



REVIEW ARTICLE

TEMPOROMANDIBULAR JOINT DYSFUNCTION: CURRENT CONCEPTS IN ETIOLOGY, DIAGNOSIS, AND EVIDENCE-BASED MANAGEMENT-A NARRATIVE REVIEW

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Abstract

Background: Temporomandibular joint dysfunction (TMD) is a common disorder affecting the temporomandibular joint, masticatory muscles, and associated structures. It has a multifactorial etiology involving mechanical, neuromuscular, inflammatory, biological, and psychosocial factors. Recent advances in diagnostic criteria, imaging techniques, and therapeutic options have improved the understanding and management of TMD.

Objective: To provide an updated narrative review of the etiology, pathogenesis, clinical manifestations, diagnosis, and evidence-based management of temporomandibular joint dysfunction, with emphasis on conservative, minimally invasive, and surgical treatment approaches.

Materials and Methods: A narrative review was performed using PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. The review included systematic reviews, meta-analyses, randomized clinical trials, clinical studies, guidelines, and consensus statements published between January 2000 and March 2026, together with landmark publications relevant to TMD diagnosis and treatment.

Results: Current evidence indicates that TMD should be regarded as a multifactorial functional disorder requiring individualized assessment. Diagnosis is primarily based on the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), supported by magnetic resonance imaging (MRI) and cone-beam computed tomography (CBCT) when clinically indicated. Conservative treatment remains the first-line approach and includes patient education, self-management, physiotherapy, therapeutic exercises, occlusal splints, pharmacological therapy, and behavioral interventions. In patients with persistent symptoms, minimally invasive procedures such as arthrocentesis, arthroscopy, and intra-articular injections of hyaluronic acid or platelet-rich plasma may improve clinical outcomes. Open surgical procedures and total joint reconstruction are reserved for severe structural abnormalities. Emerging technologies, including artificial intelligence, digital mandibular tracking, biomarkers, and regenerative medicine, may support future personalized treatment strategies.

Conclusion: Effective TMD management requires an individualized, multidisciplinary, and evidence-based approach. Early diagnosis and conservative therapy remain the foundation of treatment, whereas minimally invasive and surgical interventions should be reserved for selected patients. Future integration of digital technologies and regenerative approaches may further improve personalized patient care.

Keywords: Temporomandibular joint dysfunction; Temporomandibular joint; Orofacial pain; Diagnosis; Conservative treatment; Arthrocentesis; Multidisciplinary management.

INTRODUCTION

Temporomandibular joint dysfunction (TMJ dysfunction) represents a common functional disorder affecting the temporomandibular joint and associated

masticatory structures. It is characterized by disturbances in joint function, altered mandibular biomechanics, pain symptoms, and impairment of normal stomatognathic function. Because of the complex anatomical and functional relationships within the maxillofacial system,

TMJ dysfunction may present with a broad spectrum of clinical manifestations, including preauricular and facial pain, limitation or deviation of mandibular movements, joint sounds, impaired mastication, headaches, otologic symptoms, and a significant reduction in oral health-related quality of life.¹⁻³

Over the past two decades, the understanding of temporomandibular joint dysfunction has undergone a substantial transformation. Historically, TMJ dysfunction was frequently interpreted primarily as a local mechanical disorder associated with occlusal abnormalities, altered mandibular function, or excessive loading of the joint structures. However, contemporary evidence supports a multifactorial model in which the development and persistence of symptoms result from complex interactions among biological, mechanical, neuromuscular, inflammatory, and psychosocial factors. Biological contributors include structural alterations of the joint components, changes in neuromuscular regulation, altered pain-processing mechanisms, genetic susceptibility, and inflammatory responses. Psychosocial factors, including stress, anxiety, depression, and sleep disturbances, may influence symptom severity, pain perception, and functional impairment. This modern perspective emphasizes that TMJ dysfunction cannot be explained solely by structural abnormalities but rather reflects dynamic interactions between peripheral joint tissues, muscular function, central pain modulation pathways, and individual patient characteristics.^{2,4,6}

Epidemiological studies indicate that temporomandibular joint dysfunction represents one of the most frequently encountered functional and pain-related conditions affecting the craniofacial region. Although reported prevalence rates vary depending on diagnostic criteria, study populations, and assessment methods, clinically relevant symptoms associated with TMJ dysfunction are observed in a considerable proportion of adults. Pain-related manifestations are frequently reported among young and middle-aged individuals, with many studies demonstrating a higher prevalence among women compared with men. This difference has been associated with multiple contributing factors, including hormonal influences, variations in pain sensitivity, genetic susceptibility, and psychosocial determinants. Nevertheless, demographic characteristics alone cannot fully explain the development of TMJ dysfunction, supporting the concept that this condition results from complex interactions between multiple biological and environmental factors.^{5,9}

The clinical significance of TMJ dysfunction extends

beyond localized joint discomfort and impaired mandibular function, as it may considerably affect patients' daily activities, social interactions, and overall quality of life. Limitation of mouth opening, altered mandibular movement patterns, difficulty with mastication, joint noises, facial and cervical pain, tinnitus, and persistent discomfort may interfere with normal function and contribute to psychological burden. Increasing evidence demonstrates associations between persistent TMJ-related pain, sleep disturbances, anxiety, depressive symptoms, and altered pain modulation mechanisms. Therefore, TMJ dysfunction should be considered not merely as a localized joint disorder but as a complex functional condition involving interactions between joint structures, masticatory muscles, pain-processing mechanisms, and psychosocial factors.^{4,10}

Current evidence indicates that the development of TMJ dysfunction cannot be attributed to a single etiological factor. Instead, it results from the interaction of mechanical loading, biological changes, neuromuscular activity, inflammatory processes, and individual adaptive responses. Frequently reported contributing factors include increased masticatory muscle activity, parafunctional behaviors such as bruxism, trauma, inflammatory alterations of joint tissues, degenerative changes, genetic susceptibility, and prolonged psychological stress. These factors may influence disease development through mechanisms involving altered muscle function, increased mechanical stress on joint components, activation of inflammatory pathways, and changes in peripheral and central pain processing. Consequently, clinical manifestations and disease progression vary considerably among individuals depending on biological susceptibility, environmental influences, functional adaptation capacity, and individual responses to pain.^{6,24,26}

Recent advances in research on temporomandibular joint dysfunction have substantially influenced contemporary diagnostic strategies. Current diagnostic concepts emphasize that comprehensive clinical assessment remains the foundation of evaluation, whereas imaging and instrumental investigations should be selected according to specific clinical indications rather than applied routinely in all patients. The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) provide a standardized framework for the assessment of temporomandibular conditions through structured clinical examination, evaluation of mandibular function, and assessment of relevant clinical and psychosocial factors. The application of standardized diagnostic approaches has improved diagnostic reliability and facilitated more individualized treatment planning for patients with TMJ dysfunction.^{1,11,12}

Advanced imaging techniques provide complementary

information in patients with suspected structural abnormalities or intra-articular pathology associated with temporomandibular joint dysfunction. Magnetic resonance imaging (MRI) remains the preferred imaging modality for evaluation of the soft tissue components of the temporomandibular joint, including articular disc position and morphology, joint effusion, inflammatory changes, and early degenerative alterations. MRI findings should always be interpreted together with clinical symptoms, as structural abnormalities may also be present in individuals without clinical manifestations. Cone-beam computed tomography (CBCT) and computed tomography (CT) are primarily used for evaluation of osseous structures, including condylar morphology, cortical changes, erosive alterations, osteophyte formation, anatomical deformities, and advanced degenerative joint changes.

