Comparison of Sleep Quality Deterioration by Subgroup of Painful Temporomandibular Disorder Based on Diagnostic Criteria for Temporomandibular Disorders

Yeon-Hee Lee (omod0209@gmail.com)
Kyung Hee University Dental Hospital
Q-Schick Auh
Kyung Hee University Dental Hospital

Research Article

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Abstract

This study investigated whether sleep deterioration in patients with painful temporomandibular disorder depends on the origin of pain, and also analyzed which clinical disease characteristics and whether psychological distress affected sleep quality. A total of 337 consecutive patients (215 women; mean age, 33.01 ± 13.01 years) with painful temporomandibular disorder (myalgia [n = 120], temporomandibular joint arthralgia [n = 62], mixed joint–muscle temporomandibular disorder pain [n = 155]) based on the diagnostic criteria for temporomandibular disorder were enrolled. They completed a battery of standardized reports on clinical sign and symptoms, and answered questions on sleep quality, excessive daytime sleepiness, and patients' psychological status. The mean global Pittsburgh Sleep Quality Index scores were significantly higher in the mixed temporomandibular disorder pain group (6.97 ± 3.38) and myalgia group (6.40 ± 3.22) than in the arthralgia group (5.16 ± 2.94) ($p = 0.001$). Poor sleepers were significantly more prevalent in the mixed temporomandibular disorder pain group (76.8%) and myalgia group (71.7%) than in the arthralgia group (54.8%) ($p = 0.006$). The presence of psychological distress in the myalgia group ($\beta = 1.236$, $p = 0.022$), global severity index of the Symptom Checklist-90-Revised in the arthralgia group ($\beta = 1.668$, $p = 0.008$), and presence of headache ($\beta = 1.631$, $p = 0.002$) and self-reported sleep problems ($\beta = 2.849$, $p < 0.001$) in the mixed temporomandibular disorder pain group were associated with an increase in the Pittsburgh Sleep Quality Index score. Because there is a difference in sleep quality and influencing factors according to the pain source of painful temporomandibular disorder, and the complex interplay between sleep and pain can vary, sophisticated treatment is required for patients.

Introduction

Humans sleep for a quarter to a third of their lifetime. Humans engage in certain productive activities while awake but obtain crucial health benefits during sleep, such as energy conservation, immune function regulation, homeostasis maintenance, memory consolidation, growth and recovery of the body, and psychological relaxation during sleep [1]. Therefore, good sleep quality is a key factor underlying good physical health, emotional well-being, daytime performance, and pain control. Vice versa, poorer sleep quality is predicted by higher pain severity, poorer brain functioning, and greater psychologic distress [2].

Temporomandibular disorder (TMD) is an umbrella term for heterogeneous pain and dysfunction in the temporomandibular joint (TMJ) and masticatory muscle regions. TMD has multifactorial etiologies and is best understood within a biopsychosocial framework. TMD is caused by the accumulation of daily microtraumas in the TMJ area due to parafunctional oral habits, such as bruxism and clenching, but macrotrauma, psychological distress, and sleep problems also make complicated contributions [3]. Approximately 39% of the population has at least one sign or symptom of a TMD, and 25% have pain related to a TMD [4]. Since the publication of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) in 1992, it has been used worldwide; in 2014, the Diagnostic Criteria for TMD (DC/TMD), a revised version that can be used for practical diagnosis in the clinical field, was published [5].

In TMD diagnosis based on the DC/TMD Axis I, myalgia and arthralgia of the TMJ are the two main sub-diagnoses of TMD.

The Pittsburgh Sleep Quality Index (PSQI) is an internationally widely used instrument for assessing self-perceived sleep quality and is well validated and reliable. According to previous RDC/TMD- and PSQI-based studies, poor sleep quality is found in 60.3% of patients with TMD, and the global PSQI score in painful TMD cases was statistically higher than that in non-painful TMD cases [6]. Yatani et al. reported that up to 90% of patients with TMD commonly report poor sleep quality [7]. Although the exact mechanism of the complex interaction between TMD pain and poor sleep remains under investigation, some researchers have suggested that painful TMD diagnoses and poor sleep quality are closely related [6]. In addition, arthralgia is described as a well-defined inflammatory process, chronic myalgia is caused by enigmatic pathophysiological mechanisms that are considered to be a pain syndrome. However, a newly developed DC/TMD-based studies of sleep quality in patients with painful TMD is lacking.

In general, chronic pain has a reciprocal relationship with poor sleep quality. Chronic pain has an underlying mechanism that involves a more complex relationship between physical, psychological, and social factors than acute pain [8]. TMD is a representative form of musculoskeletal pain in the orofacial area and is prone to being chronic, and myogenous TMD tends to cause chronic pain. It was found that sleep quality was significantly worse in TMD patients with myofascial pain than in patients with TMJ intracapsular pain [9]. In addition to poor sleep, psychosocial aspects were related to the pain experience in painful TMD cases [10]. Patients with myogenous TMD had more complex medical conditions, were more psychologically vulnerable, and had worse pain than patients with arthrogenous TMD [11]. Unfortunately, few studies have documented whether sleep quality differs according to the chronicity of symptoms, the number of DC/TMD sub-diagnoses, as well as the origin of TMD pain in patients.

Taken together, we hypothesized that sleep quality differs in patients with painful TMD depending on the origin of TMD pain (myalgia, arthralgia, and muscle–joint mixed TMD pain as defined in the DC/TMD), and sleep may be worse when there are multiple origins of pain. We analyzed the association between poor sleep quality and clinical disease characteristics, excessive daytime sleepiness, and psychological distress in patients with painful TMD. Controlling the risk factors for TMD is the first step in reducing healthcare costs and preventing TMD from becoming chronic, so it is worth analyzing the factors that contribute to poor sleep quality in patients with painful TMD.

