Association between Temporomandibular Disorders Pain, Oral Behaviors, Anxiety and Stress

A Thesis

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Dedications

This thesis is dedicated to my family: my mother Anju and my father Partap for their absolute confidence in me, my husband, Anshuman for standing by me, encouraging me and be present always, my little guy Dhruv who has been supportive in his own way and, my mother in law Rashmi and my father in law Rajendra for their utmost belief in me. This thesis is also dedicated to my grandparents, who have been absolute blessings in my life.

Abstract

Aims: Oral behaviors, anxiety and stress are believed to be related to temporomandibular disorders (TMD) pain. The aims of the study were to investigate the association of TMD pain intensity with oral behaviors, anxiety and stress, and the association of oral behaviors with anxiety and stress.

Methods: From among the clinical and community-based participants in the multi-site Validation Project, 721 subjects were included in this study who had completed self-report questionnaires that reported pain intensity (Characteristic Pain Intensity [CPI]), oral behaviors (Oral Behavior Checklist [OBC]), anxiety (Symptom Checklist - 90 revised [SCL-ANX]) and stress (Perceived Stress Scale [PSS]) experienced during the previous month; and anxiety experienced during the previous week. Participants were divided into four groups based on the CPI report: no pain, mild, moderate and severe pain, and were compared using analysis of variance (ANOVA). Statistical differences between groups were evaluated using an F-test for continuous variables and Chi-square test for categorical variables. Spearman correlation coefficients were computed to examine the association of (1) CPI with OBC, SCL-ANX and PSS and (2) OBC with SCL-ANX and PSS. Simple linear regression analysis was used to investigate the bivariate relationships for outcomes CPI and OBC. The multivariate regression analysis with age and sex adjustment was conducted to examine relationship between CPI and dependent variables, and OBC and dependent variables.

Results: Using CPI as a categorical variable, pain intensity was associated by a dose-response curve relationship for each of the independent variables: OBC, SCL-ANX, and PSS (ANOVA; $p<0.0001$). Positive correlations were found between CPI

versus OBC (r=0.44, n=721), SCL-ANX (r=0.30, n=720), and PSS (r=0.21, n=721) with p<0.0001 for all correlations. Positive correlations between OBC with SCL-ANX (r=0.38, n=720) and PSS (r=0.32, n=721) with p<0.0001 were found. Using simple linear regression, OBC accounted for 18% of the variance of CPI versus SCL-ANX and PSS that explained 10% and 5% of CPI, respectively. SCL-ANX and PSS accounted for 12% and 11% of the variance of OBC, respectively. The multivariate regression model estimated that with 1SD increase of OBC, CPI will increase by 9 after adjusting for SCL-ANX, PSS, age and gender. For 1 SD increase in SCL-ANX, CPI will increase by 5 after adjusting for OBC, PSS, age and gender. For 1 SD increase in SCL-ANX, OBC will increase by 2.27 and for 1 SD increase in PSS, OBC will increase by 1.63 after adjusting for age, sex and each other. These statistically significant associations are positive and range from weak-moderate with correlation coefficients of 0.21 to 0.44. Together, these variables with age and sex adjustment explain 22% of the TMD pain intensity variability. Together, anxiety and stress with age and sex adjustment explain 19% of the variability of oral behaviors.

Conclusion: Participants with severe TMD pain intensity reported significantly higher frequency of oral behaviors and higher levels of anxiety and stress compared to participants with no and mild pain. Participants with higher frequency of oral behaviors reported significantly higher anxiety and stress compared to participants with lower frequency of oral behaviors. Participants with the highest frequency of oral behaviors (tercile III of OBC) had clinically significantly more TMD pain than those with the lowest frequency of oral behaviors (tercile I of OBC). As predicted by the biopsychosocial model, TMD pain is associated with many factors beyond those assessed in the present study.

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Introduction

Temporomandibular disorders (TMD) are the most common cause of facial pain and the second most common musculoskeletal conditions resulting in pain (after chronic low back pain).[1] Data from the National Health Interview Survey stated that 5% of US adults reported jaw or face pain in the preceding 3 months, representing 11.5 million adults.[2] The prevalence of TMD is 5-12% and annual incidence of new onset TMD is 4%[1,3] The prevalence is higher in females, and young and middle age groups.[4–6] Some individuals may experience preclinical symptoms of TMD pain and dysfunction that rarely come to the attention of health care providers.[7,8] These symptoms can progress in some patients to the development of chronic or persistent pain.[3,8,9] Patients with TMD pain are routinely seen in dental practices, primary care and otolaryngology clinics to seek care.[10–14] TMD pain is considered a public health problem.[4]

Significant associations have been reported between pain intensity, pain severity, pain-related disability and psychological variables in patients with chronic musculoskeletal conditions including TMD.[15–18] It has been reported that TMD pain patients frequently experience psychological factors that influence and contribute to the subjective pain experince.[2,3] TMD pain patients differ from healthy controls in various aspects including increased oral behaviors, anxiety and stress.[18–23] Although many studies report a positive relationship between TMD pain and anxiety, the role of stress has been argued specifically for the onset of TMD pain.[24–28] It has been speculated that stress and state anxiety have a bi-directional relationship, where

stressful situations can influence state anxiety. Relative to oral behaviors, there is extensive literature on sleep bruxism and clenching of teeth in TMD pain patients.[29–31] As well, 52% of patients with TMD pain reported tooth-contacting behaviors that are different from clenching.[32,33] Furthermore, muscle tension has been shown to occur both in presence or absence of tooth contact.[34,35] It has also been reported that TMD patients (with pain and/or disc displacement) have 3.6-4 times more non-functional tooth contact than the healthy subjects.[32,36] In addition, association between stress, muscle tension and other oral behaviors can be underestimates when using self-report instruments.[35] A definitive diagnosis of bruxism is based on self-report, clinical examination and polysomnographic recordings preferably containing audio/visual recordings.[37] Finally, it is important to evaluate the clinical significance of these findings to determine if they are relevant to understanding TMD pain and if they can have an impact on clinical care.[38–40]

This study is a secondary analysis performed with the Validation Project data collection.[41] The Validation Project data collection used simple instruments with reliable and valid psychometric properties to aid research reproducibility and validity.[42–46] The primary aim of this secondary data analysis was to investigate the statistical association and the strength of the association between oral behaviors, anxiety and stress with regard to the TMD pain intensity, that was observed in the Validation Project participants at the time of their evaluation. The secondary aim of this analysis was to assess the associations of anxiety and stress with oral behaviors. It was hypothesized that participants who reported having severe TMD pain intensity would report higher frequency of oral behaviors as well as higher levels

of anxiety and stress than participants with no and mild pain. Participants who reported having higher frequency of oral behaviors would report higher levels of anxiety and stress when compared to participants with less frequency of oral behaviors.

Materials and Methods

The multi-site Validation Project was a cross-sectional observational study. This report follows the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) statement checklist to report the components of cross-sectional studies.[47,48] Institutional Review Board (IRB) approval was obtained at each of the three study sites.

Validation Project Study Setting

The Validation Project was done at the University of Minnesota (UM), the University of Washington (UW), and the University at Buffalo (UB).[41]

Validation Project Participants

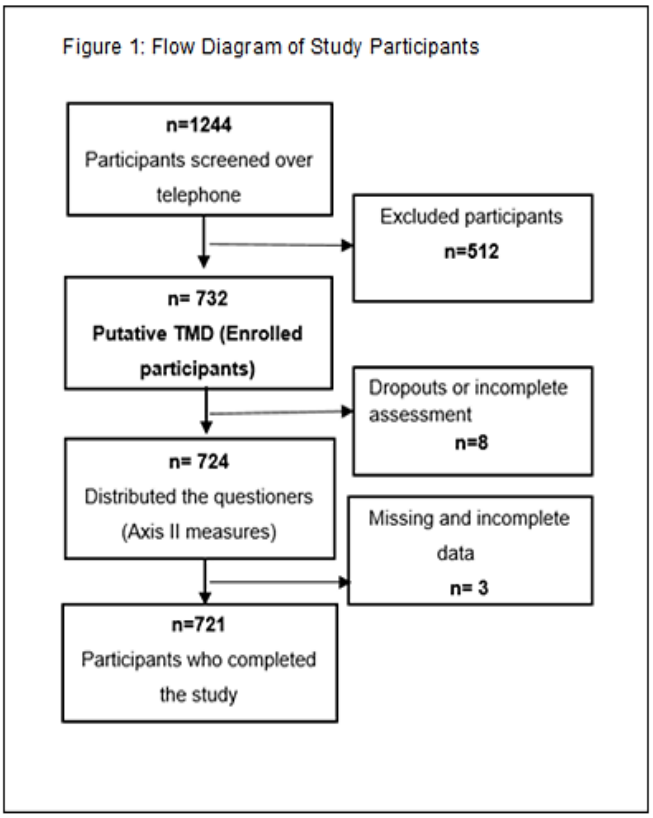
The participants in the study were recruited from August 2003 to September 2006. The study sample is a convenience sample with participants recruited from both clinic and community sources.[41] Recruitment was consecutive for three-fourths of the study sample; the final recruitment was selective to insure an adequate sample of all the most common TMD diagnoses. Participants were drawn from 2 sources: direct referrals from local health care providers to university-based TMD centers in three universities, and community advertisements. Participants aged 18 to 70 years

entered the study. 1,244 participants were screened, out of which 512 did not enter the study due to reasons listed in Schiffman et al.[41] Out of 732 participants who entered, 8 dropped out after the first visit that consisted of consent for the study, completion of questionnaires and a TMD exam. 724 participants filled out the study questionnaires. However, 3 participants failed to provide essential data and were excluded from the analyses. Thus, 721 participants completed the questionnaires measuring pain intensity, oral behaviors, anxiety and stress, however 1 participant did not complete the anxiety questionnaire. See Figure 1 flow diagram. The inclusion and exclusion criteria for participation in the Validation Project has been previously published.[41]

Validation Project Population Demographics: The sample had 128 males [18%] and 593 females [82%] between the ages of 18 and 67 years with a mean age and standard deviation [SD] of 37 [13] years.

