Temporomandibular Disorders and Their Association with Sleep Disorders in Adults: A Systematic Review

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Aims: To investigate the associations between temporomandibular disorders (TMDs) and sleep disorders in adult subjects. **Methods:** The PubMed, Embase, Evidence-Based Medicine Reviews, and ProQuest Dissertations & Theses databases were searched for studies published in English up to September 2019. Unpublished/gray literature and reference lists of identified articles were also examined. Inclusion criteria were male and female adults, presence or absence of a TMD based on the RDC/TMD or DC/TMD criteria, presence or absence of a sleep disorder according to the International Classification of Sleep Disorders, and any of the following study designs: cross-sectional, case-control, or longitudinal. Methodologic quality assessment was conducted using the National Heart, Lung, and Blood Institute quality assessment tools. **Results:** Twenty-two studies (11 cross-sectional, 9 case-control, 1 prospective cohort, and 1 mixed design) met the inclusion criteria. TMDs were assessed independently in relation to sleep bruxism (SB), obstructive sleep apnea (OSA), and sleep quality (SQ). All studies but one assessed TMDs using the RDC/TMD criteria. The relation between the TMD and the different sleep disorders was conflicting for SB and positive for OSA and SQ. Five studies were of good quality, and 17 were of fair quality. **Conclusions:** The evidence is inconclusive regarding the relationship between TMDs and SB and insufficient regarding the relationship with OSA. There is consistently fair evidence to support an association between TMD and SQ. This study highlights the need for higher-quality longitudinal studies to clarify the association between TMDs and sleep disorders. *J Oral Facial Pain Headache 2021;35:41–53. doi: 10.11607/ofph.2780*

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Temporomandibular disorders (TMDs) encompass a group of musculoskeletal and neuromuscular conditions that involve the masticatory muscles, temporomandibular joints (TMJs), and associated tissues.[1] TMDs affect 10 to 36 million adults in the US, and 40% to 75% of adults in the US have at least one sign of a TMD.[2,3] While the incidence is approximately equal in women and men,[4] these disorders are twice as prevalent in women in the general population, and the female-to-male ratio is as high as 9:1 in patient populations.[3,5] TMDs are a complex disorder, and seldom does initial onset occur in response to only one factor—rather, multiple factors in combination are required, based on the available evidence.[6–11] Among the multiple factors that contribute to onset or persistence of TMDs, sleep disorders have emerged as particularly important.

Sleep disorders are conditions that affect sleep pattern and can have deleterious consequences on an individual's overall health. The International Classification of Sleep Disorders (ICSD) recognizes 81 different sleep disorders.[12] Among these disorders, the most relevant conditions to TMDs and dental practice are obstructive sleep apnea (OSA) and sleep bruxism (SB). OSA is a sleep-related breathing disorder characterized by periodic episodes of complete or partial upper airway obstruction during sleep.[13] Several decades ago, the prevalence of OSA was estimated as 2% and 4% in middle-aged women

and men, respectively.[14] However, the prevalence appears to have increased since then, with estimated proportions of 3% and 10% in middle-aged women and men, respectively.[15] Sanders et al[16] examined the link between painful TMD and OSA and found that both women and men with 2 or more signs or symptoms of OSA had a 73% greater incidence of TMD than those with fewer signs/symptoms, independent of age, gender, race/ethnicity, obesity, smoking history, and autonomic parameters (eg, arterial blood pressure and heart rate). Chronic painful TMD was approximately 4 times as frequent among adults with a high likelihood of OSA independent of these same factors.[16] Other evidence also indicates that sleep dysregulation precedes initial onset of a painful TMD.[17] These findings are consistent in other samples of adults diagnosed with TMD who have a concurrent OSA diagnosis.[18–22]

SB is a sleep-related movement disorder that has been traditionally characterized by grinding or clenching of the teeth during sleep and is usually associated with sleep arousals.[23] This definition pervades most of the research assessing associations between TMDs and SB. The current definition of SB also includes rhythmic and nonrhythmic masticatory muscle activity. While SB is not a disorder in otherwise healthy individuals, it is considered a sign of a disorder for conditions such as OSA and rapid eye movement (REM) behavior disorders.[24] The prevalence of SB in adults is estimated at approximately 13%[25] based on the traditional characterization. SB is considered the most damaging among all oral parafunctional activities, yet little is convincingly known regarding the role of SB in the etiology of TMDs.[26] For example, Berger et al[26] evaluated the association between a TMD pain disorder and SB, waking parafunction, and mixed bruxism diagnosis (SB and waking parafunction). They found no significant association between SB and TMD pain, but they did find significant associations in men between waking parafunction and TMD pain and in women between mixed bruxism and TMD pain.[26] In contrast, Blanco Aguilera et al[27] found a strong association between SB and the presence of painful TMDs related to muscle pain and arthralgia. They found no significant association, however, between bruxism and the presence of disc displacements.[27] Finally, SB measured carefully using polysomnography did not appear to influence waking pain levels the following morning.[28]

Complicating the studies examining a causal role of sleep disorders for TMDs is that available evidence suggests that the association between pain and sleep disorders is bidirectional.[29–31] In general, pain causes arousals, which then interfere with sleep and sleep maintenance, and poor sleep adversely affects pain processing. One theory states that sleep deprivation contributes to pain sensitivity and hyperalgesia, thus exacerbating pain associated with TMD.[32–34] This suggests that pain is serving as a mediating factor for the association between TMD and sleep disorders. Strong evidence associating sleep disorders with TMDs is, not surprisingly, scarce.

Due to the scarce and conflicting evidence underlying the relationship between TMDs and sleep disorders, the objective of this systematic review was to provide a comprehensive synthesis evaluating the possible relationship between TMDs and sleep disorders in adults.

