BMC Oral Health

https://doi.org/10.1186/s12903-026-09292-5

Article in Press

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Received: 24 November 2025

Accepted: 10 July 2026

Published online: 21 July 2026

Cite this article as: Demir A., Sismanoglu S. & Röhlig B.G. Occlusal vertical dimension and temporomandibular disorders: insights into tooth wear, pain, and quality of life. *BMC Oral Health* (2026). https://doi.org/10.1186/s12903-026-09292-5

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Occlusal Vertical Dimension and Temporomandibular Disorders: Insights into Tooth Wear, Pain, and Quality of Life

Running Head: The relationship between the OVD and TMD

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Abstract

Purpose: Current literature does not fully clarify how temporomandibular joint impairment relates to occlusal vertical dimension. This study examined the association between occlusal vertical dimension and temporomandibular disorders (TMD) in a Turkish cohort.

Materials and Methods: This study was conducted by analyzing data obtained from 114 patients who visited the clinic and met the predefined inclusion criteria. For every participant, the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) questionnaire set was completed in full. Clinical assessments were then performed following the RDC/TMD Clinical Examination protocol and were finalized with a detailed extraoral evaluation. All collected data underwent comprehensive statistical processing, and the results were interpreted using a significance threshold of $p < 0.05$.

Results: The study revealed that 35.09% of participants exhibited a reduced occlusal vertical dimension, whereas 18.42% showed an increased dimension within the Turkish sample. Vertical dimension was significantly associated with depression ($p = 0.035$) and was identified as a contributor to movement-related pain (left lateral excursion pain $p = 0.02$). However, no

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statistically significant association was detected between occlusal vertical dimension and TMD ($p < 0.05$).

Conclusion: Contrary to common assumptions, occlusal vertical dimension and TMD do not appear to be related. No significant association was observed between vertical dimension and tooth wear.

Keywords: Temporomandibular Disorders, Tooth wear, Vertical Dimension of Occlusion, Psychosocial Factors, Quality of Life

1 Introduction

Temporomandibular disorders (TMD) are the most common type of non-odontogenic orofacial pain [1,2]. TMD has mostly been associated with five etiological components: parafunctional activities, trauma, extreme pain stimuli, and psychological factors such as stress, anxiety, and depression [3]. TMDs are a collective term covering various clinical problems. The temporomandibular joint and surrounding tissues are affected by TMD. Pain, restriction in mouth opening, and joint noises are frequently highlighted as primary manifestations in the literature [4]. TMD frequently manifests as joint sounds such as clicking or crepitus that occur during mandibular movements, along with pain in the temporomandibular joint or masticatory muscles and noticeable irregularities in the normal trajectory of jaw motion, including deviations or deflections [2]. Symptoms that extend beyond normal physiological limits may appear locally or as part of broader systemic involvement. Due to its anatomical proximity to various structures in the head and neck, the differential diagnosis of TMD is often challenging and may easily be confused with other regional sources of discomfort [5]. Other chronic pain disorders such as migraine, fibromyalgia, and generalized pain have been linked to TMDs [6,7,8.] The current body of literature does not clearly define a single, precise cause for temporomandibular disorders, and the etiology remains largely ambiguous [9]. However, there are five major etiologic factors identified in the literature. These are trauma, malocclusion, emotional stress, deep pain sources, and parafunctional habits [10]. Recent recommendations by the INfORM/IADR group emphasize that TMD management should be based on current scientific evidence and caution against overestimating the role of dental occlusion in the etiology of TMDs [11]. The effect of these factors on patients varies from person to person. The adverse effect of TMDs on quality of life is also widely recognized [12]. The key to enhancing quality of life could be early diagnosis, explanation, and management [8].

One of the most common reported or seen indications and symptoms of TMD is difficulty with or impairment of masticatory function [13]. Although some clinicians suggest that variations in occlusal vertical dimension (OVD) may be strongly associated with symptoms of temporomandibular disorders, the scientific literature provides minimal evidence supporting a definitive link. The Glossary of Prosthodontic Terms defines the occlusal vertical dimension as the measured distance between two predetermined anatomical or marked points, typically one located on the nasal tip and the other on the chin, when the mandible is in maximal intercuspal

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position [14]. OVD plays an important role in patient comfort, oral function, and overall esthetics [15]. When this vertical dimension is increased beyond an individual's adaptive capacity, patients may develop issues such as fatigue in the masticatory muscles, a sensation of bulkiness within the oral cavity, and difficulties related to chewing and speech [15]. There is conflicting research on whether an individual's OVD remains constant throughout their life [16]. If it does change, it will therefore affect the masticatory system's physiology and the patient's capacity for adaptation. There is some evidence that skeletal growth continues from mid adolescence into mid adulthood but at a much slower pace than from childhood to mid adolescence [16].

The existing literature does not wholly explains the mechanism of temporomandibular joint disturbance and occlusal vertical dimension. The complex and multifactorial nature of TMD has led to ongoing debates regarding the role of occlusal vertical dimension in its etiology and management. Alterations in occlusal vertical dimension, whether resulting from developmental, functional, or pathological factors, have been postulated to contribute to the onset and progression of temporomandibular disorders [17]. However, the precise mechanisms by which changes in occlusal vertical dimension influence the pathogenesis of temporomandibular disorders remain incompletely elucidated. To date, studies examining this relationship have largely focused on isolated aspects of the association. The present study aimed to provide a more comprehensive evaluation by simultaneously assessing OVD in relation to TMD diagnosis, tooth wear severity, psychological status, pain thresholds, and oral health-related quality of life within the same cohort. This study sought to explore how occlusal vertical dimension interacts with temporomandibular disorders, while also examining whether tooth wear and psychological factors in patients show any association with the presence of TMD. The null hypothesis was that there is no statistically significant association between OVD status (normal, increased, or decreased) and the presence or type of TMD diagnosis according to RDC/TMD Axis I classification.

2 Materials and Methods

2.1 Study design

This research was conducted and reported in accordance with the STROBE guidelines for observational studies, and the patient recruitment process is illustrated in the flow diagram (Figure 1). The investigation was conducted by analyzing data obtained from both patient questionnaires and comprehensive clinical examination findings. Ethical approval was obtained from the Ethics Committee of Istanbul University Faculty of Dentistry (2016/34), in accordance with the Helsinki Declaration. The participants signed the consent form individually, and the informed consent to participate was obtained from all of the participants in the study.

This research involved examining patients at Istanbul University, Faculty of Dentistry in Türkiye. As per the patient treatment protocol, patients were initially assessed in the Department of Oral and Maxillofacial Radiology. Following their diagnoses, they were referred to the appropriate departments, such as endodontics, oral and maxillofacial radiology, oral and

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maxillofacial surgery, orthodontics, pedodontics, periodontology, prosthodontics, and restorative dentistry for further treatment. Participants were recruited from individuals referred to the Department of Prosthodontics who fulfilled the inclusion criteria and provided written informed consent prior to enrollment. Eligible participants were required to be between 18 and 65 years of age, with no TMD-related treatment in the preceding three months, no active use of an occlusal splint, no planned surgical treatment within the following three months, no problems with wisdom teeth, no cancer diagnosis, no pregnancy, and no major psychiatric disorder.

A total of 150 patients were initially recruited for this study. However, 36 patients were excluded due to not meeting the eligibility criteria (n = 28) or declined participation (n = 8). Accordingly, 114 participants were finally included in the study. All participants were dentate. The sample size was calculated using G*Power software (version 3.1, Heinrich-Heine-Universität Düsseldorf, Germany) for a chi-square test with a medium effect size (w = 0.3), $\alpha = 0.05$, and power = 0.80, which indicated a minimum of 110 participants. The final sample of 114 exceeded this requirement.