The integration of clinical examination with appropriately selected imaging modalities improves diagnostic accuracy and reduces the risk of unnecessary interventions based solely on radiographic findings.^{13,14}

The therapeutic approach to temporomandibular joint dysfunction has progressively shifted from irreversible mechanical interventions toward patient-centered, minimally invasive, and evidence-based management strategies. Current recommendations support a stepwise treatment model in which reversible and conservative approaches are prioritized before invasive procedures. The primary objectives of treatment include reduction of pain, restoration of mandibular function, improvement of oral health-related quality of life, and prevention of chronic symptom progression rather than correction of anatomical abnormalities alone. This contemporary treatment philosophy reflects the recognition that structural changes identified by imaging do not always correlate directly with clinical symptoms and that treatment decisions should be based on comprehensive evaluation of each patient's functional status, pain characteristics, contributing factors, and individual expectations.¹⁵⁻¹⁷

Conservative management remains the cornerstone of treatment for temporomandibular joint dysfunction and includes patient education, self-management strategies, behavioral modification, physiotherapy, therapeutic exercises, occlusal splints, pharmacological interventions, and psychological support when clinically indicated. These approaches aim to reduce pain, improve functional adaptation, and address contributing factors rather than focusing

exclusively on anatomical correction. In patients who demonstrate insufficient improvement despite appropriate conservative therapy, minimally invasive procedures may be considered.

Arthrocentesis, arthroscopy, and intra-articular injections with agents such as hyaluronic acid and platelet-rich plasma (PRP) have been investigated as therapeutic options, particularly in selected patients with persistent intra-articular symptoms, inflammatory changes, or degenerative joint alterations. Surgical interventions, including open joint procedures and temporomandibular joint prosthetic reconstruction, remain reserved for patients with severe structural abnormalities, advanced degenerative disease, ankylosis, or failure of less invasive treatment approaches.^{18,25,26,27,28,34}

Despite substantial progress in understanding temporomandibular joint dysfunction, several aspects of its pathophysiology, diagnostic classification, and therapeutic decision-making remain under active investigation. The considerable variability of clinical manifestations, differences in diagnostic approaches, heterogeneity of treatment protocols, and complex interactions between biological and psychosocial determinants continue to represent challenges for individualized patient management. Contemporary research emphasizes the importance of standardized diagnostic approaches, evidence-based therapeutic algorithms, and multidisciplinary strategies integrating dental, medical, physiotherapeutic, and behavioral perspectives.²⁹⁻³³

Although numerous clinical studies, systematic reviews, and consensus statements have expanded current knowledge regarding temporomandibular joint dysfunction, differences in study methodologies, diagnostic criteria, patient characteristics, and outcome assessment methods continue to limit direct comparison between published findings. Therefore, an updated synthesis of contemporary concepts related to the etiology, pathogenesis, diagnosis, and evidence-based management of temporomandibular joint dysfunction remains clinically relevant. The principal contemporary treatment modalities for temporomandibular joint dysfunction and their clinical characteristics are summarized in Table 1.

Table 1. Contemporary Classification of Treatment Modalities for Temporomandibular Joint Dysfunction

Treatment modality	Main indications	Advantages	Limitations	Level of evidence
Patient education and self-management	Patients with temporomandibular joint dysfunction	Non-invasive, low cost, promotes patient participation and self-care	Requires patient adherence and motivation	High
Physiotherapy and therapeutic exercise	Functional limitation, muscular dysfunction, impaired mandibular mobility	Improves mandibular function and reduces pain	Treatment protocols and duration vary among studies	High
Occlusal splints	Bruxism, muscular pain, selected functional disorders	Reversible and conservative therapeutic option	Effectiveness depends on appropriate patient selection and indication	Moderate–High
Pharmacological therapy	Acute pain, inflammatory symptoms, muscular discomfort	Provides symptom relief and improves patient comfort	Potential adverse effects and limited role for long-term management	Moderate
Electrostimulation therapies	Chronic muscular pain and rehabilitation	Non-invasive adjunctive therapy	Limited standardization and heterogeneous evidence	Moderate
Biological therapies (PRP, hyaluronic acid)	Degenerative TMJ changes and persistent intra-articular symptoms	Potential biological and regenerative effects	Lack of standardized protocols and variable evidence quality	Moderate
Arthrocentesis	Internal derangement, persistent joint pain, limited response to conservative therapy	Minimally invasive and effective symptom improvement in selected cases	Requires appropriate patient selection	High
Arthroscopy	Persistent intra-articular pathology	Provides both diagnostic and therapeutic benefits	Technically demanding and operator-dependent	High
Open surgery and TMJ reconstruction	Severe structural pathology, ankylosis, advanced degenerative joint disease	Definitive treatment for complex structural disorders	Greater surgical morbidity and longer recovery period	High

Abbreviations: TMJ, temporomandibular joint; PRP, platelet-rich plasma.

This narrative review aims to provide a comprehensive overview of contemporary concepts regarding temporomandibular joint dysfunction, including current understanding of its etiology, pathogenesis, diagnostic approaches, and evidence-based management strategies, with particular emphasis on recent scientific developments and evolving clinical perspectives.

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2.1. Review Design

This study was designed as a narrative review aimed at providing a comprehensive and critical synthesis of current evidence regarding temporomandibular joint dysfunction (TMJ dysfunction), with particular emphasis on contemporary concepts of etiology, pathogenesis, diagnostic approaches, and evidence-based therapeutic strategies. The review methodology was developed according to the principles of narrative reviews, allowing integration and interpretation of findings from different types of scientific publications, including systematic reviews, meta-analyses, randomized clinical trials, observational studies, clinical guidelines, and expert consensus documents.

The narrative approach was selected because TMJ dysfunction represents a complex clinical condition characterized by interactions among biological, mechanical, neuromuscular, inflammatory, and psychosocial factors. This methodology enables a broad evaluation of current concepts, emerging diagnostic approaches, and evolving treatment strategies while considering differences in study designs, clinical populations, and reported outcomes.

2.2. Literature Search Strategy

A narrative literature synthesis was performed using the electronic databases PubMed/MEDLINE, Scopus, Web of Science Core Collection, and Google Scholar. The literature search included publications primarily published between January 2020 and March 2026. In addition, earlier landmark publications were considered when they represented fundamental contributions to the development of diagnostic classifications, clinical criteria, pathophysiological concepts, and treatment principles related to TMJ dysfunction.

The search strategy was developed using Medical Subject Headings (MeSH) terms and relevant keywords combined with Boolean operators. The search strategy was adapted according to the requirements of each database.

The following search terms and combinations were applied: ("temporomandibular joint dysfunction", "etiology", "pathogenesis", "diagnosis", "clinical criteria", "MRI", "CBCT", "management", "conservative treatment", "physiotherapy", "occlusal splints", "pharmacological therapy", "botulinum toxin", "electrostimulation", "TENS", "arthrocentesis", "arthroscopy", "platelet-rich plasma", "hyaluronic acid", "surgical treatment").

Additional manual searches of reference lists from relevant publications were performed to identify important studies that were not retrieved through electronic database searches.

2.3. Eligibility Criteria

Publications were considered eligible when they provided clinically relevant information regarding the etiology, pathophysiology, diagnosis, clinical manifestations, imaging assessment, or management of temporomandibular joint dysfunction.

The review included:

- systematic reviews and meta-analyses;
- randomized clinical trials;
- prospective and retrospective clinical studies;
- observational studies;
- international clinical guidelines;
- consensus statements and expert recommendations.

Articles were selected based on their relevance to contemporary concepts of TMJ dysfunction etiology, diagnosis, and management. Due to the narrative design of the review, no formal screening process, systematic review workflow, or quantitative synthesis was performed.

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2.4. Inclusion Criteria

Studies were included if they met the following criteria:

1. Focused on temporomandibular joint dysfunction or related disorders affecting temporomandibular joint function.
2. Addressed at least one of the following aspects: etiology, pathogenesis, diagnostic evaluation, clinical manifestations, imaging assessment, or therapeutic management.
3. Were published in peer-reviewed scientific journals.
4. Provided sufficient methodological information and clinically meaningful outcomes.
5. Were available as full-text publications in English.

2.5. Exclusion Criteria

The following publications were excluded:

- duplicate records;
- conference abstracts without full scientific reports;
- non-peer-reviewed materials;
- opinion articles without supporting scientific evidence;
- experimental studies without direct clinical relevance;
- publications unrelated to the etiology, diagnosis, imaging assessment, or management of TMJ dysfunction.⁶

2.6. Data Extraction and Narrative Synthesis

Relevant information was extracted from selected publications, including study design, patient characteristics, diagnostic criteria, imaging modalities, therapeutic interventions, follow-up periods, and reported clinical outcomes. The extracted evidence was organized according to the main clinical domains of TMJ dysfunction:

1. Etiology and pathogenesis;
2. Modern diagnostic approaches;
3. Conservative and non-surgical management;
4. Minimally invasive interventions;
5. Biological therapies;
6. Surgical treatment strategies;
7. Emerging technologies and future perspectives.