Materials and Methods

This systematic review followed the PICO (population, intervention, comparison, outcome) criteria and the PRISMA-P (Preferred Reporting Items for Systematic Review and Meta-Analysis protocol) guidelines.[35]

Eligibility Criteria

Studies were included based on the following criteria: male and female adults (17+ years old) with an established diagnosis of any TMD and presence of a sleep disorder. A diagnosis of TMD included any of its clinical subtypes based on the Research Diagnostic Criteria for TMD (RDC/TMD)[36] or the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)[37] with or without TMJ imaging. Studies that analyzed TMDs into subtypes and those that did not specify or analyze TMDs by subgroups were also considered. The presence of a sleep disorder was based on the ICSD[38] classification, diagnosed using either overnight polysomnography (PSG) or self-administered questionnaires. Only studies that were published in English and were prospective or retrospective longitudinal, case-control, or cross-sectional were considered.

Information Sources, Search Strategy, and Study Selection

An electronic database search in PubMed, Embase, Evidence-Based Medicine Reviews, and ProQuest Dissertations & Theses was conducted by an experienced librarian up to September 2019. A search for unpublished and gray literature was also carried out in OpenGrey. Additionally, reference lists of all identified articles were manually searched for potential studies. Language restrictions were applied, and only completed studies in English were considered.

Multiple keywords and MeSH terms were used for the electronic search. The search strategy was originally designed for PubMed (Table 1) and subsequently adapted for the remaining databases.

Table 1 PubMed Search Strategy

PubMed search	TMD, temporomandibular joint disorders [MeSH], TMJ Disorders, TMJ diseases, Temporomandibular disorder, temporomandibular joint, craniomandibular disorders, Cone-Beam Computed Tomography [MeSH], cone beam computer tomography, Cone-Beam CT, Cone Beam CT, Cone-Beam CT Scan, Volumetric CT, Magnetic Resonance Imaging [MeSH], magnetic resonance imaging, MRI, echo imaging, magnetic resonance tomography, airway management [MeSH], airway management, airway resistance [MeSH], airway resistance, pharynx [MeSH], pharynx, nasopharynx, oropharynx, airway morphology, airway obstruction [MeSH], airway obstruction, sleep quality, sleep wake disorders [MeSH], sleep wake disorders, sleep hygiene [MeSH], sleep hygiene, good sleep habits, sleep disorders, Sleep-Wake Cycle Disorders, Circadian Rhythm, Dyssomnia, sleep deprivation, sleep apnea

Two reviewers independently screened the title and abstract of each identified study for potential inclusion. The same reviewers then independently evaluated the full texts for inclusion in the qualitative review. Any disagreements at either stage were resolved by a third reviewer.

Quality Assessment

Two independent reviewers (D.S., T.A.J.) assessed the methodologic quality of the included studies using the National Heart, Lung, and Blood Institute (NHLBI)[39] quality assessment tools. These tools allow the assessment of internal validity and risk of bias. Two tools were used: one for observational cohort and cross-sectional studies, and another for case-control studies. Since the first tool was not specific for cross-sectional study designs, the quality assessment excluded criteria 6, 7, and 13 if a study was cross-sectional, as they were irrelevant to the cross-sectional methodology. All tools assessed the internal validity and risk of bias in a similar manner. The scores in each study were calculated by summing 1 point for each "yes" and 0 points for "no," "not applicable," "not reported," and "cannot determine," resulting in total scores ranging from 0 to 14, 0 to 11, and 0 to 12 for cohort, cross-sectional, and case-control studies, respectively. The quality of the studies was then graded as good if they scored ≥ 8, fair if they scored 5 to 7, or poor if they scored 0 to 4.

Results

Study Selection and Characteristics

A total of 825 articles were identified. After exclusion by title and abstract, 50 articles underwent full-text review, and 28 were excluded for different reasons (Appendix 1; all online appendices can be found at www.quintpub.com/journals). Twenty-two studies were finally included in this review (Fig 1). Most of the studies were conducted in the US, while the rest were from Brazil, China, Germany, Italy, Japan, and the Netherlands. Eleven studies were of a cross-sectional design,[18,19,27,40–47] 9 were case-control,[8,20,48–54] 1 was prospective cohort,[55] and 1 was of a mixed design (prospective cohort with case-control).[16] The sample sizes in the studies ranged from 22 to 2,595 adult subjects with an age range of 17 to 76 years old.

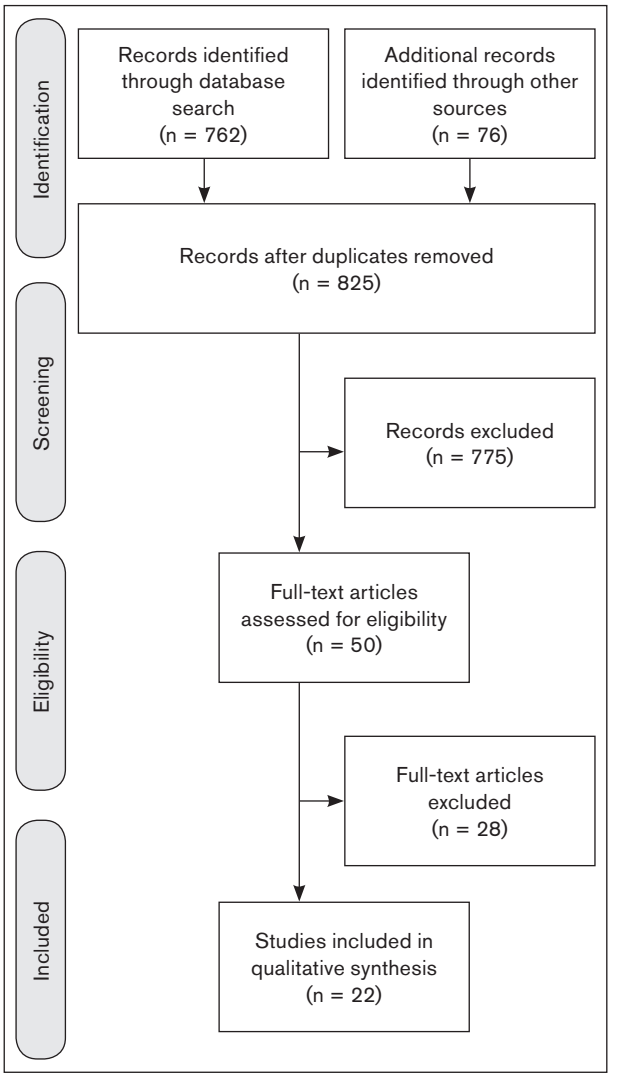

Fig 1 PRISMA flowchart of study protocol.

