joint pathology as disc displacement and joint noises. Although the evidence at present is inconclusive and does not provide information according to the type of bruxism (bruxism sleep and wakefulness), it is possible to suggest that bruxism would be associated with TMD.

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Bruxism; temporomandibular disorders; temporomandibular joint; sleep bruxism

Introduction

Bruxism is defined as 'a repetitive jaw-muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible'.[1] Also, it has been demonstrated that bruxism has two circadian manifestations because it can occur during sleep (sleep bruxism), or during wakefulness (awake bruxism). Moreover, it has been proposed that sleep or awake bruxism can be classified as possible (self-report), probable (self-report plus clinical examination) or definite (self-report plus clinical examination, plus polysomnographic recording).[1]

According to the American Academy of Orofacial Pain (AAOP), temporomandibular disorders (TMDs) are defined as 'a group of disorders involving the masticatory muscles, the temporomandibular joint (TMJ), and associated structures'.[2] TMDs have a multifactorial etiology and among them, some conditions cause trauma, as the overloading generated because of bruxism.

Muscle overloading due to tooth clenching could be associated with local blood flow and microcirculation disorders, and pain derived from an ischemia,[3] the latter related to substances that sensitize muscles nociceptors.[4]

Based on evidence, the relationship between bruxism and TMD is still controversial in the literature due to the complexity of the etiology and diagnostic of both disorders.[5] In fact, both the presence and the cause–effect relationship are still undefined [5–7] although there are some studies that demonstrate a positive relation between bruxism and TMD.[5] The lack of evidence is based essentially on methodological differences, as data interpretation, operational definitions, methodological designs and diagnostic instrumentation for both disorders.

Looking out the diversity and the scarce reviews that analysed bruxism with a specific diagnostic modality, without focus in evidence level and the insufficiency of inclusion of other languages out of English, this study aims to review the literature between 2003 and 2014. The aim was to find out if bruxism is associated with TMDs but considering the types of bruxism (sleep and awake), TMD diagnostic method, quality of evidence and all languages.

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Materials and methods

To establish the relationship between TMD and bruxism, on 31 January 2015, a systematic review of the literature was conducted between 2003 and 2014. Databases used were as follows: PubMed, Cochrane Library, Embase, Medline, BIREME, Lilacs and Scielo.

Types of studies

Observational studies, analytical case–control or cohort who have clearly defined aims to determine the relationship between bruxism and TMD.

Language studies

The search was conducted without limitation of language.

Types of participants

The studies selected for this review included subjects older than 19 years old of both genders.

Intervention type

Studies without intervention in order to relate TMD and bruxism.

Types of results

Primary outcomes: to determine the relationship between sleep and awake bruxism and TMD.

Secondary outcomes: to determine the relationship (in-person or cause and effect) between bruxism and TMD by gender. To determine the association between bruxism and TMD according to age group.

Data collection

For TMD: Data were collected from studies that showed diagnosis of TMD not limited to any method, with a clear reference to the concept and diagnosis of temporomandibular pathology.

For bruxism: Data were collected from studies that showed a diagnosis of bruxism, defining the type explicitly, according to the circadian expression (sleep, awake or both). The accepted diagnostic studies were as follows: (a) polysomnography diagnosis (PSG); (b) clinical diagnosis with or without self-report and (c) self-report and/or questionnaire. The following diagnostic modalities were accepted: possible, probable and definitive.

For the identification and selection of the number of potentially eligible studies for this review (N), a specific and individualized search strategy for each database was developed. A semantic field was determined for the term 'bruxism' and another semantic field related to the term 'TMD' (Table 1).

Databases used

1. PubMed database. Filters used were: publication dates: 10 years, 1 January 2003–31 December 2014; Age; Adult +19 years and Text Availability: Abstract.
2. The Cochrane Library. Filters: publication dates: 10 years, 1 January 2003–31 December 2014; Database: Trials.
3. Embase: publication dates: 2003–2014
4. Medline: publication dates: 2003–2014
5. BIREME: date of publication: 2003–2014
6. Lilacs: date of publication: 2003–2014
7. Scielo: date of publication: 2003–2014

Study selection and data collection

For article selection or first approach, two researchers independently selected potentially eligible articles by title and abstract. When no agreement was found, it was discussed with a third researcher about including it or not within the sample. The titles of the selected articles were transferred to an Excel table. Full articles were read, considering three questions of elimination based on the inclusion criteria for the selection of studies that would complete text analysis: (1) Is it a clinical trial? (2) Are subjects over 19 years? (3) Is the relationship between bruxism and TMD established? Articles that met these criteria were included in the review for the final analysis. The reasons why some studies were excluded were recorded in an adjacent column and presented in the results (Table 2).

Extracting data from the studies

The PICO criteria (population, intervention, control groups and outcome) were used to make the tables of analysed articles, where we defined in detail the analysis variables: population (sample size, distribution of subjects by gender and age range), intervention (main variables to compare, related to the topic, statistical analysis and confidence intervals and type of method used for the diagnosis of bruxism and TMD), comparison criteria or control (presence of any control group) and outcomes (included the answer to the hypothesis, the presence or causal relationship between bruxism and TMD).

Presentation of results and quality of evidence

The tables were developed with the summary of the main results of the studies analysed. The quality of evidence was determined by the Newcastle-Ottawa Scale (NOS),[8] which measures the quality of the evidence for case–control and cohort studies, assigning a score ranging from 0 to 9 points. For case–control studies, there are three categories: (1) selection (4 points), (2) comparability (2 points) and (3) exposure (3 points). To determine the quality of cohort studies, there were also three categories with a score of level of evidence ranging from 0 to 9 points. The categories were as follows: (1) Selection (4 points), (2) Comparability (2 points) and (3) Outcome (3 points). The quality was determined by the same two researchers in charge of search, where the highest quality achieved is obtained by those items that reached a maximum score of 9.

Table 1. Search strategy and terms used for the search.

Database and limits	Search strategy and terms
PubMed ($n = 1733$) Publication dates: 10 years, 1 January 2003–31 December 2014; Age; Adult +19 years and Text Availability: Abstract.	Bruxism [tiab] OR sleep bruxism [tiab] OR nocturnal bruxism [tiab] OR teeth grinding [tiab] OR teeth wear [tiab] OR occlusal wear [tiab] OR tooth clenching [tiab] OR tooth abrasion [tiab] OR parafunctional habits [tiab] OR teeth grinding disorder [tiab] OR nocturnal teeth grinding disorder [tiab] AND Temporomandibular joint disorders [tiab] OR Temporomandibular disorders [tiab] OR Temporomandibular joint Dysfunction Syndrome [tiab] OR Temporomandibular Joint Syndrome [tiab] OR TMJ disorders [tiab] OR TMJ diseases [tiab] OR myofascial pain [tiab] OR myofascial pain syndrome [tiab] OR craniomandibular pain [tiab] OR orofacial pain [tiab] OR arthralgia Temporomandibular joint [tiab] OR osteoarthritis temporomandibular joint [tiab] OR osteoarthrosis temporomandibular joint [tiab] OR disc displacement [tiab] OR disc displacement reduction [tiab] OR disc displacement with reduction [tiab] OR disc displacement without reduction [tiab]
The Cochrane Library ($n = 1735$) Publication dates: 2003–2014; Database: Trials.	Bruxism OR sleep bruxism OR nocturnal bruxism OR teeth grinding OR teeth wear OR occlusal wear OR tooth clenching OR tooth abrasion OR parafunctional habits OR teeth grinding disorder OR nocturnal teeth grinding disorder AND Temporomandibular joint disorders OR Temporomandibular disorders OR Temporomandibular joint Dysfunction Syndrome OR Temporomandibular Joint Syndrome OR TMJ disorders OR TMJ diseases OR myofascial pain OR myofascial pain syndrome OR craniomandibular pain OR orofacial pain OR arthralgia Temporomandibular joint OR osteoarthritis temporomandibular joint OR osteoarthrosis temporomandibular joint OR disc displacement OR disc displacement reduction OR disc displacement with reduction OR disc displacement without reduction
Lilacs ($n = 38$) Publication year: 2003–2014	Bruxism OR sleep bruxism OR nocturnal bruxism OR teeth grinding disorder AND Temporomandibular disorders OR craniomandibular disorders
Scielo ($n = 20$)	Bruxism OR sleep bruxism OR nocturnal bruxism AND Temporomandibular disorders
Bireme ($n = 212$) Año publicación: 2003–2014	Bruxism OR sleep bruxism OR nocturnal bruxism OR tooth clenching OR parafunctional habits OR teeth grinding disorder OR nocturnal teeth grinding disorder AND Temporomandibular joint disorders OR Temporomandibular disorders OR Temporomandibular joint Dysfunction Syndrome OR Temporomandibular Joint Syndrome OR TMJ disorders OR TMJ diseases OR craniomandibular disorders OR craniomandibular dysfunction
Embase and Medline ($n = 1008$) Date Publication: 2003–2014	'bruxism'/exp OR bruxism OR 'sleep'/exp OR sleep AND ('bruxism'/exp OR bruxism) OR nocturnal AND ('bruxism'/exp OR bruxism) OR parafunctional AND ('habits'/exp OR habits) AND temporomandibular AND ('joint'/exp OR joint) AND disorders OR temporomandibular AND disorders OR temporomandibular AND ('joint'/exp OR joint) AND dysfunction AND ('syndrome'/exp OR syndrome) OR tmj AND disorders AND [2003–2014]/py

Results

In all, 4746 potentially eligible articles were identified in the first approach in the 7 databases used (Table 1). Based on the selection by title and abstract, 127 studies were selected. Once tabulated in Excel table, 55 articles were eliminated for being repeated. Of the remaining 72 articles, 33 were eliminated in the reading of the full text for not meeting the inclusion criteria for this review (Table 2). Finally, 39 studies were analysed. Figure 1 summarizes the results described.