Patients' height and weight were documented to calculate their body mass index (BMI), which is obtained by dividing body weight in kilograms by the square of height in meters. Clinical assessment was concluded with an extraoral evaluation, during which the distances between eyebrow-chin, glabella-subnasal, interpupillary, and subnasal-jaw points were measured and recorded [18]. Facial proportions were assessed using the equal-thirds method, which divides the face into three vertical segments: trichion to glabella (upper third), glabella to subnasale (middle third), and subnasale to gnathion (lower third). OVD classification was based on the ratio of the glabella–subnasale distance to the subnasale–gnathion distance. A ratio of 1.0 (equal segment lengths) indicated normal OVD; a ratio greater than 1.0 indicated decreased OVD (proportionally shorter lower facial third); and a ratio less than 1.0 indicated increased OVD (proportionally longer lower facial third). All linear measurements were recorded in centimeters to one decimal place. Photographic analysis was performed according to the Wright technique: a millimetric ruler was held at the level of the pupils, and a standardized frontal photograph was taken. Photographs were taken with the patient seated upright, looking directly at the camera, with the interpupillary line and Camper's plane parallel to the horizontal plane. The mandible was in the habitual intercuspal position during all measurements. The interpupillary distance served as a calibration reference, allowing clinical measurements to be verified against photographic records. This dual-method cross-verification served as an internal consistency check for each participant. Formal intraclass correlation coefficient (ICC) testing was not performed, which is acknowledged as a limitation of the study. All measurements were performed manually (Figure 2).

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2.2 Clinical and dental examinations

Clinical examinations were performed by the same clinician for all patients, following the validated Turkish version of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD)**.** The RDC/TMD protocol consists of two axes: Axis I and Axis II. Axis I involves

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the physical evaluation using the standardized examination form, allowing the classification of temporomandibular disorders into three groups:

Group I: Myofascial pain (Ia) and myofascial pain with limited mouth opening (Ib).

Group II: Disc displacement with reduction (IIa), disc displacement without reduction with limited mouth opening (IIb), and disc displacement without reduction without limitation of mouth opening (IIc).

Group III: Presence of arthritis in the joint, including arthralgia (IIIa), osteoarthritis (IIIb), and osteoarthrosis (IIIc).

Multiple diagnoses across Groups I, II, and III could coexist in the same patient. All applicable diagnoses were recorded independently, and each diagnostic group was analyzed separately across OVD categories rather than assigning patients to a single mutually exclusive category [19,20].

Muscle tenderness was objectively measured using a pressure algometer (FDN 100, Wagner Instruments, USA), which measures in kg/cm². The algometer was positioned perpendicular to the muscle site to be tested, and pressure was gradually applied (Figure 3). Participants were instructed to signal the first moment they perceived pain. At this point, pressure application was stopped, and the reading displayed on the algometer was recorded. Measurements were taken bilaterally from specific anatomical points. For the temporal muscle, the anterior, middle, and posterior regions were assessed; for the masseter muscle, the upper, middle, and lower regions; for the sternocleidomastoid muscle, the upper, middle, and lower regions; and for the trapezius muscle, the upper, middle, and lower regions.

Alginate impressions of both maxillary and mandibular arches were obtained from each patient for the evaluation of tooth wear. The impressions were poured with dental gypsum to produce positive casts, which were examined for dentition and occlusion. Tooth wear was evaluated using the Basic Erosive Wear Examination (BEWE) index [21]. Each of the six sextants was scored individually; the cumulative score was then used for classification and statistical analysis. Based on the scores obtained from this system, individuals were categorized into four levels of tooth wear: no wear (0-2), mild wear (3-8), moderate wear (9-13), and severe wear (>14). This approach ensured a systematic and reproducible evaluation of both temporomandibular disorders and erosive tooth wear for all participants.

2.3 Assessment of patient-reported outcomes

Prior to the clinical evaluations, patients were administered questionnaires at the time of enrollment. The first is the questionnaire part of RDC/TMD, Axis II, that includes biobehavioral evaluations. These assessments include grading chronic pain (CPG) and evaluating depressive symptoms, along with both non-specific painful and non-painful physical complaints. Chronic pain

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severity is classified on a scale ranging from Grade 0 to Grade 4, with Grade 4 indicating the most severe level.

The additional questionnaires that were given out were designed to assess anxiety levels and quality of life in relation to oral health. The State-Trait Anxiety Inventory (STAI Forms Tx-1 and Tx-2), developed by Spielberger et al. and validated for Turkish by Öner, was administered to determine participants' levels of situational (state) anxiety as well as their general, long-term anxiety tendencies (trait anxiety). The Turkish version of the STAI has demonstrated satisfactory internal consistency, with Cronbach's alpha values ranging from 0.83 to 0.92. As the instrument was applied in its standardized, unmodified form, no separate reliability analysis was conducted in the current sample. The first twenty questions (Tx-1) have been designed to assess state anxiety, and the remaining twenty questions (Tx-2) have been designed to assess trait anxiety. Scores from the two scales together range between 20 and 80, with higher values indicating increased levels of anxiety.

The Oral Health Impact Profile (OHIP-14) short form was completed in order to assess the oral health-related quality of life (OHRQoL). This questionnaire consists of 14 items organized in seven sub-scales, which address aspects of oral health that may compromise someone's physical, psychological, and social well-being. OHIP-14 consists of seven conceptual dimensions: functional limitation (OHIP 14-1), physical pain (OHIP 14-2), psychological distress (OHIP 14-3), physical disability (OHIP 14-4), psychological disability (OHIP 14-5), social disability (OHIP 14-6), and handicap (OHIP 14-7). In addition to this information, three summary variables were gained from this questionnaire: prevalence, extent, and severity. Prevalence was identified by determining whether participants selected "frequently" or "always" for one or more items, by counting how many domains received these higher-frequency responses, and by evaluating the overall score obtained from all scales, which ranged from 0 to 56 points. Lower ratings indicate a better quality of life, while higher numbers indicate a worse OHRQoL.

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2.4 Statistical analysis

Statistical analyses were conducted using NCSS 2007 Statistical Software (Utah, USA). Normality of continuous variables was assessed using the Shapiro-Wilk test. Descriptive statistics were presented as mean ± standard deviation for continuous variables and as frequencies and percentages for categorical variables. Continuous variables, including BMI, age, algometer threshold values, STAI anxiety scores, and OHIP-14 scores, were compared across OVD groups using one-way ANOVA. When significant differences were detected, the Tukey HSD test was applied for post-hoc pairwise comparisons. Categorical variables, including gender, marital status, smoking status, RDC/TMD Axis I and Axis II classifications, BEWE categories, and pain parameters, were analyzed using the chi-square test. All statistical tests were two-sided, and significance was set at $p < 0.05$.

3 Results

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3.1 Sample and Demographics

A total of 114 patients (91 women, 23 men) were included in the study. The age range was 18-61 years, with a mean age of 31.3 (Table 1). Eighty-four individuals reported no systemic condition, whereas 30 reported at least one systemic disease. Occupational status comprised 28 students, 57 employed, and 29 unemployed participants; 59 were single and 55 married. Twenty-six participants were non-smokers, and 88 were smokers. Regarding BMI, 62 were within the healthy range, 11 underweight, 31 overweight, and 10 obese.

