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The Relationship Between Temporomandibular Disorder Risk, Temporal Muscle Thickness, Headache Severity, and Jaw Movements in Individuals with Tooth Loss

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Abstract:

Objective: This study was conducted to evaluate the relationship between the risk of temporomandibular joint disorder (TMD), headache severity, ultrasonographic temporal muscle thickness, and functional jaw movements in individuals presenting with tooth loss.

Methods: Thirty-eight individuals aged 21-55 years (mean 32.23±9.6) with one or more missing teeth were included in the study. TMD risk and headache intensity were documented using the Turkish-validated Fonseca Anamnestic Index (FAI) and the Visual Analog Scale (VAS), respectively. Temporal muscle thickness was assessed using a B-mode ultrasonographic device equipped with a high-frequency linear transducer in the relaxed jaw position while the participant was seated. Jaw movements were measured using a mouth goniometer.

Results: A strong positive association was identified between the risk of TMD and headache severity (r=0.96, P<0.001). In contrast, TMD risk showed strong negative associations with temporal muscle thickness (r=-0.73 (left) and r=-0.82 (right), P<0.001) and maximum mouth opening (r=-0.87, P<0.001). TMD risk exhibited moderate inverse associations with both jaw protrusion (r=-0.52) and retrusion (r=-0.61), with significance levels at P<0.05).

Conclusion: This cross-sectional correlational study suggests that early identification and management of biomechanical alterations associated with tooth loss may be important for reducing long-term functional complications through preventive dental care, timely prosthetic rehabilitation, and targeted physiotherapy.

Keywords: Temporomandibular Joint Disorder, Temporal Muscle Thickness, Headache, Jaw Movements, Tooth Loss

Tooth loss is a common and clinically significant condition that affects people of all ages. The consequences extend beyond aesthetics and mastication [1]. As well as impairing speech and reducing self-esteem, tooth loss has been linked to impaired masticatory function and an increased risk of temporomandibular disorder (TMD) [2, 3]. Persistent changes to the occlusion following tooth loss may be associated long-term effects on the jaw, masticatory muscles and the wider

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stomatognathic system. This can potentially disrupt neuromuscular balance and joint mechanics [2, 4]. At a biomechanical level, tooth loss triggers a series of adaptive responses within the masticatory system. These include changes in jaw movement, muscle activation patterns and the way in which load is distributed across the temporomandibular joints (TMJs). These adaptations may be exacerbated by accelerated alveolar bone resorption and changes in dental arch integrity, which can affect oral and systemic health [5, 6]

The functional patterns involved in chewing also tend to change in the presence of occlusal discontinuities. Although mastication is bilaterally coordinated, around 78% of people tend to favour the side with the greatest occlusal contact during lateral jaw movements [7]. This unilateral chewing pattern can lead in muscular imbalances and an uneven loading of the TMJs, potentially increasing the risk of TMD. Positional changes in teeth adjacent to edentulous spaces, including mesial drifting and super-eruption of opposing teeth [8]. Consequently, tooth loss may alter the biomechanics of the masticatory system and disrupt the equilibrium of the stomatognathic complex, leading to maladaptive changes over time [5, 7, 9]. However, evidence regarding the combined relationship between TMD risk, headache severity, ultrasonographic temporal muscle thickness, and functional jaw movements in individuals with tooth loss remains limited. Therefore, the present study aimed to investigate these associations in this specific population. We hypothesized that TMD risk would be significantly associated with temporal muscle thickness, headache severity, and jaw movements in individuals with tooth loss.

Based on these considerations, we hypothesized that there would be a significant relationship between TMD risk, temporal muscle thickness, headache, and jaw movements in individuals with tooth loss.

METHODS

Study Design

This study was designed as a cross-sectional correlational study.

Ethics

Ethical clearance for this project was granted by the Istanbul Rumeli University Ethics Committee (Decision No: 2025-11/28; Date: 26.11.2025). All data collection procedures adhered strictly to the ethical standards outlined in the Declaration of Helsinki [10].

