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ORIGINAL RESEARCH

Ultrasound assessment of temporomandibular disorders: a retrospective cross-sectional study in a tertiary referral center

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Abstract

Background: This study aimed to characterize ultrasonographic findings in patients referred to a tertiary center for temporomandibular disorders (TMDs), assess their associations with TMD diagnoses, compare symptomatic and contralateral temporomandibular joints (TMJs), and describe the demographic and clinical characteristics of this population. **Methods**: This retrospective cross-sectional study included 108 symptomatic patients referred between October 2020 and March 2026. Diagnoses were established according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD Axis I). Standardized clinical examination and bilateral high-frequency ultrasonography assessed capsular thickness, joint effusion, disc visibility, condylar translation, and popping-like movements using static and dynamic maneuvers. Within-patient comparisons and exploratory subgroup analyses were performed. **Results**: Patients were predominantly female (81.5%), with a mean age of 48.6 years and a median symptom duration of 5 years. The most common primary diagnoses were degenerative joint disease (45.4%), muscular disorders (13.9%), and reducible disc displacement (13.9%); 30% had concomitant diagnoses. Compared with contralateral joints, symptomatic TMJs showed greater longitudinal capsular thickness (median 1.68 mm (IQR 1.30) *vs.* 1.47 mm (IQR 0.60); $p = 0.047$), more frequent effusion (longitudinal: 17.6% *vs.* 0.9%, $p < 0.001$; transverse: 16.7% *vs.* 1.9%, $p = 0.011$), greater disc visibility (29.6% *vs.* 14.8%, $p = 0.021$), and more abnormal condylar translation (20.4% *vs.* 11.1%, $p = 0.021$). Transverse disc visibility and visibility at maximal opening were associated with disc displacement disorders (both $p < 0.001$). Effusion was more frequent in degenerative and inflammatory joint diseases ($p = 0.030$ and $p = 0.044$ during dynamic maneuvers, respectively). Ultrasonography identified displacement in 73.9% (17/23) of magnetic resonance imaging (MRI)-confirmed cases. **Conclusions**: Ultrasonographic findings were associated with symptomatic TMJs and specific diagnostic subgroups, particularly disc visibility in disc displacement disorders and effusion in inflammatory and degenerative intra-articular conditions. Ultrasonography may provide complementary information alongside clinical assessment and MRI.

Keywords

Temporomandibular joint; Temporomandibular disorders; Ultrasonography; Disc displacement; Joint effusion; Musculoskeletal ultrasound

1. Introduction

Temporomandibular disorders (TMDs) correspond to a heterogeneous group of musculoskeletal and intra-articular conditions affecting the temporomandibular joint (TMJ), masticatory muscles, and associated structures. They represent one of the most frequent causes of chronic orofacial pain, with prevalence estimates ranging from 10% to 30% in recent meta-analyses. TMDs predominantly affect young adults between 20 and 40 years of age, with a female predominance of approximately 1.5 to 2 times compared with men [1, 2]. Beyond pain, TMDs may lead to significant functional impairment, including limitation of mouth opening, mastication difficulties, joint sounds, and reduced quality of life. Their etiology is considered multifactorial, involving a complex interaction of biological, mechanical, and psychosocial factors. Indeed, anxiety, depression, somatosensory disturbances, and maladaptive coping have been associated with TMD occurrence

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and chronicity [3–7].

The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) [8], updated in 2014 by the International Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) Consortium Network and the Orofacial Pain Special Interest Group, provide a standardized diagnostic framework comprising two complementary axes: Axis I, which focuses on physical diagnoses, and Axis II, which assesses psychosocial status and pain-related disability. Among intra-articular disorders, disc displacement (DD) is one of the of the most frequent TMD. Disc displacement with reduction (DDwR), is characterized by anterior displacement of the articular disc in the closed-mouth position with reduction during mandibular opening, typically resulting in clicking/popping noise. In contrast, disc displacement without reduction (DDwoR), is characterized by persistent anterior disc displacement during mandibular movement and may occur with or without limited mouth opening, particularly in acute presentations [8]. Degenerative joint disease is characterized by progressive osseous changes affecting the articular surface of the TMJ, whereas inflammatory joint disorders are characterized by synovial inflammation with joint effusion and functional limitation [8, 9]. In contrast, some patients present with diffuse chronic orofacial pain extending beyond the TMJ region, associated with referred pain patterns and limited correlation between symptoms and structural abnormalities. Such presentations suggest a predominant functional and central sensitization-related component [3, 10, 11].

Clinical examination remains the cornerstone of TMD assessment; however, imaging is frequently required to confirm the diagnosis, characterize structural involvement, and guide management. Panoramic radiography provides only limited information because of superimposition artifacts and poor sensitivity for early osseous abnormalities [12, 13]. Cone-beam computed tomography (CBCT) and computed tomography (CT) allow excellent evaluation of cortical bone changes, including erosions, osteophytes, sclerosis, and condylar remodeling [14, 15]. Magnetic resonance imaging (MRI) is currently considered the reference imaging modality for soft-tissue and disc assessment of TMJ because of its superior assessment of disc position, joint effusion, synovitis, and bone marrow abnormalities [15–17]. Nevertheless, MRI remains limited by cost, accessibility, examination time, and contraindications in routine clinical practice.

Over the last decade, ultrasonography has emerged as a promising imaging modality for TMJ assessment because it is non-invasive, inexpensive, widely available, free of ionizing radiation, and allows dynamic real-time evaluation [18]. Ultrasonography can visualize the mandibular condyle, joint capsule, joint effusion, and, in selected cases, disc displacement [18–21]. Several studies comparing ultrasonography with MRI have reported encouraging diagnostic performances for anterior disc displacement and joint effusion detection, with sensitivities ranging from 79% to 95% and specificities up to 100% in some series [18, 21, 22]. Nevertheless, other studies have reported substantially lower diagnostic performances with sensitivities and specificities decreasing to approximately 60% [23]. Certainly, the literature is heterogeneous because of differences in transducer frequency, ultrasound protocols, operator experience, diagnostic thresholds, and reference imaging standards [18, 21, 22, 24, 25]. Consequently, although the evidence supporting TMJ ultrasonography has expanded considerably in recent years, important challenges remain regarding the standardization of ultrasound acquisition protocols, diagnostic criteria, and its role across the different clinical presentations of TMDs.

In addition, few studies have described the ultrasound findings across the different clinical and etiological subgroups of TMDs encountered in specialized practice. Most available studies have primarily focused on inflammatory and disc-related conditions, whereas ultrasound features associated with degenerative TMJ pathologies remain poorly characterized. Data regarding the distribution of ultrasound findings according to symptom status, as well as across clinically relevant TMD subgroups, remain limited. Furthermore, given the heterogeneity of TMDs, a better characterization of these ultrasonographic findings may contribute to a more comprehensive assessment of TMDs and improve both their characterization and diagnostic evaluation.