Materials And Methods

1. Subjects

A total of 337 consecutive patients (215 women and 122 men; mean age, 33.01 ± 13.01 years) who visited the Department of Orofacial Pain and Oral Medicine of Kyung Hee University Dental Hospital (Seoul, South Korea) over a 6-month period from October 2020 and March 2021 for the management of

painful TMD were included in this study. All patients were examined by two experts who had specialized in orofacial pain and TMD diagnosis based on the DC/TMD criteria.

Exclusion criteria were as follows: (1) patients who were under 18 years of age, (2) patients who had other systemic muscular disorders (e.g., fibromyalgia, rheumatoid arthritis, inflammatory joint disease), (3) patients who had neurologic impairment or diseases (e.g., stroke, tumor, or epilepsy), (4) patients who were pregnant, (5) patients who had a history of psychiatric disorders, and (6) patients unable to provide informed consent.

The inclusion criteria were diagnosis of painful TMD according to the DC/TMD Axis I classification, and report of pain at the TMJ and/or masticatory muscles for at least 3 months. Patients also completed a comprehensive questionnaire that included, among others, the DC/TMD questionnaire, and an oral habits questionnaire. Patients with painful TMD were then divided into three groups as follows: pain of muscle origin (myalgia, n = 120), pain of joint origin (arthralgia, n = 62), and muscle–joint mixed TMD pain (mixed TMD pain, n = 155).

All participants provided written consent for the study, which was approved by the Ethical Committee of Kyung Hee University Dental Hospital (KHD IRB no. 1804-2). The study was conducted in accordance with the principles of the Declaration of Helsinki.

2. Data Collection

Experienced orofacial pain specialists conducted comprehensive clinical and radiographic examinations. TMD pain, sleep quality, psychological profile, and excessive daytime sleepiness were assessed using standard, validated, and reliable self-reported instruments administered at the initial evaluation.

2 – 1. Characteristics of Pain

The duration of pain derived from the TMJ and/or masticatory muscles is reported in days. Temporomandibular pain was scored by the patients subjectively, ranging from 0 (no pain at all) to 10 (worst pain imaginable) using a visual analog scale (VAS).

2-2. Contributing Factors and Comorbidities

We investigated self-reported parafunctional activities using the Oral Behavior Checklist, which includes jaw-related behaviors, such as teeth clenching and bruxism. The presence of headache was evaluated using the dichotomous question, “Do you have any headaches associated with TMD?” The presence of self-assessed tinnitus, psychological distress, and sleep problems was also reported with a binary answer. That is, each variable was recorded as a binary answer (yes/no) in all patients, as described in our previous study [12].

2-3. Sleep Quality Evaluation Using PSQI

Using the 19-item PSQI, a well-validated self-report questionnaire, sleep quality in the past month was assessed. The PSQI has seven components: subjective sleep quality, sleep latency, sleep duration, sleep

efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each subscale is weighted equally, scored from 0 (good sleep/no problems) to 3 (poor sleep/severe problems), summing to a global PSQI score (range, 0–21), with higher scores denoting worse sleep quality [13]. The PSQI was used to measure sleep quality. According to the recommended cutoff point of the PSQI (> 5), the patients in this study were categorized as good sleepers (score ≤ 5) and poor sleepers (score ≥ 6).

2-4. Assessment of Psychological Distress Using the Symptom Checklist-90-Revision

The Symptom Checklist-90-Revision (SCL-90R), a validated brief self-report psychometric inventory, has been used to evaluate psychological profiles [14]. It contains 90 items, and patients rated each item on a 5-point scale (not at all, 0; extremely, 4) for how much each problem had distressed or bothered them during the past 7 days. It yielded nine subscale scores, including somatization, obsessive-compulsive, interpersonal sensitivity, anxiety, depression, hostility, phobic anxiety, paranoid ideation, and psychoticism, along with three global indices of distress (Global Severity Index, Positive Symptom Distress Index, and Positive Symptom Total). Higher T-scores of the nine subscales and three global indices on the SCL-90R indicate a greater propensity to experience psychological distress.

2–5. Excessive Daytime Sleepiness Measured Using the Epworth Sleepiness Scale

The Epworth sleepiness scale (ESS) is a validated clinical tool for evaluating excessive daytime sleepiness (EDS) [15]. The ESS is an eight-item, self-administered questionnaire designed to measure the subject's propensity to fall asleep in a variety of situations. The participant was instructed to answer how likely it is that they would fall asleep in different situations by giving a score on a 4-point scale (0–3). Thus, the total score (the sum of scores of the eight items) of the ESS ranges from to 0–24. Higher scores represent a greater possibility that the individual will fall asleep during the daytime. Unlike other scales that measure sleepiness at a single time point, the ESS is designed to evaluate the general level of sleepiness. The ESS total scores were dichotomized into scores ≤ 10 and > 10; the latter was considered to represent clinically significant EDS. We used a score > 10 on the ESS to measure excessive sleepiness.

3. Statistical Analysis

The data were analyzed using SPSS Statistics for Windows, Version 26.0, (IBM Corp., Armonk, NY, USA). Continuous variables are presented as means and standard deviations (SD), and categorical variables are presented as frequencies and percentages. The inter-rater reliability between the two experts in the diagnosis of painful TMD was assessed using Cohen's kappa coefficient and was 0.91 for myalgia, 0.94 for arthralgia, and 0.92 for mixed TMD pain groups. If the same diagnosis was not given by the two experts, the patient was finally assigned to one TMD group following in-depth discussion. Differences between the three painful TMD groups were examined using the chi-squared test for categorical variables and t-test and one-way analysis of variance (ANOVA) with Tukey's post-hoc test for numeric variables. The chi-squared test with Bonferroni adjusted post hoc analysis was used to determine the equality of proportions. Spearman's correlation coefficients (r) for global PSQI scores with demographics, TMD pain severity, and psychological profiles were calculated, ranging from − 1 to + 1, with − 1 indicating a perfectly

linear negative correlation and + 1 indicating a perfectly linear positive correlation. Subsequently, assuming that the factors showing a significant correlation with the global PSQI score are predictors, multiple linear regression analysis with a stepwise method was conducted to explore significant predictors for increasing PSQI scores in patients with painful TMD. The estimated β was calculated using multiple linear regression analyses after adjusting for age. For all analyses, a two-tailed p-value of less than 0.05 was considered statistically significant.