Participants

For the designated age group of 21-55 years, a cohort of 38 participants was determined to be sufficient. An a priori power analysis using G*Power (v. 3.1) for a two-tailed Pearson correlation analysis [11]. Assuming a moderate effect size ($r = 0.30$), $\alpha = 0.05$, and 80% statistical power, the required sample size was calculated as 38 participants. The effect size was selected according to Cohen's recommendations [12]. Because no directly comparable studies investigating the combined relationship between TMD risk, ultrasonographic muscle thickness, headache severity, and specific jaw movements were available in the literature, a moderate effect size ($r=30$) was deemed appropriate to ensure sufficient power across all secondary correlation analyses. Inclusion criteria were age within the target range, sufficient cognitive ability to comply with the assessment protocol, presenting with one or more missing teeth for longer than six months, and voluntary participation. The exclusion criteria included a history of mandibular or facial bone fractures, rheumatoid arthritis, prior TMJ surgery, previous treatment for TMD, and a diagnosis of fibromyalgia, trigeminal neuralgia, or migraine. Written informed consent was obtained from every individual following a comprehensive briefing regarding the research objectives.

Assessment

Temporomandibular Disorder (TMD) Risk

The TMD risk was assessed using the Turkish version of the Fonseca Anamnestic Index (FAI) The FAI is a 10-item questionnaire designed to assess psychological distress, functional limitations, pain frequency, and parafunctional behaviors associated with TMD. Scores on this scale vary between 0 and 100; elevated marks are indicative of more intense TMD symptoms [13]. The FAI has been demonstrated to be valid and reliable in Turkish population (Cronbach $\alpha = 0.906$; ICC=0.951) [14].

Severity of Headache

The presence and type of headaches were

evaluated strictly following the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD). Axis I protocol to differentiate primary headaches from secondary orofacial headaches. Clinical palpation was performed bilaterally on the masseter and anterior temporal muscles (applying a standardized pressure of 1 kg for 5 seconds) by a trained examiner to identify myofascial pain and its potential to provoke headache. Participants were explicitly questioned using the DC/TMD Symptom Questionnaire to rule out tension-type headaches and migraine characteristics (e.g., aura, photophobia, severe throbbing pain). A diagnosis of 'Headache Attributed to TMD' was confirmed only if the participant's report of 'familiar headache' was explicitly elicited or exacerbated during the clinical palpation of the masticatory muscles or during structural mandibular movements within the past 30 days, in strict accordance with DC/TMD clinical examination standards [15]. The intensity of the headache perceived during these maneuvers was quantified using the Visual Analog Scale (VAS) [16].

Muscle Thickness

Temporal muscle thickness was assessed using a B-mode ultrasonographic device equipped with a high-frequency linear transducer (Sonosite Edge II; scanning frequency 6–13 MHz). Measurements were performed while participants were seated comfortably with the jaw in a relaxed position. Following the protocol described by Maskos *et al*.,16 the transducer was positioned along an imaginary line between the zygomatic process of the frontal bone and the ipsilateral helix of the auricle [17]. Temporal muscle thickness was defined as the distance between the temporal fascia and the deepest point of the temporal fossa (Figure 1). The transducer was placed perpendicular to the skin surface using minimal pressure to avoid tissue compression. Bilateral measurements were obtained for all participants. All ultrasonographic assessments were performed by an examiner with 9 years of experience in musculoskeletal ultrasonography. Bilateral measurements were obtained for all participants. Three consecutive measurements were obtained from each side, and the mean value was used for statistical analysis. All ultrasonographic assessments were performed by an examiner experienced in musculoskeletal ultrasonography.