Because of substantial heterogeneity among available studies regarding patient populations, diagnostic criteria, treatment protocols, and outcome measures, a qualitative narrative synthesis was performed. The findings were critically interpreted according to clinical relevance, consistency of available evidence, methodological characteristics, and applicability to contemporary clinical practice.

2.7. Quality Considerations

As this study was designed as a narrative review, a formal risk-of-bias assessment according to systematic review methodology and quantitative meta-analysis were not performed. However, methodological characteristics of included studies, study design, level of evidence, sample characteristics, and potential limitations were considered during interpretation and synthesis of the available evidence. The strength and clinical relevance of findings were evaluated according to the consistency of reported outcomes, methodological quality of available studies, and applicability to current TMJ dysfunction management approaches.

2.8. Ethical Considerations

Ethical approval was not required for this narrative review because the study involved analysis of previously published scientific literature and did not include direct participation of human subjects, patient recruitment, or collection of individual patient data.

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3. RESULTS

3.1. Overview of Included Evidence and General Findings

The synthesis of the available literature demonstrated that temporomandibular joint dysfunction (TMJ dysfunction) represents a complex multifactorial condition involving interactions among articular structures, masticatory muscles, neuromuscular regulation, inflammatory mechanisms, and psychosocial factors. Current evidence indicates that TMJ dysfunction is no longer considered an isolated mechanical disorder but rather a multidimensional functional condition influenced by biological, biomechanical, psychological, and environmental determinants. This conceptual transition has shifted contemporary management toward a patient-centered biopsychosocial approach integrating structural, functional, and pain-related mechanisms.^{1,4,14,18}

The literature analyzed in this review included systematic reviews, meta-analyses, randomized clinical trials, observational studies, and clinical recommendations addressing different aspects of TMJ dysfunction. Although substantial heterogeneity was observed regarding diagnostic criteria, patient populations, therapeutic protocols, and outcome assessment methods, several consistent findings were identified across studies. These included the importance of standardized diagnostic approaches, early conservative management, multidisciplinary care, and individualized treatment planning based on clinical characteristics rather than isolated imaging findings.^{1,12,21,22}

Clinical manifestations demonstrated considerable variability among patients. The most frequently reported symptoms included temporomandibular and masticatory muscle pain, limitation or deviation of mandibular movements, joint sounds, impaired mastication, headaches, and associated otologic symptoms. Current evidence suggests that symptom severity is influenced not only by structural changes but also by individual pain sensitivity, psychological status, functional adaptation, and central pain-processing mechanisms.^{4,5,10,23}

The reviewed evidence demonstrated a progressive transition toward minimally invasive and reversible treatment strategies. Conservative approaches, including patient education, self-management, physiotherapy, behavioral modification, pharmacological support, and occlusal appliance therapy, remain the foundation of initial management. More invasive procedures are generally reserved for selected patients with persistent symptoms, failure of conservative therapy, or significant structural joint pathology.^{15,16,18,25,26,27}

3.2. Etiology and Pathophysiological Mechanisms of Temporomandibular Joint Dysfunction

The reviewed evidence confirmed that TMJ dysfunction develops through the interaction of multiple etiological factors rather than a single pathological mechanism. Current concepts emphasize the dynamic relationship between mechanical loading, neuromuscular activity, inflammatory processes, tissue adaptation, genetic susceptibility, and psychosocial influences.^{4,5,24} Frequently reported contributing factors include masticatory muscle overload, parafunctional activity, trauma, inflammatory joint alterations, degenerative changes, genetic predisposition, and psychological stress. However, contemporary evidence indicates that these factors should be interpreted as interacting modifiers rather than independent causes, explaining the considerable variability in clinical presentation and disease progression among patients.^{4,24,26}

3.2.1. Masticatory Muscle Dysfunction and Bruxism

Altered masticatory muscle function represents an important component in the development and maintenance of TMJ-related symptoms. Increased muscle activity, prolonged contraction, fatigue, and impaired neuromuscular coordination may contribute to myofascial pain, restricted mandibular movements, and functional limitation.^{23,24}

The role of bruxism has been substantially reconsidered in recent years. Earlier theories suggested that bruxism represented a primary etiological factor; however, current evidence indicates a more complex relationship. Bruxism is now regarded as a potential modifying factor that may increase muscular loading, aggravate existing dysfunction, and contribute to symptom persistence in susceptible individuals rather than acting as an isolated cause of TMJ dysfunction.

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3.2.2. Occlusal Factors

The relationship between occlusion and TMJ dysfunction has undergone significant revision. Earlier concepts

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considered occlusal abnormalities as the dominant cause of joint dysfunction; however, contemporary evidence does not support occlusion as an independent primary etiological factor.^{20,21}

Current studies indicate that occlusal characteristics may influence functional adaptation and load distribution within the stomatognathic system but represent only one component within a broader multifactorial model. This change in understanding has reduced the use of irreversible occlusal interventions without clear clinical indications.^{20,21,27}

3.2.3. Psychosocial and Central Pain Mechanisms

Recent studies emphasize the important contribution of psychosocial factors to the development and persistence of TMJ-related pain. Stress, anxiety, depression, sleep disturbances, and emotional disorders may influence pain modulation pathways and contribute to chronic symptom development.^{4,8,10} The involvement of central sensitization mechanisms has become increasingly recognized, particularly in patients with persistent pain symptoms. Altered central processing of nociceptive signals may explain why clinical symptoms do not always correspond directly with the extent of structural abnormalities identified by imaging.^{4,5,23}

Overall, current evidence supports a biopsychosocial model in which TMJ dysfunction results from interactions between peripheral joint structures, neuromuscular function, inflammatory processes, and individual pain-processing characteristics, as illustrated in Figure 1.^{4,5,14}

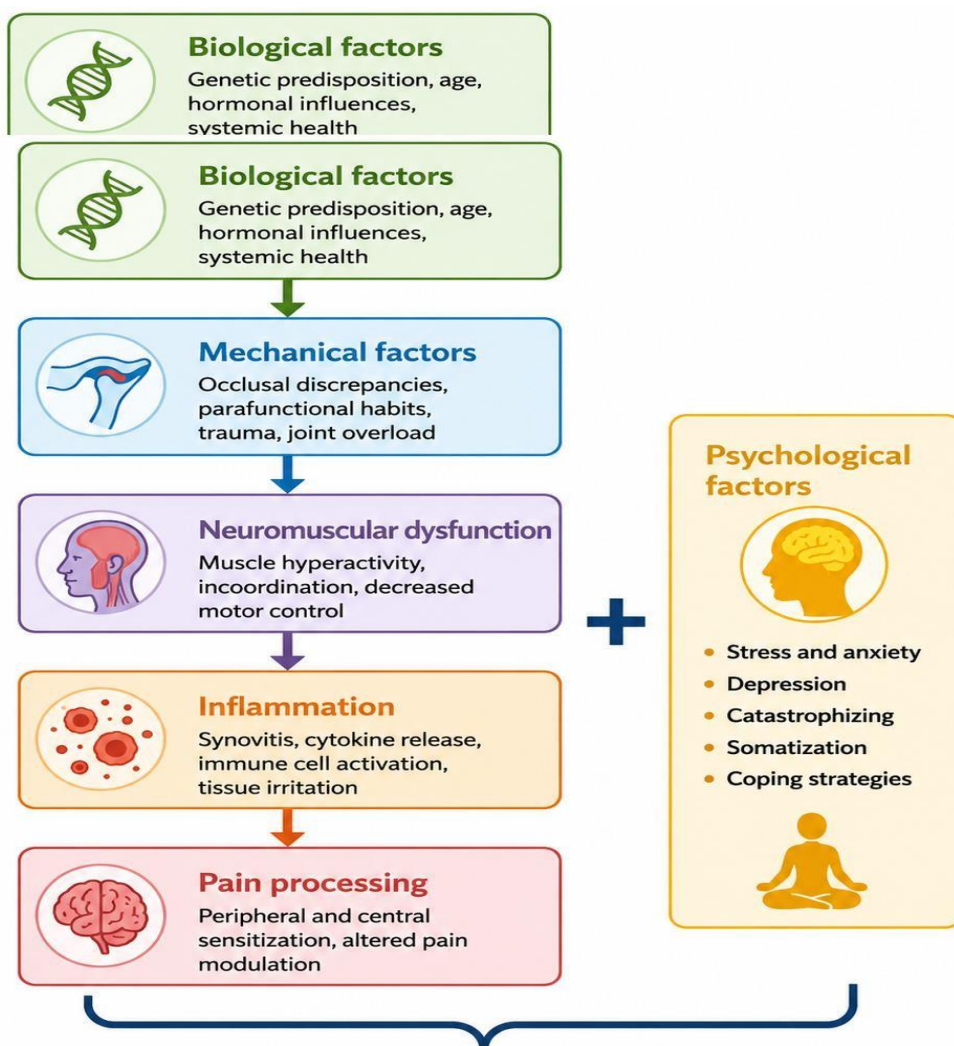


Figure 1. Contemporary Biopsychosocial Model of Temporomandibular Joint Dysfunction