Results

General Description

Table 1 presents the distribution of demographics, clinical characteristics, and contributing factors for the three TMD groups. A total of 382 patients diagnosed with painful TMD were included, and 45 patients were excluded because they lacked medical documentation. Finally, 337 patients (215 women [63.8%]; mean age, 33.01 ± 13.01 years) were assigned to the TMD group. The composition of patients in our study period with painful TMD according to the DC/TMD Axis I enrolled during the study period included 35.6% with myalgia, 18.4% with arthralgia, and 46.0% with mixed TMD pain. In other words, TMD pain of both muscular and articular origins was the most prevalent. The ratio of men to women was 1:1.76, and the proportion of women with myalgia (60.0%) or mixed TMD pain (80.0%) was significantly higher than the proportion with arthralgia (30.6%) ($p < 0.001$). TMD is thought to be sexual dimorphic and predominantly afflict women [16]. The age distribution was not significantly different between the three groups.

Table 1
Demographic characteristics of TMD patients

	Myalgia (n = 120)	Arthralgia (n = 62)	Mixed TMD pain (n = 155)		
Parameter	**n (%) or Mean ± SD**	**n (%) or Mean ± SD**	**n (%) or Mean ± SD**	**Post-hoc**	**p-value**
Demographics					
Age (years)	33.80 ± 13.36	31.93 ± 13.57	32.81 ± 12.55		0.636
Sex (female %)	72 (60.0)	19 (30.6)	124 (80.0)	1 > 2, 2 < 3	**< 0.001*** **
Clinical characteristics					
VAS	4.49 ± 2.77	4.97 ± 2.54	5.71 ± 1.93	1 < 3, 2 < 3	**< 0.001*** **
Mouth opening limitation	8 (6.7)	10 (16.1)	20 (12.9)		0.115
Symptom duration (days)	524.35 ± 2010.22	272.94 ± 469.26	620.59 ± 1171.99	1 > 2, 2 < 3	**0.044***
Contributing factors					
Bruxism	35 (29.2)	21 (33.9)	54 (34.8)		0.594
Clenching	49 (40.8)	23 (37.1)	74 (47.7)		0.284
Macrotrauma history	6 (5.0)	4 (6.5)	12 (7.7)		0.659
Tinnitus	**34 (28.3)**	9 (14.5)	**48 (31.0)**	2 < 1, 2 < 3	**0.044***
Headache	**45 (37.5)**	17 (27.4)	**99 (63.9)**	1 < 3, 2 < 3	**< 0.001*** **
Psychological distress	66 (55.0)	30 (48.4)	91 (58.7)		0.381
Self-reported sleep problem	42 (35.0)	19 (30.6)	57 (36.8)		0.694

The results were obtained from $\chi 2$ test with Bonferroni adjusted post hoc analysis and the mean difference between groups was obtained by ANOVA) with Tukey's post-hoc test. p-Value significance was set at < 0.05. *: p-value < 0.05, **: p-value < 0.01, ***: p-value < 0.001. TMD: temporomandibular disorder, VAS: visual analogue scale, SD: standard deviation, 1 in Post-hoc test: the mean value of myalgia group, 2 in Post-hoc test: the mean value of arthralgia group, 3 in Post-hoc test: the mean value of mixed TMD pain group.

The VAS score was significantly higher in patients with mixed TMD pain (5.71 ± 1.93) than in those with arthralgia (4.97 ± 2.54) and myalgia (4.49 ± 2.77) ($p < 0.001$). There was no significant difference in the frequency of mouth opening limitation between groups. The mean symptom duration was significantly longer in the myalgia (524.35 ± 2010.22 days) and mixed TMD pain groups (620.59 ± 1171.99 days) than in the arthralgia group (272.94 ± 469.26 days) ($p = 0.044$). Considering the contributing factors, the prevalence of tinnitus and headache were significantly higher in the myalgia and mixed TMD pain groups than in the arthralgia group ($p < 0.05$). The prevalence of bruxism, clenching, macrotrauma history, and psychological distress did not differ significantly between the TMD groups. There was no significant difference in the presence of self-reported sleep problems between the myalgia (35.0%), arthralgia (30.6%), and mixed TMD groups (36.8%) ($p = 0.694$). Psychological distress was observed in 55.4% of patients with painful TMD and was the most frequently observed contributing factor in all three groups, whereas a history of macrotrauma was only present in 6.5% and the least observed factor in all three groups.

PSQI in Patients with Painful TMD

The distribution of PSQI global scores for patients with painful TMD and the proportion of poor sleepers is shown in Table 2.

Table 2
Comparison of Pittsburgh Sleep Quality Index (PSQI) between TMD groups

	Myalgia (n = 120)	Arthralgia (n = 62)	Mixed TMD pain (n = 155)		
Parameter	**n (%) or Mean ± SD**	**n (%) or Mean ± SD**	**n (%) or Mean ± SD**	**Post-hoc**	**p-value**
PSQI					
Component 1: Subjective sleep quality (0–3)	1.28 ± 1.16	1.19 ± 1.40	1.52 ± 1.24		0.108
Component 2: Sleep latency (0–3)	0.83 ± 0.75	0.77 ± 0.76	0.97 ± 0.71		0.118
Component 3: Sleep duration (0–3)	0.92 ± 1.03	0.55 ± 0.72	0.88 ± 0.97	1 > 2, 3 > 2	**0.035***
Component 4: Sleep efficiency (0–3)	0.57 ± 0.98	0.18 ± 0.46	0.46 ± 0.89	1 > 2, 3 > 2	**0.016***
Component 5: Sleep disturbances (0–3)	1.22 ± 0.61	1.11 ± 0.66	1.35 ± 0.62	3 > 2	**0.023***
Component 6: Use of sleep medication (0–3)	0.14 ± 0.54	0.03 ± 0.25	0.19 ± 0.59		0.147
Component 7: Daytime dysfunction (0–3)	1.44 ± 0.91	1.32 ± 0.92	1.59 ± 0.86		0.100
PSQI global score (0–21)	6.40 ± 3.22	5.16 ± 2.94	6.97 ± 3.38	1 > 2, 3 > 2	**0.001****
Poor sleeper (PSQI global score ≥ 5)	86 (71.7)	34 (54.8)	119 (76.8)	1 > 2, 3 > 2	**0.006****