Current Sub Study Inclusion Criteria: Participants with completed questionnaires measuring pain intensity, anxiety and stress were included in the study.

Current Sub Study Exclusion criteria: Participants with incomplete questionnaires were excluded from the study.



n=number of participants

Variables

Characteristic Pain Intensity [CPI] is a self-report subscale of Graded Chronic Pain Scale developed by Von Korff, Ormel and Keefe.[49] The CPI measures the pain intensity with an 11-point numerical rating scale (NRS) for current, average and worst facial pain in the past 1 month. The scales are anchored from 0=no pain to 10=pain as bad as could be.[50] The mean of these three ratings, multiplied by 10, is the CPI score (range: 0-100).[51] In addition to using CPI as a continuous variable, four categories of CPI were used to grade TMD pain intensity: 0 (no pain), 1-39 (mild), 40-69 (moderate) and ≥70 (severe) pain.[49] CPI ratings on a continuous scale using a NRS of 0-100 mm scale have acceptable internal consistency (Cronbach's

alpha=0.77), with a normal distribution and moderate correlation (r=0.53) with measures of pain disability.[49] Temporal stability has been reported to be 2-7 days for CPI.[52] The convergent and discriminant validity are also high as shown by Lin's correlation concordance coefficient (CCC) of 0.65.[52,53] As a dichotomous variable the reliability of CPI for TMD pain is 0.80 as measured by the Guttman scale.[49] Overall, CPI is a short, reliable and valid instrument which is used in many pain conditions including TMD and other musculoskeletal disorders as well as dental emergencies, headache, and cancer.[51,53–58]

Oral behaviors checklist [OBC] is a self-report scale for identifying and quantifying the frequency of oral behaviors in the past 1 month. This instrument was developed by Ohrbach and the RDC/TMD Validation Project group.[59] With a 21-question checklist, 2 questions assess oral behaviors during sleep and 19 questions measure oral behaviors during waking hours. Each question is scored from 0-4 based on frequency of activity performed: a score of 0=none of the time; score of 1=a little of the time; score of 2=some of the time; score of 3=most of the time and score of 4=all the time; with a range of 0-84. The test-retest reliability of the 21-OBC full scale score was shown to have almost excellent reliability, ICC=0.88 [95% CI: 0.82-0.92].[60] The same study determined the Cronbach alpha as 0.72 for electronic diary items in OBC-21. OBC is considered the most descriptive assessment of oral behaviors currently available.[59–61] The categories for OBC in this study consist of three terciles computed with the same score ranges that were used for defining OBC terciles in the OPPERA study.[18,23] The score ranges of these three terciles were; I= 0-16, II=17-24,

III=25-65. Oral behaviors were also assessed on a continuum using the OBC sum score in its natural metric form.

Symptom Checklist - 90 Revised [SCL-90R] is a 90-item self-report symptom inventory that measures psychological symptoms and distress experienced in the past 7 days including “today”.[62] This instrument was developed by Derogatis.[63] The present study employed only the anxiety dimension (SCL-ANX) of the SCL-90R to evaluate the participants. General signs of anxiety include nervousness, tension, trembling, feelings of apprehension, dread, terror and panic. Participants used 0-4 scores for response options to rate the extent to which these symptoms have bothered them; 0=being not at all and 4=being extremely. A sum of 10 response items was used to calculate response for the anxiety domain with the scores ranging from 0-40. This instrument has demonstrated good internal consistency with Cronbach’s alpha for subscales ranging from 0.77 to 0.90 and test-retest reliability from 0.78 to 0.90.[64] The internal consistency for anxiety subscale ranges from 0.80 to 0.81.[65] In chronic pain patients the Cronbach’s alpha values are reported to be 0.85 for anxiety.[66] The construct validity of anxiety subscale was assessed using the trait scale of STAI (state and trait anxiety inventory) and the correlation between these 2 instruments was r=0.62.[66]

Perceived Stress Scale-10 [PSS] is a 10-item self-report measure of perceived stress developed by Cohen, Kamarck and Mermelstein.[67] PSS-10 questions have a 5-point scale where participants report their feelings and thoughts from “never” to “very often” over the past 1 month, with a range of 0-40. It has an internal reliability of 0.84, and a test-retest reliability of 0.85 over 2 days and 0.55 over 6 weeks.[67] It was

originally designed to have 14 items; the shortened 10-item version has good reliability (Cronbach alpha = 0.78-0.89).[68,69] There is also a positive correlation between STAI (state trait anxiety inventory) and PSS-10 (overall) as a measure of convergent validity.[69] Exploratory factor analysis as a measure of structural/factorial validity of PSS-10 construct accounted for 48% of variance in a two factor model.[70] Overall, the PSS is an easy-to-use questionnaire with moderate convergent, concurrent and predictive validity and good consistency.[67,68,70,71]

Use of measures in the study

Both the CPI and OBC are part of the Diagnostic Criteria for TMD (DC/TMD) Axis II assessment protocol.[61,72] The primary dependent variable for this study was TMD pain intensity measured by the CPI. The independent study variables that were evaluated for their association with CPI are oral behaviors measured by the OBC, anxiety measured by the SCL-ANX subscale, and stress measured by the PSS. The secondary dependent study variable was oral behaviors measured by the OBC with SCL-ANX and PSS as the independent variables. Table 1 lists the data collection instruments that were used. All were continuous data measures in the natural metric form, and their scale ranges are noted.

Table 1: Description of Outcome Variables				
Variables	**Definitions**	**Questionnaires**	**Scale**	**Sample Size**
Pain intensity	Worse and average pain in last month, and pain at present.	Characteristic Pain Intensity [CPI]	0-100	N= 721
Oral behaviors	Frequency of oral habits in the last month	Oral Behavior Checklist [OBC]	0- 84	N=721
Stress	Feelings over last month perceived stressful in the last month	Perceived Stress Scale [PSS]	0-40	N=721
Anxiety	General signs of anxiety in the last week	Symptom Checklist-90 revised Anxiety subscale [SCL-ANX]	0-40	N=720

Statistical analysis

Descriptive statistics for participant demographic and clinical characteristics are presented in Table 2 using means and standard deviations for the continuous variables. Absolute frequencies with their percentages within groups are presented for categorical variables. The analytical procedures for this study were the following:

1. One-way ANOVA was used to compare the means for four categories (or groupings) for CPI (no pain, mild, moderate and severe pain) to determine any statistical differences between them. Since this procedure involved continuous data and more than two groups, the F-test was employed to establish statistical difference between the means. The same procedure was used to establish any statistical differences between the four categories of CPI; regarding the separate category

means for age, Oral Behaviors Checklist (OBC), SCL-Anxiety (SCL-ANX), and Perceived Stress Scale (PSS). See Table 3.

2. The Chi-square test was used when the four CPI categories were associated with two discrete variables, sex (male, female) and OBC terciles (I, II, III). For this, statistical differences in frequency distributions within the CPI categories were evaluated using the Chi-squared statistic. See Table 3 and Table 4.

3. Spearman correlation coefficients were computed to examine the association of CPI with OBC, SCL-ANX and PSS. With OBC, SCL-ANX and PSS, all analyzed as continuous variables, Spearman correlation coefficients were also computed to evaluate bivariate associations for OBC with SCL-ANX and OBC with PSS. See Table 5.

4. Linear regression technique was employed to compute regression coefficients to measure the strength of association between the same bivariate pairings noted in (3) above: CPI & OBC, CPI & SCL-ANX, CPI & PSS, OBC & SCL-ANX as well as OBC & PSS.

5. A multivariate regression model was used to investigate the relationship of CPI as the dependent variable with all 3 independent variables above (OBC, SCL-ANX and PSS) in the model, without and with adjustment for age and sex. Due to the skewed distribution of CPI, the bootstrap method was used to construct 95% confidence intervals for each covariate. Multivariate regression analysis was also conducted to examine the relationship of OBC, now set as a dependent variable, with SCL-ANX

and PSS as the independent variables, without and with adjustment for age and sex. The full regression model for the primary dependent variable was: CPI = estimated intercept + OBC + SCL-ANX + PSS + age + sex + error. The full regression model for the secondary dependent variable was: OBC = estimated intercept + SCL-ANX + PSS + age + sex + error. See Tables 6,7 & 8.

6. SD-standardization of the multivariate regression coefficients was also performed. The relative effect sizes associated with the covariates in a multivariate regression are often difficult to compare directly with one another. This is because the regression coefficient estimates are computed to indicate the change in the dependent variable that is associated with a one-unit change in each separate covariate. However, the units for the covariates are measured on different scales and, therefore, the units are not equivalent (See Table 1 for the scale differences). SD-standardization is one method for comparing on an equivalent basis the effect sizes of covariates having different measurement scales. This is implemented by multiplying the absolute regression coefficient estimates (based on a 1-unit change) for each covariate by the standard deviation (SD) for that specific covariate within the data collection. With this standardization, the regression coefficient now represents the estimated change in the dependent variable that is associated with a 1 SD increase in the covariate. When some, or all, of the independent variables in a regression model are SD-standardized, their coefficients become directly comparable with other SD-standardized coefficients in the model as to the relative strength of their effect sizes for change in the dependent variable. See Tables 6 & 9.

Analyses were performed in SAS 9.3 (SAS Institute, Cary NC). $p<0.05$ was considered statistically significant.

Results

Participants' demographic and characteristics

The sample had 128 males [18%] and 593 females [82%] between the ages of 18 and 67 years with a mean age and standard deviation [SD] of 37 [13] years. The means and SD for CPI, OBC, SCL-ANX and PSS are listed in Table 2.