This conceptual framework explains why successful management of temporomandibular disorders requires a multidisciplinary approach that addresses both peripheral joint pathology and central pain modulation.

3.3. Contemporary Diagnostic Approaches in Temporomandibular Joint Dysfunction

The analysis of current evidence demonstrated that accurate diagnosis remains the cornerstone of effective TMJ dysfunction management. Contemporary diagnostic strategies emphasize standardized clinical assessment combined with selective use of imaging modalities according to individual clinical indications.^{1,12,22}

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3.3.1. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)

The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) represent the most widely accepted standardized diagnostic framework for evaluation of temporomandibular conditions. This system provides structured assessment of pain-related disorders and intra-articular abnormalities through patient history, clinical examination, mandibular movement evaluation, and assessment of relevant anatomical structures.^{1,12}

Studies applying DC/TMD demonstrate improved diagnostic reliability compared with previous classification approaches and provide greater consistency in both clinical practice and research investigations.^{12,22}

3.3.2. Magnetic Resonance Imaging and Soft Tissue Assessment

Magnetic resonance imaging (MRI) remains the preferred imaging modality for evaluation of soft tissue components of the temporomandibular joint. The reviewed literature confirms its value in detecting:

- disc displacement;
- joint effusion;
- inflammatory changes;
- early degenerative alterations;
- retrodiscal tissue abnormalities.

However, MRI findings should always be interpreted together with clinical symptoms and functional examination because structural alterations may also be present in asymptomatic individuals.^{13,14}

3.3.3. CBCT and Assessment of Osseous Changes

Cone-beam computed tomography (CBCT) and computed tomography (CT) remain important methods for evaluation of hard tissue alterations associated with TMJ dysfunction. These modalities are particularly useful for identifying:

- condylar remodeling;
- erosive changes;
- osteophyte formation;
- anatomical deformities;
- advanced degenerative alterations.

Current recommendations support imaging selection according to clinical necessity rather than routine application in all patients.^{13,18}

3.3.4. Emerging Digital Diagnostic Technologies

Recent publications demonstrate increasing interest in digital approaches, including mandibular motion tracking, computerized functional analysis, electromyographic assessment, and artificial intelligence-assisted imaging interpretation.

These technologies may provide additional objective information regarding mandibular function and disease

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characterization. However, current evidence remains insufficient to replace validated clinical examination methods and established diagnostic criteria.^{29–33}

The current evidence supporting different diagnostic modalities varies considerably. Established clinical assessment methods and conventional imaging techniques demonstrate stronger validation compared with emerging digital and biological diagnostic approaches. The current evidence level of major diagnostic modalities used in the evaluation of TMJ dysfunction is summarized in **Table 2**.

Table 2. Current Evidence Level of Diagnostic Modalities in Temporomandibular Joint Dysfunction

Diagnostic modality	Main clinical application	Evidence level
DC/TMD clinical criteria	Standardized clinical assessment of temporomandibular joint dysfunction	Strong
MRI	Evaluation of disc position, soft tissue structures, and intra-articular changes	Moderate–Strong
CBCT	Assessment of osseous changes and degenerative joint alterations	Moderate
Ultrasonography	Dynamic assessment and preliminary evaluation of joint structures	Emerging–Moderate
Digital mandibular tracking	Functional movement analysis and quantitative assessment of mandibular dynamics	Emerging
Artificial intelligence models	Automated image analysis, diagnostic prediction, and clinical decision support	Emerging
Biomarkers (saliva/synovial fluid)	Biological characterization and disease monitoring	Experimental

3.4. Conservative and Non-Surgical Management Strategies

The reviewed literature confirms that conservative treatment remains the cornerstone of contemporary management of temporomandibular joint dysfunction. Current international recommendations emphasize reversible, minimally invasive, and patient-centered approaches as the preferred initial therapeutic strategy. The modern treatment concept follows a stepwise model in which conservative interventions are prioritized before consideration of minimally invasive or surgical procedures.^{3,15,16,21}

The evidence-based stepwise management pathway recommended for patients with temporomandibular joint dysfunction is summarized in Figure 2.

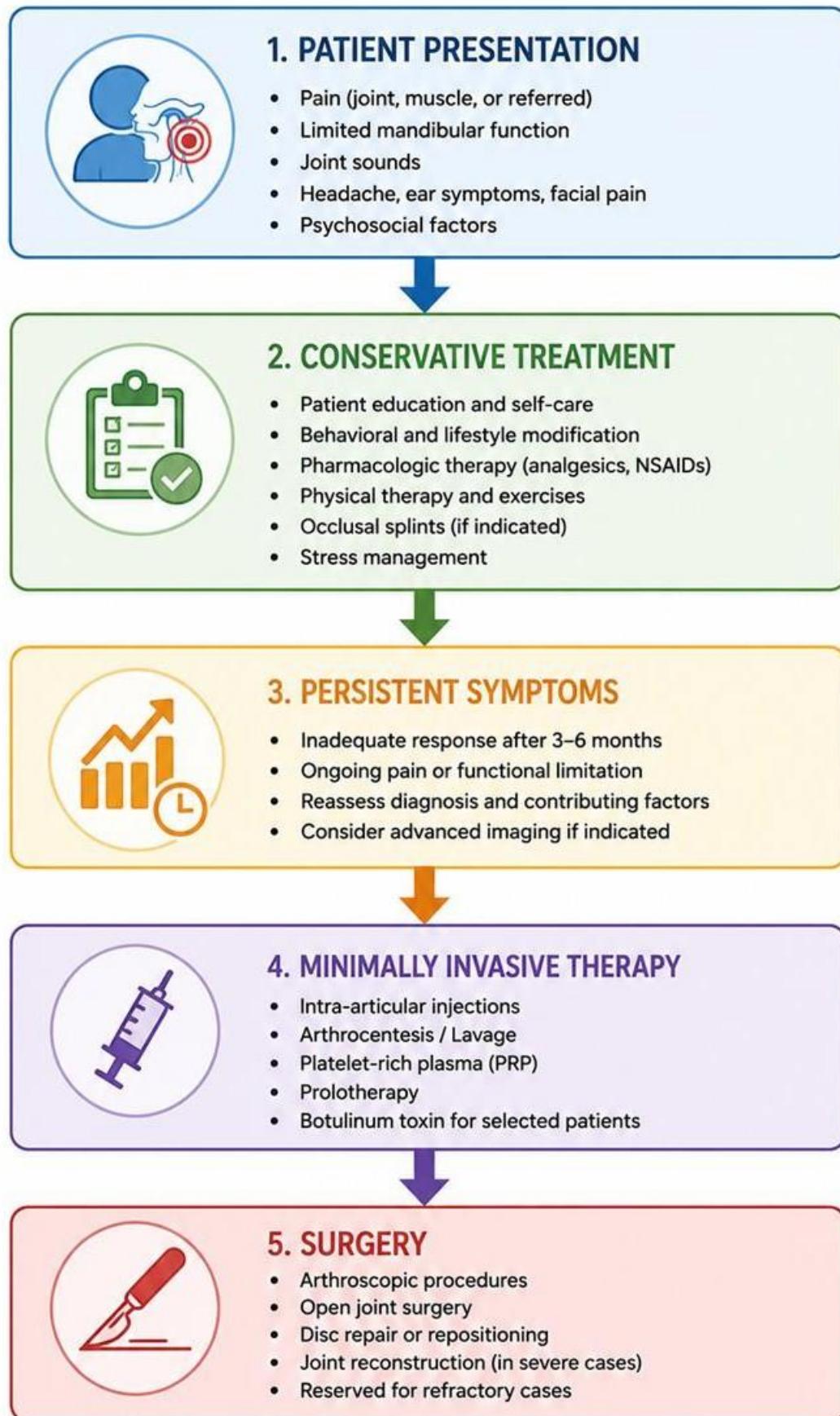


Figure 2. Evidence-Based Management Algorithm for Temporomandibular Joint Dysfunction

This stepwise algorithm reflects current international recommendations that prioritize conservative and reversible interventions before progressing to minimally invasive procedures or surgical treatment in appropriately selected patients.

