TEMPOROMANDIBULAR DISORDERS: AN UPDATED REVIEW OF ETIOPATHOGENESIS, DIAGNOSTIC STRATEGIES, AND MULTIDISCIPLINARY MANAGEMENT

Kamel Earar[1], Sonia-Teodora Statescu-Manaila[1], Genoveva-Cristina Albert[2], Alina-Ramona Dimofte[1]*, Petru Trifautanu[1], Mariana Ilie[1], Magdalena Rusu-Negraia[1]*, Edmond Paul Gheban[3], Georgia-Katerina Condurache[3], Cicerone Catalin Grigorescu[4]

1. Faculty of Medicine and Pharmacy, University "Dunarea de Jos" Galati, Romania
2. Dental Medicine, Apollonia University of Iași, Romania
3. "Grigore T. Popa" University of Medicine and Pharmacy,Faculty of Medecine, Iasi, Romania
4. Vasile Goldiș Western University of Arad, Romania

*Corresponding authors: alina.dimofte@ugal.ro, magdalenarusu@gmail.com

Abstract

Temporomandibular disorders (TMD) represent a heterogeneous group of conditions affecting the temporomandibular joint, masticatory muscles, and associated craniofacial structures. These disorders are among the most common causes of orofacial pain and functional impairment, significantly influencing patients' quality of life. The etiology of TMD is multifactorial, involving complex interactions between biomechanical stress, neuromuscular dysfunction, psychosocial factors, and degenerative changes within the temporomandibular joint. Advances in diagnostic criteria, particularly the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), have improved the standardization of clinical evaluation and facilitated more reliable classification of these conditions. Imaging techniques such as magnetic resonance imaging and cone beam computed tomography play a crucial role in the assessment of soft tissue and osseous structures of the temporomandibular joint, contributing to accurate diagnosis. Management of TMD is primarily based on conservative and multidisciplinary approaches, including occlusal splint therapy, physiotherapy, behavioral modification, and pharmacological treatment. Minimally invasive procedures such as arthrocentesis may be indicated in selected cases of intra-articular pathology. Understanding the complex pathophysiology and adopting a comprehensive diagnostic and therapeutic approach are essential for improving clinical outcomes in patients affected by temporomandibular disorders.

Keywords: anatomy, temporomandibular disorders, temporomandibular joint, occlusal splints, arthrocentesis, diagnosis, multidisciplinary management

1. Introduction and Epidemiology of Temporomandibular Disorders

Temporomandibular disorders (TMDs) represent a heterogeneous group of musculoskeletal and neuromuscular conditions affecting the temporomandibular joint (TMJ), the masticatory muscles, and associated craniofacial structures. These disorders are among the most common causes of non-dental pain in the orofacial region and constitute an important clinical concern in dental and maxillofacial practice due to their multifactorial etiology, complex symptomatology, and significant impact on functional capacity and quality of life. Clinically, TMDs may manifest through a combination of pain, joint sounds, and functional limitations such as reduced mandibular mobility or deviation during mouth opening. Understanding the epidemiological characteristics and biological mechanisms underlying these disorders is essential for establishing accurate diagnostic pathways and implementing effective therapeutic strategies [1].

In Figure 1, a comparative anatomical illustration of the temporomandibular joint (TMJ).
The left panel shows the normal anatomical relationship between the mandibular condyle, the articular disc, and the temporal bone structures, including the zygomatic

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arch. In the physiological state, the articular disc is positioned between the condyle and the articular surface, allowing smooth mandibular movements. The right panel illustrates a common pathological condition associated with temporomandibular disorders, characterized by anterior displacement and deformation of the articular disc, which may alter joint biomechanics and contribute to pain, joint sounds, and functional limitation.