The aim of the present study was therefore to investigate the potential contribution of ultrasonography in the evaluation of TMD in a tertiary-care hospital population referred for specialized consultation. To this end, we aimed to describe the prevalence and distribution of sonographic findings and to explore their association with distinct diagnostic subgroups and within-patient comparisons between the symptomatic and contralateral TMJs. Analyses across diagnostic subgroups were exploratory and intended to generate hypotheses rather than assess diagnostic discrimination or performance. The working hypothesis of this exploratory study was that ultrasonographic findings would vary according to diagnostic subgroup and between the symptomatic and contralateral TMJs, thereby potentially providing complementary information for the evaluation of TMDs.

2. Materials and methods

2.1 Study design and population

A retrospective observational cross-sectional study was conducted in a tertiary referral center, including all consecutive patients with available routine data who were evaluated between October 2020 and March 2026. Clinical and ultrasonographic data were collected from the medical records and analyzed as a single cross-sectional dataset. This retrospective study was based exclusively on data previously collected as part of routine patient care. The study did not involve any intervention on participants, any additional procedure, any randomization, or any modification of usual clinical practice. Accordingly, under Articles L.1121-1 and R.1121-1 of the French Public Health Code, this study did not fall within the scope of research involving human participants requiring an ethic committee approval. However, all patients admitted to Nantes Hospital are informed that their data may be used for research purposes. No a priori sample size calculation was performed, given the observational design of the study and the inclusion of all consecutive eligible patients during the predefined study

period.

All patients underwent a clinical evaluation performed in standard care by a rheumatologist and a maxillofacial surgeon (BLG and HB). Ultrasound examination was performed as part of the routine diagnostic work-up in the same clinical setting, according to the local practice of the tertiary center.

Importantly, the decision to perform complementary imaging examinations (such as MRI or CBCT) was not driven by the study protocol but was based solely on clinical indication as part of routine care, prior to retrospective inclusion in the study.

Patients without a final diagnosis of TMD were excluded. Because the primary analysis relied on within-patient comparisons, patients reporting bilateral TMJ symptoms were eligible for inclusion only if one TMJ could be identified as the predominant symptomatic side at the time of clinical evaluation based on the patient's history and clinical examination. In routine clinical practice, this generally corresponded to the TMJ that primarily motivated the patient's consultation. Patients in whom no predominant symptomatic side could be established were excluded from this analysis (n = 15). For the purposes of the within-patient comparison, the TMJ opposite to the symptomatic side was designated as the contralateral TMJ and served as the comparator for all ultrasonographic analyses. In patients with unilateral symptoms, this joint was asymptomatic. Among patients with bilateral symptoms who met the inclusion criteria, this contralateral TMJ was the less symptomatic joint identified during the clinical evaluation. Consequently, the term "contralateral TMJ" was used throughout the manuscript to designate the within-patient comparator, regardless of its symptom status, and should not be interpreted as a healthy control joint.

2.2 Data collection

Collected epidemiological data included age, occupation, medical history, ongoing treatments, and smoking status. Symptoms included the presence of articular noises, limited mouth opening, bruxism, joint locking, and nocturnal awakenings. These symptoms were recorded from patient self-report during the standardized clinical interview. Bruxism was based on the patient's history of awake or sleep bruxism, without the use of validated questionnaires or instrumental confirmation. Nocturnal awakenings referred specifically to awakenings attributed by the patient to TMJ pain.

A standardized clinical examination was systematically performed as part of the clinical evaluation during consultations and included palpation of the TMJs and masticatory muscles to assess pain, evaluation of joint mobility, dentition status, and mandibular opening pattern. Maximal mouth opening was measured as the maximal inter-incisal distance using a caliper, with normal mouth opening defined as >35 mm. The mandibular opening and closing path were assessed by visual observation of the inter-incisal line during mandibular movements to identify deviations. Joint noises were assessed during mandibular movements by both palpation of the TMJ and direct auscultation. Clinical joint effusion was assessed by inspection and palpation of the TMJ region for visible swelling, local fullness, or overlying erythema suggestive of joint inflammation.

2.3 Ultrasound examination

Ultrasound (US) examinations were performed using a Canon Applio i800 (Canon Medical Systems Corporation, Otawara, Japan). equipped with a high-frequency linear probe (12–18 MHz) by two rheumatologists trained and experienced in musculoskeletal ultrasound (BLG and MD). All examinations were performed according to a standardized acquisition protocol, with patients in a seated position facing the examiner. Both temporomandibular joints were systematically examined along two axes: longitudinal and transverse planes (Fig. 1A,B).

In the longitudinal plane, the probe was placed along the long axis of the ascending ramus of the mandible. This coronal section allowed visualization of the mandibular condyle, joint space, capsule and zygomatic arch, providing assessment of the lateral compartment and condylar morphology.

In the transverse plane, the probe was positioned at the level of the condyle, on Camper's line, between the nasal ala and the tragus. This approach allowed assessment of anterior disc displacement and joint effusion. A dynamic evaluation was then performed during mouth opening and closing to assess mandibular translation and disc motion.

US abnormalities were defined as follows [26]: capsular thickening (>2 mm), presence of joint effusion (defined as a compressible anechoic area anterior to the condyle measuring >2 mm) and the presence of disc material (defined as a non-compressible hypoechoic area anterior to the condyle). During the dynamic evaluation, condylar translation was visually assessed and classified as either normal or abnormal based on the observed excursion pattern. When abnormal translation was identified, the presence of a popping-like movement, defined as a sudden deviation or "jump" in the mandibular opening trajectory, was recorded. Visualization of the disc at maximal mouth opening was considered indicative of irreducible disc displacement, and its absence indicated a reducible displacement. Representative examples of normal and pathological ultrasonographic TMJ findings are provided in Fig. 2.

For patients who had undergone MRI examination, ultrasound findings were descriptively compared with MRI findings in cases clinically classified as disc displacement according to DC/TMD criteria. This exploratory analysis was limited to the description of imaging findings observed with both modalities, without assessing diagnostic performance.