Included studies

In all, 39 articles were analysed in this review. The analysis tables were prepared according to the PICO criteria (Tables 3–5). The articles analysed were summarized in: (a) bruxism diagnosed by polysomnography ($n = 7$); (b) bruxism diagnosed clinically with or without self-report ($n = 11$) and (c) bruxism diagnosed by questionnaire and/or self-report ($n = 21$).

Characteristics of participants

In relation to gender, five studies ($n = 5$) included only women in their sample.[47,48,59,61,78] Four studies ($n = 4$) did not specify the gender of the participants.[13,60,39,76]

Quality assessment

None of the reviewed articles obtained the highest score based on NOS. The range of scores was between 2 and 7.

Discussion

In this review, a high relation was founded between bruxism and TMD, but with a lower to moderate level of evidence.

All studies that were analysed showed a high bias risk in their design due to the lack of randomization and blinding, and sensibility for bruxism diagnostic as well.

Almost half of the included articles based their bruxism diagnostic on the self-report and/or surveys, and less than one-third of them based such diagnostic on self-report and/or clinical findings. Although methods had a low sensibility, 20 from 21 and 9 from 11 studies, respectively, founded a positive association between bruxism and TMD. On the other side, 4 studies from 7 that used PSG for bruxism diagnosis, demonstrated a positive association (Table 6).

The evidence, in an effort to evaluate and validate the sleep bruxism self-report in patients with TMD (predominating myofascial pain), indicate that this method would not be a good clinical predictor in case of a moderate or severe bruxism due to a high rate of false positives.[80] Such authors concluded that self-report is not a good indicator for sleep bruxism in clinical and research activities, and they do not recommended to substitute it by the PSG.[80]

In general, the studies presented a high variability in age range; however, they did not determine the risk to have bruxism with a TMD. Also, they did not demonstrate an association between gender and bruxism although there was a higher prevalence of TMD in women, suggesting a higher prevalence of bruxism.

Considering circadian manifestation of bruxism and its relation with TMD, most of the analysed studies ($n = 18$) did

Table 2. Studies retrieved in full text and excluded from the review.

First author and year	Reason for exclusion
Fernandes, 2014 [9]	Relationship between sleep bruxism and tinnitus.
Glaros, 2014 [10]	Headache associated with oral parafunctions (tooth contact time, intensity of tooth contact).
Fernandes, 2013 [11]	Changes in EMG activity and masticatory muscle pain.
Köhler, 2013 [12]	Same data as Köhler [13].
Brandini, 2012 [14]	Analysis is based on the significant association of parafunctional habits with non-carious lesions, there is no correlation with TMD.
Glaros, 2012 [15]	Evaluates only tooth clenching and not bruxism (undiagnosed).
Ommerborn, 2012 [16]	Relationship between sleep bruxism and functional occlusal parameters.
Shedden Mora, 2012 [17]	Related levels of somatization, depression, anxiety and NMMA in patients with chronic TMD.
Chandwani, 2011 [18]	Prevalence study shows no association.
González, 2011 [19]	Case series showing no association.
Lucchesi, 2010 [20]	Sleep disturbances associated with headache.
Meeder, 2010 [21]	Unable to extract data from subjects older than 19 years.
van der Meulen, 2010 [22]	Application of a questionnaire if patients think or believe that bruxism is associated with TMD.
Jesus, 2009 [23]	It was not possible to obtain the article.
Santos, 2009 [24]	TMD and tooth wear, no statistical association.
Van Selms, 2009 [25]	Relate multiple parafunctions and did not use the term bruxism.
Branco, 2008 [26]	Prevalence study shows no association.
Kanehira, 2008 [27]	TMD and bruxism with stress is associated separately (did not study relationship between TMD and bruxism).
Marklund, 2008 [28]	Same data as Marklund 2010 [29].
Mundt, 2008 [30]	Same data as Marklund 2005 [31].
Nagamatsu-Sakaguchi, 2008 [32]	Study in adolescents younger than 19 years.
Oginni, 2007 [33]	Occlusal wear and relationship with TMD. Do not define bruxism or wear cause.
Pizolato, 2007 [34]	Evaluates maximum bite force in TMD and bruxism.
Cassanova-Rosado,2006 [35]	Unable to extract data from subjects older than 19 years.
Branco, 2006 [36]	Descriptive study. Shows frequencies and establishes no association.
Winocur, 2006 [37]	Study in adolescents younger than 19 years.
Glaros, 2005 [38]	Same data as Glaros 2005 [39].
Kino, 2005 [40]	Questionnaire applied only in subjects over 12 years, it is not possible to extract data.
Matheus, 2005 [41]	It was not possible to obtain the article.
Aydin, 2004 [42]	Turkish language is not in the inclusion criteria.
Johansson, 2004 [43]	Same data as Johannson 2003 [44] and Johansson 2006 [45].
Johansson, 2003 [44]	Same data as Johansson, 2004 [43] and Johansson 2006 [45].
Molina, 2003 [46]	No TMD-related bruxism, but characterized and compared signs and symptoms of TMD between the study groups.

EMG: electromyography; NMMA: nocturnal masseter muscle activity; TMD: temporomandibular disorders.

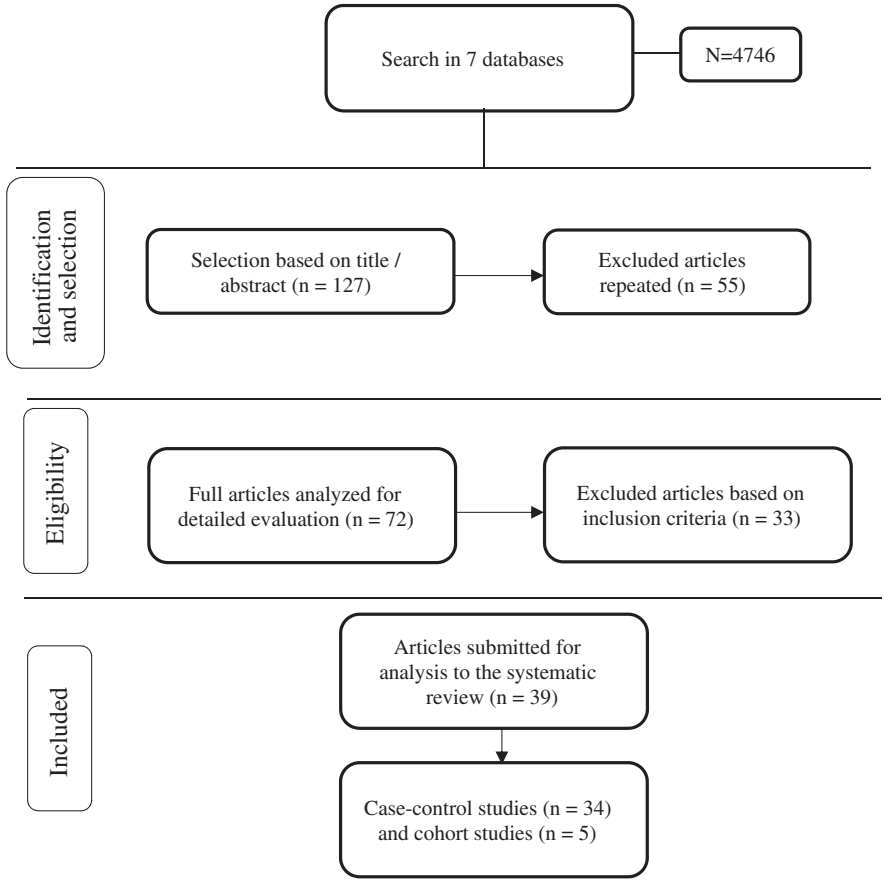

Figure 1. Search method, identification, choice and inclusion of articles.

Table 3. Summary of bruxism diagnosed based polisomnography (PSG).