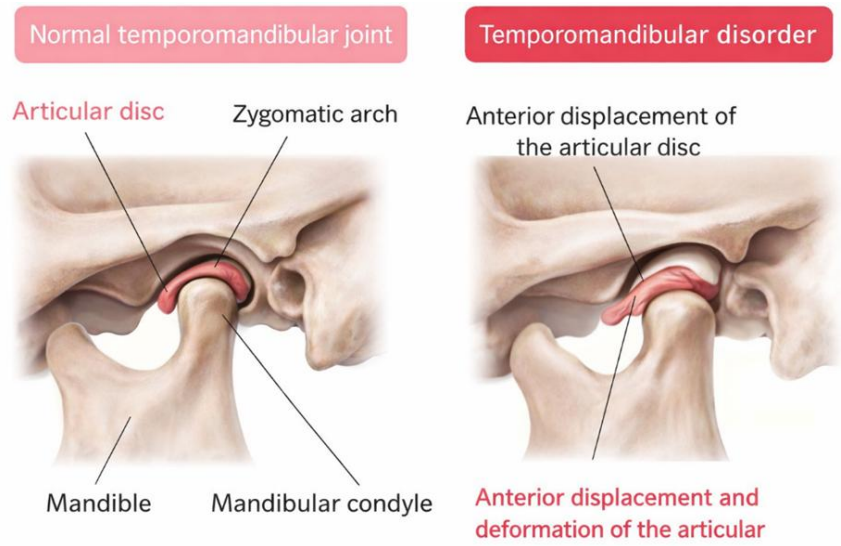

Figure 1. Comparative anatomical representation of the normal temporomandibular joint and anterior disc displacement in temporomandibular disorder (TMD).

Current evidence indicates that the pathogenesis of TMDs is multifactorial, involving a complex interaction between biological, mechanical, behavioral, and psychosocial factors. Psychological variables, including stress, anxiety, and somatization, have been demonstrated to play a significant role in the onset and persistence of temporomandibular pain. Large prospective cohort studies have shown that individuals presenting increased psychological vulnerability may exhibit a higher risk of developing TMD symptoms, suggesting that central pain modulation mechanisms contribute substantially to the disorder's clinical expression. These findings support the contemporary biopsychosocial model of TMD, which integrates structural joint alterations with neuromuscular and psychological components [1].

The need for standardized diagnostic approaches has led to the development of internationally accepted classification systems. One of the most widely used frameworks is the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), which expands earlier diagnostic taxonomies and integrates both physical diagnoses and psychosocial assessment. This classification system divides TMDs into several diagnostic groups, including myofascial pain disorders, disc displacement conditions, and degenerative joint diseases. By combining clinical examination protocols with validated psychosocial screening instruments, the DC/TMD framework improves diagnostic reliability and facilitates consistent reporting in both clinical and research settings [2].

Advances in imaging technologies have further enhanced the diagnostic evaluation of the temporomandibular joint. Modern imaging modalities allow clinicians to visualize both osseous and soft tissue structures of the TMJ, enabling more precise identification of pathological

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changes. Magnetic resonance imaging (MRI) is widely regarded as the gold standard for evaluating disc position, joint effusion, and inflammatory alterations within the joint capsule. In contrast, cone beam computed tomography (CBCT) provides high-resolution visualization of osseous components, allowing detection of cortical erosion, osteophyte formation, and condylar remodeling associated with degenerative joint disease. Recent systematic investigations have also highlighted the potential of combining MRI and CBCT through image registration techniques, which can improve the spatial correlation between hard and soft tissue structures within the joint complex [3-5].

The integration of advanced imaging methods has contributed significantly to a more comprehensive understanding of temporomandibular joint pathology. CBCT in particular has become an important diagnostic tool in dental and maxillofacial radiology because of its high spatial resolution and relatively low radiation exposure compared with conventional computed tomography. This imaging modality allows accurate evaluation of morphological alterations of the mandibular condyle and articular eminence, which are frequently associated with osteoarthritic changes in TMD patients. Radiological findings obtained through CBCT may therefore provide valuable information regarding the structural severity and progression of temporomandibular joint disorders [6].