TMDs were classified using the RDC/TMD in 21[8,18–20,27,40–55] of the studies and using the DC/TMD in 1 study.[47] TMJ status (either disc displacement or degenerative joint disease) was classified using clinical

Table 2 Design, Participants, Classification Methods, and Findings of the Studies Included

Study	Study design	Cases	Controls	Classification methods	Major study findings
Muzalev et al,[47] 2018	Cross-sectional	293 pain-related TMD patients (mean age = 40.3 y, SD = 14.7)	–	▪DC/TMD for TMD diagnosis ▪Self-reports for SB assessment	▪No significant association between self-reported SB and intensity of pain-related TMD
Muzalev et al,[48] 2017	Case-control	124 myofascial TMD patients (all female; mean age = 34.7 y)	46 pain-free controls	▪RDC/TMD for TMD diagnosis ▪RDC/SB for SB diagnosis ▪PSG recordings	▪Duration of inter-episode interval was not different between cases and controls ▪The two groups did not differ in the number of SB episodes per hour of sleep or in the duration of the episodes ▪TMD pain patients had fewer SB episodes than non-TMD controls, and thus the data failed to support that TMD can be explained by increasing number of SB episodes or decreased intervals
Benoliel et al,[53] 2017	Case-control	187 TMD patients with masticatory muscle disorders, TMJ disorders, or both (male = 77, female = 111; mean age = 21.21 y)	99 non-TMD controls (male = 52, female = 47; mean age = 20.81 y)	▪Axis I of the RDC/TMD for TMD diagnosis; sample was redistributed using DC/TMD ▪PSQI and SQ assessment	▪Poor sleep was found in 43.3% of the TMD group and in 28.3% of the controls ▪The mean scores on PSQI global and PSQI SQ were greater in the TMD group compared to controls ▪Sleep quality was positively associated with TMD disease characteristics, comorbid pain conditions, and poorer OHRQoL
Rener-Sitar et al,[8] 2016	Case-control	609 pain-related and dysfunctional pain TMD cases (85% female, mean age = 37.1 y, SD = 13.1)	88 non-TMD controls (88.6% female; mean ± SD age = 36.1 ± 12.7 y)	▪Axis I of the RDC/TMD for TMD diagnosis ▪PSQI and SQ assessment	▪Impaired SQ was present in 60.3% of the TMD cases and 40.9% of the control subjects ▪The mean PSQI values were different between TMD cases and controls ▪Mean PSQI scores did not differ across socio-demographic groups ▪In TMD cases without pain, the PSQI score was smaller in comparison to TMD cases with pain ▪For Axis II, as the symptoms of depression, somatization, chronic, and dysfunctional pain increased, SQ got worse

BDI = Beck Depression Inventory; BPI = Brief Pain Inventory; DASS-21 = Depression, Anxiety and Stress Scale-21; DC/TMD = Diagnostic Criteria for Temporomandibular Disorders; DD = disc displacement; EDS = excessive daytime sleepiness; EMG = electromyography; ESS = Epworth Sleepiness Scale; FSS = Fatigue Severity Scale; ICSD = International Classification of Sleep Disorders; ISI = Insomnia Severity Index; MFP = myofascial pain; MPI = Multidimensional Pain Inventory; OHRQoL = Oral health–related quality of life; PSG = polysomnography; OSA = obstructive sleep apnea; PSQI = Pittsburgh Sleep Quality Index; RDC/SB = Research Diagnostic Criteria for Sleep Bruxism; RDC/TMD = Research Diagnostic Criteria for Temporomandibular Disorders; RERA = respiratory effort-related arousals; SB = sleep bruxism; SCL-90-R = Revised Symptom Checklist-90; SQ = sleep quality; SF-AR = Score for Allergic Rhinitis German validated sleep questionnaire; SRSS = self-rating scale of sleep; STAI = State-Trait Anxiety Inventory.

criteria from the RDC/TMD or DC/TMD in all but 2 studies. Of those 2 studies, 1[41] used CBCT imaging for the assessment of degenerative bony changes in the TMJ, while the other[8] used both MRI and computed tomography. Additionally, two studies assessed TMDs with no explanation of the subtypes examined,[18,52] whereas the remaining studies considered diagnoses separately or in various permutations that were idiosyncratic to each study and which resulted in diagnostic heterogeneity. However, among the diagnostic permutations, a pain diagnosis or its absence was identifiable and allowed suitable reduction for the present systematic review.

The sleep disorder categories assessed were sleep-related movement disorders (mainly SB) and sleep-related breathing disorders (mainly OSA). Additionally, sleep quality (SQ) as an indirect measure of sleep efficiency and maintenance was evaluated using multiple types of self-administered questionnaires, with the majority utilizing the Pittsburgh Sleep Quality Index (PSQI).[56]

Due to the range of study designs and the complexity of the findings reported in this systematic review, a meta-analysis to explore the heterogeneity was considered beyond the scope of a single paper. A detailed description of the included studies is presented in Table 2.

Methodologic Quality Assessment of Included Studies

Table 3 presents the methodologic quality of each study. Five studies were judged to be of good qual-

Table 2 *(cont)* Design, Participants, Classification Methods, and Findings of the Studies Included