The results were obtained from $\chi 2$ test with Bonferroni adjusted post hoc analysis and the mean difference between groups was obtained by ANOVA) with Tukey's post-hoc test. p-Value significance was set at < 0.05. *: p-value < 0.05, **: p-value < 0.01. TMD: temporomandibular disorder, VAS: visual analogue scale, SD: standard deviation, 1 in Post-hoc test: the mean value of myalgia group, 2 in Post-hoc test: the mean value of arthralgia group, 3 in Post-hoc test: the mean value of mixed TMD pain group.

Based on the PSQI, poor sleep quality was more pronounced in patients with painful TMD with pain of both joint and muscle origin than in those with only one pain origin. Overall, the PSQI global score was also significantly higher in the myalgia and mixed TMD pain groups than in the arthralgia group, and the frequency of poor sleepers was significantly higher in the myalgia and mixed TMD groups than in the arthralgia group (all $p < 0.05$).

A significant proportion (70.9%) of patients with painful TMD were poor sleepers, and the proportion of poor sleepers was significantly higher among patients with myalgia (71.7%) and mixed TMD pain

(76.8%) than among patients with arthralgia (54.8%). The factors affecting sleep quality differed between the three TMD groups. Sleep disturbance occurred more frequently in patients with myalgia than in those with arthralgia, and sleep deterioration was more severe in patients with both diagnoses.

Psychological Distress in Patients with Painful TMD

Table 3 shows the psychological profiles of patients with painful TMD. Of the nine subdimensions of the SCL-90R, there were significant differences in the mean values of all items except for hostility. Interestingly, the T-scores for somatization, obsessive-compulsive, interpersonal sensitivity, and paranoid ideation were not significantly different between the myalgia and arthralgia groups but were significantly higher in patients with mixed TMD pain than in those with only myalgia or arthralgia. In addition, the mean T-scores for depression, anxiety, phobic ideation, and psychoticism were significantly higher in the mixed TMD pain group than in the myalgia group (all $p < 0.05$).

Table 3
Comparison of psychological profile with SCL-90R and excessive sleepiness scale between TMD groups

	Myalgia (n = 120)	Arthralgia (n = 62)	Mixed TMD pain (n = 155)		
Parameter	**n (%) or Mean ± SD**	**n (%) or Mean ± SD**	**n (%) or Mean ± SD**	**Post-hoc**	**p-value**
SCL-90R					
Somatization	45.75 ± 7.39	45.50 ± 8.67	48.59 ± 9.59	1 < 3, 2 < 3	**0.009****
Obsessive-compulsive	43.65 ± 9.60	42.69 ± 10.04	46.54 ± 10.83	1 < 3, 2 < 3	**0.015***
Interpersonal sensitivity	43.67 ± 9.46	43.71 ± 10.17	46.75 ± 10.81	1 < 3, 2 < 3	**0.024***
Depression	45.99 ± 30.31	44.16 ± 11.08	46.86 ± 11.85	1 < 3	0.676
Anxiety	43.77 ± 7.09	44.44 ± 9.04	46.53 ± 9.86	1 < 3	**0.029***
Hostility	44.61 ± 7.45	45.56 ± 9.04	50.83 ± 35.94		0.098
Phobic anxiety	44.10 ± 4.62	45.55 ± 8.06	47.00 ± 9.97	1 < 3	**0.013***
Paranoid ideation	43.16 ± 8.85	43.06 ± 8.32	45.90 ± 10.12	1 < 3, 2 < 3	**0.026***
Psychoticism	43.23 ± 6.66	44.56 ± 9.35	45.46 ± 9.28	1 < 3	0.098
Global severity index	43.05 ± 7.89	43.40 ± 10.19	46.44 ± 10.96	1 < 3, 2 < 3	**0.010***
Positive symptom distress	45.72 ± 7.44	45.45 ± 8.30	47.62 ± 9.46		0.104
Positive symptom total	41.79 ± 10.56	41.10 ± 12.13	45.01 ± 11.57	1 < 3, 2 < 3	**0.020***
ESS					

The results were obtained from $\chi 2$ test with Bonferroni adjusted post hoc analysis and the mean difference between groups was obtained by ANOVA with Tukey's post-hoc test. p-Value significance was set at < 0.05. *: p-value < 0.05, **: p-value < 0.01. TMD: temporomandibular disorder, VAS: visual analogue scale, SD: standard deviation, ESS: Epworth sleepiness scale, 1 in Post-hoc test: the mean value of myalgia group, 2 in Post-hoc test: the mean value of arthralgia group, 3 in Post-hoc test: the mean value of mixed TMD pain group.