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
Raphael, 2013 [47]	Cases and controls study	124 patients with myofascial pain. 46 controls. Age 39.2 (14.6), a.r: 19–78 years, All women.	TMD: RDC/TMD Bruxism: self-report, individual interview and PSG ×2 nights. 6 channels. Phasic episodes: 3 or more explosions (burst) EMG (>0.25 sec and <2.0 sec), Tonics episodes: >2.0 sec. RDC/SB criteria. More than 4 SB episodes p/h or more than 25 explosions p/h sleep. *t*-test and Pearson's correlation test, $p < .05$.	*Case*: Group I or myofascial pain according to RDC/TMD. *Control*: No report of facial pain >1 week in the last 2 years or >1 site tenderness according to RDC/TMD.	TMD higher EMG activity compared to controls. Pain before and after sleeping inversely proportional to RMMA number p/sleepy hour. Increased pain before or after sleep associated with fewer muscular events. High levels of RMS EMG activity during sleep associated with reports of pain before and after sleep. Pain assessed before sleeping or waking is associated with fewer SB.	These data are not able to determine whether the EMG activity during sleep is a risk factor for developing myofascial pain, but supports the hypothesis that a high EMG activity in the dream would be a risk factor for the course of myofascial pain.	No sample size calculation. Without randomization groups. Only women. Blinded and trained examiners in data collection PSG. Validated diagnostic methods.
Raphael, 2012 [48]	Cases and controls study	124 patients with myofascial pain. 46 controls. Age 39.2 (14.6), a.r: 19–78 years, All women.	TMD: RDC/TMD Bruxism: self-report, individual interview and PSG ×2 nights. 6 channels. Phasic episodes: 3 or more explosions (burst) EMG (>0.25 sec and <2.0 sec), Tonics episodes: >2.0 sec RDC/SB criteria. More than 4 SB episodes p/h or more than 25 explosions p/h sleep. *t*-test and Pearson's correlation test, $p < .05$.	*Case*: Group I or myofascial pain according to RDC/TMD. *Control*: No report of facial pain in the last 2 years or >1 site tenderness according to RDC/TMD.	Similar pain duration in TMD patients with and without evidence of bruxism PSG. High SB levels (RDC/SB): 10.9% in control and 9.7% in cases. Significantly higher SB in cases (55.3%) than in controls (15.2%)	There would be no relationship between SB and course of myofascial pain in TMD. Treatment of SB should not be considered to maintain or exacerbate TMD myofascial pain.	No sample size calculation. Without randomization groups. Only women. Blinded and trained examiners in data collection PSG. There is no clarity on statistics used, they are expressed in terms of percentages. Validated diagnostic methods.
Rossetti, 2008 [49]	Cases and controls study	26 patients. 17–40 years.	VAS for muscle and joint palpation based on the RDC/TMD scale. One night of PSG application. Calibration on EMG amplification. Episodes of EMG activity >20% of maximum voluntary contraction (MVC) were recorded. Chi-square test and Fisher's exact test, $p < .05$	*Active group*: 14 patients with TMD (F:8; M:6; Age 27.1 (SD 7.4 years), 17–40 years) without sleep disorders *Control group*: TMD absence ($n = 12$); 6F, 6M; 27.4 SD 5.2 years old, range 22–40 years old.	No association between bruxism and TMD with $p = .976$ and between bruxism and tenderness, $p = 1.000$. No difference between groups for variables of sleep. No difference between RMMA in bruxers with and without tenderness ($p > .05$).	Sleep bruxism is not associated with TMD or with tenderness. Pain associated only in some individuals with SB.	No sample size calculation. Without randomization groups. No information on shielding and calibration of examiners. It applies only 1 night PSG. PSG blind data analysis. Validated diagnostic methods.

(*continued*)

Table 3. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
Rossetti, 2008 [50]	Cases and controls study	60 individuals: F:48; M:12 (range 19–42 years)	TMD: RDC/TMD myofascial pain (MP) Pain: questionnaire and VAS. Sleep bruxism: PSG, examiner blind to diagnosis. Self-reported tooth clenching during the day was recorded. *t*-test, Mann–Whitney test, Chi-square test, $p < .05$.	*Group 1*: 30 individuals MP *Group 2*: 30 healthy individuals.	Significant association between SB and MP ($p < .04$; OR =3.45, 95% CI 1.07–11.19) Significant association between tooth clenching and MP ($p < .001$;.OR =12.0; 95% CI 3.26–44.15)	SB and tooth clenching significantly associated with MP. Tooth clenching more power than SB as a risk factor.	No sample size calculation. Without randomization groups. Blind examiner, without information on calibration. Validated diagnostic methods.
Rompré, 2007 [51]	Cases and controls study	100 subjects with sleep bruxism (SB) without TMD. Age 26.5 ± 0.6 years. 60% women.	SB subjects, chosen based on criteria of the AASM. Study PSG for 2 nights (first night for adaptation). Questionnaires: SB, anxiety, sleep habits, stress, fatigue, facial pain, jaw pain upon awakening, masticatory muscles fatigue on awakening. Chi-square test, nonparametric and cluster analysis, $p < .05$.	*Control group*: 43 subjects with no history of SB. 68% women. Age 24.5 ± 0.9 years. Some subjects were excluded after the second night with PSG. Comparison was made between 54 SB versus 34 without SB.	Excluded bruxism was more likely than those included to complain of jaw pain upon awakening and fatigue of masticatory muscles (OR 3.9–4.9). The pain of the excluded bruxism was slightly larger than those included ($p = .06$).	SB-RDC has a high level of discrimination between subjects with sleep bruxism and controls. The pain is often reported among subjects with low frequency SB mandibular muscle contractions.	No calculation of sample size. Without randomization. PSG analysis blind score. No Information on examiners calibration. Validated bruxism diagnostic method and TMD not validated.
Camparis, 2006 [52]	Cases and controls study	40 patients (32F, 8M). Age 36.1 ± 11.3 years. a.r: 17–54 years.	Preliminary interview. TMD: RDC/TMD Sleep bruxism (SB): PSG, RDC/TMD axis I and II Fisher's exact test and Mann–Whitney test, $p < .05$ analysis.	*Group A (GA)*: bruxism and TMD ($n = 20$) *Group B (GB)*: bruxism without TMD ($n = 20$)	*GA*: 100% myofascial pain, 10% displacement disk and 85% arthralgia without difference between two groups. 85% of episodes of bruxism related to micro awakenings. Patients without pain 20% versus pain episodes.	There is no conclusive evidence that relationship TMD and sleep bruxism.	No calculation of sample size. Higher proportion of women. Without randomization group. Trained examiner, without information on blind. Validated diagnostic methods.
Baba, 2005 [53]	Cases and controls study	103 subjects: 51F (age 23.7 ± 2.6 years) and 52M (age 24.7± years)	Questionnaire 0–4 points for 'symptoms upon awakening' and 0–52 points for 'pain/mandibular function'. Four	No control group.	There was a relationship between EMG activity and joint sounds ($p < .05$). There was no relationship between EMG activity and	Joint noises significantly related to duration of the EMG activity of the masseter muscle when sleeping.	No calculation of sample size. Without randomization group. Examiners blinded and trained for EMG data analysis.

(*continued*)

Table 3. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
			trained and calibrated examiners: Maximum mouth opening/score muscle sensitivity (0–24 points) and joint sensitivity (0–12 points)/joint noise. EMG register of right masseter: EMG device use. Bruxism potential episodes: >20% MVC (sleep bruxism). Multiple linear regression, $p < .05$.		questionnaire data, data articular sensitivity and maximum mouth opening ($p > .05$).		Validated bruxism diagnostic method and TMD non-validated diagnostic method.

AASM: American Academy of Sleep Medicine; a.r: age range; CI: confidence interval; EMG: electromyography; F: female; M: male; MP: myofascial pain; MVC: maximal voluntary clenching; OR: odds ratio; PSG: polysomnography; RDC/TMD: research criteria for temporomandibular disorders; RMMA: rhythmic masticatory muscle activity; RMS: root mean square; SB: sleep bruxism; sec: seconds; TMD: temporomandibular disorders; VAS: visual analogue scale.

not distinguish between sleep and awaken bruxism. Also, they did not evidence any tendency for having a specific temporomandibular pathology ($n = 13$) (Table 7). On the contrary, nine studies evidenced a clear relation between sleep bruxism with myofascial pain, followed by arthralgia and intracapsular disorders (Table 7). All studies that used PSG ($n = 4$), two studies that used self-report and/or clinic, and three studies that used self/report and survey founded an association. Five articles differentiated the types of bruxism according to circadian manifestation and they demonstrated an association between bruxism, and joint pathology (noise and pain), and muscle pathology. Bortolleto et al., in 2013, concluded that sleep bruxism should be associated with muscle pain, and awaken bruxism to joint pain.[66] This study had a low evidence rate and a low quality on instruments, so its results could be overestimated. Only one study (Michelotti et al.), using self-report, determined a relation between awaken bruxism and TMD (myofascial pain and disc displacement) with a moderate level of evidence.[69]

Few studies did not distinguish the type of bruxism. This situation is perhaps related to the definition of bruxism that is associated with sleep disorders, and defined by the International Classification of Sleep Disorders or ICDS-2.[81] A contribution to that was published by Lobbezoo et al. who established a bruxism definition based on the circadian manifestation, giving a clear, and an operative definition for this disorder.[1]

Although 33 from 39 studies demonstrated a positive relation between bruxism and TMD, it is not possible to confirm causality or perpetuating relationship with them. There are many other factors involved, and that were not necessarily isolated from the samples of the studies. Current evidence shows facilitating conditions involved in the development of TMD as follows: gender,[82] anxiety,[83] unilateral chewing [84] and facial skeletal structures.[85]

Relationship between bruxism and TMDs based on analysis of selected studies

The seven articles that used PSG for bruxism diagnosis were case and control studies. Also they had a low NOS punctuation scale. In three of them, it was not possible to determine an association between bruxism and TMD, but in four of them a positive relation was established. Raphael et al. diagnosed TMD through RDC/TMD, and demonstrated that the increase in EMG activity during sleep could be a risk factor for myofascial pain.[47] Rossetti et al. [50] related sleep bruxism and awaking clenching by self-report to myofascial pain according to RDC/TMD. Rompré et al. concluded that subjects with sleep bruxism could have pain related to a low frequency of mandibular muscle contractions.[51] Finally, Baba et al. demonstrated a relation between presence of joint noises and an increase in EMG activity during sleep bruxism.[53]

Nine of the studies that used clinical method to diagnose bruxism ($n = 11$) demonstrated a positive association. According to type of pathology, most of them established a relation with the TMJ, including arthralgia,[55,56]

Table 4. Summary of studies with clinical diagnosis of bruxism with or without self-report.