Table 2. Participant Demographic and Clinical Characteristics

Variables	Study Participants Count (Percent)	Study Participants Sample
Female, N [%]	593 [82%]	N=721
Age, Mean [SD]	36.8 [13.1]	N=721
CPI, Mean [SD]	33.2 [27.2]	N=721
OBC, Mean [SD]	23.2 [9.3]	N=721
SCL-ANX, Mean [SD]	0.3 [0.5]	N=720*
PSS, Mean [SD]	12.7 [6.8]	N=721

N=number of participants, SD=Standard deviation, CPI=Characteristic Pain Intensity, OBC=Oral behavior checklist, SCL-ANX=Symptom checklist 90 revised-anxiety subscale, PSS=Perceived stress scale

Primary outcome: Association of TMD pain intensity with oral behaviors, anxiety and stress

CPI was analyzed both as a categorical and as a continuous variable.

Categorical CPI: Analysis of variance (ANOVA) was conducted to analyze the differences between group means within categories of CPI and other independent variables associated with the four CPI categories. See Table 3. The score ranges of CPI for the four CPI categories were: CPI-I=0 (no pain), CPI-II=1-39 (mild), CPI-III=40-69 (moderate) and CPI-IV≥70 (severe pain). The means (SD) for CPI categories were I=0, II=22.4 [9.8], III=51.5 [7.9] and IV=79.1 [7.0], respectively. These four CPI categories showed no statistical difference in mean age estimates (ANOVA: p=0.33). In contrast, their sex distributions were statistically different (p<0.0001). Among participants with no pain (N=176) 28% were males and 72% were females, among those with mild pain (N=232) 17% were males and 83% were females, among those with moderate pain (N=219) 12% were males and 88% were females, and among those with severe pain (N=94) 12% were males and 88% were females. Mean OBC [SD] ranged from 16.0 [7.0] for no pain category (CPI-I) to 28.2 [10.3] in the severe pain category (CPI-IV) (ANOVA: p<0.0001). Mean [SD] SCL-ANX ranged from 0.1 [0.8] for CPI-I to 0.6 [0.8] for CPI-IV (ANOVA: p<0.0001). Mean PSS [SD] ranged from 10.3 [5.8] for CPI-I to 15.2 [8.4] for CPI-IV (ANOVA: p<0.0001). Overall, the participants who reported the most severe pain, also reported more frequent oral behaviors and higher levels of anxiety and stress.

Table 3: Characteristics of participants and variables of interest (categorical and continuous) by categories of CPI						
Variable	**Category**	**CPI-I No Pain (N=176)**	**CPI-II Mild (N=232)***	**CPI-III Moderate (N=219)**	**CPI-IV Severe (N=94)**	**P-value**
CPI	Mean (SD)	0.0 (0.0)	22.4 (9.8)	51.5 (7.9)	79.1 (7.0)	<0.0001
	(Min, Max)	(0.0, 0.0)	(3.3, 36.7)	(40.0, 66.7)	(70.0, 100)	
Sex	Male (%)	50 (28.4)	40 (17.2)	27 (12.3)	11 (11.7)	0.0001
	Female (%)	126 (71.6)	192 (82.8)	192 (87.7)	83 (88.3)	
Age	Mean (SD)	38 (13.0)	36 (13.3)	36.4 (13.2)	38 (12.3)	0.33
	(Min, Max)	(18.0, 66.0)	(18.0, 67.0)	(18.0, 67.0)	(18.0, 64.0)	
OBC	Mean (SD)	16.0 (7.0)	23.7 (7.4)	26.2 (9.1)	28.2(10.3)	<0.0001
	(Min, Max)	(0.0, 41.0)	(3.0, 45.0)	(6.0, 55.0)	(6.0, 65.0)	
OBC–cat	0-16 (N,%)	93 (52.8)	38 (16.4)	32 (14.6)	11 (11.7)	<0.0001
	17-24 (N,%)	64 (36.4)	100 (43.1)	63 (28.8)	24 (25.5)	
	25-65 (N,%)	19 (10.8)	94 (40.5)	124 (56.6)	59 (62.8)	
SCL-ANX	Mean (SD)	0.1 (0.2)	0.2 (0.4)	0.4 (0.5)	0.6 (0.8)	<0.0001
	(Min, Max)	(0.0, 1.2)	(0.0, 2.4)	(0.0, 3.3)	(0.0, 3.1)	
PSS	Mean (SD)	10.3 (5.8)	12.5 (6.2)	13.9 (6.6)	15.2 (8.4)	<0.0001
	(Min, Max)	(0.0, 30.0)	(0.0, 34.0)	(0.0, 31.0)	(1.0, 38.0)	

N=number of participants; SD=standard deviation; CPI=Characteristic Pain Intensity, OBC=Oral behavior checklist, OBC-cat=Oral behavior checklist categorical scale; SCL-ANX=Symptom checklist 90 revised-anxiety subscale; PSS=Perceived stress scale
*N=231 for SCL-ANX in CPI-II (Mild pain)

A chi-square test was performed to determine the relationship between three OBC categories (I=0-16; II=17-24 and III= 25-65) and CPI as shown in Table 3. The CPI categories differed significantly (p<0.0001) with regard to the frequency distributions for the OBC categories. Of the participants with no pain, 52% (N=176) were in OBC tercile I, 43% (N=232) with mild pain intensity were in OBC tercile II, and 56% (N=219) with moderate pain intensity or 62% (N= 94) with severe pain intensity were in OBC tercile III. As shown in Table 4, there was no difference in the OBC terciles with regard to the mean age of the participants. In contrast, overall the sex distributions were statistically different between groups (p<0.0001). The mean (SD) estimates for the OBC scores in the three OBC terciles are shown in Table 4.

Table 4: Baseline Oral Behaviors Checklist (OBC): OBC Terciles

Variable	Category	OBC I: 0-16 (N=174)	OBC II: 17-24 (N=251)	OBC III: 25-65 (N=296)	P-value
Sex	Male	57 (32.8)	38 (15.1)	33 (11.2)	<0.0001
	Female	117 (67.2)	213 (84.9)	263 (88.9)	
Age	Mean (SD)	38 (13.1)	38.1 (13.1)	35.1 (12.9)	0.0124
OBC	Mean (SD)	11.8 (3.6)	20.8 (2.3)	31.9 (6.5)	<0.0001

N=number of participants, Terciles=Score ranges by tercile from OPPERA, SD=Standard deviation

Figures 2-4 illustrate the findings of the association of categorical CPI with OBC, SCL-ANX and PSS in a dose-response curve. If two 95% CI do not overlap, it can be inferred that the two groups are significantly different from each other. As shown below in figures 2, 3 & 4 participants with severe CPI (CPI IV) reported significantly higher scores on OBC, SCL-ANX and PSS (p<0.0001) compared to participants in no pain (CPI I) category.

Figure 2: Dose response curve: mean distribution between Characteristic Pain Intensity categories and Oral Behavior Checklist with 95% CI

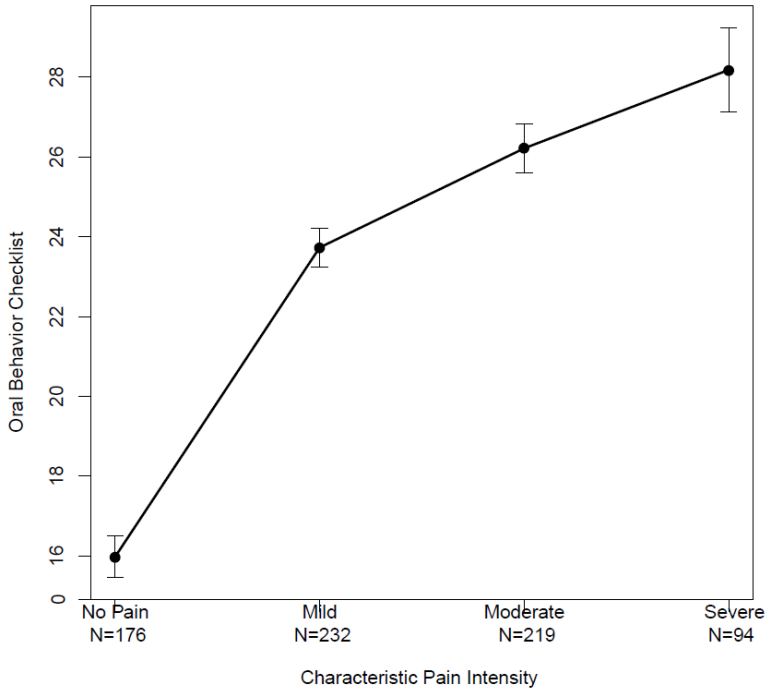


Figure 3: Dose response curve: mean distribution between Characteristic Pain Intensity categories and Symptom Checklist-90R anxiety subscale with 95% CI