3.2 Vertical Dimension Classification and Associations

Among the 114 individuals included in the study, 54 patients (47.37%) exhibited a vertical dimension within normal limits, 21 patients (18.42%) demonstrated an increased vertical dimension, and 39 patients (34.21%) presented with a reduced vertical dimension. Analysis revealed several statistically significant associations: vertical dimension differed by gender (p = 0.001), showed a correlation with body mass index (p = 0.004), and was related to the presence of muscle pain (p = 0.02) as well as depressive symptoms (p = 0.035) (Table 2).

3.3 RDC/TMD Axis I Distribution

According to the RDC/TMD Axis I classification, 31 patients were diagnosed with myofascial pain (Ia) and 27 with myofascial pain with limited mouth opening (Ib). In Group II, disc displacement with reduction (IIa) was observed in 20 patients, without reduction with limited opening (IIb) in 8 patients, and without reduction without limitation (IIc) in 1 patient. In Group III, arthralgia (IIIa) was present in 17 patients, osteoarthritis (IIIb) in 3 patients, and osteoarthrosis (IIIc) in 22 patients. Overall, arthralgia/arthritis was the most frequent diagnosis (38.6%), followed by myofascial pain (24.6%) and disc displacement (13.2%), while 23.7% of participants had no Axis I diagnosis. The distribution of these conditions was comparable across OVD groups, with arthralgia/arthritis ranging from 32.1% to 45.0%, myofascial pain from 19.0% to 28.3%, and disc displacement from 9.5% to 15.1%. Statistical analysis revealed no significant association between OVD groups and Axis I diagnoses (Chi-square test, p = 0.860).

3.4 Perceived Pain and Functional Findings

Headache was reported by 71 patients (62.3%), temporomandibular joint pain by 30 (26.3%), temporal muscle pain by 39 (34.2%), and masseter muscle pain by 111 (97.4%). Pain during jaw movement was present in 81 participants (71.1%), occurring most often during eccentric (58.8%) and centric movements (53.5%), followed by lateral (48.3%) and protrusive with opening (38.6%) movements. The distribution of perceived pain symptoms across OVD groups is summarized in Table 3. Headache and muscle pain were reported with similar frequencies across groups (p = 0.901 and p = 0.704, respectively), while joint pain tended to be more frequent in the high OVD group (42.9%) compared to the low (20.0%) and normal (24.5%) groups, although the difference was not statistically significant (p = 0.144). Mean temporal, masseter, posterior

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mandibular, and global thresholds showed no significant group differences, although trends included higher masseter thresholds in the high OVD group (2.53 ± 0.93 vs 2.16 ± 0.47; $p = 0.072$) and higher posterior mandibular thresholds in the normal OVD group (3.87 ± 0.82 vs 3.48 ± 0.71; $p = 0.065$).

3.5 RDC/TMD Axis II Distribution

Chronic pain was graded from 0 (no pain) to 4 (severe disability), with 18 participants in Grade 0, 37 in Grade 1, 55 in Grade 2, 3 in Grade 3, and 1 in Grade 4. For analysis, more than half of the participants were classified as Grade III-IV (51.8%), with similar distributions across OVD groups ($p = 0.271$). Depression was categorized as normal (n = 57), moderate (n = 38), and severe (n = 19). Severe depression was more frequent in the low (25.0%) and high OVD groups (23.8%) than in the normal OVD group (7.5%), showing a near-significant trend ($p = 0.056$). Somatic symptoms were mostly mild, with painful symptoms reported as normal in 70 participants, mild in 33, and severe in 11; non-painful symptoms were normal in 99, mild in 14, and severe in 1. Neither painful nor non-painful somatic symptom scores differed significantly across OVD groups ($p = 0.465$ and $p = 0.505$) (Table 4).

3.6 Tooth Wear (BEWE) and Associations

Based on the BEWE index, 3 participants (2.6%) had no tooth wear, 49 (43.0%) showed low, 43 (37.7%) moderate, and 14 (12.3%) high tooth wear. When stratified by OVD, most participants presented with scores of 1 or 2, while few had a score of 0 or 3. The proportion of score 3 was higher in the high OVD group (19.0%) compared with the low (7.5%) and normal OVD groups (1.9%). However, the distribution of BEWE categories across OVD groups did not reach statistical significance (Chi-square test, $p = 0.169$). Significant associations of tooth wear were instead observed with age ($p = 0.0001$), BMI ($p = 0.044$), chronic pain grade ($p = 0.025$), marital status ($p = 0.002$), muscle pain ($p = 0.004$), and smoking ($p = 0.019$) (Table 2).

3.7 Anxiety and Oral Health-Related Quality of Life

On the STAI, the mean state (TX1) and trait (TX2) anxiety scores were 42.30 ± 7.89 and 42.91 ± 9.03, respectively. Across OVD groups, STAI state and trait scores did not differ significantly ($p = 0.149$ and $p = 0.451$). The overall OHIP-14 total score was 11.96 ± 9.06, with domain means ranging from 0.96 ± 1.41 (functional limitation) to 3.16 ± 2.13 (physical pain). OHIP-14 scores were comparable across OVD groups, with mean values of 11.63 ± 8.70 in the low OVD group, 11.26 ± 8.80 in the normal OVD group, and 14.33 ± 10.37 in the high OVD group ($p = 0.511$).

4 Discussion

In this research, the potential link between OVD and TMD was investigated using the RDC/TMD diagnostic system, and additional analyses were performed to explore how OVD relates to tooth wear, anxiety levels, and overall quality of life. The findings revealed no

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statistically significant association between OVD status and the presence or type of TMD diagnosis according to RDC/TMD Axis I classification (χ^2 test, $p = 0.860$). Therefore, the null hypothesis was accepted. Furthermore, it should be emphasized that altering the vertical dimension for the purpose of treating joint disorders should be considered overtreatment and should not be accepted as a routine prosthetic or orthodontic intervention [16,22]. The clinical and ethical implications of the absent association between occlusion and TMD have been extensively discussed in the literature. The unfounded claim that dental occlusion plays a major role in TMD etiology has historically led to unnecessary and potentially harmful dental and surgical interventions [22,23]. Patients should be protected from such overtreatment, and clinicians must base their management decisions on current scientific evidence rather than outdated mechanistic assumptions [24]. This view is consistent with the recently published INfORM/IADR standard of care recommendations, which highlight that occlusal factors should not be regarded as primary etiological contributors to TMD and that irreversible occlusal interventions should be avoided [11].

The role of dental occlusion as a primary etiological factor in TMD has been progressively questioned by the literature [25]. A multivariate analysis evaluating the predictive value of occlusal variables for intracapsular TMD demonstrated that these factors accounted for no more than 4.8% to 27.1% of the total variance, with the remaining 73% to 95% attributable to non-occlusal factors [26]. In a similar study investigating eight occlusal variables in relation to masticatory muscle disorders, the total explained variance was only 10.8%, further confirming the low predictive value of occlusal features [27]. The present findings, showing no association between OVD status and TMD diagnosis, are consistent with this body of evidence and further support the view that occlusion-based explanations of TMD etiology should not guide clinical decision-making. From a prosthodontic perspective, the relationship between prosthetic rehabilitation and TMD has been critically examined. A systematic review addressing three clinical scenarios (whether prosthodontics should be used to treat TMD and/or bruxism, whether it can cause these conditions, and how it should be performed in affected patients) found no randomized clinical trials on any of these topics and concluded that prosthetic changes in dental occlusion cannot be recommended as a strategy for managing TMD or bruxism [28]. Similarly, the concept of centric relation, which has traditionally been used as a diagnostic reference for evaluating condylar position in TMD patients, has been critically re-evaluated. A recent review concluded that the diagnostic use of centric relation lacks anatomical and scientific support and suggested that it should only be considered a pragmatic maxillo-mandibular reference position when occlusal reorganization is warranted [29]. These perspectives further reinforce the view that mechanistic, occlusion-focused approaches to TMD management should be abandoned in favor of evidence-based, biopsychosocial strategies.