3.4.1. Patient Education and Self-Management

Patient education represents one of the most consistently supported components of conservative management. Contemporary approaches focus on improving patient understanding of the mechanisms contributing to temporomandibular joint dysfunction, reducing excessive mechanical loading, controlling parafunctional behaviors, modifying dietary habits, and maintaining appropriate mandibular function.

Recent systematic reviews indicate that self-management strategies, including patient education, behavioral modification, home-based exercises, and lifestyle adaptation, may contribute to reduction of pain intensity and improvement of functional outcomes. Active patient participation and adherence to recommended strategies appear to play an important role in long-term symptom control and may enhance the effectiveness of combined therapeutic approaches.^{3,15,16}

3.4.2. Physiotherapy and Functional Rehabilitation

Physiotherapy represents one of the most extensively investigated conservative approaches for temporomandibular joint dysfunction. The reviewed evidence demonstrates beneficial effects of therapeutic exercises, manual therapy, muscle stretching techniques, relaxation protocols, and mandibular movement coordination training.

These interventions may improve mandibular mobility, decrease excessive muscular tension, enhance neuromuscular coordination, and promote functional adaptation of the stomatognathic system.^{15,28,30}

Current evidence supports multimodal rehabilitation programs combining exercise therapy, manual techniques, patient education, and behavioral strategies rather than isolated therapeutic interventions. Recent systematic reviews and clinical studies suggest that combined conservative approaches may provide clinically meaningful improvements in pain reduction and mandibular function, although treatment response depends on individual patient characteristics and the underlying clinical phenotype.^{15,16,28}

3.4.3. Electrostimulation and Novel Physical Therapy Approaches

Recent publications demonstrate increasing interest in electrostimulation techniques as complementary approaches for the management of temporomandibular joint dysfunction. These methods are primarily aimed at modulating pain perception, reducing abnormal masticatory muscle activity, and improving neuromuscular coordination.^{18,19}

Among currently investigated modalities, transcutaneous electrical nerve stimulation (TENS), neuromuscular electrical stimulation, and other low-intensity electrotherapeutic approaches have been evaluated in patients with muscular pain, increased muscle tension, and functional limitation of mandibular movements.^{18,19}

The proposed mechanisms include modulation of peripheral nociceptive input, activation of inhibitory pain pathways, reduction of excessive muscle activity, improvement of local circulation, and restoration of neuromuscular balance. These effects may be particularly relevant in patients with predominant muscular manifestations associated with temporomandibular joint dysfunction.^{18,23}

However, current evidence does not support electrostimulation as an independent first-line treatment. Its greatest clinical value appears to be as an adjunctive component of multimodal rehabilitation programs that include therapeutic exercises, behavioral modification, manual therapy, and other conservative interventions.^{3,18,19}

3.4.4. Patch-Based Transcutaneous Electrostimulation in Temporomandibular Joint Dysfunction

Recent clinical investigations have introduced portable patch-based transcutaneous electrostimulation systems as a potential advancement in conservative management. Unlike conventional electrotherapy devices requiring repeated clinical visits, patch-based systems allow prolonged stimulation through adhesive electrodes placed on the skin

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surface, potentially improving treatment accessibility and patient compliance.^{18,19}

Available clinical evidence suggests that patch-based electrostimulation may contribute to reduction of pain intensity, improvement of mandibular function, and decreased muscular hyperactivity in selected patients with temporomandibular joint dysfunction.^{19,34}

A clinical investigation by Khachatryan A, Hakobyan G, et al. evaluated the effect of transcutaneous electrostimulation in patients with temporomandibular joint dysfunction associated with occlusal disturbances. The authors reported improvements in pain-related symptoms and functional parameters following electrostimulation therapy, suggesting its potential role as an adjunctive conservative treatment modality.¹⁹

Nevertheless, available evidence remains limited by relatively small sample sizes, differences in stimulation protocols, and insufficient long-term follow-up. Therefore, although patch-based electrostimulation represents a promising minimally invasive approach, further randomized controlled studies are required to determine optimal stimulation parameters, treatment duration, and long-term clinical effectiveness.^{18,19,34}

3.4.5. Pharmacological Management

Pharmacological therapy remains an important supportive component in the management of temporomandibular joint dysfunction, particularly for controlling pain, inflammatory manifestations, and muscular discomfort. Current evidence indicates that medication should not be considered as an isolated treatment approach but rather as part of a comprehensive therapeutic strategy combined with patient education, rehabilitation, and behavioral interventions.^{3,18,21}

The choice of pharmacological agents should be individualized according to the clinical characteristics of each patient, including the intensity and duration of pain, presence of inflammatory signs, muscular involvement, and associated chronic pain mechanisms.^{18,21}

3.4.5.1. Non-Steroidal Anti-Inflammatory Drugs and Analgesic Therapy

Non-steroidal anti-inflammatory drugs (NSAIDs) remain among the most commonly used pharmacological agents in patients with temporomandibular joint dysfunction, particularly during episodes of acute pain, inflammatory joint manifestations, and symptom exacerbation.

Clinical studies indicate that NSAIDs may provide short-term reduction of pain intensity and inflammatory symptoms through inhibition of cyclooxygenase-mediated inflammatory pathways and reduction of prostaglandin synthesis. However, their therapeutic effect is primarily symptomatic, and they do not directly modify the underlying mechanisms responsible for temporomandibular joint dysfunction.^{18,21}

Analgesic medications may be considered according to individual pain characteristics and clinical severity. They may provide temporary relief in patients with functional discomfort or acute exacerbations, but their prolonged use should be approached cautiously because of potential adverse effects and limited evidence regarding sustained long-term benefits.^{18,21}

Current recommendations emphasize that pharmacological therapy should be integrated with conservative interventions, including physiotherapy, functional rehabilitation, behavioral modification, and self-management strategies, rather than used as a stand-alone treatment modality.^{3,16}

3.4.5.2. Muscle Relaxants and Central Pain Modulation

Muscle relaxants may be considered in selected patients with temporomandibular joint dysfunction associated with increased masticatory muscle activity, muscle spasm, or significant muscular discomfort. Their potential benefits include temporary reduction of muscle hyperactivity, improvement of muscular relaxation, and decreased pain associated with excessive muscle contraction.^{18,21} However, clinical response may vary considerably among patients, and the use of muscle relaxants requires careful consideration of possible adverse effects, including sedation and functional impairment. Therefore, their application

should be limited to appropriate clinical situations and generally used as a short-term supportive therapy.¹⁸

In patients with chronic pain characteristics, including features of altered pain processing or central sensitization, conventional analgesic approaches may provide insufficient symptom control. Current research has emphasized the importance of therapies targeting central pain modulation mechanisms, particularly in patients whose symptoms persist despite adequate management of peripheral factors.^{4,5,10}

Recognition of central pain mechanisms has contributed to a broader understanding of temporomandibular joint dysfunction as a condition involving interactions between peripheral tissues, neuromuscular regulation, and central nervous system processing. Consequently, management of chronic pain presentations may require multidisciplinary approaches incorporating rehabilitation, behavioral strategies, psychological support, and individualized pharmacological interventions.^{4,8,10}