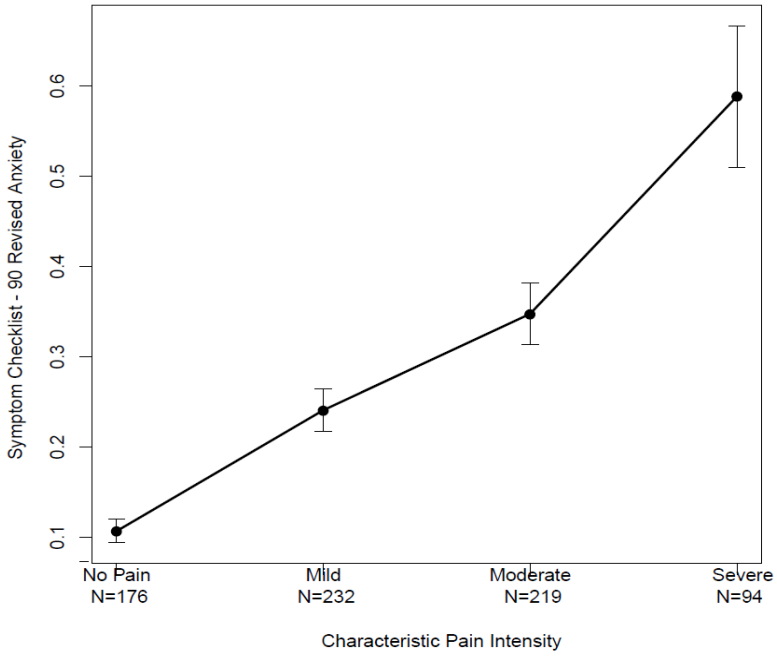
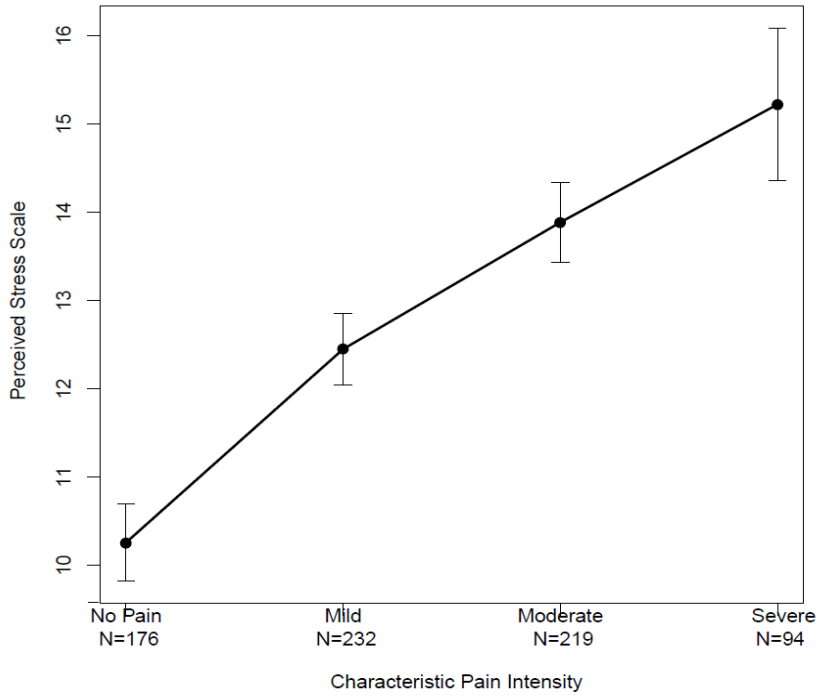


Figure 4: Dose response: mean distribution between Characteristic Pain Intensity categories and Perceived Stress Scale with 95% CI



CPI as continuous variable: Spearman correlation analysis shows positive and statistically significant ($p<0.0001$) correlation between CPI and each of three dependent variables. See Table 5. This suggests that participants reporting more severe intensity of the TMD pain report higher anxiety and stress scores as measured by the SCL-ANX and PSS, respectively.

Table 5: Correlation of CPI as a continuous variable with OBC, SCL-ANX and PSS			
Variables	**Sample size**	**Spearman Correlation Coefficient (r)**	**p-value**
CPI versus OBC	721	0.44	<0.0001
CPI versus SCL-ANX	720	0.30	<0.0001
CPI versus PSS	721	0.21	<0.0001

CPI: Characteristic Pain Intensity, OBC: Oral behavior checklist, SCL-ANX: Symptom checklist 90 revised-anxiety subscale; PSS: Perceived stress scale

Bivariate analysis was also done using a simple linear regression model. The coefficient of determinations for CPI as outcome and dependent variables, were: R^2 (OBC & CPI) = 0.18 [SE=0.1], p<0.0001; R^2 (SCL-ANX & CPI) = 0.10 [SE=2.0], p<0.0001 and R^2 (PSS & CPI) = 0.05, [SE=0.2], p<0.0001. This suggests that OBC accounted for 18% of variance of CPI, versus SCL-ANX and PSS that explained 10% and 5% of CPI, respectively.

CPI as continuous variable in multivariable linear regression

The multivariable linear regression model included all three study independent variables (OBC, SCL-ANX and PSS), as well as age and sex. SD-standardized regression coefficients and β-estimates are reported in Table 6. The model predicts that: for 1 SD increase in OBC, CPI will increase by 9 after adjusting for SCL-ANX, PSS, age and sex; for a 1 SD increase in SCL-ANX, CPI will increase by 5 after adjusting for OBC, PSS, age and sex. For 1 SD increase in PSS, CPI may or may not increase by 0.2 after adjusting for OBC, SCL-ANX, age and sex. The bootstrap 95% CI did not include zero for OBC and SCL-ANX but did for PSS. This model explained 22% of the variance (R^2=0.22) of CPI. With no adjustment for age and sex,

this analytical model explained about 21% of the variance (R^2=0.21) of CPI. Due to the skewed distribution of CPI, bootstrap method is used to construct 95% CI for each covariate.

Table 6: Multivariate regression model, adjusted for age and sex, showing changes in CPI associated with a 1-unit increase and a 1-SD increase in OBC, SCL-ANX and PSS

Estimate from Data Adjusted analysis: R-square=0.22				
Variable	**β Estimate (SE), per 1-unit increase**	**p-value**	**Bootstrap 95% CI**	**Standardized estimate (SE), per 1 SD increase**
OBC	1.0 (0.1)	<0.0001	(0.84, 1.17)	9.3 (1.0)
SCL-ANX	10.8 (2.4)	<0.0001	(6.87, 14.63)	5.1 (1.1)
PSS	0.0 (0.2)	.87	(-0.25, 0.27)	0.2 (1.1)
Sex	6.1 (2.4)	.01	(2.55, 9.80)	
Age	0.1 (0.1)	.22	(-0.01, 0.2)	1.2 (0.9)

CPI: Characteristic Pain Intensity, OBC: oral behavior checklist, SCL-ANX: Symptom checklist 90 revised-anxiety subscale; PSS: Perceived stress scale; R^2: coefficient of determination; estimate β: standardized regression coefficient; SE: standard error, p-value is obtained from linear regression

Categorical and continuous OBC: In Table 7, we report 2 study models to demonstrate the independent effect of SCL-ANX and PSS with CPI. These associations were tested by comparing the effects of the dependent variables when continuous and categorical OBC were in the regression model, versus not. The results are consistent between categorical and continuous OBC. As expected, the coefficient estimates for SCL-ANX and PSS change because of difference in the (categorical versus continuous) OBC independent variable, whichever was used in the regression model. When regression analysis was conducted using categorical OBC as an independent variable, both OBC tercile II (score range 17-24) and OBC

tercile III (score range 25-65) showed significantly different effects when compared to the reference category, OBC tercile I (score range of 0-16) (β =8.0, SE=2.5, p=0.001 for OBC category II and β=20.6, SE=2.5, p<0.0001 for OBC tercile III). These results indicate a dose response curve as do also the correlation and ANOVA analyses.

Table 7: Multivariate regression model, adjusted for age and sex, exploring effects on CPI with and without adjustment for continuous OBC and categorical OBC

	Continuous OBC as an independent variable				**Categorical OBC as an independent variable**			
	No adjustment by OBC		Adjustment with continuous OBC		No adjustment by OBC		Adjustment with categorical OBC	
Variable	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value	Estimate (SE)	p-value
Sex F vs. M	10.7 (2.5)	<0.0001	6.1 (2.4)	0.01	10.7 (2.5)	<0.0001	6.8 (2.4)	0.006
Age	0.0 (0.1)	0.8	0.1 (0.8)	0.2	0.02 (0.8)	0.8	0.1 (0.1)	0.25
OBC			1.00 (0.1)	<0.0001				
OBC 17-24 vs. 0-16							8.0 (2.5)	0.001
OBC 25-65 vs. 0-16							20.6 (2.5)	<0.0001
SCL-ANX	15.6 (2.5)	<0.0001	10.8 (2.4)	<0.0001	15.6 (2.5)	<0.0001	12.3 (2.4)	<0.0001
PSS	0.3 (0.2)	0.1	0.03 (0.2)	0.9	0.3 (0.2)	0.1	0.1 (0.2)	.070

OBC: Oral behavior checklist (continuous and categorical); SCL-ANX: Symptom checklist 90 revised-anxiety subscale; PSS: Perceived stress scale; estimate β=standardized regression coefficient; SE=standard error, coefficient estimates and p-value from linear regression are reported.

Secondary Outcome: Association of oral behaviors with anxiety and stress

Spearman correlation analysis shows a positive and statistically significant correlation between OBC and SCL-ANX (r=0.38, p<0.0001) and between OBC and

PSS (r=0.32, p<0.0001) as seen in Table 8. This suggests that participants reporting higher (or more frequent) oral behaviors report higher anxiety and stress scores as measured by the SCL-ANX and PSS.

Table 8: Correlation of OBC as a continuous variable with SCL-ANX and PSS

Variables	N	Spearman Correlation Coefficient (r)	P value
OBC vs. SCL-ANX	720	0.38	<0.0001
OBC vs. PSS	721	0.32	<0.0001

OBC: Oral behavior checklist; SCL-ANX: Symptom checklist 90 revised-anxiety subscale; PSS: Perceived stress scale; vs: versus, N: number of participants

Bivariate analysis was conducted for OBC using a simple linear regression. Modeling OBC as the outcome and the independent variables as indicated, the coefficient of determinations were: R^2(SCL-ANX and OBC) =0.12, SE=0.7 and p<0.0001; R^2(PSS and OBC) =0.11, SE=0.1 and p<0.0001. This suggests that SCL-ANX and PSS accounted for 12% and 11% of variance of OBC.