The study population consisted of consecutive patients referred for prosthetic treatment, none of whom were specifically seeking TMD advice. The relatively high prevalence of TMD findings and elevated psychological scores should be interpreted in the context of a university hospital setting, where patients with complex dental needs tend to be overrepresented. Furthermore, the RDC/TMD protocol is designed to capture all TMD-related signs and symptoms,

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including those that patients may not actively report as complaints. This should be considered when interpreting the generalizability of the findings. Only adults aged 18-64 were included, and the mean age was 31.34. This distribution is consistent with the literature reporting that TMD is most common in the 20-40 age range [3,30]. Of the participants, 91 (79.8%) were female and 23 (20.2%) were male. This finding is consistent with studies showing that women are more frequently affected by TMD [4,12]. However, it should be noted that this difference may reflect variations in healthcare-seeking behavior rather than true prevalence [31].

Statistical analysis showed that women had significantly lower OVD values than those of men ($p < 0.05$). This finding is consistent with anthropometric studies demonstrating sexual dimorphism in craniofacial morphology; however, it should be noted that this may reflect natural developmental differences rather than pathological changes [5,32]. Approximately half of the participants (48.25%) were married. Although this rate is slightly higher than in some disability studies [10], our findings showed a relationship between marital status and chronic pain associated with TMD. Married individuals were more frequently found in the moderate and severe tooth wear groups. Although no direct relationship was observed between OVD and marital status, these results suggest that there may be a correlation between marital status and tooth wear severity. This is most likely due to a confounding factor related to age, as most of the married participants in our study were in the older age group. Future analyses should control for the age factor [33]. Accordingly, these findings should be interpreted with caution, as the observed association likely reflects age-dependent confounding rather than a direct causal relationship.

Smoking may increase susceptibility to TMD through allergic and inflammatory pathways [34]. In our analysis, smoking did not exhibit any significant association with OVD; however, it was clearly linked to the severity of tooth wear, with this relationship reaching statistical significance ($p < 0.05$). Individuals who smoked were more frequently represented in the moderate and severe tooth-wear categories. This finding may be attributed either to smoking as an indicator of increased psychological stress or to its direct impact on oral tissues and on behaviors such as parafunctional habits [13,35]. According to research, people with higher BMIs are less likely to suffer from TMD pain [36]. Our findings revealed a significant association between BMI and OVD ($p < 0.05$). Individuals presenting with increased OVD exhibited higher mean BMI values compared with participants in the low OVD category. A notable association was also identified between BMI and tooth wear ($p < 0.05$). While no meaningful difference emerged between the groups showing no wear and mild wear, the average BMI of individuals with pronounced tooth wear was markedly higher than that of the other categories. This may be explained by parafunctional activities or dietary habits associated with increased BMI [37].

OVD was measured using photographic evaluation with the equal thirds method and the Wright method [38]. These methods were preferred because they are easy to apply, cost-effective, and do not involve radiation. Among the participants, 54 individuals (47.37%) exhibited a normal OVD, 21 (18.42%) demonstrated an increased OVD, and 39 (34.21%) presented with a reduced OVD. In this study, static OVD was examined alongside its potential associations with tooth wear

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and TMD. The commonly proposed sequence of "tooth wear leading to reduced OVD and subsequently to TMD" was not supported by our results [15,16]. Instead, our findings align with more recent research suggesting that the interplay among these factors is considerably more multifaceted than previously assumed [39,40]. Methodologically, while anthropometric measurements are practical in the clinic, they provide only static values and do not reflect dynamic functional conditions. Future research should utilize advanced methods such as functional assessments and 3D facial scanning [16,41]. In addition, OVD showed statistically significant associations with body mass index ($p = 0.004$), depressive symptoms ($p = 0.035$), gender ($p = 0.001$), and the presence of muscle-related pain ($p = 0.02$). However, in contrast to what might be anticipated, tooth wear did not exhibit a significant correlation with OVD. This finding may be attributed to the dentoalveolar compensation mechanism, which helps maintain vertical dimension despite progressive wear [16]. When teeth wear down, extrusion of the teeth occurs to preserve the vertical dimension. Although this mechanism preserves facial proportions in most individuals, it has biological limitations and may be insufficient in cases of rapid/severe wear or compromised periodontal support [42]. Therefore, the absence of clinically detectable changes in OVD does not imply that there is no significant loss of tooth structure.

Pain in TMD may arise from the temporomandibular joint, surrounding tissues, or psychological factors [18]. Psychological factors, particularly depression and anxiety, may serve as an intermediate link between various musculoskeletal symptoms, as emotional tension can manifest as increased muscle activity and pain [43,44]. The importance of Axis II psychosocial evaluation has been consistently emphasized in the literature, with several authors suggesting that any Axis I or functional evaluation should be interpreted within this psychosocial framework [45,46,47]. Furthermore, psychosocial factors have been shown to significantly influence pain perception, treatment outcomes, and the chronification of TMD [30,48]. In the present study, the significant association between low OVD and depression further supports the notion that psychological variables should not be overlooked in studies investigating the relationship between occlusal factors and TMD. Anxiety levels were assessed using the State-Trait Anxiety Inventory, while depression was measured using the RDC/TMD Axis II [49]. Our findings showed a significant relationship between low OVD and depression ($p < 0.05$). The rates of moderate and severe depression were higher in the low OVD group. However, no significant relationship was found between depression and tooth wear. This may reflect a bidirectional relationship in which depression triggers parafunctional behaviors and alters OVD, or OVD changes contribute to psychological distress [50]. In terms of pain distribution, left lateral movement pain showed a significant correlation with OVD groups ($p < 0.05$). Tooth wear was significantly correlated with masseter muscle pain ($p < 0.05$). These results suggest that functional pain indicators may be more sensitive than static measurements. Furthermore, the asymmetric distribution of pain highlights the need for further investigation of unilateral dysfunctions. However, no significant relationship was found between headache and TMD or tooth wear.

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Quality of life is a fundamental concept in modern healthcare approaches, and its relationship with TMD is well documented. Previous studies have shown that TMD severity reduces quality of life and that tooth wear negatively affects oral health-related quality of life [12,21]. However, there is no study in the literature that directly examines the relationship between OVD and quality of life. In our study, no significant relationship was found between OVD, tooth wear, and quality of life. This suggests that individuals may have developed adaptations to changes in OVD and tooth wear, or that the OHIP-14 questionnaire used may be insufficient to capture more subtle changes such as aesthetic or functional limitations [51].

The findings indicated that no statistically meaningful association could be identified between OVD and TMD. This outcome is consistent with recent evidence suggesting that measured increases in vertical dimension, when implemented with careful consideration of patient comfort, function, and esthetics, can often be tolerated either immediately or after only a brief adaptation period. Previous reports have indicated that OVD increases within reasonable limits (up to approximately 5 mm in most cases) can be safely achieved with fixed restorations and are generally well tolerated without the need for a provisional adaptation phase [16]. Similarly, a literature review stated that the stomatognathic system has the ability to adapt rapidly to moderate changes in OVD less than 5 mm [17]. Collectively, these findings suggest that the use of provisional restorations may not always be mandatory in clinical practice; however, considering individual variables such as the magnitude of the increase, the patient's physiological tolerance, occlusal-joint status, and esthetic expectations, provisional trials may still play an important role in the clinical decision-making process.