Overall, current evidence supports the use of pharmacological therapy as an adjunctive component within a multimodal treatment strategy. Optimal outcomes are generally achieved when medication is combined with conservative rehabilitation approaches aimed at improving function, reducing pain sensitivity, and addressing contributing factors.^{3,16,18}

3.5. Occlusal Splints and Orthopedic Management

Occlusal splints remain among the most extensively studied conservative treatment modalities for temporomandibular joint dysfunction. The reviewed evidence indicates that appropriately designed occlusal appliances may reduce excessive loading of the temporomandibular joint and masticatory muscles, improve functional stability, and contribute to symptom reduction in selected patients.^{20,21,27}

The proposed therapeutic mechanisms include redistribution of occlusal forces, reduction of parafunctional muscle activity, improvement of neuromuscular adaptation, and temporary stabilization of mandibular function. However, contemporary evidence emphasizes that occlusal splints should not be considered corrective devices for all forms of temporomandibular joint dysfunction. Their clinical effectiveness depends primarily on accurate diagnosis, appropriate patient selection, and integration into a comprehensive treatment strategy.^{3,20,21}

The role of irreversible occlusal interventions has substantially decreased in modern clinical practice. Current evidence does not support routine occlusal adjustment or extensive prosthodontic alteration solely for the management of temporomandibular joint dysfunction, as the disorder cannot be explained exclusively by occlusal abnormalities.^{20,21}

Orthopedic dental interventions may still be indicated in selected patients with significant tooth wear, occlusal instability, or functional rehabilitation requirements. In such cases, treatment objectives should focus on restoration of the overall masticatory system rather than isolated correction of occlusal relationships.^{20,21}

3.6. Botulinum Toxin Therapy

Botulinum toxin application has become an increasingly investigated therapeutic option, particularly in patients with muscular manifestations of temporomandibular joint dysfunction characterized by increased masticatory muscle activity, bruxism-related symptoms, and chronic myofascial pain.^{24,37}

The therapeutic effect is primarily associated with temporary inhibition of acetylcholine release at the neuromuscular junction, resulting in decreased muscle contraction intensity and reduction of excessive muscular activity.³⁷

Several clinical studies have reported improvement in pain scores and reduction of muscle activity following botulinum toxin injections, particularly in patients with involvement of the masseter and temporalis muscles.^{37,38}

Nevertheless, the current evidence remains heterogeneous. Differences in injection techniques, dosage protocols, outcome assessment methods, and patient selection criteria limit direct comparison among published studies.

Therefore, botulinum toxin should currently be considered a selective therapeutic option rather than a routine first-line treatment modality.^{37,38}

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Further high-quality randomized clinical trials are required to determine optimal indications, standardized injection protocols, long-term effectiveness, and safety profiles.^{37,38}

3.7. Biological Intra-Articular Therapies

Recent literature demonstrates increasing interest in biological approaches for temporomandibular joint dysfunction, particularly intra-articular administration of hyaluronic acid and platelet-rich plasma (PRP). These therapies aim to influence inflammatory processes, improve joint environment, and potentially enhance tissue repair mechanisms.^{41,45}

3.7.1. Hyaluronic Acid Injections

Hyaluronic acid therapy is based on restoration of synovial fluid characteristics, improvement of joint lubrication, reduction of friction, and modulation of inflammatory activity within the intra-articular environment.⁴¹ Clinical studies have demonstrated beneficial effects on pain reduction and improvement of mandibular function, particularly in patients with degenerative joint changes and inflammatory manifestations.^{41,42}

However, differences in molecular characteristics, injection protocols, treatment schedules, and patient selection criteria contribute to variability among reported outcomes. Further studies are required to establish standardized clinical protocols and define long-term effectiveness.^{41,42}

3.7.2. Platelet-Rich Plasma Therapy

Platelet-rich plasma therapy has attracted considerable attention due to its potential regenerative properties associated with growth factors and biologically active mediators contained within platelet concentrates.^{44,45}

The proposed mechanisms include modulation of inflammatory responses, stimulation of tissue repair pathways, improvement of joint homeostasis, and potential enhancement of regenerative processes within damaged tissues.^{44,45} Although several clinical studies have reported favorable short-term outcomes regarding pain reduction and functional improvement, substantial variability remains regarding PRP preparation methods, platelet concentration, activation protocols, injection techniques, and evaluation criteria.^{26,45} Current evidence supports PRP as a promising adjunctive biological approach; however, its definitive clinical role requires confirmation through larger controlled clinical studies with standardized protocols and longer follow-up periods.^{26,45}

3.8. Minimally Invasive and Surgical Management

The reviewed evidence confirms that minimally invasive procedures are generally reserved for patients who demonstrate insufficient improvement following appropriate conservative management or those presenting with significant intra-articular pathology. The current therapeutic philosophy emphasizes preservation of joint function and avoidance of unnecessary invasive procedures whenever possible.^{25,34,47}

3.8.1. Arthrocentesis

Arthrocentesis represents one of the most frequently applied minimally invasive procedures for selected cases of temporomandibular joint dysfunction associated with internal derangement and persistent intra-articular symptoms. The procedure involves lavage of the upper joint compartment, removal of inflammatory mediators, reduction of intra-articular adhesions, and improvement of joint mobility.^{25,34} Clinical studies demonstrate favorable outcomes in appropriately selected patients, including reduction of pain intensity, improvement of maximum mouth opening, and enhancement of mandibular function.^{25,34,48}

Although arthrocentesis is considered a relatively safe minimally invasive intervention, treatment success depends on appropriate patient selection, accurate diagnosis, and the stage of intra-articular pathology.^{34,47}

3.8.2. Arthroscopy

Temporomandibular joint arthroscopy provides both diagnostic and therapeutic advantages by allowing direct visualization of intra-articular structures and minimally invasive management of selected pathological conditions.^{49,50}

The reviewed literature indicates that arthroscopy may be beneficial in patients with persistent intra-articular symptoms, disc displacement, adhesions, and limited response to conservative treatment.^{49,50}

Compared with open surgical procedures, arthroscopy is associated with reduced surgical trauma and shorter recovery periods; however, its application requires specialized equipment, technical expertise, and appropriate clinical indications.⁴⁹

3.8.3. Open Surgical Procedures and Joint Reconstruction

Open surgical intervention remains reserved for advanced structural abnormalities, severe degenerative changes, ankylosis, trauma-related deformities, and cases in which conservative and minimally invasive approaches fail to provide adequate improvement.^{27,51}

Modern reconstructive strategies increasingly incorporate virtual surgical planning, digital technologies, and patient-specific temporomandibular joint prosthetic systems. These approaches allow individualized reconstruction and may improve anatomical restoration and functional outcomes in selected patients with severe joint pathology.^{27,28,39} A comparative overview of the principal therapeutic approaches, including their main clinical indications, advantages, and current limitations, is presented in Table 3.

Table 3. Advantages and Limitations of Contemporary Therapeutic Approaches for Temporomandibular Joint Dysfunction

Therapeutic approach	Main indications	Principal advantages	Current limitations
Patient education and self-management	Initial management of most patients	Non-invasive, improves patient participation and symptom control	Requires patient motivation and long-term adherence
Physiotherapy and functional rehabilitation	Muscular dysfunction, limited mandibular mobility, functional impairment	Improves mandibular function, reduces pain, supports neuromuscular adaptation	Treatment protocols vary
Electrostimulation therapies	Muscular pain	Non-invasive adjunctive pain modulation	Limited long-term evidence
Pharmacological therapy	Acute pain	Short-term symptom relief	Potential adverse effects
Occlusal splints	Parafunctional activity	Reversible option	Depends on diagnosis
Botulinum toxin injections	Persistent muscular hyperactivity	Reduces muscle activity	Uncertain long-term outcomes
Hyaluronic acid injections	Degenerative changes	Improves lubrication	Variable duration
Platelet-rich plasma therapy	Degenerative conditions	Potential regenerative effects	No standardized protocols
Arthrocentesis	Internal derangement	Minimally invasive	Case selection required
TMJ arthroscopy	Persistent pathology	Diagnostic and therapeutic	Requires expertise
Open surgery and reconstruction	Severe pathology	Definitive treatment	Higher morbidity

Abbreviations: TMJ, temporomandibular joint; PRP, platelet-rich plasma.