	Myalgia (n = 120)	Arthralgia (n = 62)	Mixed TMD pain (n = 155)		
Sitting and reading (0–3)	0.98 ± 0.83	0.95 ± 0.69	1.07 ± 0.74		0.483
Watching TV (0–3)	0.68 ± 0.74	0.58 ± 0.67	0.72 ± 0.67		0.400
Sitting, inactive in public place (0–3)	0.55 ± 0.61	0.61 ± 0.66	0.75 ± 0.74	1 < 3	**0.042***
As a passenger in a car for an hour without a break (0–3)	1.18 ± 0.90	1.08 ± 0.84	1.41 ± 0.90	1 < 3, 2 < 3	**0.017***
Lying down to rest in the afternoon when circumstances permit (0–3)	1.33 ± 0.85	1.44 ± 0.88	1.69 ± 0.92	1 < 3	**0.002****
Sitting and talking to someone (0–3)	0.32 ± 0.59	0.18 ± 0.39	0.39 ± 0.64		0.058
Sitting quietly after a lunch without alcohol (0–3)	1.14 ± 0.87	1.26 ± 0.79	1.48 ± 0.85	2 < 3	**0.004****
In a car, while stopped for a few minutes for traffic (0–3)	0.38 ± 0.55	0.45 ± 0.69	0.52 ± 0.70		0.243
ESS total score (0–24)	6.56 ± 3.56	6.55 ± 3.50	8.04 ± 3.82	1 < 3, 2 < 3	**0.001****
ESS total score ≥ 10 (Excessive daytime sleepiness)	23 (19.2)	12 (19.4)	46 (29.7)		0.082

The results were obtained from $\chi 2$ test with Bonferroni adjusted post hoc analysis and the mean difference between groups was obtained by ANOVA with Tukey's post-hoc test. p-Value significance was set at < 0.05. *: p-value < 0.05, **: p-value < 0.01. TMD: temporomandibular disorder, VAS: visual analogue scale, SD: standard deviation, ESS: Epworth sleepiness scale, 1 in Post-hoc test: the mean value of myalgia group, 2 in Post-hoc test: the mean value of arthralgia group, 3 in Post-hoc test: the mean value of mixed TMD pain group.

EDS in Patients with Painful TMD

The total ESS score was significantly higher in the mixed TMD pain group (8.04 ± 3.82) than in the myalgia (6.56 ± 3.56) and arthralgia groups (6.55 ± 3.50) (p = 0.01), whereas the proportion of patients experiencing EDS (ESS > 10) did not differ significantly between the three groups (myalgia: 19.2%, arthralgia: 19.4%, mixed TMD pain: 29.7%).

The daytime sleepiness score was higher among patients with mixed TMD pain than in those with myalgia under two conditions: sitting inactive in a public place and lying down to rest in the afternoon when circumstances permit. In the condition of sitting quietly after lunch without alcohol, the degree of daytime sleepiness in the mixed TMD pain group was higher than that in the arthralgia group. In the case

of being a passenger in a car for an hour without a break, daytime sleepiness was higher in the mixed TMD group than in the myalgia and arthralgia groups. However, there was no significant difference between groups in the degree of daytime sleepiness in the following four conditions: sitting and reading, watching TV, sitting and talking to someone, and stopping for a few minutes in traffic in a car.

Correlations between PSQI Global Scores and Other Factors

Figure 1 shows the results of Spearman's correlation analysis between the PSQI global scores and all other variables examined in this study. The specific related factors and their correlation strengths were different for each group. In the myalgia group, psychological distress ($r = 0.306$, $p < 0.001$) strongly correlated with PSQI global score. In the mixed TMD pain group, tinnitus ($r = 0.195$, $p = 0.015$) and headache ($r = 0.293$, $p = 0.001$) significantly correlated with PSQI global score. Self-reported sleep problems investigated using dichotomous questions positively correlated with the PSQI global score in all three groups (myalgia: $r = 0.552$, $p < 0.001$; arthralgia: 0.359, $p = 0.004$; mixed TMD pain: $r = 0.486$, $p < 0.001$).

The correlation between the PSQI global score and psychological profiles was remarkable. The psychological profiles of the three groups significantly correlated with sleep quality. Regarding the nine subscales of the SCL-90R, all nine subscales correlated with an increase in PSQI global scores, and all subscales excluding hostility significantly positively correlated with PSQI global scores in the mixed TMD pain group. Total ESS scores significantly positively correlated with PSQI global scores only in the arthralgia group ($r = 0.303$, $p = 0.017$).

In all three groups, demographics such as age and sex, VAS, and mouth opening limitation did not show any significant relationship with PSQI global scores.

Predicting the Factors Influencing Sleep Quality

Following the Spearman's correlation analysis, multiple linear regression analysis was performed on 17 predictor variables that significantly correlated with the PSQI global score (Fig. 2). Regarding contributing factors, increased PSQI global scores were predicted by psychological distress ($\beta = 1.236$, $p = 0.022$) and self-reported sleep problems ($\beta = 3.115$, $p < 0.001$) in the myalgia group, and headache ($\beta = 1.631$, $p = 0.002$) and self-reported sleep problems ($\beta = 2.849$, $p < 0.001$) in the mixed TMD pain group. The existence of self-reported sleep problems expressed as a dichotomy (yes or no) was strongly associated with the PSQI global score. In arthralgia, the global severity index of the SCL-90R was a predictor of the PSQI global score only in the arthralgia group ($\beta = 1.668$, $p = 0.008$).

Discussion

Clinical characteristics differed according to TMD diagnosis based on DC/TMD, and their effect on sleep quality also differed according to the origin of TMD pain. TMD is an umbrella term, and the signs and symptoms of patients with TMD are diverse. As mentioned above, painful TMD is not only observed in

patients with myalgia, arthralgia, and mixed TMD pain, but also in patients with aggravated psychological pain as determined by DC/TMD Axis II [17]. Poor sleepers accounted for 70.9% of patients with painful TMD, and the proportion of poor sleepers was significantly higher in the myalgia (71.7%) and mixed TMD pain groups (76.8%) than in the arthralgia group (54.8%). The proportion of poor sleepers was previously reported to be 60.3% among patients with TMD, regardless of the presence of pain [6]. The PSQI global score was also significantly higher in the myalgia and mixed TMD pain groups than in the arthralgia group, indicating that pain originating from the muscles interfered with sleep quality more than pain originating from the joints. Although few studies have reported that the severity of sleep quality varies with painful TMD sub-diagnosis according to the DC/TMD, our results suggest that sleep and related clinical factors vary between different groups of TMD.