Jaw Movements

The following jaw movements were assessed in a seated position using the TheraBite Jaw ROM Scale: maximum mouth opening (MMO), protrusion, and retrusion [18]. For MMO assessment, participants were instructed to open their mouth as wide as possible without discomfort and maintain the position for approximately two seconds. The TheraBite Jaw ROM Scale was positioned between the upper and lower central incisors, and the measurement was recorded in millimeters. Protrusion and retrusion movements were measured using the horizontal scale provided on the reverse side of the Thera Bite Jaw

FIGURE 1. Ultrasonographic image of the temporal muscle thickness measurement

ROM Scale. For protrusion, participants were instructed to bring their lower jaw forward as far as possible. The measurement was calculated by recording the horizontal distance from the labial surface of the maxillary central incisors to the labial surface of the mandibular central incisors at maximum protrusion, adjusted for the participant's baseline overjet. For retrusion, the horizontal displacement of the mandibular midline relative to the maxillary midline was recorded from the maximum intercuspal position moving posteriorly. Three measurements were obtained for each movement under the same standardized conditions, and the mean value was used for statistical analysis. All measurements were performed by the same examiner under standardized conditions.

Statistical Analysis

SPSS software version 25 was used for statistical analyses. Visual (histograms, probability plots) and analytical (Kolmogorov–Smirnov) methods were used to test whether the continuous data were normally distributed. Descriptive data were reported as mean ± standard deviation for continuous variables, and as frequencies and percentages for ordinal variables. All variables included in the correlation analyses demonstrated approximately normal distributions based on visual and analytical assessments; therefore, Pearson correlation analysis was considered appropriate. Pearson's correlation test was used to calculate the correlation coefficients between predefined variables. The strength of Pearson's correlation was classified as follows: $r \geq 0.8$, very strong; $0.6 \leq r < 0.8$, strong; $0.4 \leq r < 0.6$, moderate; $0.2 \leq r < 0.4$, weak; and $r < 0.2$, very weak. A Type I error rate of 5% ($\alpha = 0.05$) was used to determine statistical significance [19].

RESULTS

The study sample consisted of 38 individuals, characterized by a mean age of 32.23±9.6 years, an average body weight of 71.78±14.5 kg and mean height of 170.63±10.4 cm. Regarding gender distribution, 21 (55.3%) participants were male and 17 (44.7%) were female. In terms of marital status, 22 (57.9%) participants were single, while 16 (42.1%) were married. Analysis of missing tooth side revealed that 24 (63.15%) participants had missing teeth on the left side, whereas 14 (36.8%) had missing teeth on the right side. Regarding chewing preference, 23 (60.6%) participants predominantly favored the right side, while 15 (39.4%) participants favored the left. Furthermore, the descriptive statistics of clinical variables, including FAI score, headache score, right and left temporal muscle thickness, and jaw movements were summarized in the Table 1.

The Pearson correlation analysis revealed significant associations between TMD risk, as measured by the FAI, and all six clinical variables, with correlation coefficients ranging from r= -0.52 to r = 0.96. A very strong positive correlation was observed between TMD risk and headache severity

TABLE 1. Demographic and Dental Characteristics of the Study Participants

Variables		Mean	SD
Age (year)		32.23	9.6
Weight (kg)		71.78	14.5
Height (cm)		170.63	10.4
FAI		31.2	18.58
Headache score (VAS)		4.21	2.55
Right temporal muscle thickness (mm)		8.09	2.14
Left temporal muscle thickness (mm)		7.77	2.24
MMO (mm)		47.11	6.95
Jaw Protrusion (mm)		5.74	1.51
Jaw Retrusion (mm)		3.01	1.61
		n	**%**
Gender	Male	21	55.3
	Female	17	44.7
Marital status	Single	22	57.9
	Married	16	42.1
Missing tooth side	Left	24	63.15
	Right	14	36.8
Chewing side	Left	15	39.4
	Right	23	60.6

FAI, Fonseca anamnestic index; MMO, maximum mouth opening; S, standard deviation.

TABLE 2. **Correlations Between Temporal Muscle Thickness, Headache, Temporomandibular Joint Dysfunction Risk, and Jaw Movements**

Variables	Headache (VAS)	Left temporal muscle thickness	Right temporal muscle thickness	MMO	Jaw protrusion	Jaw retrusion
TMD Risk (FAI)	r=0.96 (95% CI:0.85 to 0.98) **(P<0.001)**	r= -0.73 (95% CI: -0.68-0.77) **(P<0.001)**	r= -0.82 (95% CI: -0.76-0.86) **(P<0.001)**	r= -0.87 (95% CI: -0.83-0.91) **(P<0.001)**	r= -0.52 (95% CI: -0.48-0.549 **(P=0.015)**	r= -0.61 (95% CI: -0.57-0.63) **(P=0.035)**

CI, confidence interval; FAI, Fonseca anamnestic index; MMO, maximum mouth opening; TMD, temporomandibular disorder; VAS, visual analog scale.
Statistically significant P-values are shown in bold.