2.4 Diagnostic classification

Patients were classified according to a primary diagnosis considered most clinically relevant at the time of consultation. Any additional diagnosis potentially contributing to the symptoms at the time of consultation was recorded as a secondary diagnosis. Based on the primary diagnosis, patients were categorized into seven diagnostic subgroups: degenerative disease, muscular disorders (including myalgia and myofascial pain), Disc displacement with reduction (DDwR), Disc displacement without reduction (DDwoR), joint arthritis, primary condylar disorders (including idiopathic condylar resorption and idiopathic condylar hyperplasia), and a functional and complex pain presentation subgroup. This classification was

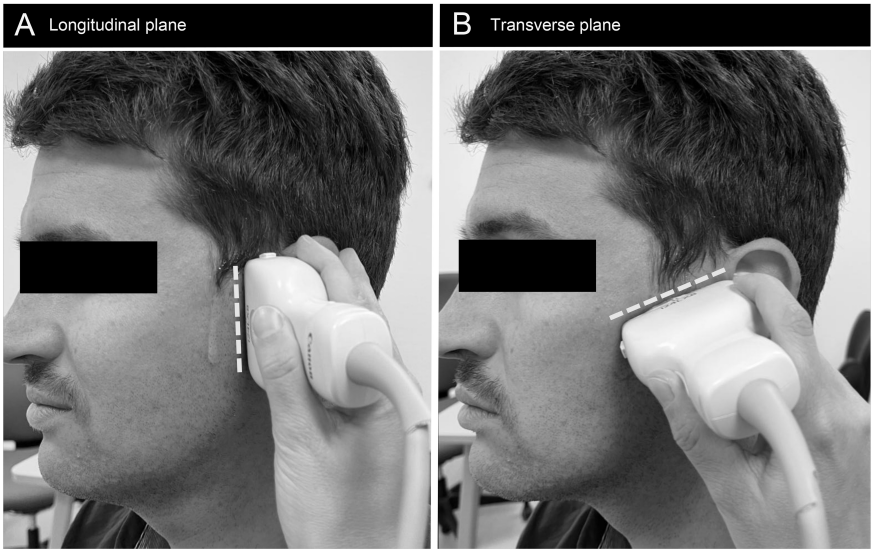


FIGURE 1. Ultrasound probe positioning for temporomandibular joint examination. (A) Longitudinal plane: the probe is aligned with the long axis of the mandibular ramus. (B) Transverse plane: the probe is positioned along Camper's line. Dashed line indicates probe orientation.

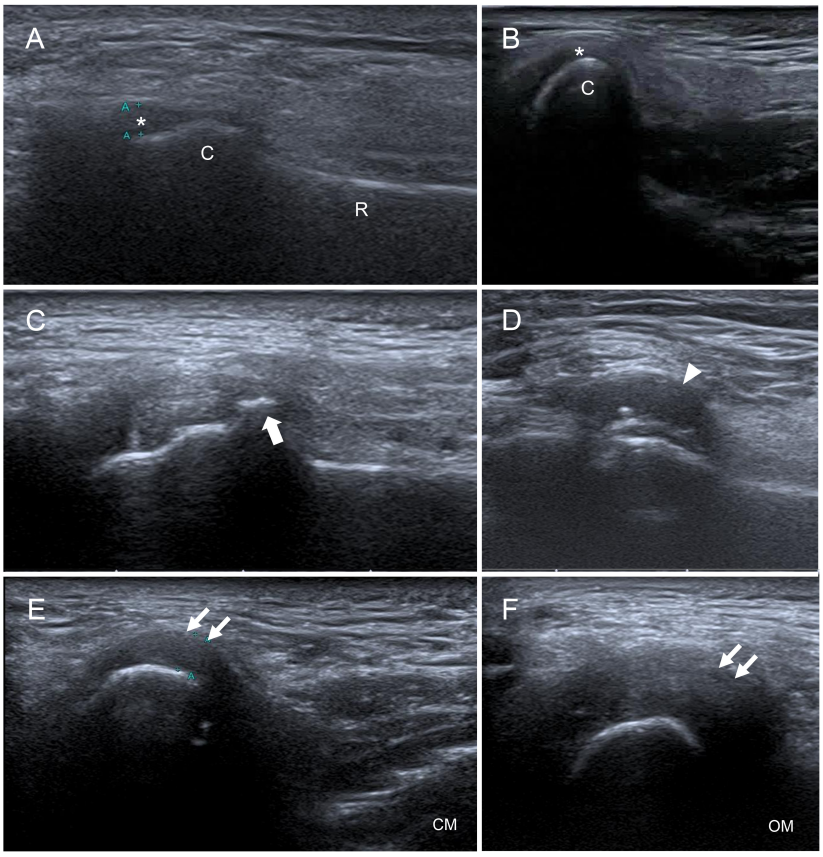


FIGURE 2. Ultrasonographic appearance of normal and pathological temporomandibular joints (TMJ). (A) Longitudinal sonographic view of a normal TMJ. The mandibular condyle (C) appears as a thin hyperechoic cortical line continuous with the mandibular ramus (R). (B) Transverse sonographic view of a normal TMJ. The articular capsule appears as a thin hypoechoic band in both views (*). (C) Capsular thickening associated with osteoarthritic changes and marginal osteophyte formation (white arrow). (D) Longitudinal view showing joint effusion, visible as a compressible anechoic collection within the joint space (arrowhead). (E) Reducible anterior disc displacement in the closed-mouth (CM) position. The disc is identified as an anterior hypoechoic structure (arrow). (F) Irreducible anterior disc displacement with persistent visualization of the disc in the open-mouth (OM) position (arrow).

used for exploratory, hypothesis-generating analyses of potential differences in ultrasonographic findings across clinically relevant TMD subgroups.

Diagnostic classification was based on the Axis I clinical diagnostic criteria of the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD, 2014). Diagnoses were established jointly by the treating rheumatologist and maxillofacial surgeon (BLG and HB) on the basis of patient history, standardized clinical examination findings, and, when available, conventional imaging findings (CBCT or MRI), without consideration of the ultrasonographic findings.

The functional/complex pain presentation subgroup was created specifically for the purpose of the present study and did not represent a validated DC/TMD diagnostic category. Indeed, it is well established that TMDs are strongly influenced by psychological and somatosensory factors affecting both pain intensity and clinical presentation. Classification into this subgroup was based on predefined clinical features including widespread or diffuse pain extending beyond the TMJ region, with involvement of the masticatory and cervical muscles, headache or cervical pain associated with jaw function, and, a discrepancy between symptom severity and the extent of structural TMJ abnormalities observed clinically or on conventional imaging. These features were considered suggestive of altered pain processing, potentially including central sensitization although this mechanism was not objectively assessed using validated instruments. Structural abnormalities such as disc displacement or osteoarthritic changes could be present but were considered insufficient to fully explain the overall clinical presentation.

2.5 Statistical analysis

Statistical analyses were performed using SPSS software (Version 28.0.1.1 (15), IBM Corp., Armonk, NY, USA). Normality of data distribution was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests.

Continuous variables were expressed as mean ± standard deviation (SD) for normally distributed data, or as median ± interquartile range (IQR) otherwise. Categorical variables were presented as frequencies and percentages.