This study has certain limitations that should be acknowledged. The most significant limitation is the cross-sectional design and absence of long-term follow-up, which prevents assessment of temporal changes in OVD and limits understanding of the dynamic nature of these measurements over time. Longitudinal studies with extended follow-up periods would provide more comprehensive insights into OVD variations and their clinical implications. Additionally, while the sample size provides adequate statistical power for the primary analyses, a larger and more diverse cohort could enhance the generalizability of findings and enable more detailed subgroup comparisons. Furthermore, the relatively large number of variables assessed in relation to the sample size precluded the use of multivariate regression modeling, which could have provided a more comprehensive understanding of the interrelationships among OVD, TMD, and psychosocial factors. A further limitation is that formal intraclass correlation coefficient (ICC) testing for the anthropometric measurements was not performed, and the repeatability of skin-based landmark identification across examiners was not independently verified. Additionally, TMD assessment was performed using RDC/TMD rather than the more recent DC/TMD framework; therefore, the findings should be interpreted with caution, and direct comparison with contemporary DC/TMD-based studies may be limited. Despite these constraints, the current study offers valuable insights and establishes a foundation for future longitudinal investigations in this area. Future studies should aim to overcome these limitations. Longitudinal cohort designs will

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better explain the temporal relationships between OVD, tooth wear, and TMD. Randomized controlled trials can reveal the therapeutic effects of OVD modifications. More precise measurements can be made using advanced imaging techniques (e.g., 3D facial scanning, cephalometric analysis). Finally, mechanistic research is needed to understand the limits and failure points of the dentoalveolar compensation mechanism, along with interventional studies evaluating treatment outcomes when this capacity is exceeded.

The results of this research offer several important clinical implications. First, routine adjustment of the OVD for TMD treatment should be avoided, as this approach is not supported by scientific evidence. Second, a comprehensive diagnostic approach encompassing not only dental but also psychosocial factors should be adopted in patient evaluation. Third, the limitations of the dentoalveolar compensation mechanism should be recognized; this mechanism preserves the OVD in most cases, but it is not unlimited. Finally, treatment approaches should be individualized and implemented within a multidisciplinary framework that includes psychological support when necessary.

5 Conclusion

In conclusion, this study found no statistically significant association between OVD status and TMD diagnosis according to RDC/TMD Axis I classification. These findings do not support the routine modification of OVD as a treatment strategy for TMD. A comprehensive, individualized diagnostic approach that incorporates both clinical and psychosocial factors remains essential in the management of these patients.

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6 Declarations

Abbreviations:

TMD : Temporomandibular disorders

OVD : occlusal vertical dimension

OHIP : Oral Health Impact Profile

OHRQoL : Oral health-related quality of life

Ethics approval and consent to participate: Ethical approval was obtained from the Ethics Committee of Istanbul University Faculty of Dentistry (2016/34), in accordance with the Helsinki Declaration. The participants signed the consent form individually and the informed consent to participate was obtained from all of the participants in the study.

Consent for publication: Participants gave written informed consent for their personal or clinical details along with any identifying images to be published in this study.

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Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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

Clinical trial number: not applicable.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contributions: A.D. and B.G.R. conceptualised and designed the study; A.D. and B.G.R. recruited and screened the patients. A.D. collected clinical data. A.D and S.S. analysed the data. A.D. and S.S. interpreted the analysed data. A.D. and S.S. drafted the manuscript. A.D., B.G.R. and S.S. revised the manuscript. All authors read and approved the final manuscript.

Acknowledgements: This work is dedicated to the memory of Prof. Dr. Z. Haluk Keskin, who passed away in July 2025. He served as the PhD advisor of the corresponding author and is remembered with deep respect and gratitude.

7 References

1. Ruparel SB, Akopian AN. Mechanisms of orofacial pain. Frontiers in Pain Research. 2024; 5, 1496188.

2. Alrizqi AH, Aleissa BM. Prevalence of temporomandibular disorders between 2015-2021: a literature review. Cureus. 2023; 15(4).

3. Minervini G, Franco R, Marrapodi MM, Crimi S, Badnjević A, Cervino G, Bianchi A, Cicciù M. Correlation between temporomandibular disorders (TMD) and posture evaluated trough the diagnostic criteria for temporomandibular disorders (DC/TMD): a systematic review with meta-analysis. Journal of clinical medicine. 2023; 12(7), 2652.

4. Gil-Martínez A, Grande-Alonso M, López-de-Uralde-Villanueva I, López-López A, Fernández-Carnero J, La Touche R. Chronic Temporomandibular Disorders: disability, pain intensity and fear of movement. The journal of headache and pain. 2016; 17(1), 103.

5. Durham J. Temporomandibular disorders (TMD): an overview. Oral Surgery. 2008; 1752-2471, 1(2).

6. Yakkaphan P, Lambru G, Renton T. Impact of migraine and fibromyalgia on temporomandibular disorder: A retrospective study on pain, psychological factors and quality of life. J Oral Rehabil. 2024; 51(10), 2029-2042.

7. Dahan H, Shir Y, Velly A, Allison P. Specific and number of comorbidities are associated with increased levels of temporomandibular pain intensity and duration. J Headache Pain. 2015; 16, 528.

ARTICLE IN PRESS

8. Palmer J, Durham J. Temporomandibular disorders. BJA Educ. 2021; 21(2), 44-50.

9. Ohrbach R, Sharma S. Temporomandibular disorders: definition and etiology. In Seminars in Orthodontics 30. 2024; 237-242.

10. Chisnoiu AM, Picos AM, Popa S, Chisnoiu PD, Lascu L, Picos A, Chisnoiu R. Factors involved in the etiology of temporomandibular disorders- a literature review. Clujul medical. 2015; 88(4), 473.

11. Manfredini D, Häggman-Henrikson B, Al Jaghsi A, Baad-Hansen L, Beecroft E, Bijelic T, Bracci A, Brinkmann L, Bucci R, Colonna A, Ernberg M, Giannakopoulos NN, Gillborg S, Greene CS, Heir G, Koutris M, Kutschke A, Lobbezoo F, Lövgren A, Michelotti A, Nixdorf DR, Nykänen L, Oyarzo JF, Pigg M, Pollis M, Restrepo CC, Rongo R, Rossit M, Saracutu OI, Schierz O, Stanisic N, Val M, Verhoeff MC, Visscher CM, Voog-Oras U, Wrangstål L, Bender SD, Durham J; International Network for Orofacial Pain and Related Disorders Methodology. Temporomandibular disorders: INfORM/IADR key points for good clinical practice based on standard of care. Cranio. 2025; 43(1), 1-5.

12. Miettinen O, Lahti S, Sipilä K. Psychosocial aspects of temporomandibular disorders and oral health-related quality-of-life. Acta Odontologica Scandinavica. 2012; 70(4), 331-336.

13. Ferreira CLP, Sforza C, Rusconi FM, Castelo PM, Bommarito S. Masticatory behaviour and chewing difficulties in young adults with temporomandibular disorders. Journal of oral rehabilitation. 2019; 46(6), 533-540.

14. Layton DM, Morgano SM, Muller F, Kelly JA, Nguyen CT, Scherrer SS, Salinas TJ, Shah KC, Att W, Frelich MA, Ferro KJ. Glossary of prosthodontic terms 2023. J Prosthet Dent. 2023; 130(4S1), e1-e126.