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3.9. Overall Summary of Results

The synthesis of the available evidence demonstrates that temporomandibular joint dysfunction represents a complex clinical condition requiring an individualized, stepwise, and multidisciplinary management approach. The reviewed literature confirms that conservative and reversible interventions remain the foundation of treatment, while minimally invasive and surgical procedures should be reserved for carefully selected patients with persistent symptoms, significant intra-articular pathology, or advanced structural abnormalities.^{3,15,34,27}

Current therapeutic concepts emphasize restoration of mandibular function, reduction of pain, improvement of quality of life, and prevention of chronic symptom progression rather than correction of isolated anatomical changes. This approach reflects the contemporary understanding that structural findings observed on imaging do not always correlate directly with clinical symptoms and that treatment decisions should be based on comprehensive evaluation of functional status, pain characteristics, and individual patient factors.^{1,12,14,16}

The evidence reviewed in this study demonstrates that conservative approaches, including patient education, self-management strategies, physiotherapy, therapeutic exercises, pharmacological support, and occlusal splint therapy, provide the basis for initial management in the majority of patients. These approaches aim to improve functional adaptation, reduce muscular overload, and modulate pain mechanisms while minimizing unnecessary invasive interventions.^{3,15,16,18}

For patients who demonstrate insufficient improvement after appropriate conservative therapy, minimally invasive procedures such as arthrocentesis, arthroscopy, and intra-articular biological therapies may provide additional therapeutic benefits. However, the clinical effectiveness of these interventions depends on accurate diagnosis, appropriate patient selection, and standardized treatment protocols.^{25,34,41,44}

3.10. Emerging Technologies and Future Perspectives

Recent advances in digital technologies, regenerative medicine, and personalized healthcare are expected to influence future approaches to diagnosis and management of temporomandibular joint dysfunction. Emerging concepts aim to improve diagnostic precision, characterize individual disease patterns, and optimize treatment selection according to specific patient characteristics.²⁹⁻³³

Artificial intelligence and machine learning-based models are increasingly investigated for automated image interpretation, prediction of disease progression, and clinical decision support. Although preliminary findings demonstrate promising diagnostic potential, current applications remain limited by the need for large validated datasets and prospective clinical evaluation.^{29,30,32,33}

Digital mandibular tracking systems and computerized functional assessment technologies may provide objective quantitative information regarding mandibular movement patterns, functional limitations, and treatment outcomes. These technologies may contribute to more accurate functional assessment and personalized rehabilitation planning.^{30,32}

Biological approaches, including platelet-rich plasma, regenerative therapies, and biomarker-based disease characterization, represent another important area of future development. These strategies aim to improve understanding of joint biology and potentially promote tissue repair; however, their routine clinical implementation requires further validation through standardized clinical trials.^{26,31,40,44}

Patient-specific implants and computer-assisted surgical planning have already demonstrated clinical value in complex temporomandibular joint reconstruction. The integration of virtual planning, three-dimensional technologies, and individualized prosthetic design may further improve functional restoration in patients with severe structural abnormalities.^{27,28}

The main emerging technologies and future directions expected to influence personalized management of temporomandibular joint dysfunction are summarized in Table 4.

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Table 4. Future Directions in Personalized Management of TMD

Emerging technology	Expected clinical application	Current evidence
Artificial intelligence	Automated diagnosis and prediction	Emerging
Machine learning models	Personalized treatment planning	Emerging
Digital mandibular tracking	Functional assessment	Moderate
Biomarkers	Disease monitoring	Experimental
PRP and regenerative medicine	Joint repair	Moderate
Patient-specific implants	Individualized reconstruction	High
Precision medicine	Personalized treatment	Future direction

Although these emerging approaches demonstrate considerable potential, further high-quality prospective studies, standardized diagnostic criteria, and validated clinical protocols are required before their widespread integration into routine management of temporomandibular joint dysfunction.

Overall, current evidence supports a personalized treatment paradigm in which diagnosis, therapeutic selection, and long-term follow-up are adapted to the specific clinical characteristics, functional status, and needs of each patient.
3,16,29–33

DISCUSSION

The present narrative review demonstrates that the contemporary concept of temporomandibular joint dysfunction (TMJ dysfunction) has progressively moved beyond the traditional mechanical interpretation of joint pathology toward a broader functional and patient-centered model. The findings of this review indicate that the clinical expression of TMJ dysfunction cannot be explained exclusively by structural alterations of the temporomandibular joint but reflects the interaction of anatomical, neuromuscular, inflammatory, and psychosocial factors. This interpretation is consistent with current international literature, which emphasizes that pain perception, functional limitation, and treatment response are determined not only by tissue changes but also by individual biological adaptation and central pain-processing mechanisms.
1,4,5,16

The present analysis supports the current shift toward a biopsychosocial understanding of TMJ dysfunction. Previous concepts that attributed disease development mainly to occlusal abnormalities or excessive mechanical loading have gradually been replaced by a multifactorial model. Our findings indicate that mechanical stress, muscular dysfunction, inflammatory processes, parafunctional activity, and psychosocial influences should be considered interacting contributors rather than isolated causes. This approach corresponds with recent evidence demonstrating that no single etiological factor is sufficient to explain the development and persistence of symptoms in patients with TMJ dysfunction.
4,5,21,24

An important observation from the reviewed literature is the increasing importance of standardized diagnostic approaches. The current evidence confirms that clinical examination remains the primary component of diagnosis, while imaging methods should provide additional information in selected cases. The findings of this review are in agreement with previous studies demonstrating that the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) improve diagnostic consistency and allow more reliable classification of clinical conditions. At the same time, the interpretation of MRI and CBCT findings requires caution because structural changes may be present in individuals without significant symptoms. Therefore, our analysis supports an integrated diagnostic strategy combining patient history, clinical examination, functional assessment, and selectively applied imaging techniques rather than imaging-based diagnosis alone.
1,12,13,14

The treatment concepts identified in this review reflect a substantial change in clinical practice. The current evidence supports a stepwise therapeutic approach in which reversible and conservative interventions are considered the preferred initial strategy. Our analysis confirms that patient education, self-management, physiotherapy, and behavioral modification remain the foundation of treatment because they address functional adaptation, muscle activity, pain-related behavior, and patient participation. These findings correspond with recent systematic reviews and clinical

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recommendations indicating that conservative management provides clinically meaningful improvement in many patients while avoiding unnecessary invasive procedures.^{3,15,16,18}

The role of physiotherapy requires particular consideration because it represents one of the most consistently supported conservative interventions. The reviewed evidence suggests that therapeutic exercises, manual therapy, and neuromuscular rehabilitation may improve mandibular function and reduce pain, especially in patients with predominant muscular involvement. However, our analysis also identified considerable variability among rehabilitation protocols, including differences in exercise type, duration, and outcome assessment. This limitation is consistent with previous publications and highlights the need for standardized rehabilitation protocols adapted to specific clinical phenotypes of TMJ dysfunction.^{15,30,35,36}

The evaluation of electrostimulation approaches represents one of the emerging aspects identified in this review. Available evidence suggests that transcutaneous stimulation techniques may provide additional benefits through modulation of pain pathways and regulation of muscular activity. The findings from clinical investigations, including studies evaluating patch-based transcutaneous electrostimulation, indicate potential improvement in pain and functional parameters. However, compared with established conservative therapies, the current evidence remains limited by small patient cohorts, heterogeneous protocols, and insufficient long-term evaluation. Therefore, based on the available data, electrostimulation should be considered an adjunctive rehabilitation modality rather than a replacement for conventional treatment strategies.^{18,19,31,32} The present review also demonstrates that pharmacological therapy should be interpreted as a supportive component rather than a definitive treatment approach. Although NSAIDs, analgesics, and muscle relaxants remain useful for short-term symptom control, current understanding of chronic TMJ dysfunction-related pain indicates that peripheral inflammation represents only one component of a more complex pain mechanism. The involvement of central sensitization and altered pain modulation explains why pharmacological treatment alone often provides insufficient long-term improvement. These observations support a multidisciplinary approach combining medication with rehabilitation and behavioral strategies.^{4,8,18}