An in-depth discussion on the reason for the difference in sleep quality according to the origin of TMD pain is needed. While myalgia and arthralgia are subgroups under the collective term of TMD, muscle pain differs in many ways from joint pain; their causes, underlying mechanisms, subjective features, and treatment strategies are inevitably different. Among TMD sub-diagnoses, arthralgia is accompanied by a well-defined inflammatory process mediated by various inflammatory cytokines, whereas chronic myalgia presents an enigmatic pathophysiological mechanism [18]. Muscle pain is poorly localized and has a pressing quality, marked tendency towards referral of pain, and more affective aspect; arthralgia is well-localized and has a stabbing quality, no tendency toward referral of pain, and less affective aspect. Central sensitization and neuropathic features can contribute to progressive pain in patients with advanced osteoarthritis [19]. However, central sensitization has been researched more in terms of muscle pain. Central sensitization may play a fundamental role in abnormal and widespread pain sensitivity in patients with myalgia [20].

Unlike arthralgia, myalgia is often accompanied by changes in psychological state. In general, psychosocial factors, such as depression and tension personality, are more frequently observed in patients with myogenous TMD [21]. Anxiety and stress-related bruxism activity are positively associated with myogenous TMD pain [21]. Therefore, analgesic and anti-inflammatory drugs are prescribed for arthrogenous pain; however, antidepressants, anticonvulsants, and muscle relaxants are commonly prescribed for myogenous pain. In addition, widespread muscle pain has many comorbid symptoms besides musculoskeletal pain, such as sleep difficulties, fatigue, dizziness, paresthesia, cognitive dysfunction, and symptoms from overlapping conditions such as headaches, irritable bowel syndrome, and restless leg syndrome [22]. However, studies on etiopathology and underlying mechanisms according to TMD sub-diagnosis based on the DC/TMD are extremely limited, and more detailed studies are needed.

As hypothesized, sleep was more disturbed in the mixed TMD pain group with both joint- and muscle-derived pain than in those with pain from a single origin. This suggests that when symptoms are complex with multiple origins of pain, psychological aspects can be more vulnerable to poor sleep quality. According to Trivedi et al., as the number of physical symptoms a patient has increases, the morbidity of depression also increases [23]. When there are multiple causes of TMD pain, the psychological aspects can

be more complex. Patients with multiple TMD diagnoses have higher rates of depression and somatization [24]. Manfredini et al. reported a tendency to have higher SCL-90-R scores in patients with myofascial pain combined with TMJ pain than in those with TMJ pain alone [25]. However, Reissmann et al. reported that the location of pain in TMD patients was not a major factor when predicting psychosocial profiles and current pain severity [26]. Regarding chronicity, symptom duration was significantly longer in the myalgia and mixed TMD pain groups than in the arthralgia group in this study. The discrepancy between our results and those of Reissmann et al. might be explained by the fact that they did not consider symptom duration and pain chronicity as the study's main variables.

The chronicity of TMD symptoms is closely linked to poor sleep quality in patients with painful TMD. As acute pain progress to the chronic phase, psychosocial factors and the central pain control system can be more impaired. More specifically, the mixed TMD pain group had the most patients with chronic status among the three TMD groups, and the myalgia group had more patients with chronic pain status than the arthralgia group. This result suggests that chronic pain can further distort and worsen sleep. The prevalence of chronic pain ranges from 10–40% [27], which is similar to the prevalence of sleep disorders (10–36%) [28]. Sleep disorders have been found to affect 88% of patients with chronic pain [29]. Conversely, more than 40% of patients with sleep disorders report chronic pain [30]. Considering the chronicity of TMD pain, sleep problems should be further studied in patients with painful TMD.

In general, the relationship between pain and poor sleep phenomena is bidirectional since disturbed sleep affects pain perception by lowering the pain threshold, and patients with pain have poor sleep in terms of sleep efficiency, sleep latency, and awakenings after sleep onset [31]. Therefore, optimal TMD pain management should consider both phenomena. Furthermore, both chronic pain and sleep disturbances share an array of psychological health issues. Although the degree of correlation varied between the painful TMD groups, the T-score of the nine parameters of the SCL-90R positively correlated with the PSQI global score. Chronic pain and sleep problems have psychological comorbidities, especially depression [32]. Regarding changes in the brain, dysregulation of neurotransmitters in the brain is linked to both chronic pain and depression, and this linkage makes pain patterns more complex and exacerbates pain [33]. Chronic pain is also related to anatomical alterations in brain regions involved in cognitive and emotional modulation of pain [34]. Thus, there may be a brain circuit that responds differently to noxious stimuli in patients with chronic painful TMD compared to those with acute TMD or non-painful TMD. These complex interactions may explain why patients with TMD pain of mixed origin develop psychological distress and are at increased risk of sleep problems and central amplification of pain.

Female sex is a major risk factor for chronic pain and poor sleep quality. In the myalgia and mixed TMD pain groups, the proportion of women was higher than that in the arthralgia group. Women are more exposed to chronic pain than men and are more prone to co-occurrence of chronic pain with depression and anxiety [8]. In a previous study using the SCL-90R in TMD patients, depression and somatization scales were higher in women than in men [35]. In addition, there is a tendency for increased prevalence of tinnitus in patients with chronic pain [36]. In the present study, the prevalence of tinnitus and headache was

highest in the mixed TMD pain group. Chronic pain and tinnitus have several similarities and are frequently associated with hypersensitivity to sensory stimuli. Both are abnormal and variable subjective sensations, often not fully explained by initial peripheral lesions; thus, they are referred to as phantom sensations. Moreover, patients suffering from these two conditions often share the same psychological traits with an increased propensity for anxiety and depression [37,38]. Although research on the exact mechanism is needed, the overlap of pain and psychological distress is particularly pronounced in patients with chronic pain and headache [39].