Beyond conventional imaging methods, additional diagnostic tools have been explored to evaluate specific aspects of TMJ dysfunction. Ultrasonography has emerged as a non-invasive technique capable of detecting disc displacement and joint effusion in certain clinical scenarios. Although its diagnostic sensitivity is generally lower than that of MRI, ultrasonography offers advantages such as accessibility, reduced cost, and the possibility of dynamic evaluation during mandibular movements. Systematic reviews and clinical studies suggest that, when performed by experienced clinicians, ultrasonography may represent a useful adjunctive diagnostic method for assessing temporomandibular joint disc position and structural integrity [8,9].

Nuclear medicine techniques have also been investigated for evaluating metabolic activity within the temporomandibular joint. Bone scintigraphy and single-photon emission computed tomography (SPECT) provide functional information regarding bone turnover and inflammatory activity, which may assist in the identification of active degenerative processes. These imaging modalities have demonstrated potential utility in detecting osteoarthritic changes and evaluating condylar growth activity in patients presenting mandibular asymmetry or painful temporomandibular joint conditions. Quantitative analysis of scintigraphic uptake may therefore contribute to improving diagnostic accuracy in selected clinical contexts [10–13].

Although diagnostic technologies continue to evolve, the clinical management of TMD remains strongly influenced by early and accurate identification of pathological changes within the temporomandibular joint. Therapeutic interventions often depend on the severity and nature of the underlying disorder, ranging from conservative approaches to minimally invasive procedures. Among these, arthrocentesis has gained increasing attention as a therapeutic option for internal derangements of the TMJ. Clinical studies have demonstrated that joint lavage procedures can improve mandibular mobility and reduce pain by eliminating inflammatory mediators and restoring normal intra-articular dynamics. In some cases, the procedure may be combined with intra-articular injections such as sodium hyaluronate in order to enhance lubrication and promote joint function recovery [4,14].

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2. Etiopathogenesis of TMD

The etiopathogenesis of temporomandibular disorders (TMD) is complex and multifactorial, involving the interaction of biomechanical, neuromuscular, inflammatory, and behavioral factors that contribute to functional impairment of the temporomandibular joint (TMJ) and the masticatory system. Contemporary research emphasizes that TMD should not be interpreted as a single pathological entity but rather as a spectrum of disorders affecting both muscular and intra-articular components of the stomatognathic system. These pathological processes may develop gradually as a result of cumulative microtrauma, altered occlusal dynamics, and dysregulation of neuromuscular control mechanisms [15].

One of the most frequently discussed mechanisms in the development of TMD is the imbalance between functional loading and the adaptive capacity of the temporomandibular joint structures. Excessive or abnormal mechanical forces generated during mastication or parafunctional habits such as bruxism may lead to progressive degeneration of articular cartilage and remodeling of the mandibular condyle. Occlusal instability and altered mandibular biomechanics can further exacerbate joint stress, promoting inflammatory responses within the synovial membrane and surrounding connective tissues. These processes may ultimately contribute to the onset of painful dysfunction and restricted mandibular mobility [15].

Occlusal factors have long been considered a potential contributor to TMD development, particularly in relation to abnormal mandibular positioning and uneven distribution of occlusal forces. Occlusal splint therapy is often employed to reduce excessive joint loading and stabilize mandibular movements. Clinical studies and systematic reviews suggest that occlusal appliances may alleviate symptoms by promoting neuromuscular relaxation, decreasing parafunctional activity, and redistributing occlusal contacts. Although the precise mechanism of action remains debated, evidence indicates that splint therapy may contribute to symptom relief in patients presenting with myogenous or mixed TMD conditions [16,17].

In recent years, meta-analytical investigations have provided further insights into the therapeutic and etiological relevance of occlusal stabilization devices. Network meta-analyses of randomized clinical trials have demonstrated that occlusal splints may produce measurable improvements in pain intensity and mandibular function in patients with temporomandibular disorders. However, some authors have highlighted that the observed therapeutic benefits may also be partially influenced by placebo effects or behavioral modifications induced by treatment adherence. This suggests that the etiopathogenesis of TMD involves not only structural alterations but also neuromodulatory and psychosocial mechanisms that influence pain perception and functional outcomes [18,19].