Comparisons of continuous paired variables between symptomatic and contralateral sides were performed using the paired Student *t*-test. Comparisons of paired categorical variables between symptomatic and contralateral sides were performed using McNemar's test. Comparisons between independent categorical variables were performed using Pearson's chi-square test. For subgroup analyses of continuous variables, the non-parametric Kruskal-Wallis test was used when normality assumptions were not met. A p-value < 0.05 was considered statistically significant.

3. Results

3.1 Patient characteristics

The study population characteristics (n = 108) are summarized in Table 1. Mean age was 48.6 years with a significant female predominance (81.5%), and the median symptom duration was 5.0 years (IQR 4). Regarding medical history, 28.7% of patients (n = 31) reported anxiety-depressive disorders, with 18.5% currently under antidepressant therapy and 8.3% under anxiolytics. Notably, 10.2% of patients had a history of fibromyalgia or chronic pain. Inflammatory and rheumatic diseases were prevalent (23.1%), mainly represented by spondyloarthropathy (n = 10) and juvenile idiopathic arthritis (n = 7). A history of TMJ trauma or surgery was found in 19.4% of cases. Pharmacological treatments included biotherapies or Janus Kinase (JAK) inhibitors (11.1%), conventional synthetic disease-modifying antirheumatic drugs (csDMARDs) (10.2%) and nonsteroidal anti-inflammatory drugs (NSAIDs) (7.4%).

3.2 Symptoms and management prior to the consultation

Regarding symptoms prior to consultation (n = 108), pain was the most prevalent complaint (96.3%, n = 104), leading to nocturnal awakenings in 21.3% of cases (n = 23). Dysfunctional joints were less frequent, with articular locking reported by 22.2% of patients (n = 24) and bruxism by 19.4% (n = 21). Joint noises were common, including popping/clicking (40.7%, n = 44) and crepitus (35.2%, n = 38). Finally, half of the cohort (50%, n = 54) reported a perceived limitation in joint range of motion. 92.6% of patients already had previously undergone CBCT (Cone-Beam Computed Tomography) (n = 100) and 59.3% had undergone MRI of the temporomandibular joint (n = 64). Regarding prior treatments, a majority of patients had undergone physiotherapy (63.9%, n = 69), followed by occlusal splint therapy (55%, n = 59), botulinum toxin injection in masticatory muscles (30.6%, n = 33) and a minority had surgery on the joint (9.3%, n = 10) and intra-articular injection (6.5%, n = 7).

3.3 Physical examination

Clinical findings at the consultation examination are summarized as follows. Notably, no signs of joint effusion were clinically detectable in any patient. Regarding articular noises, popping/clicking was observed in 30.6% of cases (n = 33) and crepitus in 24.1% (n = 26). Dental class examination (performed on 69 patients, 39 missing data) revealed a prevalence of Class I (55.1%, n = 38) and Class II (37.7%, n = 26), Class III concerned only 7.2% (n = 2). Functional assessment showed that 40.7% of patients had a limited mouth opening (<35 mm), while 48.1% presented masticatory muscle tenderness upon palpation. Mandibular opening paths were abnormal in 43.5% of cases, characterized by lateral deviation (27.8%) or popping-like movement (13.9%).

3.4 Primary and secondary diagnosis

Among the 108 included patients, the most frequent primary diagnosis was degenerative temporomandibular joint disease (45.4%, n = 49), followed by muscular disorders (13.9%, n = 15) and disc displacement with reduction (DDwR) (13.9%, n = 15). Patients with functional and complex pain presentation accounted for 12.0% of cases (n = 13), while disc displacement without reduction (DDwoR) (5.6%, n = 6), primary condylar pathology (4.6%, n = 5), and joint arthritis (4.6%, n = 5) were less frequent.

TABLE 1. Baseline characteristics of the study population.

Variable	Overall (n = 108)
Age, mean (SD), yr	48.6 (18.1)
Sex, n (%)	
● Women	88 (81.5)
● Men	20 (18.5)
Symptom duration, median (IQR), yr	5.0 (4)
Smoker, n (%)	11 (10.2)
Medical history, n (%)	
● History of TMJ surgery/trauma	21 (19.4)
● Anxiety/depressive disorders	31 (28.7)
● Chronic pain (including fibromyalgia)	11 (10.2)
● Inflammatory/rheumatic disease	25 (23.1)
Spondyloarthropathy (including Psoriatic arthritis (PsA))	10 (9.2)
Rheumatoid arthritis	3 (2.8)
Juvenile idiopathic arthritis	7 (6.5)
Undifferentiated rheumatic disease	5 (4.6)
● Sleep apnea (OSAS)	5 (4.6)
● Cardiovascular disorders	12 (11.1)
● Neurological disorders*	6 (5.5)
Current treatments	
● Biologic/targeted therapy	12 (11.1)
● Conventional DMARDs (methotrexate, hydroxychloroquine)	11 (10.2)
● Systemic corticosteroids	5 (4.6)
● NSAIDs	8 (7.4)
● Opioids (tramadol, morphine)	6 (5.6)
● Neuropathic pain agents (gabapentin, amitriptyline)	5 (4.6)
● Antidepressants (any)	20 (18.5)
● Anxiolytics (any)	9 (8.3)
● Antihypertensive treatment	14 (13.0)
● Lipid-lowering treatment	4 (3.7)
● Antiepileptics	2 (1.9)
● Other systemic treatments	4 (3.7)

**Neurological disorders: migraine, epilepsy, history of transient ischemic attack.*
NSAIDs: Non-steroidal anti-inflammatory drugs; DMARDs: disease-modifying antirheumatic drugs; SD: standard deviation; IQR: interquartile range; TMJ: temporomandibular joint; OSAS: obstructive sleep apnea syndrome.

Regarding secondary diagnoses, 63.9% of patients had no associated secondary diagnosis. When present, secondary diagnoses were most commonly degenerative (7.4%, n = 8), disc displacement without reduction (DDwoR) (7.4%, n = 8), and disc displacement with reduction (6.5%, n = 7), followed by primary condylar pathology (5.6%, n = 6), joint arthritis (4.6%, n = 5), functional and complex pain presentation (3.7%, n = 4), and muscular (0.9%, n = 1) disorders.

3.5 Ultrasound examination

Overall, among the 216 joints examined, 54.2% (n = 117) showed no ultrasonographic abnormality according to the predefined sonographic criteria. When joints were analyzed according to symptom status, ultrasonographic abnormalities were identified in 30.6% (n = 33) of contralateral joints and in 61.1% (n = 66) of symptomatic joints.