Study	Study design	Cases	Controls	Classification methods	Major study findings
Lei et al,[40] 2015	Cross-sectional	510 MFP TMD patients (mean age = 31.06 y, SD = 14.40)	–	▪RDC/TMD for TMD diagnosis ▪SRSS and DASS-21 for sleep disturbance and psychologic distress assessment	▪Patients with MFP showed significantly higher scores of distress than those without MFP ▪The prevalence of comorbidity of sleep disturbance with psychologic distress in patients with MFP was significantly higher than in patients without MFP ▪Sleep disturbance and psychologic distress symptoms such as anxiety are possible risk indicators for MFP
Sierwald et al,[49] 2015	Case-control	733 pain-related TMD patients (82% female, mean age = 41.4 y, SD = 16.3)	890 non-TMD controls (57% F, mean age = 40.4 ± 11.8 y)	▪Axis I of the RDC/TMD for TMD diagnosis (German version) ▪Self-report measurement of SB	▪Nocturnal clenching or grinding (SB) was reported by 23.5% of the controls and 49.4% of the TMD patients ▪SB is a significant risk factor for TMD pain, risk increased with simultaneous occurrence of awake bruxism and SB
Schmitter et al,[54] 2015	Case-control	22 MFP TMD patients (mean age = 45.0 y, SD = 13.6)	22 non-TMD controls (mean age = 45.2 ± 9.0 y)	▪RDC/TMD for TMD diagnosis ▪PSQI + SF-AR questionnaires for SQ assessment ▪Portable EMG device for SB assessment	▪PSQI score was higher in TMD group compared to controls ▪According to the SF-AR, the SQ score was higher in controls than in cases ▪According to the SF-AR, 23% of the controls and 14% of the TMD patients were "long sleepers" ▪Self-reported bruxism was much higher in the TMD group (86.1%) than in the controls (31.8%) ▪Using EMG data, muscle activity was not different between cases and controls ▪On the basis of episodes per hour, in the TMD group, 95% were bruxers compared to 68% in the control group
Dias et al,[41] 2015	Cross-sectional	45 female TMD patients with degenerative changes (mean age = 43 y, SD = 6.2)	–	▪Axis I of the RDC/TMD and bilateral CBCT imaging for TMD diagnosis ▪PSQI for SQ assessment ▪ICSD for the diagnosis of SB	▪75.6% had a poor SQ rating, while 24.4% were classified as having a good pattern of sleep ▪The presence of degenerative bone changes in the TMJ was observed in 67% of the poor SQ group, characterized by planning, osteophyte sclerosis, and erosion ▪Among those classified with good SQ, 81.8% had some type of degenerative bone change ▪There was no relationship between type of SB (centric, eccentric, or both) and presence of degenerative changes of the TMJ ($P = .277$)
Dubrovsky et al,[20] 2014	Case-control	124 females diagnosed with MFP TMD	46 control F	▪RDC/TMD Group I (with MFP) for TMD diagnosis ▪ESS questionnaire for assessment of sleepiness ▪PSG recordings for sleep and respiratory parameters	▪TMD cases had a greater number of awakenings and also showed almost twice as many arousals associated with all types of respiratory events (apneas, hypopneas, and RERA events) ▪TMD cases with chronic MFP showed a mild degree of objective sleep disturbance and a mild increase in upper airway resistance during sleep, and both appear to relate to acute MFP levels at night
Blanco Aguilera et al,[27] 2014	Cross-sectional	1220 TMD patients with muliptle subtypes (age range= 40-60y [38.6%], 18-29 y [21.8%], 30-40 y [21.5%])	–	▪RDC/TMD for TMD pain diagnosis ▪Self-report assessment of SB	▪The severity of acute pain was higher in the group with bruxism than in the group without bruxism ▪Perceived SB was more prevalent in the groups with a higher pain interference with activities of daily living ▪There was a strong relation between SB and painful symptoms of TMD, especially muscle disease accompanied by arthralgia ▪There was no association between the presence of disc displacements and SB

Table 2 *(cont)* Design, Participants, Classification Methods, and Findings of the Studies Included

Study	Study design	Cases	Controls	Classification methods	Major study findings
Sanders et al,[16] 2013	Prospective cohort, and case-control	2,604 participants in the cohort study (age range = 18–44 y) 1,614 participants with high likelihood of OSA in the case-control study	Random sample of 102 controls with low likelihood of OSA	▪RDC/TMD for TMD diagnosis ▪PSQI and the 4-item STOP screening questionnaire for OSA diagnosis	▪Within the prospective cohort, first-onset TMD was two times higher in the 60% of people with high likelihood of OSA relative to people with low likelihood of OSA ▪In the case-control study of chronic TMD, compared to controls, chronic TMD cases had threefold greater odds of high likelihood of OSA
Sener and Guler,[51] 2012	Case-control	130 TMD patients with MFP and DD (female = 81, male = 49; mean ages = 30.0 y and 31.0 y, respectively)	64 non-TMD controls (female = 32, male = 32; mean ages = 27.2 y and 27.5 y, respectively)	▪RDC/TMD for TMD diagnosis ▪PSQI for SQ assessment	▪SQ, sleep latency, habitual sleep efficiency, sleep disturbance, and PSQI total score were different between patients with MFP and controls ▪SQ was no different between patients with disc displacement and those with MFP or controls
Raphael et al,[50] 2012	Case-control	124 female patients diagnosed with MFP TMD (mean age = 39.2, SD = 14.6 y)	46 non-TMD controls	▪RDC/TMD for TMD diagnosis ▪Self-reports and PSG for SB assessment	▪19.6% of controls and 64.5% of cases grind their teeth at night ▪10.9% of controls and a statistically similar 9.7% of cases had high levels of SB activity ▪Pain duration was similar for patients with TMD with and without PSG evidence of SB
Fernandes et al,[42] 2012	Cross-sectional	272 painful TMD patients (87.5% female; mean ages = 36.9 y for female and 38.7 y for male)	58 controls with no painful TMD or SB diagnosis	▪Axis I of RDC/TMD for TMD diagnosis ▪Clinical diagnostic criteria proposed by American Academy of Sleep Medicine for the assessment of bruxism	▪The prevalence of SB was 62.9%, and 90.6% of those patients had painful TMD ▪There is an increased risk for MFP and arthralgia in individuals with self-reported SB ▪Patients with painful TMD showed increased risk for moderate to severe levels of depression and nonspecific physical symptoms, and this risk increased in the presence of SB
Smith et al,[19] 2009	Cross-sectional	53 MFP TMD patients (> 80% female, mean age = 33.6 y)	–	▪Axis I of RDC/TMD for TMD diagnosis ▪SQ assessed using: BPI, BDI, STAI, ISI, PSQI, FSS, and ESS ▪PSG for the presence of a sleep disorder ▪Laboratory pain testing	▪89% of participants met the criteria for at least one sleep disorder, and 43.4% were diagnosed with 2 or more sleep disorders ▪High rates were found for primary insomnia and sleep apnea ▪The data indicate a relationship between primary insomnia and hyperalgesia, suggesting the possibility that clinical insomnia may play a role in TMD and other central sensitivity syndromes
Cunali et al,[18] 2009	Cross-sectional	87 patients with mild to moderate OSA (female = 41, male = 46; mean age = 46 y, SD = 2.19) 45 TMD patients	–	▪RDC/TMD for TMD diagnosis ▪Diagnosis of OSA was done at a clinic according to clinical and PSG criteria proposed by the American Academy of Sleep Medicine ▪ESS for self-reported EDS	▪Of the 87 patients with mild to moderate OSA, 52% presented some type of sign and/or symptom of TMD ▪Prevalence of TMD was high among OSA patients referred for oral appliance therapy