15. Yadfout A, El Aoud J, Merzouk N, Slaoui Hasnaoui J. Increasing vertical dimension of occlusion (VDO). Clinical, Cosmetic and Investigational Dentistry. 2024; 135-142.

16. Lassmann Ł, Calamita MA, Manfredini D. Myths surrounding vertical dimension of occlusion in restorative dentistry: A scoping review. Journal of Esthetic and Restorative Dentistry. 2025; 37(1), 94-105.

17. Moreno-Hay I, Okeson JP. Does altering the occlusal vertical dimension produce temporomandibular disorders? A literature review. J Oral Rehabil. 2015; 42(11), 875-82.

18. Goldstein G, Goodacre C, MacGregor K. Occlusal vertical dimension: best evidence consensus statement. Journal of Prosthodontics. 2021; 30(S1), 12-19.

19. Manfredini D, Arveda N, Guarda-Nardini L, Segù M, Collesano V. Distribution of diagnoses in a population of patients with temporomandibular disorders. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012 Nov;114(5):e35-41.

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20. Kurup S, Perez-Pino A, Litt M. The association between temporomandibular disorders signs and symptoms, bruxism, and health variables: A cross-sectional study. Cranio. 2025 Nov;43(6):1083-1091.

21. Bartlett D, O'Toole S. Tooth wear: best evidence consensus statement. Journal of Prosthodontics. 2021; 30(S1), 20-25.

22. Greene CS, Manfredini D. Overtreatment "successes"—what are the negative consequences for patients, dentists, and the profession?. Journal of Oral & Facial Pain and Headache. 2023; 37(2), 3290.

23. Manfredini D, Bender S. The professional burden of protecting TMD patients. Cranio. 2024; 42(6), 639-640.

24. Manfredini A, Saracutu OI, Greene CS, Ferrari M, Manfredini D. Patient Experiences With Temporomandibular Disorders: A Survey on the Pathways in Diagnosis and Treatment. J Oral Rehabil. 2025; 52(9), 1481-1488.

25. Manfredini D. Occlusal Equilibration for the Management of Temporomandibular Disorders. Oral Maxillofac Surg Clin North Am. 2018; 30(3), 257-264.

26. Pullinger AG, Seligman DA. Quantification and validation of predictive values of occlusal variables in temporomandibular disorders using a multifactorial analysis. J Prosthet Dent. 2000; 83(1), 66-75.

27. Landi N, Manfredini D, Tognini F, Romagnoli M, Bosco M. Quantification of the relative risk of multiple occlusal variables for muscle disorders of the stomatognathic system. J Prosthet Dent. 2004; 92(2), 190-5.

28. Manfredini D, Poggio CE. Prosthodontic planning in patients with temporomandibular disorders and/or bruxism: A systematic review. J Prosthet Dent. 2017; 117(5), 606-613.

29. Manfredini D, Ercoli C, Poggio CE, Carboncini F, Ferrari M. Centric relation-A biological perspective of a technical concept. J Oral Rehabil. 2023; 50(11), 1355-1361.

30. Heikkinen EV, Kakko N, Näpänkangas R, Vuollo V, Harila V, Sipilä K. Prevalence of temporomandibular disorders (TMD) and their association with sociodemographic factors and depression/anxiety symptoms in Northern Finland Birth Cohort 1986. Cranio. 2026; 44(1), 15-25.

31. Kesterke MJ, Raffensperger ZD, Heike CL, Cunningham ML, Hecht JT, Kau CH, Nidey NL, Moreno LM, Wehby GL, Marazita ML, Weinberg SM. Using the 3D Facial Norms Database to investigate craniofacial sexual dimorphism in healthy children, adolescents, and adults. Biology of sex differences. 2016; 7(1), 23.

ARTICLE IN PRESS

32. Koudelová J, Brůžek J, Cagáňová V, Krajíček V, Velemínská J. Development of facial sexual dimorphism in children aged between 12 and 15 years: a three-dimensional longitudinal study. Orthodontics & craniofacial research. 2015; 18(3), 175-184.

33. Liu B, Zhang M, Chen Y, Yao Y. Tooth wear in aging people: an investigation of the prevalence and the influential factors of incisal/occlusal tooth wear in northwest China. BMC oral health. 2014; 14(1), 65.

34. Saracutu OI, Pollis M, Bracci A, Ferrari M, Manfredini D. Relationship Between Cigarette Smoking and Awake Bruxism: Does Smoking Increase the Frequency of Masticatory Muscle Activities?. Journal of Oral Rehabilitation. 2025; 52(5), 667-677.

35. Bruguiere F, Sciote JJ, Roland-Billecart T, Raoul G, Machuron F, Ferri J, Nicot R. Pre-operative parafunctional or dysfunctional oral habits are associated with the temporomandibular disorders after orthognathic surgery: an observational cohort study. Journal of oral rehabilitation. 2019; 46(4), 321-329.

36. Wang X, Yang Y, Lin L, Yao Q, Zhang J. Obesity and temporomandibular joint disorders: a systematic review and meta-analysis. BMC Oral Health. 2023; 23(1), 607.

37. Chalub LLFH, Ferreira RC, Vargas AMD. Influence of functional dentition on satisfaction with oral health and impacts on daily performance among Brazilian adults: a population-based cross-sectional study. BMC Oral Health. 2017; 17(1), 112.

38. Lin YC, Scialabba R, Lee JD, Sun J, Lee SJ. Assessment of occlusal vertical dimension change in mechanical and virtual articulation: a pilot study. Dentistry Journal. 2022; 10(11), 212.

39. Eliassen M, Hjortsjö C, Olsen-Bergem H, Bjørnland T. Self-exercise programmes and occlusal splints in the treatment of TMD-related myalgia—Evidence-based medicine?. Journal of Oral Rehabilitation. 2019; 46(11), 1088-1094.

40. Fayad MIA. Literature review of vertical dimension in prosthodontics theory and practice-Part 1: Theoretical foundations. Cureus. 2024; 16(6).

41. Srinivasan R, Chander NG, Reddy JR, Balasubramanian M. Differences in quality of life and patient satisfaction between complete denture occlusion schemes: A parallel randomized control trial. The Journal of Prosthetic Dentistry. 2023; 129(5), 748-753.

42. Sekulic S, John MT, Häggman-Henrikson B, Theis-Mahon N. Dental patients' functional, pain-related, aesthetic, and psychosocial impact of oral conditions on quality of life—Project overview, data collection, quality assessment, and publication bias. Journal of oral rehabilitation. 2021; 48(3), 246-255.

43. Alrashdan MS, Al-Omiri MK. Psychosocial profiles and their correlation with physical diagnosis in temporomandibular disorders, a preliminary report. Cranio. 2025; 43(1), 91-99.

ARTICLE IN PRESS

44. Canales GT, Guarda-Nardini L, Rizzatti-Barbosa CM, Conti PCR, Manfredini D. Distribution of depression, somatization and pain-related impairment in patients with chronic temporomandibular disorders. J Appl Oral Sci. 2019; 27, e20180210.

45. de Almeida Hoff E, Grossi RK, Bozzetti Pigozzi L, Bueno CH, Pattussi MP, Rossi T, Quarti Irigaray T, Weber JBB, Grossi ML. Depression and the risk of developing temporomandibular disorders in different diagnostic groups: A systematic review with meta-analysis. Cranio. 2025; 43(5), 730-742.