Ultrasound characteristics of the symptomatic side showed a median capsular thickness of 1.68 mm (IQR 1.30, n = 83) in the longitudinal plane and 2.02 mm (IQR 1.60, n = 80) in the transverse plane. Joint effusion was detected in 17.6% (n = 19) of cases longitudinally and 16.7% (n = 18) transversally. During dynamic assessment, normal condylar translation was observed in 79.6% (n = 86) of patients, while popping-like movement occurred in 4.6% (n = 5). Transverse disc visibility

was reported in 29.6% of cases (n = 32), with persistent visualization at the end of dynamic maneuvers in 9.3% (n = 10), consistent with disc displacement without reduction (DDwoR). Post-maneuver joint effusion remained present in 15.7% of patients (n = 17).

In contrast, findings on the contralateral TMJ revealed lower median thickness (Longitudinal: 1.47 mm, IQR 0.60 and Transverse: 1.77 mm, IQR 0.80 ($p = 0.047$)). Joint effusion was rare (0.9% to 1.9%) and absent during dynamic movement. Normal translation was frequent (88.9%), with minimal disc visibility (2.8%) or popping-like movement (2.8%) reported.

Comparison between the contralateral and symptomatic side are summarized in Table 2. Longitudinal capsular thickness was significantly greater on the symptomatic side ($p = 0.047$). Joint effusion (17.6% *vs.* 0.9%, $p < 0.001$ and 16.7% *vs.* 1.9%, $p = 0.011$ on longitudinal and transverse views respectively), disk visibility (29.6% *vs.* 14.8%, $p = 0.021$) and abnormal condylar translation during dynamic assessment (20.4% *vs.* 11.1%, $p = 0.021$) were also more frequent on the symptomatic side. Nevertheless, ultrasonographic abnormalities were not restricted to clinically symptomatic joints and were also observed in contralateral TMJs.

3.6 Subgroups analyses

All analyses across diagnostic subgroups were exploratory and hypothesis-generating.

Patient characteristics and clinical symptoms according to the primary diagnosis are presented in **Supplementary Table 1**. Age differed significantly across diagnostic groups ($p = 0.031$), with younger patients in primary condylar pathologies, whereas no significant differences were observed for sex distribution, symptom duration, pain, articular locking, bruxism, or limited range of motion (all $p > 0.05$). A borderline statistically significant difference between diagnostic groups was observed for crepitus ($p = 0.050$).

Clinical examination findings according to diagnostic subgroups are presented in **Supplementary Table 2**. Muscular pain was observed most frequently in the muscular disorders and functional and complex pain presentation subgroups ($p < 0.001$), while articular sounds, particularly popping/clicking, were noted in varying proportions, including 66.7% of patients in the disc displacement with reduction subgroup ($p = 0.003$). No significant differences were observed between diagnostic groups in terms of mouth opening limitation or mandibular opening pathway. Clinical examination did not detect any joint effusion in any subgroup (0%), in contrast to findings identified on ultrasound.

Ultrasound findings on the symptomatic side according to diagnostic subgroups are presented in Table 3.

Capsular thickness did not differ significantly between groups. Similarly, joint effusion assessed on the longitudinal view showed no significant intergroup differences. In contrast, the distribution of several ultrasound features differed across diagnostic categories.

Disc visibility on the transverse view differed significantly between groups ($p < 0.001$), being predominantly observed in patients with disc displacement with reduction (DDwR) (73.0%) and disc displacement without reduction (DDwoR) (83.3%). Lower proportions were observed in degenerative joint disease (18.4%), joint arthritis (20%), muscular disorders (20%), and functional and complex pain presentation (23.1%), whereas no disc visibility was identified in primary condylar pathology. During dynamic evaluation, persistence of disc visibility at the end of mandibular maneuvers was observed almost exclusively in the disc displacement without reduction subgroup (83.3%) ($p < 0.001$).

TABLE 2. Comparison of imaging features between symptomatic and contralateral side.

	Symptomatic side	Contralateral side	*p*-value
Capsular thickness[a], median (IQR)			
Longitudinal view	1.68 (1.30)	1.47 (0.60)	0.047*
Transverse view	2.02 (1.60)	1.77 (0.80)	0.274
Joint effusion, n (%)			
Longitudinal view	19 (17.6)	1 (0.9)	<0.001*
Transverse view	18 (16.7)	2 (1.9)	0.011*
Disk visibility in transverse view, n (%)	32 (29.6)	16 (14.8)	0.021*
Dynamic maneuvers, n (%)			
Abnormal condyle translation	22 (20.4)	12 (11.1)	0.021*
Disc visibility at the end of maneuvers	10 (9.3)	3 (2.8)	0.065
Popping-like movement	5 (4.6)	3 (2.8)	0.687
Joint effusion at the end of maneuvers	17 (15.7)	0 (0.0)	-

Continuous variables are expressed as median (IQR) and categorical variables as n (%).
p-values calculated using Paired t-test for capsular thickness and McNemar's test for paired categorical variables.
**Statistically significant at $p < 0.05$.*
[a]: Variable available for only 69 out of 108 patients.
IQR: interquartile range.

TABLE 3. Ultrasound findings according to clinical diagnosis.

	Primary condylar pathology (n = 5)	Degenerative joint disease (n = 49)	Joint arthritis (n = 5)	Disc displacement with reduction (n = 15)	Disc displacement without reduction (n = 6)	Muscular disorders (n = 15)	Functional and complex pain presentation (n = 13)	*p*-value
Longitudinal view								
Capsular thickness, median (Min–Max), mm	1.49 (1.40–1.50)[a]	2.1 (0.36–3.90)[b]	1.91 (0.69–4.90)[c]	1.60 (0.70–2.70)[d]	1.40 (0.80–4.50)[e]	1.20 (0.80–2.75)[f]	1.49 (0.95–2.30)[g]	0.185
Joint effusion, n (%)	0 (0)	14 (28.6)	2 (40)	1 (6.7)	1 (16.7)	0 (0)	1 (7.7)	0.058
Transverse view								
Capsular thickness, median (Min–Max), mm	1.0 (0.87–1.20)[a]	2.2 (0.62–4.70)[b]	1.93 (0.84–4.20)[c]	2.40 (1.42–6.80)[d]	1.95 (1.20–8.60)[e]	1.40 (1.0–3.30)[f]	1.56 (0.65–2.90)[g]	0.067
Joint effusion, n (%)	0 (0)	14 (28.6)	2 (40)	1 (6.7)	0 (0)	0 (0)	1 (7.7)	0.03*
Disk visibility, n (%)	0 (0)	9 (18.4)	1 (20)	11 (73.0)	5 (83.3)	3 (20)	3 (23.1)	<0.001*
Dynamic maneuvers, n (%)								
Abnormal condyle translation	1 (20)	11 (22.4)	2 (40)	2 (13.3)	3 (50)	1 (6.7)	2 (15.5)	0.325
Disc visibility at the end of maneuvers	0 (0)	5 (10.2)	0 (0)	0 (0)	5 (83.3)	0 (0)	0 (0)	<0.001*
Popping-like movement	0 (0)	2 (4.1)	0 (0)	0 (0)	0 (0)	1 (6.7)	2 (15.4)	0.533
Joint effusion at the end of maneuvers	0 (0)	13 (26.5)	2 (40)	1 (6.7)	0 (0)	0 (0)	1 (7.7)	0.044*

Continuous variables are expressed as median (IQR or Min–Max) and categorical variables as n (%).

p-values calculated using the Kruskal-Wallis test for non-parametric continuous variables (Capsular thickness) and Pearson's Chi-square test for categorical variables (Effusion, Visibility, Translation, Material presence).