BDI = Beck Depression Inventory; BPI = Brief Pain Inventory; DASS-21 = Depression, Anxiety and Stress Scale-21; DC/TMD = Diagnostic Criteria for Temporomandibular Disorders; DD = disc displacement; EDS = excessive daytime sleepiness; EMG = electromyography; ESS = Epworth Sleepiness Scale; FSS = Fatigue Severity Scale; ICSD = International Classification of Sleep Disorders; ISI = Insomnia Severity Index; MFP = myofascial pain; MPI = Multidimensional Pain Inventory; OHRQoL = Oral health–related quality of life; PSG = polysomnography; OSA = obstructive sleep apnea; PSQI = Pittsburgh Sleep Quality Index; RDC/SB = Research Diagnostic Criteria for Sleep Bruxism; RDC/TMD = Research Diagnostic Criteria for Temporomandibular Disorders; RERA = respiratory effort-related arousals; SB = sleep bruxism; SCL-90-R = Revised Symptom Checklist-90; SQ = sleep quality; SF-AR = Score for Allergic Rhinitis German validated sleep questionnaire; SRSS = self-rating scale of sleep; STAI = State-Trait Anxiety Inventory.

Table 2 *(cont)* Design, Participants, Classification Methods, and Findings of the Studies Included

Study	Study design	Cases	Controls	Classification methods	Major study findings
Benoliel et al,[55] 2009	Prospective cohort	328 patients with orofacial pain, TMD included (female = 221, male = 107; mean age = 43.8 y, SD = 17.7)	–	▪RDC/TMD for TMD diagnosis ▪Verbal self-reports for rates of pain-related awakening from sleep via a standardized question	▪29.8% of subjects complained of being regularly woken up from sleep by pain ▪Patients with pain-related awakenings showed significantly higher pain intensity than those without
Selaimen et al,[52] 2006	Case-control	72 TMD patients	30 non-TMD controls	▪RDC/TMD for TMD diagnosis ▪BDI (scores 0 to 63) for depression assessment ▪Validated PSG and 19-item self-administered sleep questionnaire for sleep assessment	▪TMD patients showed sleep scores 46.6% higher than controls ▪In the BDI, TMD patients had scores that were 59.2% higher than controls ▪Individuals considered to have sleep disorders had 5 times the risk of becoming TMD patients
Camparis and Siqueira,[43] 2006	Cross-sectional	100 SB patients (female = 80, male = 20; mean age = 36.1 y, SD = 11.3)	–	▪Axis I of the RDC/TMD and self-reports for TMD diagnosis ▪The EDOF-HC protocol to characterize orofacial pain (Orofacial Pain Clinic, Hospital das Clínicas) ▪Orthopantomography of the jaw	▪Self-reported RDC/TMD characteristics showed presence of diurnal tooth grinding/clenching, uncomfortable bite, morning stiffness, TMJ clicking, and ringing in ears ▪Statistical differences between long-standing bruxism with and without chronic facial pain
Camparis et al,[44] 2006	Cross-sectional	40 SB patients (female = 32, male = 8; mean age = 36.1 y, SD = 11.3) Group A: Bruxism with MFP TMD (n = 20) Group B: Bruxism without MFP TMD (n = 20)	–	▪Axis I of the RDC/TMD for TMD diagnosis ▪PSG for SB assessment	▪15% of patients in group A (bruxism with TMD) did not have any trouble falling asleep, whereas 85% did ▪In group B (bruxism without TMD), 55% did not have trouble falling asleep, and 45% did ▪In group A, 90% related restless or disturbed sleep; in group B, 60% related restless or disturbed sleep
Vazquez-Delgado et al,[45] 2004	Cross-sectional	67 with MFP TMD, 67 with intracapsular pain, 67 with chronic daily headache	–	▪Axis I of the RDC/TMD for TMD diagnosis ▪PSQI for SQ assessment	▪MFP groups revealed higher levels of psychologic distress than the chronic daily headache group and intracapsular pain group in most psychologic domains ▪SQ was significantly worse in the MFP group than in the daily headache and intracapsular pain groups
Yatani et al,[46] 2002	Cross-sectional	137 TMD patients with MFP, internal derangement, capsulitis/synovitis, osteoarthritis, and other (female = 124, male = 13; mean age = 36.25 y, SD = 11.81)	–	▪RDC/TMD for TMD diagnosis ▪PSQI for SQ assessment ▪MPI for chronic pain ▪Psychologic symptoms assessed using the SCL-90-R	▪No significant differences between good and poor sleepers for gender, age, primary diagnosis of TMD, pain duration, and self-reported pain severity ▪There is a positive relationship between sleep disturbance and pain severity in TMD patients ▪There is a positive relationship between sleep disturbance and psychologic symptoms in TMD patients

Table 3 Methodologic Quality Assessment of Included Studies

Study	Quality assessment[a]
Muzalev et al,[47] 2018	Good
Muzalev et al,[48] 2017	Fair
Benoliel et al,[53] 2017	Good
Rener-Sitar et al,[8] 2016	Fair
Lei et al,[40] 2015	Fair
Sierwald et al,[49] 2015	Fair
Schmitter et al,[54] 2015	Fair
Dias et al,[41] 2015	Fair
Dubrovsky et al,[20] 2014	Good
Blanco Aguilera et al,[27] 2014	Fair
Sanders et al,[16] 2013	Good[b]
Sener and Guler,[51] 2012	Fair
Raphael et al,[50] 2012	Fair
Fernandes et al,[42] 2012	Fair
Smith et al,[19] 2009	Fair
Cunali et al,[18] 2009	Fair
Benoliel et al,[55] 2009	Fair
Selaimen et al,[52] 2006	Good
Camparis et al,[44] 2006	Fair
Camparis and Siqueira,[43] 2006	Fair
Vazquez-Delgado et al,[45] 2004	Fair
Yatani et al,[46] 2002	Fair