Successful TMD treatment is possible by considering sleep quality in painful TMD. As sleep problems can be the underlying factors for the onset and development of TMD along with psychosocial profiles, these factors should be examined along with clinical symptoms in patients with painful TMD. In addition to conventional treatment strategies, sleep education, interdisciplinary care with sleep experts, and several psychological approaches, such as biofeedback, stress management, and relaxation training, may be effective in the management of myogenous TMD and mixed TMD pain. Until now, the association between sleep bruxism and TMD has been continuously studied [40]. However, sleep itself and overall sleep quality and quantity in patients with painful TMD based on the DC/TMD have rarely been evaluated. Global efforts are needed to present treatment guidelines for each subgroup according to the DC/TMD as much as efforts to increase the accuracy of subgroup diagnosis.

Our study has several limitations. We did not use investigations such as polysomnography (PSG) or actinography, which are considered the gold standard for sleep evaluation. Especially, PSG presents the results of objectively measuring various aspects of sleep. However, PSG has a weakness in that it cannot be performed in a comfortable environment, such as at home where the patient sleeps every day. Thus, it only reflects the results obtained in the laboratory for just a few days. In addition, there are physical and time limitations for PSG-based research in many patients. Our study was designed as a retrospective study to investigate the conditions under which sleep quality deteriorates in patients with painful TMD; therefore, the causal relationship cannot be clarified. It merely suggests statistically related factors. However, we assessed the sleep of 337 patients with painful TMD using the PSQI, a sophisticated and reliable questionnaire. Subsequent large-scale longitudinal studies and prospective study designs are needed to clarify our findings.

Declarations

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Institutional Review Board Statement: The research protocol was reviewed in compliance with the Helsinki Declaration and approved by the Institutional Review Board of the Kyung Hee University Dental Hospital (KHD IRB no. 1804-2).

Informed consent statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Since these are patient data, if there is a request for data disclosure, the KHU-IRB will discuss the request before disclosure.

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Conflicts of Interest: The authors declare no conflict of interest.

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Figures

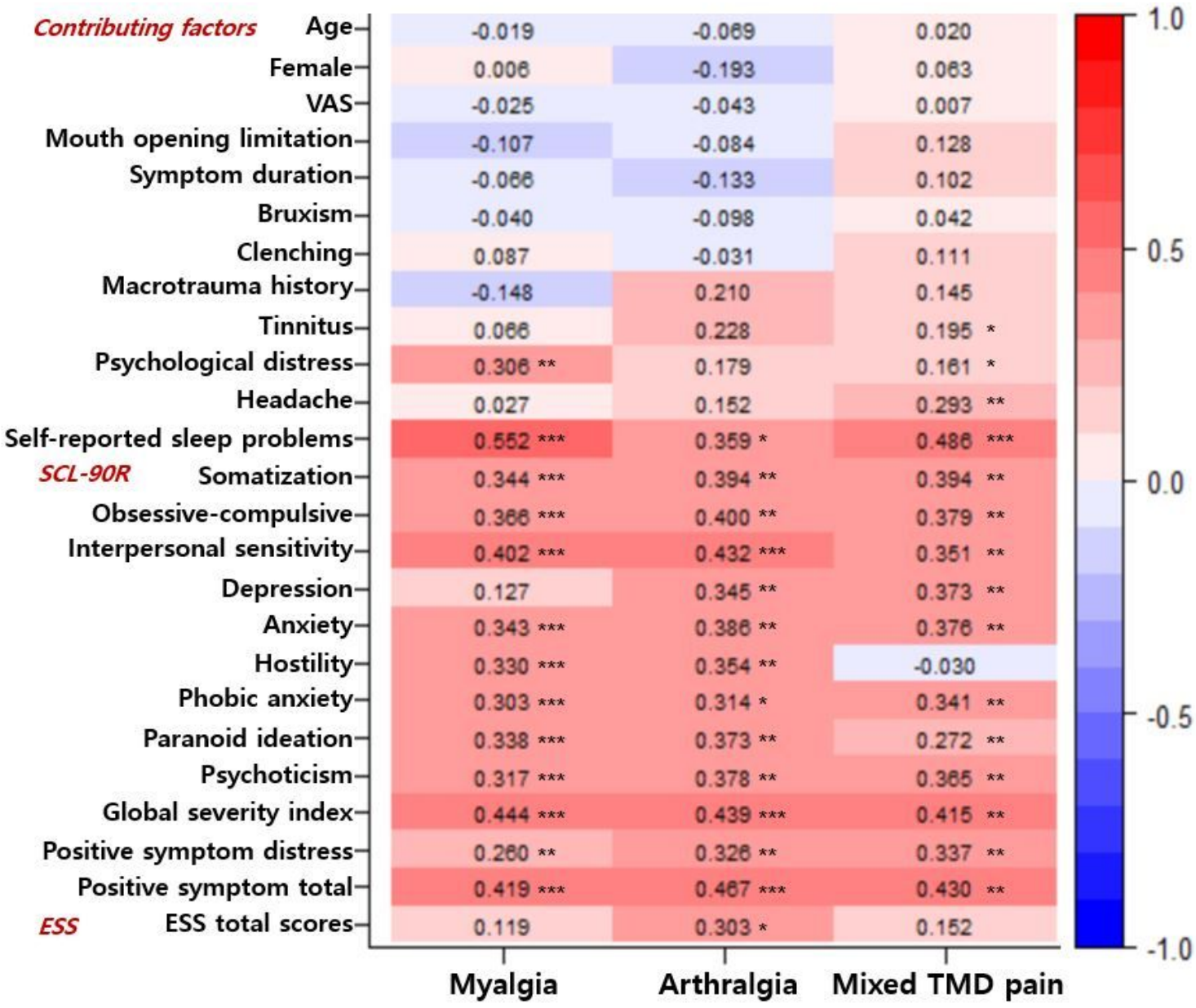
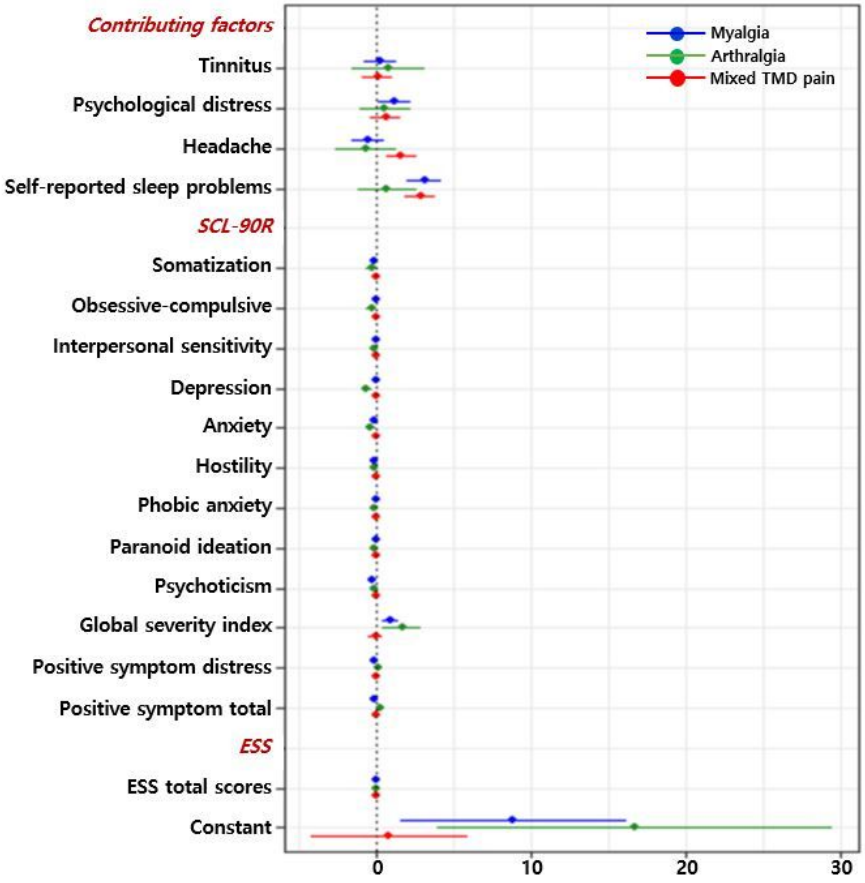