**Statistically significant at $p < 0.05$.*

Capsular thickness measurements were available only for patients in whom ultrasound images had been stored during routine clinical practice, preventing retrospective measurement in the remaining cases: [a]available case n = 3, [b]available case n = 33, [c]available case n = 4, [d]available case n = 6, [e]available case n = 12, [f]available case n = 11, [g]available case n = 8. Min: minimum; Max: maximum.

Joint effusion findings also varied significantly according to diagnosis. Joint effusion on the transverse view differed across groups ($p = 0.030$), with higher frequencies observed in degenerative joint disease (28.6%) and joint arthritis (40%) compared with other diagnostic categories. Similarly, effusion persisting at the end of dynamic maneuvers was more frequently identified in degenerative joint disease (26.5%) and joint arthritis (40%) ($p = 0.044$).

Abnormal condylar translation did not differ significantly across groups ($p = 0.325$), although higher proportions were observed in disc displacement without reduction (50%), degenerative joint disease (22.4%), and functional/complex pain presentation (15.5%) subgroups. In contrast, popping-like movements were infrequently detected during dynamic evaluation and showed no significant association with diagnostic subgroups ($p = 0.533$).

In the subgroup of patients with a clinical diagnosis of disc displacement and available MRI examination, descriptive comparison between MRI and ultrasonographic findings was performed. Among the 23 patients, disc displacement was detected by MRI in 22 cases (95%), whereas ultrasound identified disc displacement in 17 cases (73.9%). Disc displacement without reduction was identified in 13 cases on MRI compared with 6 cases on ultrasound. These results are summarized in Table 4.

TABLE 4. Detection of disc displacement by MRI and US in patients with disc displacement and prior MRI examination.

Findings	MRI (n = 23)	US (n = 23)
Disc displacement detected, n (%)	22 (95.7)	17 (73.9)
Irreducible disc displacement, n (%)	13 (56.5)	6 (26.1)

MRI: magnetic resonance imaging; US: ultrasound.

4. Discussion

The present findings are consistent with our working hypothesis that ultrasonographic findings may vary according to diagnostic subgroups and, within individual patients, between the symptomatic and contralateral TMJs. It provides a comprehensive characterization of a tertiary referral cohort of patients with temporomandibular disorders, highlighting the complexity and chronicity of presentations encountered in specialized care. Patients were characterized by prolonged symptom duration, chronic pain, frequent previous investigations, and substantial prior therapeutic management before referral. Clinical assessment allowed patients to be categorized into diagnostic subgroups, while ultrasonography appeared to provide complementary descriptive information regarding structural TMJ abnormalities, their distribution according to symptom status and, on an exploratory basis, across diagnostic subgroups.

The demographic profile of this tertiary cohort is consistent with previous epidemiological studies on TMD, notably the marked female predominance observed in tertiary care populations. Women represented 81.6% of patients in this study, in agreement with previous reports by Vrbanović *et al*. [27] and Anastassaki *et al*. [28], who similarly described predominantly female referral cohorts. Patients referred to our tertiary center presented with long-standing disease with prolonged symptom duration across diagnostic groups. Most patients had already undergone extensive imaging investigations before referral, including CBCT in 92% and MRI in 59% of cases. Previous therapeutic interventions were frequently reported, particularly physiotherapy and occlusal splints. Comparable findings were reported in previous studies, with a high rate of physiotherapy use in patients with TMD [27, 28], reflecting its role as a commonly applied first-line management strategy in clinical practice. The heterogeneity of prior and ongoing treatments may have influenced clinical presentation and symptom severity, reflecting the real-world nature of a tertiary care population.

Degenerative joint disease represented the most frequent primary diagnosis in the cohort, contrasting with older tertiary-care studies in which disc displacement disorders predominated. In the cohorts described by Vrbanović *et al*. [27] and Anastassaki *et al*. [28], disc displacement accounted for approximately 45% and 29% of diagnoses, whereas osteoarthritis represented only 7.2% and 10%, respectively. This discrepancy may partly reflect differences in diagnostic classification systems, particularly the use of older TMD criteria in previous studies, but also differences in referral settings and patient recruitment. In contrast to our university hospital–based tertiary referral center, the cohort described by Vrbanović *et al*. [27] was recruited in a dental school setting, while the study by Anastassaki *et al*. [28] originated from a specialized outpatient clinic. Our multidisciplinary university hospital setting, including rheumatology expertise, likely concentrates more complex and chronic cases, including patients with degenerative TMJ involvement, as patients are often referred after failure of primary care management. Consistently with this observation, more recent epidemiological studies conducted in tertiary care settings have reported osteoarthritic changes on CT imaging in approximately 30% of patients with painful TMD [29]. While structural abnormalities do not consistently reflect clinical symptom severity, inflammatory osteoarthritis may represent a distinct and more symptomatic phenotype. In this regard, Song *et al*. [30] demonstrated that higher subjective pain at initial evaluation was associated with increased destructive change index (DCI) scores both before and after treatment, suggesting a potential association between symptomatic inflammatory activity and structural progression.

Another major finding was the high prevalence of multiple concomitant diagnoses. Nearly 30% of patients presented at least one secondary TMD diagnosis, emphasizing the multifactorial nature of TMD and the frequent overlap between muscular, articular, and functional disorders. This proportion was substantially higher than the 20% reported by Vrbanović *et al*. [27]. Subgroup overlap and heterogeneous clinical presentations are expected when applying DC/TMD criteria in real-world populations, as patients frequently present with multiple coexisting diagnostic features across Axis I categories.