Multivariate linear regression was conducted for OBC as the outcome variable with SCL-ANX and PSS as independent variables while adjusting for age, sex and each other. For 1 SD increase in SCL-ANX, OBC will increase by 2.3 and for 1 SD increase in PSS, OBC will increase by 1.6 after adjusting for age, sex and each other. This model explained 19% of the variance in OBC (R^2 =0.19), as seen in Table 9. With no age and sex adjustment, the model explained about 15% of the variance (R^2 =0.15).

Table 9: Multivariate analysis for evaluation of the associations of OBC with SCL-ANX and PSS			
Estimate from Data Adjusted analysis: R^2 =0.19			
Variable	**β Estimate (SE)**	**p-value**	**Standardized estimate (SE)**
SCL-ANX	4.8 (0.8)	<0.0001	2.3 (0.4)
PSS	0.2 (0.1)	<0.0001	1.6 (0.4)
Sex	-4.7 (0.8)	<0.0001	
Age	-0.1 (0.0)	0.007	-0.8 (0.3)

OBC=oral behavior checklist, SCL-ANX=Symptom checklist 90 revised-anxiety subscale; PSS=Perceived stress scale; R^2=coefficient of determination; estimate β=standardized regression coefficient; SE=standard error, p-value is obtained from linear regression

Discussion

The primary outcome in the present cross-sectional study was to investigate the strength, direction and significance of the association of TMD pain intensity with oral behaviors and psychological variables. This study reports the statistical and clinical significance of the association of TMD pain intensity with oral behaviors. Participants with severe TMD pain intensity reported significantly higher frequency of oral behaviors and higher levels of anxiety and stress compared to participants with no and mild pain. The strength of the correlation between TMD pain intensity and oral behaviors was a moderate positive relationship that was statistically significant.[73,74] The association between TMD pain intensity versus anxiety and stress was a weak positive relationship that was also statistically significant.[73,74] The overall effect of these finding was that oral behaviors, anxiety and stress explained 22% of TMD pain intensity variability. Individually, 18% of the variance of TMD pain intensity was

accounted by oral behaviors. The secondary outcome of this study was to do the same assessments with oral behaviors versus anxiety and stress. This study also quantifies the relationship of both anxiety and stress with oral behaviors. Participants with higher frequency of oral behaviors reported significantly higher anxiety and stress compared to participants with lower frequency of oral behaviors. The strength of the correlation between oral behaviors and anxiety was a moderate positive relationship and between oral behaviors and stress was a weak positive relationship.[73,74] The overall effect of these findings was that together, anxiety and stress adjusted for age and sex, explained 19% of the variability of oral behaviors. By providing the measurable effect of the associations, our results have extended the findings of the previous studies that used a similar construct between TMD pain, oral behaviors and psychological variables.[75,76] The percentage of explained variance singly by the study variables and the whole model are also consistent with the current concept of a complex multifactorial pattern for TMD and pain research in general; where a single characteristic or a simple model can explain only a part of variance.[3,9,77]

Clinical significance

Although we have quantified the direction and magnitude of our statistically significant results, there is a need to assess the clinical importance of the results. When assessing clinical important differences in pain intensity, current recommendations focus on the magnitude of pain reduction with treatment.[38,78] When using a 0-10 point NRS for assessing pain intensity, it has been recommended that pre- to post-treatment reduction in pain intensity of approximately 2.0 points represent “much better,” “much improved,” or “meaningful” decreases in chronic

pain.[78–80] Although this study is not a treatment outcome study, this was the best reference we could find to assess clinical significance for differences in pain intensity. The only clinically significant findings we found was a 20-unit increase in CPI with higher tercile of OBC III (score 25-65) compared to OBC I (score 0-16) (see Table 7). There were approximately 3 SD in the mean OBC increase from tercile I to tercile III for the expected change in CPI to be clinically significant. This suggests that participants with the highest frequency of oral behaviors (tercile III of OBC) had clinically significantly more TMD pain (20/100) than those with the lowest frequency of oral behaviors (tercile I of OBC). Finally, we are unable to assess the clinical significance of differences in anxiety and stress relative to oral behaviors since the clinically important difference for different levels of oral behaviors has not been established.

Oral behaviors

The OBC is regarded as the most comprehensive instrument to identify maladaptive oral behaviors that occur during waking and sleep.[52,59,72,81] Oral, masticatory, and facial behaviors that do not serve any functional purpose are broadly termed as oral behaviors.[82] The Oral Behaviors Checklist scale emerged as the strongest predictor of incident TMD among all clinical variables both examiner assessed and self-reported instruments in the OPPERA project (Orofacial Pain: Prospective Evaluation and Risk Assessment).[23] The Clinical findings from OPPERA's baseline case-control study also indicated significant differences between chronic TMD cases and controls with respect to frequency of oral behaviors[18]

On the contrary, no contribution of oral behaviors to myofascial pain has also been reported.[83,84] Such findings can be related to difficulty in identifying the oral behaviors which contribute to the pain during the day.[60] Van der Meulen et all reported that there was no significant correlation between the Dutch version of the OBC and CPI (r=0·069, p=0.39).[83] In the same study the spearman's correlation coefficients between OBC and anxiety (r=0.44, p<0.001), and OBC and stress (r=0.43, p<0.001) as measured by Dutch SCL-90 and a seven-point stress questionnaire were statistically significant. The investigator reported that "the results of the Dutch studies offer no explanation for the difference in outcome with most other self-report studies".[83] A previous study from the same group evaluated relationships between a 12-item Dutch Oral Parafunctions Questionnaire (OPQ) and CPI in two cohorts ("frequency" and "stressfulness") of TMD pain patients.[84] A principal component analysis of the responses led to 3 factor scales in both cohorts: BRUX scale for bruxism activities; BITE scale for biting activities (e.g., chewing gum, nails); and a SOFT scale for soft tissue activities (e.g., tongue, lips). Statistical significance was reported for 2 of the 6 relationships (p<0.05), but with a very low explained variance (approximately 3.5%). In contrast with the present study, where the model explained 22% of variability of CPI and OBC explained 18% of the variance of CPI. There was no difference in the explained variance when OBC was used as continuous compared to categorical variable. There can be a few explanations for this difference in results: (1) the scoring of OBC in terciles based on cumulative score in the present study as opposed to factor scoring using subgroups as mentioned above and (2) different ways of phrasing the questions of the oral parafunction instrument in 2 cohorts.

In general, past research has focused either on waking state parafunction or sleep bruxism compared to a few studies using the entire OBC.[85–87] The results of the current study corroborate findings from previous studies showing positive and statistically significant relationship of oral behaviors with TMD pain.[3,18,23,65] A statistically significant association has also been demonstrated, using self-report, between daytime clenching, and wake time non-functional tooth contact with masticatory myofascial pain.[36,82,88] A case-control study showed a 17-fold elevated odds of TMD among people in the upper tercile of the OBC (with score range from 25-62 distribution) relative to people in the lowest tercile (0-16).[18] Another study using waking state OBC and high pain intensity (51-100) showed a statistically significantly higher mean OBC score (1.27) than those with no pain (0.85) or low pain intensity (0.98); $p<0.002$.[86] Oral behaviors have been shown repeatedly to be good predictors of jaw pain intensity in TMD patients when they are compared to healthy controls.[18,34,65]

The explained variance of TMD pain intensity is lower in the present study compared to a study conducted by Glaros et al using predictors including jaw tension (relaxed-extremely tense), efforts (tooth contact), mood (happy-sad), stress (none-extremely high) and outcome as jaw, face or head pain (11 point NRS).[34] This model accounted for 69% of the variance TMD pain in subjects with myofascial pain, or myofascial pain and arthralgia when jaw tension was included, and 46% of the variance on its exclusion. The difference between these results can be explained, in part, by methodological differences (ecological study). The Glaros study was done using

‘experience sampling methodology’ (ESM) which is characterized by repeated measurements in a natural environment. The data was collected for a week at multiple times a day which could improve the accuracy of reported oral behaviors compared to instruments like the OBC that retrospectively assess oral behaviors in the “last month” and may be are impacted by recall bias. Although its validity as compared to other traditional measurements is unreported, there is evidence that ESM measures the true value rather than a construct measured through questionnaires.[82,89] If this is true, then the effect of oral behaviors may have been underestimated in the present study.

Anxiety

The results of present study are comparable to previous reports of a positive association between anxiety and TMD pain, and anxiety and oral behaviors.[25,90,91] In the OPPERA case control study, TMD cases had higher mean scores (by at least 2 times) than controls across all SCL-90R subscales with a standardized odds ratio of 1.4 for anxiety subscale (controls: mean [SE] =0.19 [0.01], TMD cases: mean [SE]= 0.35 [0.03] $p<0.0001$).[92] TMD cases also reported higher means for state and trait anxiety on the State-Trait Anxiety Inventory (STAI).[25] Anxiety as measured by the STAI and the SCL-90-R-anxiety sub-scores were correlated in a chronic pain patient population with $r=0.62$ indicating good concurrent validity.[66] Another case control study reported that higher levels of anxiety increased the risk of having pain related TMD by 4%.[25] Also, a higher score of anxiety (OR = 5.12; 95% CI: 1.36; 19.41) has been associated with chronic MFP.[65] Finally, the present study’s results are comparable to Ahlberg et all, who investigated the association of anxiety and stress with bruxism using self-reported instruments including the SCL-90R anxiety

subscale.[93] Their results had a dose response relationship as well, with severe bruxers reporting significant higher odds of anxiety compared to non-or-mild bruxers. Anxiety above the overall mean score (OR 2.2; 95% CI 1.3-3.6) was more than twice as likely among frequent bruxers than non-or-mild bruxers.[93]