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
Alves, 2013 [54]	Cases and controls study.	80 subjects (73F, 7M).	TMD: clinical examination of signs and symptoms of dysfunction. Bruxism (day and night): clinical examination and questionnaire used in previous study. In addition, a questionnaire developed by researchers about mastication and bruxism implications. Student's *t*-test, Chi-square test, $p < .05$.	*Group 1 (G1)*: Bruxism, F:37; M:3 (age 33.4 ± 11.5 years) *Group 2 (G2)*: No Bruxism M: 4; F: 36 (age 36.3 ± 10.1 years).	In G1 observed: limited eating mandibular movement ($p \leq .01$), facial pain when chewing ($p \leq 0.007$), facial muscles fatigue ($p \leq 0.004$), headache ($p \leq 0.02$) and articular noise ($p \leq 0.001$).	Masticatory function was reduced in G1, it may be the result of hyperactivity of the masticatory muscles caused by increased muscle tension.	No sample size calculation. Without randomization groups. Examiners trained, without information on blind. No validated diagnostic methods. Analysis does not differentiate types of bruxism.
Fernandes, 2012 [55]	Cases and controls study.	272 participants. F:87.5%; 36.9 m.a.	TMD: Clinical Protocol orofacial pain (questionnaire AAOP) and RDC/TMD (Axis I and II). Sleep bruxism: AASM Chi-square test, 95%, $p < .05$.	*4 groups study*: *G1*: No TMD pain without SB *G2*: No TMD pain and SB *G3*: With TMD pain and SB *G4*: With TMD pain without SB.	Risk of myofascial pain and arthralgia increases in subjects reporting nocturnal bruxism ($p < .0001$ and $p < .001$, respectively).	SB patients showed increased myofascial pain and arthralgia.	No sample size calculation Without randomization groups. Higher proportion women. Trained examiner, without information on shielding. Validated diagnostic methods.
Manfredini, 2010 [56]	Cases and controls study.	276 patients; F: 193; M: 83. Age 32.2 ± 5.7 years, a.r: 25–44 years old.	Analysis of multiple occlusal factors. TMD: RDC/TMD. Bruxism: clinical examination. Multiple logistic regression Chi-square test, $p < .05$.	*G1*: Patients diagnosed IIIa group arthralgia. *G2*: Diagnosis group IIIb osteoarthritis patients.	Univariate analysis showed an association between the presence of TMJ and bruxism ($p = .025$). Multivariate analysis shows no significant association. T significant factors, bruxism and overjet > = 5 mm, specificity was 48.2% and 91.5% and sensitivity 65.4% and 18.2%, respectively.	Overbite greater than or equal to 4 mm combined with clinical diagnosis of bruxism (OR = 4.62), greater than or equal 5mm overjet (OR = 2.83) and asymmetric molar ratio combined with clinically diagnosed bruxism (OR = 2.77) have higher chance of TTM IIIa and IIIb group	No sample size calculation Without randomization groups. Trained examiner, without information on blind. No validated diagnostic method bruxism, TMD validated.
Li, 2009 [57]	Cases and controls study.	40 subjects. 24F, 16M.	Bruxism: International Classification of Sleep Disorders (ICSD).	*Bruxers*: $n = 24$. 14F, 10M, age 24.38 ± 3.85 years. Divided into three groups.	No significant difference for all parameters TMJ vibration between MB and	In the TMJ vibration analysis, it was concluded that bruxism induces abnormal	No sample size calculation. Without randomization groups. No information on

(*continued*)

Table 4. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
			Bruxers were grouped according to Molina criteria. TMD: Questionnaire and clinical examination (status of TMJ), maximum opening and closing pattern examination. TMJ evaluation using Bio JVA system to assess damage, internal degeneration and degenerative conditions. TMJ surface vibration was analysed by two piezoelectric accelerometers. Mann–Whitney analysis and Chi-square test, $p < .05$.	*Mild bruxism (MB)*: $n = 9$ (37.5%) *Moderate bruxers*: $n = 13$ (54.2%) *Severe bruxism*: $n = 2$ (8.3%) Moderate and severe bruxism same group (MSB) *No bruxers*: $n = 16$. 10F, 6M. 23.89 ± 1.98 years.	control group ($p > .05$). The total integral, integral >300 Hz, and the peak amplitude of bruxism group was significantly higher in the MB group ($p < .05$). Vibratory radio TMJ: asymptomatic (75%), MB (77.8%) and MSB (100%). The value of MSB group much larger.	vibrations in the TMJ. Moreover, alterations in the TMJ produced by bruxism may be related to the pathogenesis of TMD	shielding and calibration of examiners. Validated diagnostic method bruxism and TMD not validated. Analysis does not differentiate types of bruxism.
Mehulić, 2009 [58]	Cases and controls study.	42 subjects. 18–65 years old. F: 72%; M: 28%.	*TMD*: questionnaires and clinical examination. Index Helkimo. Bumann manual functional diagnosis (clinical examination, joint and muscular palpation) *Bruxism*: clinical examination and study in articulator. Analysis *t*-test, Chi-square test, univariate and multivariate regression, $p < .05$.	Bruxism subjects ($n = 22$) and patients without bruxism ($n = 20$).	No difference in muscle palpation, deviation and deflection opening. Most common neuromuscular dysfunction in bruxism subjects. No difference in muscle condition groups ($p = .795$) with a trend to be more frequent in patients with bruxism. Difference in anterior-medial dislocation with disc replacement in patients without bruxism ($p = .049$).	Bruxers with more common muscle disorders (neuromuscular incoordination). Patients without bruxism have disorders in disk-condyle complex. There are differences in TMD symptoms between the two study groups.	No calculation of sample size. Without randomization groups. Higher proportion women. No information on blind and calibration of examiners. No validated diagnostic method bruxism, TMD validated. Analysis does not differentiate types of bruxism.
Janal, 2007 [59]	Cases and controls study.	51F with myofascial pain (m.a: 34.5 ± 11.0 years old)	Bruxism: 2 weeks to assess changes in tooth wear (TW). Every night questionnaire SCL-90R applied, stressful life, self-reported bruxism, intensity of spontaneous and	Control group: 12 women	Similar proportion of new/old features in 2 weeks (TW). Major TW patients with myofascial pain controls (1.34 versus 1.23)	Study fails to support the model in which tooth wear keeps pain. Without demonstrating that tooth grinding or tightening start pain.	No sample size calculation. Without randomization groups. Only women. Blinded and trained examiners.

(*continued*)

Table 4. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
			widespread pain. Control of influence of diet on dental wear TMD (MP): RDC/TMD *t*-test used to compare groups and correlation test, $p < .05$.		TW high levels associated with fewer reports of muscle pain or tenderness. Grinding teeth is related to pain palpation report only unilateral pain.		No validated bruxism diagnostic method, TMD validated.
Schierz, 2007 [60]	Cases and controls study.	646 participants. a.r: 35–44 years old.	Bruxism: the anterior teeth wear of maxillary and mandibular scale of 0–4 points was considered as an indicator. TMD: self-reported pain through RDC/TMD (German version) or Helkimo index. Chi square test, multiple logistic regression, $p < .05$.	TMD group versus healthy group.	TMJ pain risk increased 11% as increased tooth wear category, without being significant ($p = .66$).	Anterior tooth wear does not define a relevant increase in risk for TMD in individuals aged 35–44 years.	No calculation of size or randomization groups. No specific gender ratio. Examiners calibrated, without information on blind. Bruxism diagnostic method not validated, and TMD validated.
Storm, 2007 [61]	Cases and controls study.	68F. a.r: 21–70 years. m.a: 13.1 ± 49.7 years	TMD: RDC/TMD and Helkimo index. Bruxism: parafunctions determined by questionnaire (tooth wear evaluated). Load test, MVC for 30 sec to cause pain and fatigue. Chi-square test, analysis parametric and nonparametric, $p < .05$.	*Controls*: 46 women without TMD *Cases*: 22 women with TMD.	45% of cases developed symptoms compared with 15% of controls $p = .007$ for the load test. Joint pain in 26% cases with $p = .002$ Awareness of clenching teeth, $p = .002$, OR = 6.6 Awareness of grinding teeth, $p = .6$, OR =1.35	The engine of the jaw, especially 'tooth clenching' behaviour is significant in patients with TMD.	No calculation of sample size. Without randomization groups. Only women. Blind examiner without calibration information. No validated diagnostic method bruxism, TMD validated. Analysis does not differentiate types of bruxism.
Güler, 2003 [62]	Cases and controls study.	64 patients with clinical diagnosis bruxism behaviour and TMD degenerative disease (52F, 12M; 29 years, a.r: 13–63)	Clinical findings: preauricular pain and chewing muscles VAS scale. MNR 1.5 T (128 TMJ). Evaluated position disc, degenerative changes Bruxism: clinical diagnosis (unspecified). Chi-square analysis	*Control group*: 30 patients without bruxism and TMD. M: 4; F: 26 (26; 14–50 years old). *Study group (SG)*: 64 patients with bruxism and degenerative disease.	Significant unilateral and bilateral Degenerative disease versus control group ($p < .05$). SG relationship between condylar changes and severity of degenerative TMD. DDwR 55%	High prevalence condyle changes in patients with bruxism.	No calculation of sample size. Without randomization groups. Higher proportion women. Blinded examiners, without information on calibration. No validated diagnostic method bruxism,