The cohort also demonstrated a substantial burden of comorbidities, particularly chronic pain syndromes and anxiety or depressive disorders. These findings are consistent with previous studies demonstrating a higher prevalence of psychological distress, altered pain modulation with somatosensory

disturbance, and chronic pain comorbidities in TMD populations compared with healthy controls [3, 5–7]. Chronic pain conditions are increasingly understood through mechanisms of central sensitization and altered neuroplasticity, which may amplify nociceptive processing and contribute to persistent pain despite limited or stable structural abnormalities [6]. The prolonged symptom duration observed in the cohort, with a median duration of approximately five years, could therefore partly explain the discordance observed between persistent symptoms and imaging findings particularly in patients with long-standing disease. Maladaptive coping mechanisms have also been proposed to promote symptom persistence through enhanced pain-related attention and increased somatic sensitivity [31]. Within our cohort, these mechanisms remain hypothetical as no validated measures of central sensitization or psychological status were collected. This phenomenon may be particularly relevant in patients classified within the functional and complex pain presentation subgroup who represented approximately 12% of cases. These patients demonstrated heterogeneous clinical presentation, combining multiple overlapping symptoms. More than half presented joint noises such as popping/clicking, while muscular pain was also prevalent. Interestingly, patients within this subgroup also demonstrated some of the longest symptom durations in the cohort, which may suggest an association between chronicity and clinical complexity. Future studies incorporating validated Axis II instruments and standardized measures of central sensitization would be valuable to further investigate the relationship between psychosocial factors and imaging findings in TMD patients.

Regarding imaging assessment, several ultrasonographic findings differed between the symptomatic and contralateral TMJs and, in exploratory analyses, across specific TMD subgroups.

Capsular thickness tended to be higher on symptomatic side. Although the difference reached statistical significance between symptomatic and contralateral joints in the longitudinal view, capsular thickness did not significantly differ across diagnostic subgroups in either longitudinal or transversal views. These findings are partly consistent with the prospective study by Erturk *et al*. [20], in which patients with symptomatic TMD showed increased joint space measurements when pain was associated with intra-articular disorders, whereas reduced joint space distances were observed in patients with pain attributed to muscular disorders. Interestingly, the asymptomatic joints in their study demonstrated a median capsular thickness of 1.29 mm, with a significant difference compared with symptomatic joints, similarly to our findings. The absence of significant differences between diagnostic subgroups should nevertheless be interpreted cautiously. Capsular thickness measurements were available only in a subset of patients because ultrasound images had not been systematically archived during routine clinical practice. This reduced sample size may have limited the statistical power to detect differences between diagnostic subgroups. Moreover, observations from some diagnostic subgroups should be interpreted cautiously because of their limited sample size and should therefore be considered hypothesis-generating.

Joint effusion was more frequently observed in symptomatic joints and in patients with inflammatory or degenerative intra-articular disorders, both of which may be associated with intra-articular fluid accumulation. Interestingly, no joint effusion was identified during routine clinical examination in the cohort. This result is not unexpected, as the deep anatomical location of the TMJ considerably limits the ability of clinical inspection and palpation to detect intra-articular effusion. These ultrasonographic findings are consistent with previous studies evaluating the diagnostic performance of ultrasonography for TMJ effusion. Jank *et al*. [32] reported a specificity of 100% for the detection of joint effusion by ultrasonography, although sensitivity was lower (81%). Similarly, the study by Mello *et al*. [33] also demonstrated a specificity of 100%, but with a markedly lower sensitivity of 20%. Taken together, our findings interpreted in the light of previous studies, suggest that ultrasonographic detection of joint effusion may provide complementary information regarding intra-articular involvement, whereas its absence does not reliably exclude joint pathology. Conversely, joint effusion remained uncommon in muscular disorders and in the functional/complex pain presentation subgroup, although these exploratory subgroup findings should not be interpreted as evidence of diagnostic discrimination.

Concerning disc visualization, exploratory subgroup analyses showed differences in transverse disc visibility across diagnostic subgroups, with higher proportions observed in disc displacement disorders. The transverse view appeared valuable for the assessment of joint effusion and disc visualization because it may improve visualization of the anterior and lateral compartment of the TMJ. Nevertheless, interpretation can sometimes be challenging, particularly when differentiating small joint effusions from laterally displaced disc material, which may explain the 18.4% rate of disc visibility observed in the degenerative joint disease subgroup.

Dynamic assessment provided complementary information regarding TMJ function during mandibular movement. Persistence of disc material at the end of dynamic maneuvers was more frequently observed in patients classified as disc displacement without reduction (DDwoR). Although this finding may reflect persistent disc displacement during mouth opening, it should be interpreted cautiously, as failure to visualize the disc during examination may also result from technical factors, including probe positioning and image quality, anatomical variability, and the operator-dependent nature of ultrasonography. Importantly, MRI was not systematically available to confirm disc displacement. Dynamic examination also provided information on condylar translation with abnormalities more frequently observed on symptomatic sides, suggesting that dynamic ultrasonography may provide complementary functional information in the evaluation of TMD. Conversely, dynamic abnormalities were not specific to disc displacement alone, as altered condylar translation are also observed in degenerative disorders and the functional/complex pain presentation subgroup, although these exploratory findings should be interpreted cautiously given the small subgroup size.

Interestingly, no ultrasonographic finding appeared to specifically characterize the functional and complex pain presentation subgroup. This observation may suggest that symptoms in these patients are only partially explained

by structural TMJ abnormalities and further highlights the importance of integrating imaging findings with the overall clinical assessment.

An additional finding of interest was that nearly one-third (30.6%) of contralateral TMJs exhibited at least one ultrasonographic abnormality. This finding is consistent with previous imaging studies, which have shown that structural abnormalities may be present even in the absence of clinical symptoms [34, 35]. In particular, Jerele *et al*. [34] reported that contralateral TMJs in patients with unilateral TMD frequently exhibit MRI abnormalities, including disc displacement, osteoarthritic changes, and joint effusion. These ultrasound findings may reflect subclinical structural abnormalities but could also be explained by the limited specificity of certain ultrasonographic findings when interpreted in isolation, operator-dependent variability, or the inherent limitations of classifying TMJs according to the predominant symptomatic side for some patients. Furthermore, unilateral TMD may be associated with bilateral structural or functional adaptations, suggesting that the contralateral TMJ should not be regarded as equivalent to a healthy control joint. In the absence of a healthy control group, it remains uncertain whether these abnormalities are specific to contralateral TMJs in patients with TMD or may also be observed in the general population. These observations further emphasize the imperfect relationship between imaging findings and clinical presentation.

In the subgroup of patients with clinically suspected disc displacement, MRI identified disc displacement in 95% of cases (22/23), whereas ultrasonography identified disc displacement in 73% of cases (17/23). This exploratory descriptive comparison involved a small and selected subgroup number of patient and was not designed to assess diagnostic performance. Nevertheless, these observations can be contextualized by the heterogeneous results reported in the literature, with sensitivities for ultrasound detection of disc displacement ranging from 65.8% in the study by Tognini *et al*. [36] to as high as 95% in the series reported by Jank *et al*. [32]. These exploratory observations do not establish the diagnostic accuracy of ultrasonography for disc displacement, while MRI remains the reference imaging modality for detailed soft-tissue evaluation and assessment of disc reducibility.