[a]Using the National Health Heart, Lung, and Blood Institute quality assessment tools, quality was graded as good if the score > 8, fair if 5–7, and poor if 0–4.
[b]Scored using the tools for cohort and cross-sectional studies (score = 10) and case-control studies (score = 9) due to a mixed study design.

ity[16,20,47,52,53] and 17 to be of fair quality for different reasons.[8,18,19,27,40–46,48–51,54,55] Overall, all of the included studies clearly stated their research objectives and specified their inclusion and exclusion criteria. The participation rate of eligible subjects was greater than 50% across all studies. All studies clearly defined and described their sample populations; however, only 5 provided a justification for their sample sizes.[16,20,52–54] Ten studies measured and controlled for confounding factors,[16,19,20,27,40,46,47,49,52,53] while 12 studies did not.[18,40-45,48,50,51,54,55]

Association Between TMDs and SB

Ten studies assessed the relationship between TMDs and SB.[19,27,41–44,47–50] Of these 10 studies, 6 measured SB using self-report questionnaires,[27,41–43,47,49] 2 used laboratory PSG,[44,48] and 2[19,50] used both self-report questionnaires and PSG. The total sample size in these studies was 3,944 adults, including 1,031 healthy subjects recruited from the general population as controls and 2,913 individuals with different types of TMD. Of the 10 studies, 3 were case-control[48–50] and 7 were cross-sectional.[19,27,41–44,47]

In their case-control study, Sierwald et al[49] evaluated the association between painful TMDs and both self-reported SB (single question: grind or clench during sleep) and waking parafunction (single question: grind or clench during the day) as assessed using the standardized RDC/TMD symptom questionnaire. SB was reported by approximately 50% of the cases diagnosed with a TMD in comparison to only 24% of the controls. Their results also showed that the odds for painful TMD increased markedly with the presence of waking parafunction (odds ratio [OR] =2.9, 95% CI = 2.1, 3.8) and of SB (OR = 2.3, 95% CI = 1.8, 2.9). They also concluded that the risk for painful TMD was greatly increased in the simultaneous presence of waking parafunction and SB (OR = 7.7, 95% CI = 5.4, 11.1).

In their cross-sectional studies, Blanco Aguilera et al,[27] Fernandes et al,[42] and Camparis and Siqueira[43] evaluated the association between SB and several clinical subtypes of TMD such as myofascial pain, disc displacement, and arthralgia. Blanco Aguilera et al[27] found a high frequency of SB in patients with muscle pain accompanied by arthralgia. They also found a positive association between SB and women under the age of 60 who present with painful symptoms of a TMD. A similar association was found between SB and the presence of chronic pain. However, they found no significant association between SB and the presence of disc displacements. Fernandes et al[42] arrived at a similar conclusion of a strong relationship between SB and the occurrence of a painful TMD, especially those with myofascial pain (OR = 6.9, 95% CI = 3.6, 13.2; $P < .0001$) or arthralgia (OR = 6.9, 95% CI = 3.5, 14.0; $P < .0001$). Camparis and Siqueira[43] evaluated SB in 100 consecutive patients who were divided into two groups, those without orofacial pain (n = 30) and those with orofacial pain (n = 70). They found a greater frequency of SB with orofacial pain (82.8%) than SB without orofacial pain (60%, $P = .001$).

Six studies[19,41,44,47,48,50] reported either no association or a negative association between SB and painful TMD. Muzalev et al[48] investigated whether the interval between SB events is different between participants with and without painful TMD. They found that participants with painful TMD had fewer bruxism episodes than controls. They reported similar find-

ings in a subsequent cross-sectional study of 293 pain-related TMD patients who self-reported SB.[47] Camparis et al[44] characterized SB in consecutive patients with and without painful TMD and found a nonsignificant 20% higher frequency of bruxism episodes per hour of sleep in those without painful TMD (8 episodes) compared to those with pain (6.2 episodes). Raphael et al[50] assessed the relationship of PSG-determined SB in patients with myofascial TMD recruited from an orofacial pain clinic and in demographically matched non-TMD controls. A high level of SB activity was observed in 10% of the painful TMD cases and in 11% of the controls. The authors concluded that the commonly held belief that SB has an association with a myofascial TMD should be abandoned. Smith et al[19] characterized sleep disorder rate in 53 women with myofascial pain TMD and found that 73.6% of the sample had self-reported SB. Yet, when SB was assessed using PSG, the prevalence was found to be 17.3%. These findings, however, did not achieve statistical significance. Dias et al[41] assessed the presence of degenerative changes in the TMJ among 45 adult women diagnosed with SB and found no significant association between the different types of SB and TMD. Pushing the question further, an intensity gradient was investigated regarding the putative associations of self-reported SB and waking parafunction with painful TMD.[47] The intensity of painful TMD was not associated with SB and was only weakly associated with waking parafunction.