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Table 4. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
					versus 38% in bruxism control. Compared to 86% DDwoR TMJ study group versus 24% control.		TMD validated.
Manfredini, 2003 [6]	Cases and controls study.	289 subjects. M: 93; F: 196. Average 34.4 years old, SD: 13.8 years.	*Bruxism*: (AAOP). No difference between awake and sleep bruxism. *Bruxism*: when there was one positive aspect for clinical examination and the examination of one positive anamnesis. *TMD*: questionnaire (subjective description of signs and symptoms) and RDC/TMD, conducted by another examiner. Fisher's exact test and Chi-square test, $p < .05$.	Subjects without TMD ($n = 77$) Without bruxism and with bruxism. TMD subjects ($n = 212$) with bruxism and without bruxism.	Difference in prevalence of bruxism between patients with and without TMD ($p < .05$). By pathology group RDC/TMD, there were different subjects without TMD and prevalence bruxism with myofascial pain ($p < .05$), myofascial pain + displacement disc ($p < .01$), myofascial pain + displacement disk + other joint disease ($p < .01$)	Bruxism has a greater relationship with muscle disorders than with joint pathology.	No calculation of sample size. Without randomization group. Trained examiner, without information on blind. Bruxism and TMD diagnosis method validated. Analysis does not differentiate types of bruxism.
Pergamalian, 2003 [63]	Cases and controls study.	84 TMD patients (84% F–16% M; 29.1 ± 8.1 years old)	*TMD*: RDC/TMD. TW using models Calibrating two examiners *Bruxism*: Questionnaire, presence/frequency ANCOVA, MANOVA, Pearson's correlation test, $p < .05$.	Independent variable bruxism No bruxism, $n = 10$ Occasional bruxism, $n = 27$ Frequent bruxism, $n = 40$ Seven subjects excluded for inconsistencies in the interview and questionnaire.	Numbers joint pain sites varies according to classification of bruxism ($p < .05$), muscle pain of sites does not change ($p = .52$).	No association between myofascial pain (MP) and TW. Bruxism is related to high levels of muscle pain. Report of minimum bruxism and non-bruxism was associated with high levels of TMJ pain.	No calculation of sample size. Without randomization groups. Examiners blind and calibrated. Diagnosis of bruxism no validated method, TMD validated.

AAOP: American Academy of Orofacial Pain; AASM: American Academy of Sleep Medicine; a.r: age range; DDwoR: displacement disc without reduction; DDwR: displacement disc with reduction; F: female; M: male; m.a: mean age; MNR: magnetic nuclear resonance; MVC: maximal voluntary clenching; OR: odds ratio; RDC/TMD: research criteria for temporomandibular disorders; SB: sleep bruxism; TMD: temporomandibular disorders; TMJ: temporomandibular joint; TW: tooth wear.

Table 5. Summary of bruxism diagnosed based questionnaire/self-report studies.

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
Blanco Aguilera, 2014 [64]	Cases and controls study	1220 patients. 1020 F (84.4%) y 190 M (15.6%) a.r: 18–60 years	TMD: RDC/TMD. Calibrated examiners. Previous history of joint blockage 14 question as RDC/TMD Pain intensity (CPI) scale using GPS (0–10) Sleep bruxism (SB) questionnaire based on questions 15c modified RDC/TMD Logistic regression and *t*-test, $p < .05$.	G0: No muscle pain ($n = 29$) G1: muscle pain (MP) ($n = 127$) G2: Muscle pain and discopathy ($n = 237$) G3: Muscle pain and artropathy ($n = 350$) G4: Muscle pain + discopathy- + artropathy ($n = 377$) G5: Joint locking.	G4 (OR = 2.04) and G3 (OR = 1.64) significance only with respect to G0. G2 close to statistical significance (OR = 1.48). G5 without association with perceived bruxism (OR = 1.17). SB and pain intensity: higher in the group with regard to perception of bruxism without perception of bruxism group ($p < .0001$).	Strong association between SB and the presence of painful symptoms of TMD, especially muscle pathology accompanied by arthralgia. No significant difference in reporting the presence of bruxism and disc displacement.	No sample size calculation. Without randomization group. Higher proportion women. No information on blind and calibration of examiners.SB no validated diagnostic method, and TMD validated.
Ferreira, 2014 [65]	Cases and controls study	201 undergraduate students. a.r: 17–34 years, m.a: 20.5 years. 146F, 55M.	Bruxism: Self-reported parafunctional habits and application of questionnaire 2 questions. TMD: RDC/TMD validated for Brazil. Occlusal examination, evaluating discrepancy between MIC and centric relation (CR) with Jig wore. Evaluation interference in laterality and protrusion. Evaluation: overjet, overbite, open bite and crossbite. Chi-square analysis and logistic regression, $p < .05$.	TMD subjects (group I or G-MPD–group II or G-DD) or without TMD versus subjects with presence or absence of parafunctional habits (teeth grinding and clenching). Subjects with or without TMD versus occlusal characteristics (overjet, overbite, open bite, crossbite). TMD versus functional alterations.	Tooth clenching: 85 subjects (42.3%), with G-MPD, $n = 26$ and G-DD with $n = 13$. Tooth grinding 26 subjects; subjects diagnosed with G-MPD, $n = 7$ and subjects diagnosed with G-DD, $n = 6$. Only Tooth clenching association with G-MPD ($p = .000$). No difference between occlusal factors and TMD groups. Tooth clenching + overjet correlate with myofascial pain.	Only tooth clenching and overjet were associated with myofascial pain (G-MPD).	No sample size calculation. Without randomization group. Higher proportion women. Calibrated examiner, without information about blind. No validated diagnostic method bruxism and TMD validated (not considered analysis group III).
Bortolleto, 2013 [66]	Cases and controls study	172 subjects. 69.19% F, 30.81% F. m.a: 34.82, a.r: 17.70–78 years.	Awake and sleep bruxism: AAOP questionnaire validated, self-administered, nine questions with VAS. TMD: Anamnesis for clinical examination to TMD and wear facets. Calibrated examiners. Chi-square analysis, unit or multivariate logistic regression. 95% CI, $p < .05$.	TMD subjects with awake and sleep bruxism. TMD patients without awake and sleep bruxism.	Awake bruxism: Joint pain, 22.39% ($p = .042$). Pain maximum aperture 13.48% ($p = .011$). Subjects awake bruxism at risk 2.1 times for joint pain ($p = .044$). Sleep bruxism: facial pain 48.35% ($p = .003$). 2.5-fold risk for muscle pain ($p = .004$).	Awake bruxism habit is the most common and is associated with joint pain, followed sleep bruxism associated with muscle pain, both are risk factor for TMD. The other habits studied did not have the same association.	No calculation of sample size. Without randomization group. Calibrated examiners, without information on shielding. Validated diagnostic method bruxism and TMD no validated method.
Köhler, 2012 [13]	Cases and controls study	Population study in 1983, 1993 and 2003.	Questionnaire: bruxism, facial trauma history and TMD treatment.	Three random samples by year (1704 subjects):	All symptoms strongly associated with tooth wear and	Report bruxism increased during the study period	No sample size calculation.