Nevertheless, there are studies which have found no association between anxiety and TMD.[27,94,95] Possible explanations for these differences may be due to methodological differences: differences in defined variables (e.g., state or trait anxiety; the trait part has been shown to include depression related items), types of bruxism (e.g., higher relationship is seen between awake bruxism and anxiety), choice of self-reported measures (e.g., SCL-90R as a unidimensional or multidimensional measure, German version of hospital anxiety and depression scale, Taylor manifest anxiety scale and chronic pain battery), population type (chronic pain populations), and population with clinical diagnosis of anxiety and depression).[27,94,96–99] However, we believe that using the SCL-90R anxiety sub-scale is appropriate to assess the present study's aims and given that its anxiety dimension is widely used in research with numerous pain conditions including TMD, allowing for comparison of our results with other studies. High consistency of SCL-90R tests' dimension scores across respondent characteristics such as sex and age - especially in studies with large sample sizes has been demonstarted.[99] As well, the reliability of SCL-ANX is high in chronic pain population with Cronbach alpha=.85.[66]

Stress

The significance of stress with oral behaviors and masticatory myofascial pain has been reported in the literature.[82] Several studies have reported that relative to pain-

free populations, patients with TMD have reported higher levels of psychosocial stress.[19,36,92] When using PSS (0–40 scale), TMD cases reported modest difference compared to controls (controls: n=1,603; mean=14.66 SE=.16; TMD cases n=183, mean=16.8, SE=.51; p<0.0001).[92] PSS predicted the incidence of TMD in univariate analysis but was nonsignificant in multivariable analysis.[54,100] The results of our study are consistent with these findings as the association of TMD pain intensity with stress became non-significant in our multivariate analysis. Although multiple studies have shown correlation of TMD pain and stress, results of multivariable models provide rigorous evidence.

Studies have repeatedly reported that stress is associated with bruxism.[34,101–103] In the present study, PSS was moderately associated with OBC and explained about 11% of variance in OBC. This was comparable to a previous study that reported severe and more frequent bruxers had higher stress measure (OR 2.5; 95 % CI 1.5-4.2).[93]

Strengths and Limitations

The present study assessed both the statistical significance of our models and clinical significance of these findings with standardized estimates. The large sample size of the present study composed of both normal and a broad spectrum of participants from both community and clinical settings allows for good generalizability of the results.

Patient-reported outcomes (PROs) have become important constructs in patient-centered research and clinical practice.[104,105] The NRS pain intensity scale has been

reported to be the most practical index based on comparative criteria study for judging pain intensity scales.[45] The CPI, by assessing 3 dimensions of pain intensity (average, worse and current pain) is considered complete as it measures both central tendency and time course of pain.[51] All instruments used in this study are valid, short and reliable instruments. By using the OBC, we also have included a wider range of oral behaviors which have shown to contribute to TMD pain. The CPI and OBC are also part of the Diagnostic Criteria for Temporomandibular Disorders and therefore can be used in both the clinical and research settings.[72]

The present study's findings have limitations. This is a cross-sectional study and its findings cannot establish causality. Also, the original Validation Project was not designed to address the aims of the present study.[41] Rather it was based on Statement for Reporting studies of Diagnostic accuracy (STARD) guidelines that recommend when developing diagnostic criteria for diseases, new diagnostic criteria are first developed and evaluated using a sample of individuals with the target condition free of significant co-morbidities.[106] Thus, it is possible that our results may have been different if we had participants with other co-morbid pain conditions. Also, the population of the study is a convenience sample selected from both community and clinic sources. However, we speculate that the associations we found could be higher with just clinic cases because of their chronicity and recurrence of painful episodes over time.[3] Furthermore, this study was designed as a qualitative assessment through use of participants' reports alone. Finally, the use of SCL-ANX and PSS identifies "psychological distress", rather than a definitive diagnosis of

anxiety and stress. It would require a psychologist/psychiatrist or a gold standard such as structured interview to diagnose them.

Conclusion

Participants with severe TMD pain intensity reported significantly higher frequency of oral behaviors and higher levels of anxiety and stress compared to participants with no and mild pain. Participants with higher frequency of oral behaviors reported significantly higher anxiety and stress compared to participants with lower frequency of oral behaviors. However, the prediction models for pain intensity and oral behaviors did explain approximately a fifth of their variance. Participants with the highest frequency of oral behaviors (tercile III of OBC) had clinically significantly more TMD pain than those with the lowest frequency of oral behaviors (tercile I of OBC). These findings are reasonable given that many biopsychosocial variables are related to TMD pain beyond those assessed in the present study.

References

1. Prevalence of TMJD and its Signs and Symptoms. National Institute of Dental and craniofacial Resrach. https://www.nidcr.nih.gov/research/data-statistics/facial-pain/prevalence.
2. Maixner W, Williams DA, Smith SB, Slade GD. Overlapping Chronic Pain Conditions: Implications for Diagnosis and Classification. *J Pain*. 2016. doi:10.1016/j.jpain.2016.06.002.
3. Slade GD, Ohrbach R, Greenspan JD, et al. Painful Temporomandibular Disorder: Decade of Discovery from OPPERA Studies. *J Dent Res*. June 2016. doi:0022034516653743 [pii].
4. de Leeuw R, Gary klasser D. *Orofacial Pain, Guidelines for Assessment, Diagnosis and Management; the American Academy of Orofacial Pain*. sixth. Quintessence; 2018.
5. LeResche L. Epidemiology of temporomandibular disorders: implications for the investigation of etiologic factors. *Crit Rev Oral Biol Med*. 1997;8(3):291-305.
6. Slade GD, Bair E, Greenspan JD, et al. Signs and symptoms of first-onset TMD and sociodemographic predictors of its development: The OPPERA prospective cohort study. *J Pain*. 2013. doi:10.1016/j.jpain.2013.07.014.
7. Schiffman EL, Fricton JR, Haley DP, Shapiro BL. The prevalence and treatment needs of subjects with temporomandibular disorders. *J Am Dent Assoc*. 1990;120(3):295-303. doi:S0002-8177(90)03015-X [pii].
8. Slade GD, Sanders AE, Bair E, et al. Preclinical episodes of orofacial pain symptoms and their association with health care behaviors in the OPPERA prospective cohort study. *Pain*. 2013;154(5):750-760. doi:10.1016/j.pain.2013.01.014.
9. A. Pizzo P, M. Clark N, Carter Pokras O. *Relieving Pain in America: A Blueprint for Transforming Prevention, Care, Education, and Research*.; 2011. doi:10.3109/15360288.2012.678473.
10. Lindfors E, Tegelberg Å, Magnusson T, Ernberg M. Treatment of temporomandibular disorders – knowledge, attitudes and clinical experience among general practising dentists in Sweden. *Acta Odontol Scand*. 2016. doi:10.1080/00016357.2016.1196295.
11. Gnauck M, Magnusson T, Ekberg EC. Knowledge and competence in temporomandibular disorders among Swedish general dental practitioners and dental hygienists. *Acta Odontol Scand*. 2017. doi:10.1080/00016357.2017.1331373.
12. Adèrn B, Stenvinkel C, Sahlqvist L, Tegelberg Å. Prevalence of temporomandibular dysfunction and pain in adult general practice patients. *Acta Odontol Scand*. 2014. doi:10.3109/00016357.2013.878390.
13. Macfarlane T V., Blinkhorn AS, Davies RM, Kincey J, Worthington H V. Oro-facial pain in the community: Prevalence and associated impact. *Community Dent Oral Epidemiol*. 2002. doi:10.1034/j.1600-0528.2002.300108.x.
14. Cooper BC, Cooper DL. Recognizing otolaryngologic symptoms in patients

with temporomandibular disorders. *Cranio*. 1993. doi:10.1080/08869634.1993.11677977.

15. Bair MJ, Wu J, Damush TM, Sutherland JM, Kroenke K. Association of depression and anxiety alone and in combination with chronic musculoskeletal pain in primary care patients. *Psychosom Med*. 2008;70(8):890-897. doi:10.1097/PSY.0b013e318185c510 [doi].
16. Linton SJ. A review of psychological risk factors in back and neck pain. *Spine (Phila Pa 1976)*. 2000;25(9):1148-1156. doi:10.1097/00007632-200005010-00017.
17. Costa YM, Conti PCR, de Faria FAC, Bonjardim LR. Temporomandibular disorders and painful comorbidities: clinical association and underlying mechanisms. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2017;123(3). doi:10.1016/j.oooo.2016.12.005.
18. Ohrbach R, Fillingim RB, Mulkey F, et al. Clinical findings and pain symptoms as potential risk factors for chronic TMD: descriptive data and empirically identified domains from the OPPERA case-control study. *J Pain*. 2011;12(11 Suppl):T27-45. doi:10.1016/j.jpain.2011.09.001 [doi].
19. Beaton RD, Egan KJ, Nakagawa-Kogan H, Morrison KN. Self-reported symptoms of stress with temporomandibular disorders: comparisons to healthy men and women. *J Prosthet Dent*. 1991;65(2):289-293.
20. Rantala MA, Ahlberg J, Suvinen TI, et al. Temporomandibular joint related painless symptoms, orofacial pain, neck pain, headache, and psychosocial factors among non-patients. *Acta Odontol Scand*. 2003;61(4):217-222.
21. Rollman GB, Gillespie JM. The role of psychosocial factors in temporomandibular disorders. *Curr Rev Pain*. 2000;4(1):71-81.
22. Jones DA, Rollman GB, Brooke RI. The cortisol response to psychological stress in temporomandibular dysfunction. *Pain*. 1997;72(1-2):171-182.
23. Ohrbach R, Bair E, Fillingim RB, et al. Clinical orofacial characteristics associated with risk of first-onset TMD: the OPPERA prospective cohort study. *J Pain*. 2013;14(12 Suppl):T33-50. doi:10.1016/j.jpain.2013.07.018 [doi].
24. Kindler S, Samietz S, Houshmand M, et al. Depressive and anxiety symptoms as risk factors for temporomandibular joint pain: a prospective cohort study in the general population. *J Pain*. 2012;13(12):1188-1197. doi:10.1016/j.jpain.2012.09.004 [doi].
25. Reissmann DR, John MT, Seedorf H, Doering S, Schierz O. Temporomandibular disorder pain is related to the general disposition to be anxious. *J oral facial pain headache*. 2014;28(4):322-330. doi:10.11607/ofph.1277 [doi].
26. Lajnert V, Franciskovic T, Grzic R, et al. Depression, somatization and anxiety in female patients with temporomandibular disorders (TMD). *Coll Antropol*. 2010;34(4):1415-1419.
27. Giannakopoulos NN, Keller L, Rammelsberg P, Kronmuller KT, Schmitter M. Anxiety and depression in patients with chronic temporomandibular pain and in controls. *J Dent*. 2010;38(5):369-376. doi:10.1016/j.jdent.2010.01.003 [doi].
28. Vedolin GM, Lobato V V, Conti PC, Lauris JR. The impact of stress and

anxiety on the pressure pain threshold of myofascial pain patients. *J Oral Rehabil*. 2009;36(5):313-321. doi:10.1111/j.1365-2842.2008.01932.x [doi].