In summary, the evidence is conflicting regarding the relationship between TMDs and SB. Four studies found a positive association between SB and TMDs,[27,42,43,49] while the rest reported negative or no significant associations.[19,41,44,47,48,50]

Association Between TMDs and OSA

Four studies investigated the possible relationship between TMDs and OSA[16,18] with a combined sample of 6,164 adult subjects. In a prospective cohort and case-control study, Sanders et al[16] tested the hypothesis that signs and symptoms of OSA are associated with the occurrence of a painful TMD. In adults who were free of any diagnosed TMD at enrollment, signs and symptoms of OSA were associated with increased incidence of first-onset painful TMD; those adults who reported two or more signs/symptoms of OSA had a 73% greater incidence of first-onset painful TMD. In comparison to controls without a painful TMD, individuals with a chronic painful TMD had 3-fold greater odds of having OSA (OR = 3.0; 95% CI = 1.8, 5.0). Cunali et al[18] evaluated patients diagnosed with OSA who were seeking oral appliance therapy and found a high prevalence of unspecified TMD (52%). They emphasized the importance of conducting a structured TMD examination, such as with the RDC/TMD, and making it a routine part of OSA assessment. In a case-control study, Dubrovsky et al[20] evaluated sleep and respiratory disturbance in 124 myofascial pain TMD cases and in 46 demographically matched controls. They reported an increased frequency of respiratory effort–related arousals (RERAs) in the TMD group compared to the controls (4.3/hour vs 2.6/hour, respectively; $P = .02$). These results remained significant after adjusting for multiple confounders, including BMI and age (B = 1.13, SE = 0.43, $P = .01$). Additionally, they found arousals to be significantly elevated in TMD cases over controls (6/hr vs 3.5/hr, respectively; $P = .02$). Smith et al,[19] in their cross-sectional study of 53 TMD patients with myofascial pain, reported an OSA frequency of 28.4% among the sample, determined using PSG.

To summarize, current evidence, although limited, suggests a positive association between painful TMD and OSA.

Association Between TMDs and SQ

Twelve studies examined the SQ of subjects diagnosed with a TMD. Six were case-control,[8,20,51–54] five were cross-sectional,[19,40,41,45,46] and one was prospective cohort[55]; the total sample size was 2,767 subjects (2,351 with TMD and 416 non-TMD controls). SQ was examined using the PSQI in the majority of studies,[8,19,20,41,45,46,53,54] as listed in Table 2.

Schmitter et al,[54] Benoliel et al,[53] Dubrovsky et al,[20] Smith et al,[19] Vazquez-Delgado et al,[45] Selaimen et al,[52] and Lei et al[40] revealed that participants with a TMD suffered from poor sleep in comparison to healthy subjects. Benoliel et al[55] conducted a prospective cohort study in 328 patients with orofacial pain, including TMD as defined by the RDC/TMD, by asking a standardized question of whether pain awakened the patients from sleep. In their study, 29.8% of participants complained of being regularly woken from sleep by the pain. Rener-Sitar et al[8] investigated multiple subtypes of TMD in relation to SQ. The subtypes were myofascial pain with and without limited opening, disc displacement with reduction, disc displacement without reduction and without limited opening, arthralgia, and osteoarthrosis of the TMJ. Disc displacement diagnoses were based on MRI, and osteoarthrosis was based on computed tomography. They found poor SQ to be more frequent in the TMD cases (60.3%) compared to the controls (40.9%); in addition, SQ was worse in the TMD cases, with a mean PSQI score of 7.0 (95% CI = 6.7, 7.4), compared to 5.2 (95% CI = 4.6, 5.9) in controls. They also determined that SQ was poor in TMD cases with dysfunctional chronic pain (defined as chronic pain of grades III and IV using the Graded Chronic Pain Scale[57]). Sener and Guler[51] compared different subtypes of TMD (myofascial pain

[n = 65]; disc displacement with or without reduction [n = 65]) in relation to SQ and found poor SQ in TMD patients compared to controls, but found no significant differences among the distinct subtypes of TMD. Yatani et al[46] not only reported a significant association between poor SQ and a painful TMD, but also noted that psychologic symptoms were similarly associated.

The cross-sectional study by Dias et al[41] in adult women diagnosed with SB also evaluated the relation between SQ and TMD. The investigators found that 75.6% had poor SQ; however, they found no association between SQ and a painful TMD.

In summary, there is limited evidence supporting a positive association between TMDs and poor SQ.

Discussion

The possible relationship between TMDs and sleep disorders has been a compelling topic of research for the past decade. The objective of this systematic review was to shed light on this complex relationship. Overall, TMDs were shown to have a positive relationship with multiple types of sleep conditions, but the number of studies with acceptable quality was low, which limits the generalizability of their results.

Ten studies of fair to good quality assessed the relationship between TMD and SB. Four of the studies found a positive relationship between SB and the presence of TMD and its subtypes,[27,42,43,49] whereas the rest found that relationship to be reversed or nonexistent.[19,41,44,47,48,50] Six studies used a subjective measure via questionnaires,[27,41-43,47,49] two used an objective measure of SB via PSG,[44,48] and two[19,50] used both subjective and objective measures of SB. According to Raphael et al,[58] self-reported bruxism was not found to be a useful indicator of SB. Thus, an overestimation of the diagnosis of SB may have happened in the studies relying on self-report for the bruxism diagnosis, potentially leading to a biased association between TMD and SB in comparison to the results of the studies that used PSG. Moreover, several of those studies did not include noncase control groups[42,48]; instead, they included controls with pain-free TMD. When studies[49,50] that used non-TMD (healthy) controls were further scanned, the association between TMD and SB was still conflicting. In addition, it is unclear whether the observed positive associations were merely due to chance since the majority of the studies did not control for potential confounders such as psychologic comorbidities. Few[27,49] attempted to control for some confounders via logistic regression analyses and reported positive associations between TMD and SB. Future studies with high-quality designs are warranted to further elucidate this association while controlling for known confounders.

Future studies may also consider separating subtypes of painful TMD into myofascial pain and TMJ arthralgia. A recent study by Santiago and Raphael[59] compared SB among women with masticatory myofascial pain determined using the RDC/TMD criteria and subcategorized into muscle pain only and muscle and joint pain groups. The samples were compared to nonpainful TMD controls. They reported a significant positive association between SB and the muscle pain–only group (adjusted OR = 11.12, 95% CI = 2.56, 48.37), but not for the muscle and joint pain group. Thus, distinguishing types of painful TMD may yield different results and improve our understanding of the assumed associations between SB and TMDs.