Regarding the strengths of this study, its real-life tertiary-care design reflects routine clinical practice in a specialized referral center. The multidisciplinary evaluation combining rheumatology and maxillofacial surgery expertise enabled comprehensive and standardized clinical assessment of patients with complex TMD presentations. Another strength is the clinical relevance of the ultrasonographic assessment protocol, which included both static and dynamic analyses. This approach allowed exploration of the potential role of ultrasonography in providing descriptive information on both structural abnormalities and TMJ mechanics during mandibular movement. Finally, this study contributes to the growing literature investigating the role of ultrasonography in TMD assessment, while simultaneously providing a detailed characterization of a tertiary-care TMD population.

Several important limitations should be acknowledged. First, the observational cross-sectional design and the absence of blinding between the clinical and ultrasonographic assessments may have introduced observation bias and limited causal interpretation of the associations between imaging findings and diagnoses. Second, ultrasonographic evaluation remains operator-dependent, and no formal assessment of intra- or inter-observer reliability was performed. Therefore, the reproducibility of our findings across different operators remains to be established. Third, MRI correlation was not systematically available for all patients, preventing direct comparison between ultrasonographic findings and the current imaging gold standard. Consequently, MRI comparison was restricted to a small subgroup and was intended as a descriptive exploratory analysis rather than an assessment of diagnostic performance. Therefore, sensitivity, specificity, and predictive values were not calculated, and the present data does not allow reliable assessment of disc reducibility by ultrasonography. Another important methodological limitation concerns the within-patient comparison design. Patients with bilateral TMJ pain without a clearly identifiable predominant symptomatic side were excluded because the analysis was designed to compare joints within the same individual. Although this approach reduced inter-individual variability, it may have introduced selection bias, limited the applicability of these findings to patients with bilateral symptoms and may have led to the underrepresentation of patients with more complex or advanced bilateral TMD presentations, frequently encountered in tertiary referral settings. Furthermore, among the included patients with bilateral symptoms, the contralateral TMJ corresponded to the less symptomatic joint rather than to a symptom-free joint. Consequently, the within-patient comparison may have reduced the contrast between the two TMJs. Importantly, the contralateral TMJ should not be regarded as equivalent to a healthy control joint. However, because contralateral joints in patients with TMD are known to exhibit structural abnormalities more frequently than TMJs from healthy controls, the use of an intra-individual comparator remains clinically relevant despite its inherent limitations. Moreover, diagnostic classification was based on routine clinical assessment, complemented by conventional imaging findings when available. Although this approach reflects routine clinical practice, some degree of diagnostic misclassification cannot be excluded, particularly in patients presenting with overlapping TMD phenotypes. In addition, bruxism was assessed solely from the patient's self-reported history, without the use of validated questionnaires or instrumental confirmation, which may have led to some degree of misclassification. Another methodological limitation concerns the definition of the functional and complex pain presentation subgroup, which was based on predefined clinical features rather than validated DC/TMD Axis II instruments or other standardized measures of altered pain processing. Although some of these clinical features may be compatible with mechanisms such as central sensitization, this mechanism was not objectively assessed or confirmed. Consequently, some degree of classification bias cannot be excluded for this subgroup. Furthermore, several diagnostic subgroups included relatively small and unequal numbers of patients, limiting statistical power and increasing the risk of type I and type II errors. Consequently, all subgroups analysis should be considered exploratory and hypothesis-generating,

requiring confirmation in larger cohort. Finally, this study was conducted in a tertiary referral center, where patients are more likely to present with chronic, complex, or treatment-refractory TMDs. Consequently, our findings may not be fully generalizable to patients managed in primary care or general dental practice, who often present with less severe or earlier-stage disease.

5. Conclusions

This study provides a comprehensive characterization of patients with TMD referred to a tertiary-care center, highlighting the complexity and chronicity of presentations encountered in specialized care. Despite the heterogeneity of these presentations, a standardized diagnostic workup integrating clinical evaluation and, when available, conventional imaging allowed patients to be categorized into distinct and coherent diagnostic subgroups. The ultrasonographic findings in this study provide a descriptive overview of ultrasound abnormalities observed in a highly selected tertiary care cohort. Several ultrasonographic findings differed between the symptomatic and contralateral TMJs, while exploratory analyses identified differences across diagnostic subgroups. These observations should be considered exploratory and interpreted cautiously, particularly given the small subgroup size and other methodological limitations of the study. Overall, these findings suggest that ultrasonography may contribute to the characterization of structural TMJ abnormalities and provide complementary information during the evaluation of TMDs, when interpreted in conjunction with the overall clinical assessment. Given the methodological limitations of this study, ultrasonography should be regarded as a complementary imaging modality rather than a standalone diagnostic tool, while MRI remains the reference standard for soft-tissue abnormalities evaluation and for assessment of disc reducibility.

ABBREVIATIONS

CBCT, cone-beam computed tomography; csDMARDs, conventional synthetic disease-modifying antirheumatic drugs; CT, computed tomography; DCI, destructive change index; DC/TMD, Diagnostic Criteria for Temporomandibular Disorders; DMARDs, disease-modifying antirheumatic drugs; IQR, interquartile range; JAK, Janus kinase; MRI, magnetic resonance imaging; NSAIDs, non-steroidal anti-inflammatory drugs; OSAS, obstructive sleep apnea syndrome; PsA, psoriatic arthritis; RDC/TMD, Research Diagnostic Criteria for Temporomandibular Disorders; SD, standard deviation; TMD, temporomandibular disorder; TMJ, temporomandibular joint; US, ultrasonography or ultrasound; DDwR, disc displacement with reduction; DDwoR, disc displacement without reduction; DD, disc displacement; CM, closed-mouth; OM, open-mouth.

AVAILABILITY OF DATA AND MATERIALS

Data and materials are available on demand.

AUTHOR CONTRIBUTIONS

BLG—conceived and supervised the study; contributed to data collection, provided imaging data, participated in data analysis and interpretation, and critically revised the manuscript. MD—collected and curated the data. BLG and MD—performed the statistical analyses and drafted the manuscript. HB—contributed to patient recruitment, data collection, and critical revision of the manuscript. PC and PG—contributed to patient referral and critically revised the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This retrospective study was based exclusively on data previously collected as part of routine patient care. The study did not involve any intervention on participants, any additional procedure, any randomization, or any modification of usual clinical practice. Accordingly, under Articles L.1121-1 and R.1121-1 of the French Public Health Code, this study did not fall within the scope of research involving human participants requiring CPP approval. In accordance with institutional policy, all patients admitted to Nantes University Hospital are informed that their anonymized clinical data may be used for research purposes unless they object. Specific informed consent was obtained from the patient for publication of the anonymized clinical photograph shown in Fig. 1.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://files.jofph.com/files/article/2120749413682823168/attachment/Supplementary%20material.docx.

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