Beyond mechanical and occlusal factors, demographic and clinical variables have also been associated with the development and progression of temporomandibular disorders. Observational studies have identified correlations between TMD prevalence and certain sociodemographic characteristics, including age, sex, and lifestyle factors. For instance, women are generally reported to exhibit higher rates of temporomandibular dysfunction, a phenomenon that has been partially attributed to hormonal influences and differences in pain sensitivity. Additionally, lifestyle-related factors such as stress exposure, sleep disturbances, and occupational strain may contribute to the exacerbation of TMD symptoms by promoting sustained muscular tension and altered mandibular function [20].

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The multifactorial nature of TMD is further illustrated by the wide range of therapeutic approaches evaluated in clinical research. Conservative treatment modalities, including occlusal appliances, pharmacological management, and behavioral interventions, are frequently employed as first-line therapies. Comparative clinical investigations have explored differences between soft and hard occlusal splints, demonstrating that both types of appliances may provide symptomatic improvement in selected patient populations. These findings suggest that therapeutic success is often dependent on individualized treatment planning and the specific pathophysiological mechanisms underlying each patient's condition [21].

Additional clinical studies have examined the short-term effectiveness of conservative therapeutic strategies on pain intensity, sleep quality, and overall quality of life in individuals with temporomandibular disorders. Randomized clinical trials indicate that conservative interventions may significantly reduce pain levels and improve functional outcomes, particularly when combined with patient education and behavioral guidance. These results reinforce the concept that TMD pathogenesis is closely linked to both physical and psychosocial determinants that influence disease progression and response to therapy [22].

Physical therapy has also gained increasing recognition as an important component of the multidisciplinary management of temporomandibular disorders. Therapeutic exercises aimed at improving mandibular mobility, muscle coordination, and postural alignment may enhance the effectiveness of occlusal appliance therapy. Randomized controlled trials evaluating combined therapeutic approaches have demonstrated that integrating physiotherapy with occlusal splint treatment may lead to improved clinical outcomes compared with splint therapy alone [23,24].

3. Diagnostic Strategies in Temporomandibular Disorders

The diagnosis of temporomandibular disorders (TMD) requires a comprehensive and systematic approach that integrates clinical examination, standardized diagnostic criteria, and advanced imaging methods. Because TMD encompasses a wide spectrum of conditions affecting the temporomandibular joint (TMJ), the masticatory muscles, and associated structures, accurate diagnosis is essential for establishing appropriate therapeutic strategies and preventing disease progression. Contemporary diagnostic protocols emphasize a multidimensional evaluation that includes both structural and functional assessment of the stomatognathic system [1].

A fundamental component of TMD diagnosis is the clinical examination. The diagnostic process typically begins with a detailed medical and dental history focused on the onset, duration, and characteristics of pain, as well as functional limitations such as restricted mouth opening, joint sounds, or mandibular deviation during movement. Clinical assessment also includes palpation of the masticatory muscles and TMJ structures, evaluation of mandibular range of motion, and identification of joint noises such as clicking or crepitation. These clinical findings help differentiate between muscular disorders and intra-articular pathologies, which represent the two principal categories of TMD [1,2].

In order to standardize the diagnostic process, internationally recognized classification systems have been developed. The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) represent one of the most widely adopted frameworks for diagnosing TMD in both clinical practice and research. This system expands earlier diagnostic taxonomies by

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integrating physical diagnoses with psychosocial assessment. Through the use of structured examination protocols and validated questionnaires, the DC/TMD classification improves diagnostic reliability and allows clinicians to distinguish between conditions such as myofascial pain, disc displacement, and degenerative joint disease [2].