29. Manfredini D, Winocur E, Guarda-Nardini L, Paesani D, Lobbezoo F. Epidemiology of bruxism in adults: a systematic review of the literature. *J Orofac Pain*. 2013;27(2):99-110. doi:10.11607/jop.921 [doi].
30. Paesani DA, Lobbezoo F, Gelos C, Guarda-Nardini L, Ahlberg J, Manfredini D. Correlation between self-reported and clinically based diagnoses of bruxism in temporomandibular disorders patients. *J Oral Rehabil*. 2013;40(11):803-809. doi:10.1111/joor.12101.
31. Manfredini D, Winocur E, Guarda-Nardini L, Lobbezoo F. Self-reported bruxism and temporomandibular disorders: findings from two specialised centres. *J Oral Rehabil*. 2012;39(5):319-325. doi:10.1111/j.1365-2842.2011.02281.x [doi].
32. Funato M, Ono Y, Baba K, Kudo Y. Evaluation of the non-functional tooth contact in patients with temporomandibular disorders by using newly developed electronic system. *J Oral Rehabil*. 2014. doi:10.1111/joor.12129.
33. Sato F, Kino K, Sugisaki M, et al. Teeth contacting habit as a contributing factor to chronic pain in patients with temporomandibular disorders. *J Med Dent Sci*. 2006.
34. Glaros AG, Williams K, Lausten L. The role of parafunctions, emotions and stress in predicting facial pain. *J Am Dent Assoc*. 2005;136(4):451-458. doi:S0002-8177(14)65317-4 [pii].
35. Glaros AG, Marszalek JM, Williams KB. Longitudinal Multilevel Modeling of Facial Pain, Muscle Tension, and Stress. *J Dent Res*. 2016;95(4):416-422. doi:10.1177/0022034515625216.
36. Chen CY, Palla S, Erni S, Sieber M, Gallo LM. Nonfunctional tooth contact in healthy controls and patients with myogenous facial pain. *J Orofac Pain*. 2007;21(3):185-193.
37. Klasser GD, Pain CO, Rei N, Lavigne GJ, Frcd C. Sleep Bruxism Etiology : The Evolution of a Changing Paradigm. 2015;(C).
38. van Grootel RJ, van der Glas HW. Statistically and clinically important change of pain scores in patients with myogenous temporomandibular disorders. *Eur J Pain*. 2009;13(5):506-510. doi:10.1016/j.ejpain.2008.06.002.
39. Kropmans TJ, Dijkstra PU, Stegenga B, Stewart R, de Bont LG. Smallest detectable difference in outcome variables related to painful restriction of the temporomandibular joint. *J Dent Res*. 1999;78(3):784-789. doi:10.1177/00220345990780031101.
40. Kovacs FM, Abraira V, Royuela A, et al. Minimal clinically important change for pain intensity and disability in patients with nonspecific low back pain. *Spine (Phila Pa 1976)*. 2007;32(25):2915-2920. doi:10.1097/BRS.0b013e31815b75ae.
41. Schiffman EL, Truelove EL, Ohrbach R, et al. The Research Diagnostic Criteria for Temporomandibular Disorders. I: overview and methodology for assessment of validity. *J Orofac Pain*. 2010;24(1):7-24.
42. Conti PC, de Azevedo LR, de Souza N V, Ferreira F V. Pain measurement in

TMD patients: evaluation of precision and sensitivity of different scales. *J Oral Rehabil*. 2001;28:534-539. doi:jor727 [pii].

43. Mannion AF, Balague F, Pellise F, Cedraschi C. Pain measurement in patients with low back pain. *Nat Clin Pract*. 2007;3(11):610-618. doi:ncprheum0646 [pii].
44. Jensen MP, Karoly P, Braver S. The measurement of clinical pain intensity: a comparison of six methods. *Pain*. 1986;27(1):117-126. doi:0304-3959(86)90228-9 [pii].
45. Ferreira-Valente MA, Pais-Ribeiro JL, Jensen MP. Validity of four pain intensity rating scales. *Pain*. 2011;152(10):2399-2404. doi:10.1016/j.pain.2011.07.005.
46. Turk DC, Melzack RE. Handbook of pain assessment: chapter 16,Bradley, McKendree Smith , assessment of psychological status using interviews and self reported instruments. 2001.
47. Vandenbroucke JP, von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *Int J Surg*. 2014;12(12):1500-1524. doi:10.1016/j.ijsu.2014.07.014 [doi].
48. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. 2014;12(12):1495-1499. doi:10.1016/j.ijsu.2014.07.013 [doi].
49. Von Korff M, Ormel J, Keefe FJ, Dworkin SF. Grading the severity of chronic pain. *Pain*. 1992;50(2):133-149. doi:0304-3959(92)90154-4 [pii].
50. Dworkin SF, Sherman J, Mancl L, Ohrbach R, LeResche L, Truelove E. Reliability, validity, and clinical utility of the research diagnostic criteria for Temporomandibular Disorders Axis II Scales: depression, non-specific physical symptoms, and graded chronic pain. *J Orofac Pain*. 2002;16(3):207-220.
51. Dworkin SF, Von Korff M, Whitney CW, Le Resche L, Dicker BG, Barlow W. Measurement of characteristic pain intensity in field research. *Pain*. 1990;41:S290.
52. Ohrbach R. Assessment and further development of RDC/TMD Axis II biobehavioural instruments: a research programme progress report. *J Oral Rehabil*. 2010;37(10):784-798. doi:10.1111/j.1365-2842.2010.02144.x [doi].
53. Ohrbach R, Turner JA, Sherman JJ, et al. The Research Diagnostic Criteria for Temporomandibular Disorders. IV: evaluation of psychometric properties of the Axis II measures. *J Orofac Pain*. 2010;24(1):48-62.
54. Su N, Lobbezoo F, van Wijk A, van der Heijden GJMG, Visscher CM. Associations of pain intensity and pain-related disability with psychological and socio-demographic factors in patients with temporomandibular disorders: a cross-sectional study at a specialised dental clinic. *J Oral Rehabil*. 2017;44(3):187-196. doi:10.1111/joor.12479.
55. Emshoff R, Emshoff I, Bertram S. Estimation of clinically important change for visual analog scales measuring chronic temporomandibular disorder pain. *J*

Orofac Pain. 2010;24(3):262-269. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=20664827.

56. Currie CC, Stone SJ, Durham J. Pain and problems: A prospective cross-sectional study of the impact of dental emergencies. *J Oral Rehabil*. 2015;42(12):883-889. doi:10.1111/joor.12333.
57. Jensen MP, Wang W, Potts SL, Gould EM. Reliability and Validity of Individual and Composite Recall Pain Measures in Patients with Cancer. *Pain Med (United States)*. 2012;13(10):1284-1291. doi:10.1111/j.1526-4637.2012.01470.x.
58. Dworkin SF, Turner JA, Mancl L, et al. A randomized clinical trial of a tailored comprehensive care treatment program for temporomandibular disorders. *J Orofac Pain*. 2002;16(4):259-276. http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L35549117%5Cnhttp://sfx.library.uu.nl/utrecht?sid=EMBASE&issn=10646655&id=doi:&atitle=A+randomized+clinical+trial+of+a+tailored+comprehensive+care+treatment+program+for+temporomandib.
59. Markiewicz MR, Ohrbach R, McCall Jr WD. Oral behaviors checklist: reliability of performance in targeted waking-state behaviors. *J Orofac Pain*. 2006;20(4):306-316.
60. Kaplan SE, Ohrbach R. Self-Report of Waking-State Oral Parafunctional Behaviors in the Natural Environment. *J oral facial pain headache*. 2016;30(2):107-119. doi:10.11607/ofph.1592.
61. Schiffman E, Ohrbach R. Executive summary of the Diagnostic Criteria for Temporomandibular Disorders for clinical and research applications. *J Am Dent Assoc*. 2016;147(6):438-445. doi:10.1016/j.adaj.2016.01.007 [doi].
62. Derogatis LR. SCL-90-R Symptom Checklist-90-R administration, scoring and procedures manual. Minneapolis, MN: National Computer Systems. *CIT0011*. 1994.
63. Derogatis LR. SCL-90-R Administration, Scoring & Procedures Manual-II. Towson, MD. *Clin Psychom Res*. 1983.
64. Derogatis LR. Symptom Checklist-90-R (SCL-90-R): Administration, scoring, and procedures manual (3rd ed.). *Minneapolis, MN NCS Pearson*. 1994.
65. Velly AM, Gornitsky M, Philippe P. Contributing factors to chronic myofascial pain: a case-control study. *Pain*. 2003;104(3):491-499. doi:S0304395903000745 [pii].
66. Hardt J, Gerbershagen HU, Franke P. The symptom check-list, SCL-90-R: its use and characteristics in chronic pain patients. *Eur J Pain*. 2000;4(2):137-148. doi:10.1053/eujp.2000.0162 [doi].
67. Cohen S, Kamarck T, Mermelstein R. A Global Measure of Perceived Stress. *J Health Soc Behav*. 1983;24(4):385. doi:10.2307/2136404.
68. Taylor JM. Psychometric analysis of the Ten-Item Perceived Stress Scale. *Psychol Assess*. 2015;27(1):90-101. doi:10.1037/a0038100 [doi].
69. Roberti JW, Harrington LN, Storch EA. Further Psychometric Support for the 10-Item Version of the Perceived Stress Scale. *J Coll Couns*. 2006.

doi:10.1002/j.2161-1882.2006.tb00100.x.

