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RELATIONSHIP BETWEEN STOMATOGNATHIC SYSTEM ALIGNMENT AND CRANIOMANDIBULAR DYSFUNCTION: MECHANISMS, REHABILITATION STRATEGIES, AND CLINICAL OUTCOMES

Narrative Review (ID: 1683)

Dr. Taimia Tahir[1]*
[1]Orthopaedic Manual Physical Therapy, Riphah International University Lahore, Pakistan.
Corresponding Author: Dr. Taimia Tahir, taimiatahir756@gmail.com, Orthopaedic Manual Physical Therapy, Riphah International University Lahore, Pakistan.
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ABSTRACT

Craniomandibular dysfunction (CMD) is a multi-factorial disorder affecting the temporomandibular joint, masticatory muscles, occlusion, cervical spine and related neuromuscular structures. Alterations in stomatognathic alignment may contribute to CMD through complex biomechanical, postural, neurological, and psychosocial mechanisms. This review discusses stomatognathic system alignment and the influence of it on CMD, including pathophysiological mechanisms, diagnostic methods, rehabilitation interventions, and clinical results. There are indications that the abnormal occlusion, muscular hyperactivity, cervical postural dysfunction and parafunctional habits can compromise the biomechanics of the mandible and add stress to structures of the TMJ. Neurological mechanisms (trigemino-cervical convergence, central sensitization) also play a role in chronic pain and functional impairment. Comprehensive clinical examination, with the help of imaging and standardized diagnostic criteria such as RDC/TMD and DC/TMD, is required for diagnostic evaluation. Various conservative multi-disciplinary rehabilitative strategies have proven to be effective for reducing pain and enhancing mandibular function and quality of life, such as occlusal therapy, physiotherapy, neuromuscular rehabilitation, and psychosocial management. But there is some controversy about direct causal involvement of occlusal and postural factors because of heterogeneity in the available literature. Overall, CMD should be considered a complex biopsychosocial disorder requiring individualized and multidisciplinary management strategies.

Keywords: *Craniomandibular dysfunction, Temporomandibular disorders, Stomatognathic system, Occlusion, Rehabilitation*

INTRODUCTION

Definition of Craniomandibular Dysfunction and Temporomandibular Disorders: Craniomandibular dysfunction (CMD), which falls under the umbrella of temporomandibular disorders (TMDs), is a complex and diverse group of musculoskeletal and neuromuscular disorders that involve the temporomandibular joint (TMJ), the masticatory musculature, associated craniofacial structures, and related cervical components (Michelotti, 2020). These disorders are associated with pain, abnormal movement of the mandible, joint sounds and functional disturbances of mastication, speech and oral function. TMDs are now regarded as one of the most common causes of non-dental orofacial pain and are thought to be a significant public health problem because of their chronicity and multifactorial etiology (Donnarumma et al., 2022). The TMJ is one of the most complicated synovial joints in the human body, depending on the coordinated interaction among the osseous structures, the components of the articular discs, ligaments, muscles and neural pathways. If there is any breakdown in the biomechanical relationship of this system, it can contribute to functional impairments and symptoms of the CMD (Sakul et al., 2018). According to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD), these disorders can be divided into pain-related disorders, intra-articular disorders and degenerative joint diseases, with both physical and psychosocial aspects of the disease process highlighted (Warzocha et al., 2024).

Epidemiological studies have reported that approximately 5-12% of the global population is affected by TMD; and it is found to be more prevalent in women, especially between age groups of 20-45 years (Mishra, 2020). But, there may be temporomandibular dysfunction in a larger proportion of people who aren't feeling any symptoms. Symptom rates are highly dependent on the diagnostic criteria, population characteristics, and study methods. However, despite these differences, TMD is one of the most prevalent chronic pain conditions of the craniofacial area (Ferreira et al., 2016). The clinical consequences of CMD are not only related to the function of the individual joints. Patients often experience poor quality of life, psychological distress, poor sleep quality, loss of productivity at work and restricted social interaction (Alhashim et al., 2025). Persistent pain related to TMD has also been seen to be connected with anxiety and depression, in addition to central sensitisation mechanisms, making diagnosis and management even more challenging. Because of its multifactorial nature, CMD is currently regarded as not just a problem of the joints but a complex biopsychosocial disorder that encompasses structural, functional, behavioral and neuromuscular interactions (Ferrillo et al., 2022).