Imaging plays a crucial role in the evaluation of temporomandibular joint disorders, particularly when structural abnormalities are suspected. Magnetic resonance imaging (MRI) is considered the gold standard for assessing soft tissue structures of the TMJ, including the articular disc, retrodiscal tissues, and joint effusion. MRI provides detailed visualization of disc position and morphology, making it particularly valuable in diagnosing internal derangements such as anterior disc displacement with or without reduction. Furthermore, MRI allows detection of inflammatory changes within the joint capsule and synovial membrane, which may be associated with painful dysfunction [3,5].

Cone beam computed tomography (CBCT) is widely used for the evaluation of osseous components of the temporomandibular joint. This imaging modality offers high spatial resolution and enables accurate visualization of condylar morphology, cortical integrity, and degenerative bone changes. CBCT is particularly useful for identifying osteoarthritic alterations, including condylar erosion, flattening, sclerosis, and osteophyte formation. Due to its relatively low radiation dose compared with conventional computed tomography, CBCT has become an essential diagnostic tool in dentomaxillofacial radiology [6].

Recent studies have explored the possibility of combining MRI and CBCT datasets through image registration techniques in order to obtain a more comprehensive visualization of the temporomandibular joint. By integrating soft tissue and bone imaging, this approach may enhance diagnostic accuracy and facilitate a better understanding of the spatial relationship between the articular disc and osseous structures [3,5].

In addition to these imaging techniques, ultrasonography has been investigated as a non-invasive diagnostic method for assessing disc displacement and joint effusion. Although ultrasonography has lower sensitivity than MRI, systematic reviews suggest that it may serve as a useful adjunctive diagnostic tool in certain clinical contexts due to its accessibility, low cost, and absence of radiation exposure [8].

Functional imaging techniques have also been evaluated for assessing temporomandibular joint pathology. Bone scintigraphy and single-photon emission computed tomography (SPECT) provide information regarding metabolic activity and bone remodeling processes within the TMJ. These methods may assist in identifying active degenerative changes or condylar growth abnormalities, particularly in patients presenting with painful joint conditions or mandibular asymmetry [10-13]. Various imaging modalities have been used to improve diagnostic accuracy in temporomandibular joint disorders. A summary of the main diagnostic techniques and their clinical indications is presented in Table 1.

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Table 1. Diagnostic Methods Used in Temporomandibular Disorders

Diagnostic method	Evaluated structures	Clinical advantages	Limitations	Ref.
Clinical examination	Masticatory muscles, joint sounds, mandibular mobility	First-line diagnostic approach; non-invasive; easily performed in clinical practice	Limited ability to detect structural joint alterations	[1,2]
Magnetic resonance imaging (MRI)	Articular disc, synovial tissues, joint effusion	Gold standard for soft tissue evaluation; accurate visualization of disc displacement	Higher cost and limited accessibility in some clinical settings	[3,5]
Cone beam computed tomography (CBCT)	Condylar morphology, cortical bone structures	High spatial resolution for osseous components; widely used in dentomaxillofacial radiology	Limited evaluation of soft tissues	[6]
Ultrasonography	Disc position, joint effusion	Non-invasive, accessible, relatively low cost	Operator-dependent; lower diagnostic sensitivity compared with MRI	[8,9]
Bone scintigraphy / SPECT	Bone metabolic activity, condylar growth activity	Useful for detecting active degenerative processes	Limited anatomical detail; complementary diagnostic method	[10–13]

4. Multidisciplinary Management of Temporomandibular Disorders

The management of temporomandibular disorders (TMD) is based on a multidisciplinary and stepwise therapeutic approach aimed at reducing pain, restoring mandibular function, and preventing progression of joint pathology. Current clinical guidelines emphasize that most TMD cases can be successfully managed through conservative and minimally invasive interventions, reserving surgical treatment for severe or refractory conditions. Because TMD etiology is multifactorial, effective treatment often requires the integration of dental, medical, and physiotherapeutic strategies tailored to the individual patient [1,2].