46. De La Torre Canales G, Câmara-Souza MB, Muñoz Lora VRM, Guarda-Nardini L, Conti PCR, Rodrigues Garcia RM, Del Bel Cury AA, Manfredini D. Prevalence of psychosocial impairment in temporomandibular disorder patients: A systematic review. J Oral Rehabil. 2018; 45(11), 881-889.

47. Manfredini D, Winocur E, Ahlberg J, Guarda-Nardini L, Lobbezoo F. Psychosocial impairment in temporomandibular disorders patients. RDC/TMD axis II findings from a multicentre study. J Dent. 2010; 38(10), 765-72.

48. Ferreira I, Sahm BD, Dos Reis AC. Association between anxiety and temporomandibular dysfunction in adult patients - a systematic review. Cranio. 2025; 43(6), 903-909.

49. Spielberger CD. State-trait anxiety inventory for adults. 1983.

50. Holmgren E, Schartz D, Ramesh NP, Sylvester K, Eskey C. Penetrating midface trauma: a case report, review of the literature, and a diagnostic and management protocol. Journal of Oral and Maxillofacial Surgery. 2021; 79(2), 430-e1.

51. Campos LA, Peltomäki T, Marôco J, Campos JADB. Use of oral health impact profile-14 (OHIP-14) in different contexts. What is being measured?. International Journal of Environmental Research and Public Health. 2021; 18(24), 13412.

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8 Figures

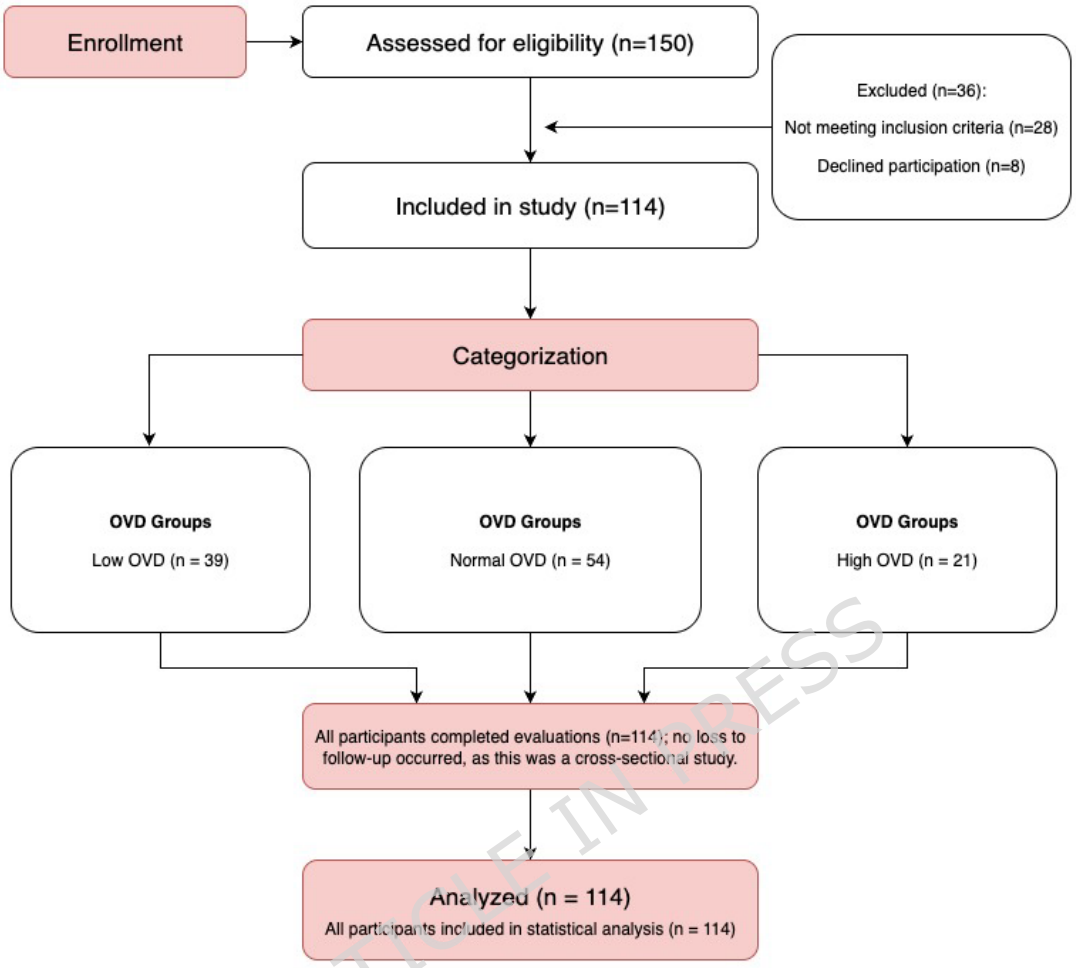
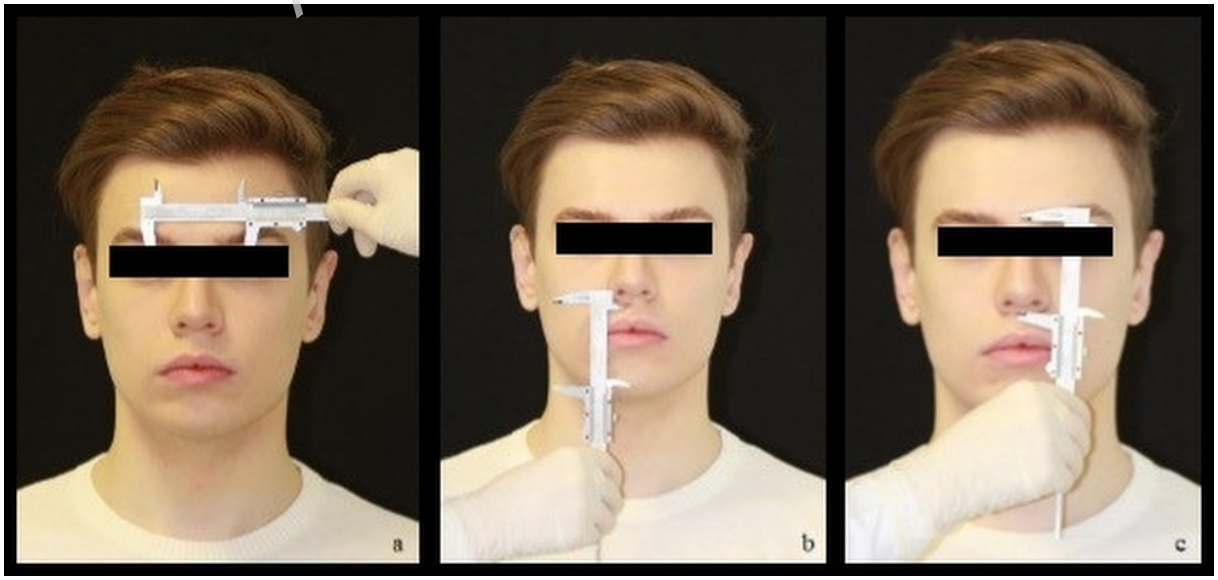


Figure 1 Patient flow diagram based on STROBE guidelines



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Figure 2 (a) Intrapupillary distance, (b) Subnasal-Gnathion, (c) Glabella-Subnasal