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Table 5. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
		1704 subjects a.r: 20–70 years.	TMD: interview and Helkimo index. Binary logistic regression. Univariate regression (UR) and multiple regression analysis (MR), $p < .05$.	1983, 1993 and 2003 grouped by 100 subjects in each age group as 20, 30, 40, 50, 60 and 70.	clench (except crepitus). Bruxism symptoms dependent: dislocation OR = 3.9 (UR/MR), $p < .001$; difficulty opening UR, OR = 3.1, $p < .0001$; MR: OR = 3.9, $p < .001$; pain jaw movement, UR: OR = 5.2, $p < .001$; MR: OR = 4.9, $p < .0001$. Bruxism, dependence for dysfunction Index (Ai) UR: OR = 2.6, $p < .0001$; MR: OR = 2.4, $p < .0001$.	and deterioration of health perception were mostly associated with TMD symptoms and dysfunction index.	Randomization groups (method not explained). Trained interviewers, without information on blind. No validated diagnostic method bruxism, and TMD method validated.
Manfredini, 2012 [67]	Cases and controls study	Padova University, Italy: 219 patients. F: 74.4%. 42.9 years (±16.1). a.r: 18–81 years. Tel Aviv University: $n = 397$. F: 79.6%. 35.6 years (±14.7). a.r: 18–84 years.	TMD: RDC/TMD Awake and sleep bruxism: self-report and questionnaire. Chi-square test, $p < .05$.	Group 1: Padova University, Italy Group 2: Tel Aviv University.	Myofascial pain more prevalent in Tel Aviv (36.8%) combined with inflammatory and degenerative disorders in Padova (27.4%), $p < .001$. At least one positive response questionnaire on bruxism, $p < .001$. More bruxism in patients with myofascial pain only.	The characteristics of samples studied and the different interpretation of the same pattern of diagnosis may influence the epidemiological reports of bruxism and TMD and relationship between them.	No sample size calculation. Without randomization groups. Higher proportion women. No information on blind and calibration examiners. No validated diagnostic method bruxism. TMD diagnostic method validated.
Yachida, 2012 [68]	Cases and controls study	115 individuals. 39M. m.a: 36.8 ± 14.0 years. 76F m.a: 32.9 ± 10.2 years.	Craniofacial pain (CP) = TMD and tension headache (TH). TMD: RDC/TMD. Sleep bruxism (SB):self-report, questionnaire RDC/TMD. Two groups with/without CP and with/without TH were divided into subgroups: with/without SB. All RDC/TMD and McGill pain questionnaire 3 calibrated examiners. Portable EMG device 1 channel. *t*-test and ANOVA, $p < .05$.	CP subjects versus No pain versus TH versus subjects Healthy.	Significant difference in EMG activity of CP subjects with SB and without pain with SB ($p < .05$). EMG positive correlation between activity and number of painful muscles – pain intensity – McGill questionnaire and levels of depression ($p < .05$).	There are no major differences between patients with different conditions of craniofacial pain and patients without pain in terms of EMG activity during sleep.	No sample size calculation. Without randomization groups. Formation of groups is indicated. Calibrated examiners. No blind information. Validated diagnostic methods.

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Table 5. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
Marklund, 2010 [29]	Cohort study	280 students 98M, 182F.	Bruxism: questionnaire TMD: RDC/TMD and frequency questionnaire and symptoms and TMD. 95% Multiple regression, odds ratio.	Cases: report signs and symptoms incidence or maintenance TMD Control: no signs and symptoms Without persistence and incidence TMD	Self-reported bruxism associated with signs and symptoms start in the TMJ. Predictive incidence of positive bruxism (0.47) and negative (0.75). Self-reported bruxism OR 2.4. Persistence TMD-Bruxism OR = 3.1.	The self-reported bruxism and crossbite increase the risk in the incidence and duration of signs and symptoms of TMD	No sample size calculation. No randomization group. Blinded and calibrated examiners. No validated diagnostic method bruxism, TMD validated.
Michelotti, 2010 [69]	Cases and controls study	Total subjects: 668 a.r: 11–79 years. TMD diagnosis 557 subjects 33.2 years: SD 14.4 years. M: 127 (a.r: 11–79 years) 34.5 ± 15.4 years. F: 430 (a.r: 12–76 years); 32.9 ± 14.1 years.	TMD: RDC/TMD Axis I. Bruxism: patient questionnaire, applied with respect to grinding or clenching tooth day according to modified questions RDC/TMD (question 15 Axis 1: during the day you keep the teeth in contact, is this what makes your jaw grinding or clenching? Multinomial logistic regression test, $p < .05$.	Control group (without pathology TMD). $N = 111$ subjects (55M, 56F) Group 25–37 age group; $n = 34$ Group 38–79 years; $n = 54$ Pathology group: (Group I–II and III RDC/TMD) $n = 557$ Group I: 408; Group II: 133; Group III: 16	Report of tooth clenching and grinding in the day 2 times more frequent in subjects with TMD compared to the control group and is a risk factor for myofascial pain and disk displacement. No association parafunctions oral and arthralgia, arthritis and osteoarthritis. Group I: age 25–37 years, $p = .085$, OR= 1.601 Group II: 25–37 years old, $p = .047$, OR = 2.004 Group III: 25–37 years, $p = .942$, OR = 0.957.	Parafunctional daytime activities can be a risk factor for TMD subgroup. More specifically, tooth clenching and grinding of the day was a risk factor for myofascial pain and disk displacement.	No sample size calculation. Without randomization group. Calibrated examiner without blind information. No validated diagnostic method bruxism, TMD validated. No clear definition of awake bruxism.
Österberg, 2007 [70]	Cohort study	Two cohorts of subjects 70 years of age born in 1922 ($n = 422$); F:232; M:190 1930 ($n = 484$); F:249, M:235	Two cohorts: subjects examined interval 8 years. TMD symptoms questionnaire index 0–5 (5 questions). Bruxism: questionnaire, one question. Pearson correlation analysis, logistic regression model, $p < .05$.	Cohort 1 (examination year 1992–1993); $n = 422$; F: 232; M: 190. Cohort 2 (examination year 2000/2001): $n = 484$; F: 249; M: 235.	High correlation of TMD and bruxism index, $p < .001$. Index TMD significant association, $p < .001$; OR= 2.23.	TMD symptoms associated with bruxism and psychosomatic factors and overall health.	No calculation of sample size and randomization group. Only one age group. No Information examiners calibration or shielding. No validated diagnostic methods.
Camparis, 2006 [71]	Cases and controls study	100 patients. F: 80; M: 20. a.r: 13–66 years; SD 36.1 years ±11.3	Bruxism: grinding overnight self-report, confirmed by a family member and/or roommate.	Group A (GA): bruxism without orofacial pain; $n = 30$, 17–66 years, mean 33 years, M:18; F:12	Prevalent symptoms in Group B (tooth grinding and clenching daytime, uncomfortable bite,	There are significant differences in long-standing bruxism with and without	No sample size calculation. Without randomization group.

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Table 5. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
			Orofacial pain questionnaire standardized protocol according EDOF-HC TMD: RDC/TMD Chi-square test, $p < .05$.	Group B(GB): bruxism with orofacial pain; $n = 70$; 13–59 years, 37.5 years; 62M, 8H	morning stiffness, clicking on TMJ and tinnitus. GA: myofascial pain (0.0%) offset disc (10.0%), arthralgia 6.7%. GB: myofascial pain (95.7%), disk displacement (22.8%) and arthralgia (77.1%).	chronic facial pain. The frequency and location of the bilateral pain was statistically different regarding no pain bruxism.	Higher proportion women. Trained examiner without blind information. No validated diagnostic method bruxism, TMD validated.
Johansson, 2006 [45]	Cases and controls study	Two samples: 50 years ($n = 12,468$) and 60 years ($n = 6232$). M: 50.6%, F: 49.4%.	Questionnaire: 53 questions, 123 items on oral and general health. Logistic regression analysis.	Subjects with and without TMD.	TMD pain 12.1% Bruxism: 79.9% of TMD pain Bruxism: odds ratio for TMD pain (OR= 4.2) Difficulty opening mouth (OR= 2.0).	There is a relationship between bruxism and TMD.	No calculation of sample size. Without randomization group. No Information examiners calibration or blind. No validated diagnostic methods.
Sato, 2006 [72]	Cases and controls study	508 TMD patients with more than 1 week.	TMD: questionnaire RDC/TMD Axis I. Questionnaire: (1) Background personal; (2) Subtype TMD Axis I RDC/TMD; (3) Value VAS pain intensity Bruxism: questionnaire. 25 questions. Asked: 'do you often let your upper and lower teeth contact continuously during your work or at rest?' Analysis, logistic regression, $p < .05$.	Association between TCH and TMD was analysed in 229 chronic pain (CP) patients (85.6% women, mean 32 years). Improvement and no improvement (compared to pain levels presented in the first visit).	Patients wear by 'Teeth contacting habit' (TCH) was 52.4% in patients with chronic pain in TMD. TCH is a risk factor for TMD (OR= 1.994)	Half TMD patients had TCH. TCH could be a prolongation factor TMD pain.	No calculation of sample size. Without randomization groups. No Information examiners calibration or blind. No validated diagnostic method bruxism, TMD validated.
van der Meulen, 2006 [73]	Cohort study	Two cohorts of patients 'Cohort frequency or CF': 226 patients F: 88.5%; a.r: 13–76 years, m.a: 38.5 ± 13.3 years. 'Cohort degree of stress or CDS' 303 patients. F: 83.8%. a.r: 14 83 years; 37.2 ± 14.2 years.	Validated questionnaire (12 questions parafunctional habits after 2–3 weeks TMD diagnosis). Difference between two cohorts questionnaire application. Cohort frequency: 12 parafunctions occurrence. Ordinal scale of 5 points to respond. Cohort degree of stress: questions as perceived stress level.	No control group	There is no relationship between the BRUX scale and CPI values. Cohort frequency (CF): negative relationship between the BITE scale and CPI values ($p = .010$) Cohort degree of stress (CDS): Positive relationship between SOFT scale and CPI values ($p = .013$). CPI little variance explained by oral parafunctions.	No clinical relevance related to different types of oral parafunctions with self-report and discomfort for TMD. Causal relationship between TMD and bruxism if exists, is small.	No sample size calculation. Absence control group. No information examiners calibration or blind. Validated diagnostic methods.