Conservative therapy represents the first line of treatment in the majority of TMD cases. Patient education and behavioral modification play an essential role in reducing excessive functional loading of the temporomandibular joint. Recommendations typically include avoidance of parafunctional habits, limitation of excessive mandibular movements, and implementation of relaxation techniques aimed at reducing muscular tension. Such measures may contribute to decreasing joint overload and improving neuromuscular coordination within the masticatory system [1].

Occlusal splint therapy is among the most frequently employed therapeutic modalities in the management of

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temporomandibular disorders. Occlusal appliances are designed to stabilize the mandibular position, redistribute occlusal forces, and reduce hyperactivity of the masticatory muscles. Meta-analytical studies have demonstrated that splint therapy can significantly reduce pain intensity and improve mandibular function in patients presenting with myogenous or mixed TMD conditions. Both hard and soft occlusal splints have been investigated, with evidence suggesting that each may provide clinical benefits depending on the specific characteristics of the disorder and patient compliance [15–17].

Recent network meta-analyses of randomized clinical trials have further supported the effectiveness of occlusal stabilization appliances in the management of painful temporomandibular disorders. These studies indicate that occlusal splints may produce meaningful reductions in pain and functional limitation. However, some authors emphasize that part of the therapeutic effect may be related to behavioral or placebo mechanisms associated with treatment adherence [18,19].

Physical therapy has also emerged as an important component of multidisciplinary TMD management. Therapeutic exercises aimed at improving mandibular mobility, muscle coordination, and postural alignment can enhance the effectiveness of occlusal splint therapy. Randomized clinical trials have demonstrated that combining physiotherapy with occlusal appliances may result in superior outcomes compared with splint therapy alone, particularly in patients with myofascial pain disorders [23].

In cases of intra-articular pathology, minimally invasive procedures such as arthrocentesis may be considered when conservative measures fail to achieve adequate symptom control. Arthrocentesis involves lavage of the temporomandibular joint to remove inflammatory mediators and restore normal joint biomechanics. Clinical studies have shown that this procedure may significantly improve mandibular mobility and reduce joint pain, especially in patients with internal derangements of the TMJ [4,14].

Overall, the management of temporomandibular disorders requires an individualized and interdisciplinary approach that integrates conservative therapy, occlusal rehabilitation, physiotherapy, and, when necessary, minimally invasive interventions. Such a comprehensive strategy allows clinicians to address both the structural and functional components of temporomandibular dysfunction while optimizing long-term clinical outcomes [1,15].

Current therapeutic approaches for temporomandibular disorders include a wide range of conservative and minimally invasive interventions. The principal treatment modalities and their clinical indications are summarized in Table 2.

Table 2. Therapeutic Approaches for Temporomandibular Disorders

Treatment modality	Mechanism of action	Clinical indications	Key references
Occlusal splints	Stabilization of mandibular position and redistribution of occlusal forces; reduction of muscular hyperactivity	Myogenous TMD, bruxism, occlusal instability	[15–19,21]
Physiotherapy	Improves mandibular mobility, muscle coordination, and postural control	Myofascial pain disorders and muscular dysfunction	[23,24]
Conservative therapy	Behavioral modification, patient education, and functional rest of the temporomandibular joint	Mild to moderate temporomandibular disorders	[22]

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Arthrocentesis	Lavage of the temporomandibular joint to remove inflammatory mediators and restore joint mobility	Internal derangements and persistent joint dysfunction	[4,14]

5. Future Perspectives and Emerging Approaches in Temporomandibular Disorders

Despite significant progress in understanding temporomandibular disorders (TMD), many aspects of their pathophysiology, diagnosis, and treatment remain incompletely elucidated. The complex and multifactorial nature of TMD continues to challenge clinicians and researchers, emphasizing the need for improved diagnostic accuracy and more individualized therapeutic strategies. Future research directions increasingly focus on integrating advanced imaging technologies, improved diagnostic classifications, and multidisciplinary treatment protocols in order to optimize patient outcomes [1,2].