(r=0.96, P<0.001). All jaw range-of-motion variables were significantly and inversely correlated with TMD risk, with MMO showing the strongest negative association (r= –0.87, P<0.001), followed by jaw retrusion (r= –0.61, P<0.035) and jaw protrusion (r= –0.52, P=0.015). Notably, MMO demonstrated a higher level of statistical significance (P<0.001) compared with the two horizontal movement variables (P=0.015 and P=0.035, respectively) (Table 2).

DISCUSSION

This study identified significant correlations between TMD risk, headache severity, bilateral temporal muscle thickness, and jaw movement patterns in individuals with tooth loss. The significant associations observed among the measured variables have demonstrated that individuals with a higher risk of TMD are more likely to experience severe headaches, reduced MMO, and decreased temporal muscle thickness.

As previously emphasized and supported by the current study, tooth loss can alter the preferred chewing side and disrupt the biomechanics of the masticatory system, ultimately causing overload within the stomatognathic system [4, 20]. Biomechanical modeling has demonstrated that the absence of posterior teeth increases the load on the TMJs and associated muscles as more anterior teeth are engaged during mastication, leading to a redistribution of forces that contributes to elevated joint stress [21]. Although the masticatory system can adapt to tooth loss through behavioral and musculoskeletal adjustments, these compensatory mechanisms rarely fully compensate for the biomechanical inefficiencies and reduced masticatory performance, potentially resulting in chronic overload and degenerative changes within the stomatognathic system [20, 23, 24]. Consequently, although multiple factors contribute to the etiology of the disease [25], degenerative changes of the TMJs and a heightened risk of TMD appear to be significantly more prevalent in cases of complete or partial edentulism, driven primarily by altered chewing patterns and changes in dental occlusion resulting from tooth loss [7, 9].

The current study further revealed a significant association between TMD risk and headache severity, bilateral temporal muscle thickness, and jaw movement patterns. A previous study reporting a significant correlation between TMD and headache supports our findings regarding the relevant association described above [26]. The very strong correlation observed between TMD risk and headache severity may partly reflect overlapping symptom constructs assessed within the FAI, particularly pain-related items, rather than a purely independent biomechanical association. Although a very strong positive correlation was found between TMD risk and headache severity, this result warrants cautious interpretation given the high correlation coefficient and potential clinical overlap between the two conditions. Interestingly, while TMD risk was linked to all measured jaw movements, headache severity did not show a significant correlation with protrusion and retrusion. This disparity suggests that while headache is a major component of TMD-related distress, its clinical manifestation in individuals with tooth loss may be more closely associated with muscle morphometry and vertical opening rather than horizontal jaw excursions. This statistically significant relationship may be explained by several underlying mechanisms, including shared anatomical pathways, dysfunction of pain modulatory systems, and psychological or behavioral factors [27-29]. For example, the trigeminal nerve serves as a common pathway for both TMD and headaches. Convergence of sensory inputs from the trigeminal nerve and the cervical spine within the trigeminocervical complex can may be associated with referred pain [28]. Furthermore, our findings demonstrated a significant negative relationship between TMD risk and temporal muscle thickness, indicating that TMD may be associated with morphological alterations in the temporalis muscle. This is aligned with previous research indicating that individuals with muscular TMD exhibit a significant reduction in temporalis muscle thickness compared to healthy controls [30]. Finally, the relationship observed between TMD and jaw movement patterns (i.e., protrusion, retrusion, and mouth opening) in the present study is likely multifactorial, involving both structural and functional abnormalities. For instance, individuals with TMD frequently experience increased pain during repetitive jaw movements, which may lead to a reduced range of motion, slower opening and closing velocities, and overall impaired jaw function [31]. However, the exceptionally strong correlation observed between TMD risk and headache severity (r = 0.96) in our findings must be interpreted with clinical caution. This extraordinarily high coefficient may partly reflect a degree of 'construct overlap' within the FAI, which includes several items specifically related to pain and headache. Furthermore, given our relatively small sample size, there is a distinct risk of statistical overestimation, as smaller cohorts are inherently more susceptible to inflated effect sizes. Therefore, while this robust association underscores a tight integration between orofacial biomechanics and headache pathology, it should be regarded as a strong clinical trend rather than an absolute value until validated by larger-scale investigations.