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Table 5. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
			TMD: RDC/TMD Axis II. CPI was used; 3 questions of intensity of pain. CPI values 0–100 Bruxism: scales: BRUX, BITE, SOFT. Regression analysis, $p < .05$.				
Ahlberg, 2005 [74]	Cases and controls study	1500 subjects. Group work shifts. M: 45 years (±10.6); F: 42.6 years (± 10.7) Workers day: M: 47.4 years (±9.7); F: 45.5 years (± 10.1).	TMD: RDC/TMD axis II (chronic pain) Bruxism: standardized questionnaire, self-frequency of wear or clench tooth (never, rarely, sometimes, often, continuously) Chi-square test, regression model, $p < .05$.	Workers with regular shifts, $n = 750$ turn 8 h × day. Men 56.6%. Workers with irregular shifts ($n = 750$). 46.7% men.	Orofacial pain associated with frequent bruxism, $p < .001$; female, $p < .001$; and sleep disruption, $p < .01$.	Association between perception of orofacial pain and bruxism report. Bruxism together with sleep disruption may participate simultaneously in developing orofacial pain.	No calculation of sample size. No randomization groups. No information blind and examiners calibration. No validated diagnostic method bruxism. TMD validated. Analysis does not differentiate types of bruxism.
Glaros, 2005 [39]	Cases and controls study	96 subjects with TMD in a central facial pain or from general population.	TMD: RDC/TMD by two calibrated examiners. Quiz time and intensity of tooth contacts. VAS scale for pain and stress. Questionnaire yes/no tooth contacts. Linear regression analysis, $p < .05$.	Subjects with myofascial pain (MP; $n = 24$), myofascial pain + arthralgia (MP + A; $n = 21$), disk displacement (DD; $n = 24$) Subjects without TMD ($n = 27$)	Myofascial pain (MP) + high intensity of arthralgia when teeth are in contact. High levels of MP when teeth are in intense contact versus disk displacement and controls. Correlation between muscle tension and jaw pain.	Parafunctions that increase muscle tension and emotional states are good predictors of levels of mandibular pain in TMD patients and healthy subjects.	No calculation of sample size. No randomization groups. Blind examiners No validated diagnostic method bruxism. TMD validated. No diagnosis parafunctions neither bruxism is defined.
Kobs, 2005 [75]	Cases and controls study	307 subjects. M:140; F:167; a.r: 20–54 years; m.a: 35.4 years	Signs and symptoms of dysfunction in the stomatognathic system (sensitivity joint noise joint, muscle pain, muscle pain opening (active–passive), opening deviation. Chi-square test, $p < .05$.	TMD subjects: $n = 114$. Subjects without TMD: $n = 193$	Group clench teeth: 53.1% bilateral masticatory sensitivity and 31.2% in the 'non-clenchers' group ($p = .001$)	There is a relationship between the incidence of dental clench and pathological phenomena in the muscles and joints.	No calculation of sample size. No randomization groups. No information blind and examiners calibration. No validated diagnostic methods.
Magnusson, 2005 [76]	Cohort study	320 subjects aged 7, 11 and 15 years.	20-year follow-up. TMD: Clinical examination. Clinical dysfunction index (Di), Helkimo index. Parafunctions oral questionnaire. Sleep and awake bruxism.	No control group.	Associated symptoms but weakly correlated to tooth-clenching and tooth-grinding (r_s values ranging between 0.11 and 0.53, p values	A significant correlation between reported bruxism and TMD symptoms. Baseline report of tooth-grinding at night was a predictor	No calculation of sample size. No randomization groups. Calibrated examiners, without information blind.

(*continued*)

Table 5. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
			Combining daytime tooth-clenching and/or tooth-grinding at night. Clinical examination to assess the amount of occlusal wear. Questionnaire symptoms of masticatory system. Logistic regression, $p < .05$.		ranging between 0.05 and 0.001). Predictor of symptoms of TMD: 3 independent variables: index occlusal wear (OR = 4.3, $p = .014$), clinically recorded TMJ clicking (OR 3.3, $p < .0001$), and reported tooth-grinding at night (OR = 2.2, $p = .023$). Bruxism + other oral parafunctions (OR 7.7, $p = .0031$), and bruxism (OR 5.3, $p = .016$).	of TMD treatment during the observation period.	No validated diagnostic bruxism. TMD method validated. Analysis does not differentiate types of bruxism.
Mundt, 2005 [31]	Cases and controls study	2963 subject: F:1493; M:1470 a.r: 35–74 years	8 calibrated examiners. Review status of missing teeth and dental prosthesis. TMD: Academy of orofacial pain: pain/muscle tenderness and/or TMJ palpation. Bruxism: self-reported dichotomous interview. occlusal support: Eichner index. logistic regression, Chi-square test, $p < .05$	Male gender patients versus women.	Bruxism is associated with tenderness/muscle pain in women ($p \leq 0.001$) and TMJ pain/tenderness in women ($p = .001$) and men ($p = .028$)	In men and women, the presence of bruxism is associated with TMD.	No calculation of sample size. Without randomization group. Calibrated examiners without blind information. No validated diagnostic method of bruxism and validated method for TMD.
Miyake, 2004 [77]	Cases and controls study	3557 students. 20.4 (±2.1 years) a.r: 18–26 years M: 2516; F:1041	TMD: 3 questions symptoms questionnaire. According to Onizawa and Yoshida study. Parafunctions oral questionnaire: nine questions. Two questions for sleep and awake bruxism. Chi-square analysis. Alfa 5%. TMD association force and factors expressed in odds ratio (OR). Multiple logistic regression, $p < .05$.	Association between symptoms of TMD and oral parafunctions through questionnaires (no control group)	Tooth clench increases risk noises in the temporomandibular joint (OR = 1.86, $p < .001$), TMJ pain (OR = 1.79, $p = .001$ and impaired mouth opening (OR = 1.88, $p < .001$).	Association between parafunctional activities and symptoms of TMD.	No calculation of sample size. Without randomization group. Blind examiners, without information on calibration. No validated diagnostic methods. No control group

(*continued*)

Table 5. Continued

Author and year	Type of study	Population	Intervention	Comparison (control group)	Outcome	Conclusions	Comments
Fujita, 2003 [78]	Cases and controls study	57 women examined between 1995 and 1998. 12 years and 10 months–42 years and 2 months. m.a: 23 years and 6 months.	TMD: 'The Craniomandibular Disorders Protocol'. Questions and clinical examination. Bruxism: self-report.	Subjects with TMD (primary symptoms and symptoms) and subjects with habits (bruxism, unilateral chewing, crunch, tongue thrusting, abnormal posture and other habits).	Primary symptoms: 40.4% joint noises. 26.3% sound articulate and pain. Presenting symptoms: Most common noise and joint pain (35.1%). 87.7% had oral habits. Bruxism present in 47.4%. Subjects with bruxism and unilateral chewing showed more complex symptoms.	Comparing primary habits, patients with bruxism and unilateral chewers were more complex symptoms of TMD.	No sample size calculation. Only women. Without randomization group. No Information blind or calibration of examiners. Unclear methods and unvalidated diagnoses. Analysis does not differentiate types of bruxism.
Velly, 2003 [79]	Cases and controls study	183 patients (a.r: 18–60 years)	TMD: myofascial pain (MP) by RDC/TMD Bruxism: self-report questionnaire Two blind examiners. Multivariable logistic regression, $p < .05$.	G1: 83 patients. Myofascial pain (MP) (M:16, F:67) G2: 100 patients. Control	Only tooth clenching and tooth grinding and clenching were associated with MP. Only grinding was not associated with MP.	Tooth clenching (with or without grinding) are associated with chronic MP.	No calculation of sample size. Without randomization group. Blind examiners, without information on calibration. No validated diagnostic method bruxism, TMD validated.

AAOP: American Academy of Orofacial Pain; a.r: age range; C.I.: confidence interval; CPI: characteristic pain intensity; EMG: electromyography; F: female; M: male; m.a: mean age; OR: odds ratio; RDC/TMD: research criteria for temporomandibular disorders; SB: sleep bruxism; TCH: teeth contacting habit; TMD: temporomandibular disorders; TMJ: temporomandibular joint; VAS: visual analogue scale.

osteoarthritis,[56] disc displacement and myofascial pain,[6] degenerative pathology,[62] joint pain,[61] joint noises and joint pathology (with no specification).[57] Also, they observed a relation between bruxism with myofascial pain,[55] muscles disorders,[58] myofascial pain and disc displacement,[6] muscle pain,[63] and facial pain during chewing.[54] These studies had a low to moderate evidence level (NOS Scale) and also, most of them, did not make a distinction between sleep and awaken bruxism.

According to the last international consensus, bruxism diagnosis made by self-report is classified as possible bruxism.[1] This definition of bruxism was used in half of the articles that were analysed. Nevertheless, Raphael et al. concluded that the self-reported bruxism is not a useful indicator.[80] This is the cause of a high positive relation between oral para-functions and pain that those studies presented, compared with those that used PSG for diagnosing bruxism.