One of the most promising developments in TMD research involves the refinement of diagnostic imaging techniques. Advanced imaging modalities such as magnetic resonance imaging (MRI) and cone beam computed tomography (CBCT) have already improved the visualization of both soft and hard tissue structures of the temporomandibular joint. Recent investigations have explored the potential of combining these imaging techniques through image registration methods, allowing simultaneous evaluation of articular disc position and osseous morphology. This integrated approach may enhance diagnostic precision and facilitate a more comprehensive understanding of structural alterations within the temporomandibular joint complex [3,5,6].

In addition to structural imaging, non-invasive diagnostic methods such as ultrasonography have gained increasing attention in recent years. Although ultrasonography does not currently replace MRI in evaluating disc displacement, systematic reviews suggest that it may serve as a useful adjunctive tool due to its accessibility, cost-effectiveness, and absence of radiation exposure. Continued technological advancements and improved operator experience may further increase the diagnostic reliability of this modality in the future [8,9,23].

Functional imaging techniques may also play an expanding role in the evaluation of temporomandibular joint pathology. Bone scintigraphy and single-photon emission computed tomography (SPECT) provide valuable information regarding bone metabolic activity and inflammatory processes within the joint. These techniques may assist clinicians in identifying active degenerative changes or abnormal condylar growth patterns, which are particularly relevant in patients presenting with mandibular asymmetry or progressive osteoarthritic alterations [10–13].

Another important direction in TMD management involves the development of optimized conservative and minimally invasive treatment protocols. Occlusal splint therapy continues to be widely used, and recent meta-analyses indicate that stabilization appliances may contribute to significant improvements in pain and mandibular function in selected patients. However, ongoing research aims to clarify the mechanisms underlying their therapeutic effect and to identify patient subgroups that may benefit most from this intervention [15,18,24].

Furthermore, increasing attention is being directed toward multidisciplinary therapeutic strategies that combine dental treatment with physiotherapy and behavioral interventions. Clinical studies have demonstrated that integrating physical therapy with occlusal splint therapy may enhance treatment outcomes by improving muscle coordination, mandibular mobility, and overall functional rehabilitation. Such

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integrated treatment models reflect the growing recognition that TMD involves both biomechanical and psychosocial components requiring coordinated management [25,26,27].

In conclusion, future advances in the diagnosis and management of temporomandibular disorders will likely arise from the integration of improved diagnostic technologies, refined classification systems, and personalized treatment strategies. Continued research into the complex interactions between structural, neuromuscular, and psychosocial factors will be essential for developing more effective and targeted therapeutic approaches for patients affected by temporomandibular disorders [1,2].

Conclusions

Temporomandibular disorders represent a complex group of conditions involving the temporomandibular joint, masticatory muscles, and associated craniofacial structures. Their multifactorial etiology reflects the interaction between biomechanical stress, neuromuscular dysfunction, psychosocial influences, and structural joint alterations. Advances in diagnostic criteria and imaging modalities, including MRI and CBCT, have significantly improved the understanding of temporomandibular joint pathology. These developments have enabled more precise identification of structural and functional abnormalities, supporting more accurate diagnosis and facilitating the selection of appropriate therapeutic strategies for patients presenting with temporomandibular dysfunction.

The management of temporomandibular disorders increasingly relies on a multidisciplinary and patient-centered approach that integrates conservative therapy, occlusal rehabilitation, physiotherapy, and minimally invasive procedures when indicated. Evidence suggests that most patients benefit from non-surgical interventions aimed at reducing pain, improving mandibular function, and restoring joint homeostasis. Emerging diagnostic techniques and evolving therapeutic protocols continue to refine the clinical management of these disorders. Future research should focus on improving diagnostic accuracy, identifying reliable biomarkers of disease activity, and developing personalized treatment strategies that address both the biological and psychosocial dimensions of temporomandibular disorders.

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