Figure 1

Correlations of PSQI global scores with clinical characteristics and contributing factors for TMD. P-value was considered as significant when p-value < 0.05 (*: p < 0.05, **: p < 0.01, ***: p < 0.001).



	Myalgia β (lower CI, upper CI)	Arthralgia β (lower CI, upper CI)	Mixed TMD pain β (lower CI, upper CI)
Tinnitus	0.224(-0.849, 1.297)	0.797(-1.529, 3.123)	0.07(-0.948, 1.088)
Psychological distress	1.236(0.181, 2.291)	0.594(-0.987, 2.176)	0.602(-0.332, 1.536)
Headache	-0.521(-1.554, 0.512)	-0.594(-2.569, 1.382)	1.631(0.614, 2.649)
Self-reported sleep problems	3.115(2.036, 4.194)	0.691(-1.200, 2.582)	2.849(1.841, 3.857)
SCL-90R			
Somatization	-0.086(-0.211, 0.039)	-0.311(-0.591, -0.030)	0.011(-0.095, 0.117)
Obsessive-compulsive	-0.043(-0.142, 0.055)	-0.288(-0.593, 0.017)	0.025(-0.103, 0.153)
Interpersonal sensitivity	-0.047(-0.192, 0.099)	-0.104(-0.334, 0.126)	0.015(-0.098, 0.128)
Depression	0.002(-0.014, 0.018)	-0.602(-0.969, -0.234)	0.041(-0.038, 0.120)
Anxiety	-0.171(-0.325, -0.017)	-0.339(-0.646, -0.032)	-0.049(-0.190, 0.093)
Hostility	-0.180(-0.319, -0.041)	-0.164(-0.372, 0.045)	-0.011(-0.024, 0.001)
Phobic anxiety	-0.013(-0.151, 0.126)	-0.131(-0.287, 0.024)	0.022(-0.054, 0.097)
Paranoid ideation	-0.062(-0.158, 0.034)	-0.174(-0.440, 0.092)	-0.004(-0.090, 0.082)
Psychoticism	-0.196(-0.381, -0.012)	-0.095(-0.386, 0.197)	-0.004(-0.142, 0.134)
Global severity index	0.968(0.423, 1.513)	1.668(0.459, 2.877)	-0.006(-0.459, 0.446)
Positive symptom distress	-0.092(-0.217, 0.033)	0.081(-0.140, 0.302)	-0.009(-0.160, 0.143)
Positive symptom total	-0.150(-0.338, 0.037)	0.228(-0.029, 0.484)	0.038(-0.109, 0.185)
ESS			
ESS total scores	-0.036(-0.174, 0.103)	0.065(-0.184, 0.315)	0.069(-0.065, 0.202)
Constant	8.837(1.551, 16.123)	16.638(3.884, 29.392)	0.828(-4.220, 5.875)

Figure 2

Linear regression analysis when assuming PSQI global scores as an independent variable. Myalgia group: R=0.689, R-squared=0.475, and adjusted R-squared=0.387; Arthralgia group: R=0.675, R-squared=0.455, and adjusted R-squared=0.245; Mixed TMD pain group: R=0.640, R-squared=0.410, and adjusted R-squared=0.337.