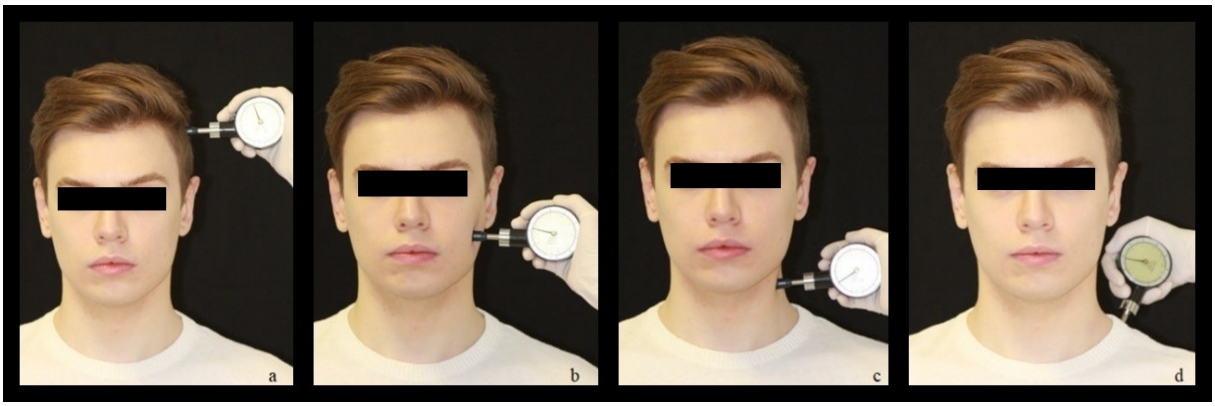


Figure 3 Algometer measurements; (a) Temporal, (b) Masseter, (c) Sternocleidomastoid, (d) Trapezius)

9 Tables

Table 1. Comparison of demographic characteristics across vertical dimension groups

Variable	Normal (n=54)	High (n=21)	Low (n=39)	*p*-value
Age	30.22 ± 11.31	34.00 ± 11.18	31.46 ± 10.76	0.418 *ns*
Gender	Male: 13 (24.1%) Female: 41 (75.9%)	Male: 9 (42.9%) Female: 12 (57.1%)	Male: 1 (2.6%) Female: 38 (97.4%)	0.001**
BMI	24.53 ± 5.65	26.77 ± 4.03	22.50 ± 3.54	0.004**
Marital status	Single: 29 (53.7%) Married: 25 (46.3%)	Single: 8 (38.1%) Married: 13 (61.9%)	Single: 22 (56.4%) Married: 17 (43.6%)	0.371 *ns*
Systemic disease	Absent: 43 (79.6%) Present: 11 (20.4%)	Absent: 15 (71.4%) Present: 6 (28.6%)	Absent: 26 (66.7%) Present: 13 (33.3%)	0.362 *ns*
Smoking status	Non-smoker: 41 (75.9%) Smoker: 13 (24.1%)	Non-smoker: 15 (71.4%) Smoker: 6 (28.6%)	Non-smoker: 32 (82.1%) Smoker: 7 (17.9%)	0.616 *ns*
Occupation	Employed: 24 (44.5%) Unemployed: 14 (25.9%) Student 16 (29.6%)	Employed: 13 (61.9%) Unemployed: 5 (23.8%) Student: 3 (14.3%)	Employed: 19 (48.7%) Unemployed: 11 (28.2%) Student: 9 (23.1%)	0.112 *ns*

Values are presented as mean ± SD or frequency (%). One-way ANOVA and Chi-square test were used. *Post-hoc Tukey test showed significant BMI difference between High vs. Low groups (p = 0.003).* ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; *ns* = not significant.

Table 2. Statistical evaluation of vertical dimension and tooth wear variables

Variable	Test	Statistic	*p*-value
Vertical dimension × Gender	Chi-square	$\chi^2 = 10.98$	0.001**
Vertical dimension × BMI	One-way ANOVA	$F = 5.94$	0.004**
Vertical dimension × Muscle pain (Lateral excursion)	Chi-square	$\chi^2 = 7.93$	0.020*
Vertical dimension × Depression	Chi-square	$\chi^2 = 6.75$	0.035*
Tooth wear × Age	One-way ANOVA	$F = 8.92$	0.001***
Tooth wear × BMI	One-way ANOVA	$F = 3.26$	0.044*
Tooth wear × Marital status	Chi-square	$\chi^2 = 12.19$	0.002**
Tooth wear × Smoking	Chi-square	$\chi^2 = 5.52$	0.019*
Tooth wear × Muscle pain (Masseter)	Chi-square	$\chi^2 = 11.08$	0.004**

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Tooth wear × RDC/TMD Axis I Group II	Chi-square	$\chi^2 = 11.08$	0.004**
Tooth wear × RDC/TMD Axis II (Chronic pain)	Chi-square	$\chi^2 = 7.36$	0.025*
Tests used: One-way ANOVA and Chi-square. Statistical significance set at $p < 0.05$; ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; *ns* = not significant.			

Table 3. Distribution of pain parameters across vertical dimension groups.

Pain parameter	Normal (n=54)	High (n=21)	Low (n=39)	*p*-value
Pain during mouth opening	None: 27 (50%) Present: 27 (50%)	None: 7 (33.3%) Present: 14 (66.7%)	None: 19 (48.7%) Present: 20 (51.3%)	0.049*
Pain during closing	None: 47 (87.0%) Present: 7 (13.0%)	None: 18 (85.7%) Present: 3 (14.3%)	None: 28 (71.8%) Present: 11 (28.2%)	0.216 *ns*
Pain during lateral movement	None: 41 (75.9%) Present: 13 (24.1%)	None: 17 (81.0%) Present: 4 (19.0%)	None: 20 (51.3%) Present: 19 (48.7%)	0.010**
Pain during protrusion	None: 34 (63%) Present: 20 (37%)	None: 14 (66.7%) Present: 7 (33.3%)	None: 24 (61.5%) Present: 15 (38.5%)	0.163 *ns*
Pain during palpation	None: 34 (63.0%) Present: 20 (37.0%)	None: 15 (71.4%) Present: 6 (28.6%)	None: 13 (33.3%) Present: 26 (66.7%)	0.004**
Values are presented as frequency (%). Chi-square test was used. Post-hoc tests indicated significantly higher palpation and lateral movement pain in the Low group compared to the Normal and High groups. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; *ns* = not significant.				

Table 4. Comparison of RDC/TMD Axis II distribution across vertical dimension groups

Axis II parameters	Normal (n=54)	High (n=21)	Low (n=39)	*p*-value
Chronic pain grade	No pain: 9 (16.7%) Grade I-II: 44 (81.5%) Grade III-IV: 1 (1.8%)	No pain: 4 (19%) Grade I-II: 16 (76.2%) Grade III-IV: 1 (4.8%)	No pain: 5 (12.8%) Grade I-II: 32 (82.1%) Grade III-IV: 2 (5.1%)	0.379 *ns*
Depression (SCL-90)	Normal: 34 (63%) Moderate: 16 (29.6%) Severe: 4 (7.4%)	Normal: 10 (47.6%) Moderate: 6 (28.6%) Severe: 5 (23.8%)	Normal: 13 (33.4%) Moderate: 16 (41%) Severe: 10 (25.6%)	0.033*
Nonspecific physical symptoms	Normal: 40 (74.1%) Moderate: 11 (20.4%) Severe: 3 (5.6%)	Normal: 14 (66.7%) Moderate: 5 (23.8%) Severe: 2 (9.5%)	Normal: 20 (51.3%) Moderate: 13 (33.3%) Severe: 6 (15.4%)	0.058 *ns*
Values are presented as frequency (%). Chi-square test was used. *Post-hoc comparisons indicated significantly higher depression scores in the Low vertical dimension group compared to the Normal group.* Significance levels: ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$; ns = not significant.				

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