Future research should incorporate larger and more diverse cohorts, including prosthetic users, to mitigate potential sample bias and allow for a more detailed comparative analysis of how different stages of tooth loss and rehabilitation status impact TMD risk and muscle morphometry. In addition, future studies should employ multivariable analytical approaches to control for potential confounding factors such as age, sex, bruxism, number of missing teeth, prosthetic status, and chewing-side preference.

Strengths and Limitations

This study has several methodological strengths. First, it employed a multidimensional assessment by simultaneously evaluating TMD risk, headache severity, bilateral temporal muscle thickness measured by ultrasonography, and jaw movement patterns in individuals with tooth loss. This comprehensive approach allowed the relationships between patient-reported symptoms, muscle morphology, and functional jaw performance to be examined within the same cohort. Second, the inclusion of ultrasonographic assessment provided an objective and non-invasive evaluation of temporal muscle morphology in addition to functional clinical assessments.

This study has several limitations. First, the relatively small sample size (n = 38) may limit the generalizability of the findings and may have contributed to an overestimation of the observed correlation coefficients. Second, the strong correlation between TMD risk and headache severity should be interpreted with caution because the Fonseca

Anamnestic Index (FAI) includes pain- and headache-related items, potentially introducing construct overlap. Third, individuals with complete dentures or other dental prostheses were excluded, and the number and distribution of missing teeth were not analyzed separately, limiting the applicability of the findings to the broader population with tooth loss. Finally, the cross-sectional design precludes any conclusions regarding causal relationships between TMD risk, headache severity, temporal muscle thickness, and jaw movement patterns.

CONCLUSION

The present study showed a significant relationship between TMD risk, headache severity, temporal muscle thickness, and jaw movement patterns in individuals with tooth loss. Higher TMD risk was strongly associated with increased headache intensity, reduced temporal muscle thickness, and limitations in MMO and other jaw movements. Study findings suggested that tooth loss may be associated with alterations in the biomechanical balance of the stomatognathic system, which may contribute to muscular and functional impairments and an increased risk of TMD-related symptoms. Early identification of these associated functional and muscular alterations may support preventive dental care, timely prosthetic rehabilitation, and physiotherapy-based management strategies.

Ethics Approval and Consent to Participate

This study was approved by the Istanbul Rumeli University Ethics Committee (Decision No: 2025-11/28; Date: 26.11.2025). All procedures were conducted in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its later amendments. Written informed consent was obtained from all individual participants included in the study.

Clinical Trial Registration

Not Available.

Data Availability Statement

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

Authors' Contribution

Study Conception: ÜE, HB; Study Design: ÜE, HB; Supervision: ÜE, HB; Funding: N/A; Materials: N/A; Data Collection and/or Processing: ÜE; Statistical Analysis and/or Data Interpretation: HB; Literature Review: ÜE, HB; Manuscript Preparation: ÜE, HB; Critical Review: ÜE, HB.

Conflict of Interest Statement

All authors have completed the ICMJE uniform disclosure form and declare that no potential conflicts of interest, financial or otherwise, exist regarding the research, authorship, or publication of this manuscript.

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Generative Artificial Intelligence Statement

During the preparation of this manuscript, the authors used AI to assist with English language refinement, improvement of grammar and clarity, and structural organization of section headings. The AI tool was not used to generate scientific content, perform data analysis, interpret results, or draw conclusions. All content was critically reviewed, revised, and approved by the authors, who take full responsibility for the accuracy and integrity of the manuscript. All content of the study was produced by the authors in accordance with scientific research methods and academic ethical principles.

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