70. Cohen S, Williamson G. Perceived stress in a probability sample of the United States. *Soc Psychol Heal*. 1988. doi:10.1111/j.1559-1816.1983.tb02325.x.
71. Lee EH. Review of the psychometric evidence of the perceived stress scale. *Asian Nurs Res (Korean Soc Nurs Sci)*. 2012;6(4):121-127. doi:10.1016/j.anr.2012.08.004 [doi].
72. Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for Clinical and Research Applications: recommendations of the International RDC/TMD Consortium Network* and Orofacial Pain Special Interest Groupdagger. *J oral facial pain headache*. 2014;28(1):6-27. doi:10.11607/jop.1151 [doi].
73. Taylor R. Interpretation of the Correlation Coefficient: A Basic Review. *J Diagnostic Med Sonogr*. 1990;6(1):35-39. doi:10.1177/875647939000600106.
74. Mukaka MM. Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Med J*. 2012;24(3):69-71. doi:10.1016/j.cmpb.2016.01.020.
75. Johansson A, Unell L, Carlsson G, Soderfeldt B, Halling A, Widar F. Associations between social and general health factors and symptoms related to temporomandibular disorders and bruxism in a population of 50-year-old subjects. *Acta Odontol Scand*. 2004;62(4):231-237. doi:3JG6H2YXWNLMDC84 [pii].
76. Epker J, Gatchel RJ, Ellis 3rd E. A model for predicting chronic TMD: practical application in clinical settings. *J Am Dent Assoc*. 1999;130(10):1470-1475. doi:S0002-8177(15)60347-6 [pii].
77. Wright AR, Gatchel RJ, Wildenstein L, Riggs R, Buschang P, Ellis 3rd E. Biopsychosocial differences between high-risk and low-risk patients with acute TMD-related pain. *J Am Dent Assoc*. 2004;135(4):474-483. doi:S0002-8177(14)61233-2 [pii].
78. Armijo-Olivo S, Warren S, Fuentes J, Magee DJ. Clinical relevance vs. statistical significance: Using neck outcomes in patients with temporomandibular disorders as an example. *Man Ther*. 2011;16(6):563-572. doi:10.1016/j.math.2011.05.006.
79. Farrar JT, Young JP, LaMoreaux L, Werth JL, Poole RM. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain*. 2001;94(2):149-158. doi:10.1016/S0304-3959(01)00349-9.
80. Farrar JT, Portenoy RK, Berlin JA, Kinman JL, Strom BL. Defining the clinically important difference in pain outcome measures. *Pain*. 2000;88(3):287-294. doi:10.1016/S0304-3959(00)00339-0.
81. Ohrbach R, Markiewicz MR, McCall Jr WD. Waking-state oral parafunctional behaviors: specificity and validity as assessed by electromyography. *Eur J Oral Sci*. 2008;116(5):438-444. doi:10.1111/j.1600-0722.2008.00560.x [doi].
82. Ohrbach R, Michelotti A. The Role of Stress in the Etiology of Oral Parafunction and Myofascial Pain. *Oral Maxillofac Surg Clin North Am*. 2018. doi:10.1016/j.coms.2018.04.011.
83. van der Meulen MJ, Lobbezoo F, Aartman IHA, Naeije M. Validity of the Oral

Behaviours Checklist: correlations between OBC scores and intensity of facial pain. *J Oral Rehabil*. 2014;41(2):115-121. doi:10.1111/joor.12114.

84. van der Meulen MJ, Lobbezoo F, Aartman IH, Naeije M. Self-reported oral parafunctions and pain intensity in temporomandibular disorder patients. *J Orofac Pain*. 2006;20(1):31-35.
85. van Selms M, Muzalev K, Visscher C, Koutris M, Bulut M, Lobbezoo F. Are Pain-Related Temporomandibular Disorders the Product of an Interaction Between Psychological Factors and Self-Reported Bruxism? *J Oral Facial Pain Headache*. 2017. doi:10.11607/ofph.1909.
86. Khawaja SN, Nickel JC, Iwasaki LR, Crow HC, Gonzalez Y. Association between waking-state oral parafunctional behaviours and bio-psychosocial characteristics. *J Oral Rehabil*. 2015;42(9):651-656. doi:10.1111/joor.12302.
87. Manfredini D, Lobbezoo F. Role of psychosocial factors in the etiology of bruxism. *J Orofac Pain*. 2009;23(2):153-166.
88. Glaros AG, City K, Williams K, City K. Tooth contact versus clenching: oral parafunctions and facial pain. *J Orofac Pain*. 2012.
89. Shiffman S, Stone AA, Hufford MR. Ecological Momentary Assessment. *Annu Rev Clin Psychol*. 2008;4:1-32. doi:10.1146/annurev.clinpsy.3.022806.091415.
90. Manfredini D, Landi N, Fantoni F, Segu M, Bosco M. Anxiety symptoms in clinically diagnosed bruxers. *J Oral Rehabil*. 2005;32(8):584-588. doi:JOR1462 [pii].
91. Manfredini D, Arreghini A, Lombardo L, et al. Assessment of Anxiety and Coping Features in Bruxers: A Portable Electromyographic and Electrocardiographic Study. *J oral facial pain headache*. 2016;30(3):249-254. doi:10.11607/ofph.1616 [doi].
92. Fillingim RB, Ohrbach R, Greenspan JD, et al. Potential psychosocial risk factors for chronic TMD: descriptive data and empirically identified domains from the OPPERA case-control study. *J Pain*. 2011;12(11 Suppl):T46-60. doi:10.1016/j.jpain.2011.08.007 [doi].
93. Ahlberg J, Lobbezoo F, Ahlberg K, et al. Self-reported bruxism mirrors anxiety and stress in adults. *Med Oral Patol Oral Cir Bucal*. 2013;18(1):e7-11. doi:18232 [pii].
94. Stockstill JW, Callahan CD. Personality hardiness, anxiety, and depression as constructs of interest in the study of temporomandibular disorders. *J Craniomandib Disord*. 1991;5(2):129-134.
95. Tavares LM, da Silva Parente Macedo LC, Duarte CM, de Goffredo Filho GS, de Souza Tesch R. Cross-sectional study of anxiety symptoms and self-report of awake and sleep bruxism in female TMD patients. *Cranio*. April 2016:1-4. doi:10.1080/08869634.2016.1163806 [doi].
96. McKinney MW, Londeen TF, Turner SP, Levitt SR. Chronic TM disorder and non-TM disorder pain: a comparison of behavioral and psychological characteristics. *Cranio*. 1990;8(1):40-46.
97. Jensen HH, Mortensen EL, Lotz M. Scl-90-R symptom profiles and outcome of short-term psychodynamic group therapy. *ISRN Psychiatry*. 2013;2013:540134. doi:10.1155/2013/540134 [doi].

98. Paap MCS, Meijer RR, Cohen-Kettenis PT, et al. Why the factorial structure of the SCL-90-R is unstable: Comparing patient groups with different levels of psychological distress using Mokken Scale Analysis. *Psychiatry Res*. 2012;200(2-3):819-826. doi:10.1016/j.psychres.2012.03.012.

99. Paap MCS, Meijer RR, van Bebber J, et al. A study of the dimensionality and measurement precision of the SCL-90-R using item response theory. *Int J Methods Psychiatr Res*. 2011;20(3). doi:10.1002/mpr.347.

100. Fillingim RB, Ohrbach R, Greenspan JD, et al. Psychological factors associated with development of TMD: the OPPERA prospective cohort study. *J Pain*. 2013;14(12 Suppl):T75-90. doi:10.1016/j.jpain.2013.06.009 [doi].

101. Huhtela OS, Napankangas R, Joensuu T, Raustia A, Kunttu K, Sipila K. Self-Reported Bruxism and Symptoms of Temporomandibular Disorders in Finnish University Students. *J ORAL FACIAL PAIN HEADACHE*. 2016;30(4):311-317. doi:10.11607/ofph.1674.

102. Winocur E, Uziel N, Lisha T, Goldsmith C, Eli I. Self-reported bruxism - associations with perceived stress, motivation for control, dental anxiety and gagging. *J Oral Rehabil*. 2011;38(1):3-11. doi:10.1111/j.1365-2842.2010.02118.x [doi].

103. Abekura H, Tsuboi M, Okura T, Kagawa K, Sadamori S, Akagawa Y. Association between sleep bruxism and stress sensitivity in an experimental psychological stress task. *Biomed Res*. 2011;32(6):395-399. doi:JST.JSTAGE/biomedres/32.395 [pii].

104. Botturi D, Rodella S. Patient-reported outcomes: definition and measurement. *Recenti Prog Med*. 2014;105(6):233-242. doi:10.1701/1543.16851 [doi].

105. Hadjistavropoulos T, Craig KD. A theoretical framework for understanding self-report and observational measures of pain: a communications model. *Behav Res Ther*. 2002;40(5):551-570.

106. Bossuyt PM, Reitsma JB, Bruns DE, et al. The STARD statement for reporting studies of diagnostic accuracy: explanation and elaboration. *Ann Intern Med*. 2003;138(1):W1-12. doi:200301070-00012-W1 [pii].