So, the relation between bruxism, TMD and pain could be determined by the diagnostic instruments and also by preconceived ideas that patients have on bruxism.[86] For that reason, Paesani et al. performed a correlation study to find out the relation between bruxism diagnostic performed by self-report by a survey and performed by clinical history and clinical exam. They concluded that there is a positive correlation between self-report and clinical findings in diagnosis of awaken bruxism.[86]

In conclusion, the importance of these studies conclusions is to validate that the association between bruxism, TMD and orofacial pain would depend on the diagnostic instruments for all pathologies.

Table 6. Summary of studies with different methodologies for the diagnosis of TMD and bruxism [337].

	Bruxism's diagnostics		
TMD diagnostics	Polysomnographic	Clinics/ self-report	Questionnaire/ self-report
RDC/TMD	$n = 5$	$n = 6$	$n = 10$
Helkimo index	$n = 0$	$n = 1$	$n = 2$
AAOP	$n = 0$	$n = 0$	$n = 1$
Signs and symptoms	$n = 1$	$n = 2$	$n = 2$
Questionnaire	$n = 1$	$n = 0$	$n = 5$
Others	$n = 0$	$n = 2$	$n = 1$
Total	7	11	21

AAOP: American Academy of Orofacial Pain; RDC/TMD: research diagnostic criteria for temporomandibular disorders.

Bruxism and TMDs based on experimental studies

To understand mechanisms, onset and perpetuation of pain related to TMD and consequences of bruxism over the masticatory system, the analysis of experimental studies is important. According to Dawson, dental clenching could be considered as a risk factor for myofascial pain and proprioceptive allodynia.[87] On experimental studies, where a dental clenching was stimulated in healthy subjects and in

Table 7. Bruxism association between temporomandibular disorders, according to the classification of bruxism, temporomandibular pathology type and quality of evidence according NOS scale.

		Relationship bruxism – TMD			Without relationship bruxism – TMD		
Author	Year	Bruxism's type	Pathology (TMD)	Score	Author	Year	Score
Raphael [47]	2013	Sleep bruxism	Myofascial pain	5	Raphael [48]	2012	5
Alves [54]	2013	Sleep and awake bruxism	Joint/facial pain	3	Rossetti [49]	2008	5
Blanco Aguilera [64]	2014	Sleep bruxism	Muscular/arthralgia	6	Janal [59]	2007	2
Ferreira [65]	2014	Bruxism	Myofascial pain	2	Schierz [60]	2007	4
Bortolleto [66]	2013	Sleep and awake bruxism	Muscular (SB) – Joint (AB)	3	Camparis [52]	2006	3
Fernandes [55]	2012	Sleep bruxism	Arthralgia – myofascial pain	4	van der Meulen [73]	2006	2
Köhler [13]	2012	Bruxism	Signs and symptoms	5			
Manfredini [67]	2012	Sleep and awake bruxism	Myofascial pain	5			
Yachida [68]	2012	Sleep bruxism	Craniofacial pain	5			
Manfredini [56]	2010	Bruxism	Arthralgia – osteoarthritis	5			
Marklund [29]	2010	Bruxism	Signs and symptoms	4			
Michelotti [69]	2010	Awake bruxism	Myofascial pain – DD	4			
Li [57]	2009	Sleep bruxism	Joint	4			
Mehulić [58]	2009	Bruxism	Muscular	3			
Rossetti [50]	2008	Sleep bruxism	Myofascial pain	5			
Rompré [51]	2007	Sleep bruxism	Pain	4			
Storm [61]	2007	Bruxism	Joint	7			
Osterberg [70]	2007	Bruxism	Signs and symptoms	4			
Camparis [71]	2006	Sleep bruxism	MP/DD/arthralgia	3			
Johansson [45]	2006	Bruxism	Signs and symptoms	4			
Sato [72]	2006	Bruxism	TMJ pain	3			
Ahlberg [74]	2005	Bruxism	Orofacial pain	3			
Baba [53]	2005	Sleep bruxism	Joint noises	3			
Glaros [39]	2005	Bruxism	Mandibular pain	4			
Kobs [75]	2005	Bruxism	Muscular and joint	3			
Magnusson [76]	2005	Sleep and awake bruxism	Signs and symptoms	5			
Mundt [31]	2005	Bruxism	Muscular and joint pain	5			
Miyake [77]	2004	Sleep and awake bruxism	Joint (pain, noises)	3			
Fujita [78]	2003	Bruxism	Joint (pain, noises)	2			
Güler [62]	2003	Bruxism	Joint (degenerative)	4			
Manfredini [6]	2003	Bruxism	Muscular/muscular + joint	4			
Pergamalian[63]	2003	Bruxism	Muscular (pain)	4			
Velly [79]	2003	Bruxism	Myofascial pain	5			

AB: awake bruxism; DD: disk discplacement; MP; myofascial pain; SB: sleep bruxism; TMD: temporomandibular disorders; TMJ: temporomandibular joint.

patients with myofascial pain as well, an increasing secretion of peripheral serotonine (5HT) and glutamate on the patients was observed.[88,89] Experimental models based on conscious dental clenching generating isometric contractions by prolonged periods are considered valid and adequate to reproduce pain characteristics of subjects with myofascial pain.[87] Many authors support this method. Svensson et al. concluded that with 15 min of continuing clenching at 25% of the maximal voluntary clenching force (MVCF), patients should feel a moderate level of pain without presence of mechanic hyperalgesia.[90] The same authors also concluded that with 60 min of continuing clenching at 10% of the MVCF, patients should feel a high level of pain.[91] Other studies have also focused on continuous clenching and obtained different results according to the method. Hedenberg-Magnusson et al. induced a repetitive voluntary clenching at 50% of the MVCF for 30 s each 1.5 min during 30 min, and they observed a low pain level.[92] Also, Torisu et al. [93] concluded that continuous clenching at 10% of the MVCF for 30 min should induce a low pain level. Other studies with different method arrived to the same results, that is, with different models of clenching activity, they obtained a low level of pain.[92] Different results were obtained by Von Korff et al. [94] and Farella et al. [95] who induced voluntary clenching at different intensities for 6 times and 5 min each one. They observed moderate levels of pain persisting for 1 day after and also a short-term mechanic hyperalgesia.

Those studies have been performed inducing tooth clenching out of Maximal Intercuspation (MIC). Takeuchi et al. simulated an incisive clenching at 10% of MVCF during 2 h for 3 consecutive days. They did not obtained muscle or joint pain, suggesting other associated factors.[96]

On the other side, based on finite element modelling, when an overload due to prolonged tooth clenching was simulated as in bruxism, an increase in stress was observed on retrodiscal tissues. According to the authors, its effect could generate a degenerative pathology as osteoarthritis or disc perforation.[97] As well, Commisso et al. using the same method, simulated a rhythmic pattern with a 10% and a 20% of the MVCF.[98] They concluded that stress level over disc tissues is not proportional to muscle activation, but the situation could damage the articular disc.

In general, it is supposed that this situation should be similar to myofascial pain because similar values have been obtained when data are recorded from subjects with myofascial pain. The matter is that etiology and pathogenesis of myofascial pain are not an acute entity and pain results of all the studies are more similar to delayed onset muscle soreness. So there is still the doubt.

There is evidence about the association between masticatory muscular activity of the temporal and masseter muscles during sleep and awaken times, as risk factors for TMD. Despite these findings, the increase in muscle activity cannot be associated with bruxism, due to the low methodological quality of the studies based on non-standardized self-report surveys and poor characterization of bruxism in base to tooth wear, as well.[99]

Agreements and disagreements with other reviews

Two reviews with a similar methodology and objectives with this study were found.[5,100] All agree that there is a lack of a good level of evidence to establish an accurate relationship between bruxism and TMD, and all concluded that there is a low sensibility to establish a correct diagnostic of bruxism.

Discrepancies observed were mainly due to search method, and inclusion–exclusion criteria, as well. Comparing with Manfredini et al.'s article,[5] it can be observed that they did not establish differences between sleep and awaken bruxism. Also, inclusion criteria concerning language, in this review were broader. Moreover, Cunali et al. [100] only evaluated the relationship between sleep bruxism and TMD through a PSG analysis and RDC/TMD instrument, respectively, and concluded that it is not possible to establish a positive relation between both pathologies.

In relation to other studies that did not use similar search method and analysis to this research, they concluded that bruxism could be considered as a risk factor for TMD and headache.[101,102] The main discrepancies between these studies and this one lie on design, analysis method and data recruitment. So their conclusions could be overestimated.

Due to the evidence level, variability on diagnostic methodology for bruxism and TMD, a meta-analysis is not feasible.

Conclusion

Establishing a relationship between bruxism and TMD has been one of the most controversial aspects to demonstrate in literature and although many studies and reviews have been made, it is not yet possible to consistently conclude from high-quality studies a relationship between sleep and awake bruxism and TMD.

In relation to the findings in this review, we can conclude the following:

- Evidence-based diagnosis with PSG was not as conclusive as those performed based on clinical diagnostic survey to determine the bruxism–TMD relationship, and mostly was not established.
- Sleep bruxism would be associated with myofascial pain, arthralgia and joint pathology as disc displacement and joint noises.
- Despite the presence of studies with heterogeneous designs, and based on the studies reviewed, it may be suggested that subjects with sleep and awake bruxism would be associated with the presence of TMD.
- More cohort studies are required, with higher levels of evidence to determine the causal relationship between bruxism and TMD.

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