The changing role of occlusal therapy represents another important aspect of modern TMJ dysfunction management. Our findings confirm that contemporary evidence no longer supports irreversible occlusal procedures as routine treatment. Although occlusal splints may provide symptomatic improvement in selected patients, their effectiveness depends on accurate diagnosis and appropriate indication. This perspective is consistent with current literature demonstrating that occlusion should be considered one component of functional adaptation rather than the primary cause of disease.^{20,21,27} Biological therapies, including platelet-rich plasma and hyaluronic acid injections, represent promising but still developing treatment options. The findings of this review indicate that these approaches may provide clinical benefits, particularly in patients with degenerative or inflammatory joint changes. However, comparison between studies remains difficult because of differences in preparation methods, injection protocols, and outcome measurements. Therefore, although regenerative approaches represent an important future direction, their routine clinical application requires further validation through well-designed controlled studies.^{26,41,44} The current evidence also supports the selective use of minimally invasive procedures in patients who do not achieve sufficient improvement with conservative management. Arthrocentesis and arthroscopy have demonstrated clinical value in appropriately selected patients with persistent intra-articular pathology. Nevertheless, the reviewed literature indicates that these procedures should be integrated into a stepwise treatment concept rather than considered early interventions. Open surgery and temporomandibular joint reconstruction remain necessary for severe structural abnormalities, advanced degeneration, ankylosis, and complex conditions where less invasive approaches are inadequate.^{25,27,34,28}

A major implication of this review is that future management of TMJ dysfunction will increasingly depend on personalized approaches. Emerging technologies, including artificial intelligence, digital functional analysis, biological markers, and patient-specific reconstruction methods, may improve diagnostic precision and allow better prediction of treatment outcomes. However, most emerging approaches remain at an early stage of clinical validation, and their integration into routine practice requires confirmation through prospective studies with standardized methodologies.²⁹⁻³³ The main contribution of this narrative review is the integration of current evidence across diagnostic, conservative, minimally invasive, and surgical domains into a clinically oriented framework. The reviewed literature demonstrates that successful management of TMJ dysfunction depends not on a single therapeutic intervention but on individualized decision-making based on disease characteristics, symptom severity, functional impairment, and patient-specific factors. The proposed stepwise treatment algorithm (Table 5) reflects this evidence-based approach by prioritizing conservative and reversible therapies while reserving invasive procedures for carefully selected cases. Despite significant progress in understanding TMJ dysfunction, several challenges remain, including variability in diagnostic criteria, differences in treatment protocols, and limited long-term evidence for several emerging therapies. Future research should focus on

standardized clinical phenotyping, personalized treatment algorithms, and integration of digital and biological technologies into multidisciplinary care pathways. Overall, current evidence supports a patient-centered and individualized model in which the primary objectives are pain control, restoration of function, prevention of chronic disability, and improvement of quality of life.^{3,16,29–33}

Based on the available evidence discussed in this review, the management of temporomandibular joint dysfunction should follow a stepwise and individualized approach. Conservative and reversible therapies should represent the initial treatment strategy in most patients, whereas minimally invasive and surgical procedures should be reserved for cases with persistent symptoms, functional impairment, or structural joint pathology that does not respond adequately to non-invasive management. An evidence-based treatment algorithm summarizing the recommended therapeutic sequence is presented in Table 5.

Table 5. Evidence-Based Stepwise Management Algorithm for Temporomandibular Joint Dysfunction

Clinical presentation	First-line	Second-line	Advanced
Mild muscular TMD	Education, self-management	Physiotherapy	—
Myofascial pain	Physiotherapy	Medication, electrostimulation	Botulinum toxin
Bruxism	Behavioral modification	Physiotherapy	Botulinum toxin
Disc displacement with reduction	Conservative care	Splint	Arthrocentesis
Disc displacement without reduction	Physiotherapy	Arthrocentesis	Arthroscopy
Degenerative TMJ disease	Conservative	HA/PRP	Arthroscopy/open surgery
Ankylosis	—	—	Open surgery/TMJ reconstruction

Abbreviations: TMJ, temporomandibular joint; PRP, platelet-rich plasma; NSAIDs, non-steroidal anti-inflammatory drugs.

The proposed algorithm is intended to assist clinicians in selecting treatment strategies according to disease severity, clinical presentation, and individual patient characteristics. Although treatment decisions should always remain individualized, current evidence consistently supports conservative and minimally invasive approaches as initial management strategies, while surgical procedures should be reserved for carefully selected patients with advanced structural pathology or failure of less invasive therapies.

Limitations of the Review

Although this narrative review provides an updated overview of contemporary concepts in the etiology, diagnosis, and evidence-based management of temporomandibular joint dysfunction, several limitations should be considered. As a narrative review, this study was not designed to perform quantitative synthesis or meta-analysis; therefore, treatment effects were not statistically pooled. The aim was to integrate and critically interpret available evidence from clinical studies, systematic reviews, guidelines, and expert recommendations. A major limitation of the current literature is the considerable heterogeneity among studies regarding diagnostic criteria, patient populations, treatment protocols, and outcome assessment methods. Although standardized

systems such as the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) have improved diagnostic consistency, differences between investigations continue to limit direct comparison of findings.^{1,12,22}

In addition, several emerging therapeutic approaches, including electrostimulation, biological therapies, and botulinum toxin applications, are supported by studies with limited sample sizes, heterogeneous protocols, and relatively short follow-up periods. Therefore, their long-term effectiveness requires further confirmation through well-designed clinical trials.^{31–34,37–40,41–45}

The multifactorial nature of TMD represents another important challenge, as treatment outcomes are influenced by biological characteristics, pain perception,

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psychological factors, functional adaptation, and patient adherence. These variables contribute to differences in therapeutic response and complicate the development of universal treatment protocols.^{4,5,9,24} Despite these limitations, the present review summarizes current evidence supporting a transition toward individualized, multidisciplinary, and evidence-based management of temporomandibular joint dysfunction.

Future Perspectives and Emerging Trends

Future management of temporomandibular joint dysfunction is expected to increasingly incorporate personalized medicine, digital technologies, and regenerative approaches. Advances in artificial intelligence and machine learning may improve diagnostic accuracy through automated image analysis, disease pattern recognition, and prediction of treatment response.^{29–33,45} Digital functional assessment technologies, including mandibular motion tracking, computerized analysis of functional parameters, and advanced imaging-based evaluation, may provide additional information for individualized treatment planning. However, their routine clinical application requires further validation.^{30–33} Regenerative strategies, including platelet-rich plasma, hyaluronic acid, and other biological approaches, represent promising options, particularly for degenerative joint conditions. Nevertheless, differences in preparation protocols, injection techniques, and treatment methods currently limit definitive conclusions regarding their clinical superiority.^{41–45} Minimally invasive technologies, improved arthroscopic techniques, image-guided interventions, and portable electrostimulation systems may further expand conservative and minimally invasive treatment options. Future research should focus on standardized protocols, long-term outcomes, and identification of biomarkers capable of predicting disease progression and treatment response.^{17,31–34,46–}

⁵⁰ The future direction of TMD management is likely to move toward precision-based approaches integrating clinical findings, imaging characteristics, functional parameters, psychosocial factors, and biological information to develop individualized therapeutic pathways.^{5,18,31,41–45}

CONCLUSION

Temporomandibular joint dysfunction represents a complex multifactorial condition requiring a multidisciplinary and individualized approach. Current evidence supports conservative and reversible interventions, including patient education, self-management, physiotherapy, therapeutic exercises, behavioral modification, pharmacological support,

and appropriately selected occlusal appliances, as the preferred initial treatment strategies. Minimally invasive procedures, biological therapies, and surgical interventions should be reserved for carefully selected patients with persistent symptoms, intra-articular pathology, or advanced structural abnormalities. Emerging technologies, including artificial intelligence, digital diagnostics, regenerative medicine, and personalized treatment approaches, may further improve future management; however, their clinical implementation requires confirmation through high-quality prospective studies. Overall, contemporary TMD management should focus on reducing pain, restoring mandibular function, preventing chronic disability, and improving quality of life through evidence-based and patient-centered care.

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Ethical Approval

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Competing Interests

The authors declare no conflict of interest.

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