The basis for diagnosis of disc displacements also affects potential bias in reported associations. For example, Blanco Aguilera et al[27] reported a positive but nonsignificant association between SB and disc displacement (OR = 1.23, 95% CI = 0.50, 3.21); the latter, however, was diagnosed using only the RDC/TMD clinical criteria. However, disc diagnosis via the RDC/TMD questionnaire has been shown to have poor validity[36] due to the possibility of misclassification bias, and therefore the use of MRI for disc diagnosis[60] would have improved the accuracy of disc position and form assessments.[61]

There was a surprisingly small number of studies evaluating the relationship between any TMD and OSA, and only four were included in this systematic review. Two studies[16,20] were of good quality, while the other two[18,19] were of fair quality. In their prospective cohort OPPERA (Orofacial Pain Prospective Evaluation and Risk Assessment) study, Sanders et al[16] followed a population free of TMD at enrollment and identified possible OSA using the 4-item STOP (snoring, tiredness during sleep, observed apnea, and high blood pressure) screening questionnaire. They measured the incidence of new signs and symptoms of TMD that would develop over time. Their findings strongly suggested that OSA contributes to the emergence of TMD signs and symptoms and thus suggests a close relationship between the two conditions. Similarly, their case-control study reported higher odds of OSA in patients with chronic TMD. This study had multiple strengths, including the prospective cohort design, the very large and population-based sample, the comprehensive OPPERA protocol, and the adjustment for potential known confounders. Yet, their study was limited by the subjective nature of OSA assessment via self-report questionnaires. The 2017 guidelines published by the American Academy of Sleep Medicine indicate that questionnaires must not be used to clinically diagnose OSA in the absence of a PSG study.[62] Consequently, generalizability of the findings from Sanders et al[16] to the individual patient is limited.

Cunali et al[18] arrived at a similar conclusion with their cross-sectional study. They found a high prevalence of TMDs in a population of patients referred from a sleep clinic for oral appliance therapy. Their OSA diagnosis was established using clinical and PSG criteria for mild to moderate OSA following the ICSD-2. However, the small sample size, the lack of a matched control group without an OSA diagnosis, the absence of association statistics, and the unspecified mixture of TMDs weakens their conclusions. In addition, selection bias may have resulted in an increased association between TMDs and OSA. Smith et al[19] conducted a study in 53 myofascial pain TMD patients and also found approximately one-third of the sample presenting with PSG-diagnosed OSA. However, their study was cross-sectional, had a small sample size, and did not include a separate control group for comparison. Dubrovsky et al[20] compared 124 myofascial pain TMD cases and 46 demographically matched controls and found the frequency of RERAs and arousals to be higher in the TMD cases than in the controls. However, the study reported no significant difference in Apnea Hypopnea index or Respiratory Disturbance Index between the cases and controls. This study was conducted in a woman-only sample, and thus the results cannot be generalized to other populations. Given the current small number of studies and the methodologic concerns, no conclusions could be made, and future studies are clearly warranted.

Overall, multiple studies have shown that TMDs are associated with poor SQ. Expectedly, an individual's sleep would be disrupted due to pain if they have a chronic pain condition. However, this relationship has been shown to be much more complex due to the lack of evidence on whether the association is reciprocal or unidirectional and the exact mechanisms that explain this association.

Both Rener-Sitar et al[8] and Sener and Guler[51] conducted case-control studies that measured SQ in relation to a few subtypes of TMD and demonstrated that among the cases with TMD, cases with Axis I painful TMD had more impaired sleep than cases with a TMJ problem that was pain-free. Agreeing with the above findings, Benoliel et al,[53] Dubrovsky et al,[20] Smith et al,[19] and Vazquez-Delgado et al[45] reported a positive association between TMD and poor SQ. These results, however, should be interpreted with caution. First, most of these studies used the PSQI as their primary measurement of SQ. While PSQI is a valid and reliable tool,[63–67] Grandner et al[68] described it as being more indicative of general dissatisfaction with sleep rather than any specific sleep-related disturbance. Second, multiple studies measured SQ in TMD cases only and failed to measure it in matched non-TMD controls, which could introduce bias.[19,41,45,46] Finally, an individual's SQ might be affected by other factors, such as familial history, comorbidities, lifestyle, or diet.[69] All these aforementioned reasons might have threatened the validity of the results, and thus the consistently positive association that was found between TMD and SQ may be overestimated. More cohort studies with low risk of bias are important to be executed in the future to identify whether there is a cause-effect relationship between the two conditions.

Conclusions

Evidence on the association between TMDs and SB is inconclusive. In spite of the fair to good quality of the four studies that reported a positive association between TMDs and OSA, no conclusions could be made about this outcome due to the limited evidence. There is consistent evidence to support a link between TMD and poor SQ. Research is indubitably lacking, and more longitudinal studies with a high level of evidence are necessary to further explore the causal relationship between TMDs and sleep disorders.

Key Findings

- TMDs are linked to poor sleep quality.
- The correlation of TMDs with SB and OSA is less clear.
- High-quality studies are severely needed to identify whether there is a cause-effect relationship between TMDs and sleep disorders.

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Appendix 1 Articles Excluded During Full-Text Review and Reasons for Exclusion

Article	Reason for exclusion
Lee and Kim,[1] 2020 Lei et al,[2] 2016 Drabovicz et al,[3] 2012 Nagamatsu-Sakaguchi et al,[4] 2008	Participants not adults
Muzalev et al,[5] 2020 Smardz et al,[6] 2019 Ey-Chmielewska et al,[7] 2014 Kato et al,[8] 2013 Collesano et al,[9] 2004	No diagnosis of TMDs using the RDC/TMD or DC/TMD or diagnostic criteria not met
de Resende et al,[10] 2019 Thymi et al,[11] 2019 Tavares et al,[12] 2016 Sanders et al,[13] 2016 Oliveira et al,[14] 2015 Fernandes et al,[15] 2013 Paesani et al,[16] 2013 Mundt et al,[17] 2011	Not relevant to the review
Jiménez-Silva et al,[18] 2017 Sommer et al,[19] 2015 Manfredini and Lobbezoo,[20] 2010	Systematic review
Bishop,[21] 2013 Lobbezoo and Lavigne,[22] 1997	Narrative literature review
Richman,[23] 2013	Unable to retrieve the full text
Tonial et al,[24] 2014	TMD inclusion criteria not clear
Zhao et al,[25] 2017 Xia et al,[26] 2016 Lei et al,[27] 2016 Martins et al,[28] 2016	Not translated into English

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