The Stomatognathic System: The stomatognathic system is a complex of highly interconnected anatomical and functional structures which are involved in mastication, swallowing, speech, breathing and craniofacial stability. It consists of: temporomandibular joints, dentition of the maxilla and mandible, periodontal structures, masticatory muscles, muscular tissue of the neck, neural networks and related skeletal structures (Saratti et al., 2022). To achieve functional equilibrium and biomechanical efficiency in the craniofacial region, it is crucial that these elements are coordinated properly (Yu et al., 2021a). The temporomandibular joint is the main articulating structure of the stomatognathic system that allows complex rotational and translational movements of the mandible. The TMJ functions in harmony with the occlusal contacts and the neuromuscular control mechanisms which allows the mandible to move smoothly during chewing and speech (Lee, 2024). Changes in the mechanics of the joints, position of the discs, or muscular coordination can throw this balance out of sync and cause functional disorders (Bordoni and Brizuela, 2025). Another basic element of Stomatognathic system is Occlusion which is defined as the relationship of the upper and lower teeth in static and/or dynamic movements of the mandible (Sivam and Chen, 2021). Even distribution of masticatory forces and optimum muscle activity are related to balanced occlusion. On the other hand, occlusal discrepancies can lead to abnormal loading patterns in the TMJ and the muscles surrounding it, including crossbite, deep bite, open bite, and premature contacts (Rokaya, 2024).The muscular component of the stomatognathic system comprises the masseter, temporalis, medial and lateral pterygoid muscles, and accessory cervical head and mandibular stabilising muscles (Basit et al., 2023). These muscles are under highly coordinated neuromuscular control, through the trigeminal nerve and central nervous system pathways mainly (Terrier et al., 2022). Hyperactivity, fatigue and trigger point formation have been implicated in the pathogenesis of TMD and are examples of disturbances in muscular activity (Furquim et al., 2015). The anatomical and functional connection of the stomatognathic system with the cervical spine is also underlined by increasing data. It has been suggested that the cranio-cervical region is a biomechanical unit and that changes in the position of the head, the position of the cervical spine or cervical muscle tension have a potential to affect mandibular mechanics and vice versa (Armijo-Olivo, 2016). Anatomical convergence of trigeminal and cervical afferents adds to the literature for the interconnection of the craniofacial and cervical pain systems. A dysfunction in any part of the system can be a leading factor in compensatory changes and symptom development across the entire cranio-cervical complex (Michalakis et al., 2024).

Why Alignment Matters: A functional balance, efficient force distribution and neuromuscular co-ordination rely on alignment within the stomatognathic system (Ono and Yonemitsu, 2025). Occlusal, mandibular, cervical, and muscular disturbances can cause a biomechanical imbalance and play a role in the initiation or exacerbation of craniomandibular dysfunction (Omar et al., 2023). It has long been thought that malocclusion may play a role in the etiology of TMD. The occlusal discrepancies can affect the position of the mandible and cause a higher mechanical stress in the TMJ and masticatory muscles (Pascu et al., 2025). Posterior crossbite, deep overbite, anterior open bite, unilateral occlusal contacts, and others are conditions that have been linked to abnormal muscle activation and altered mandibular movements (Iodice et al., 2016). There is some controversy regarding the true causative link, but occlusal instability can lead to functional overload and increase the risk of susceptible individuals experiencing temporomandibular symptoms (Cocoș et al., 2025). Forward head posture and cervical misalignment have also been receiving a great deal of focus in the modern research of TMJ. An AHP can cause adaptive changes in mandibular position and cervical muscle activity, which may impact TMJ biomechanics (Yin et al., 2025). An abnormal curve of the cervical spine and muscular tension in the neck and shoulder area can cause additional tension and pain in the craniofacial muscles. Several studies have shown that there are links between cervical dysfunction and the severity of TMD, which suggests that there is an integrated cranio-cervical-mandibular system (Armijo-Olivo, 2016). Another key mechanism involved in the connection between alignment disturbances and CMD is muscle dysfunction. Occlusal instability, postural compensation, parafunctional habits, and psychologic stress can be responsible for hyperactivity of masticatory and cervical muscles (Topaloğlu and Poorshiri, 2024). When this is sub-acute or chronic, it can cause fatigue, ischemia, myofascial trigger points, and even pain sensitization. Neuromuscular coordination is important for functional alignment, and electromyographic studies have shown that the muscle recruitment patterns of patients with TMD are altered (Shah et al., 2015).

Cranio-cervical interactions are another emerging area of interest. The cervical spine is in direct association with the mandibles, so that there is a bidirectional relationship between biomechanical and neurological influences (Ren, 2016). Compensatory cervical changes may result from dysfunction with cervical posture which can affect mandibular movement and occlusal relationships, and vice versa. It is important to understand that TMD is not a solitary joint disorder, but part of an interconnected relationship to the postural and musculoskeletal health of a person (Dipalma et al., 2025).

Current Controversies: Although the association between stomatognathic alignment and craniomandibular dysfunction has been investigated extensively, there is still great debate about the nature and extent of this association (Fornai, 2023). One of the major controversies is the role of occlusal and postural abnormalities as primary aetiological factors in TMD or simply secondary adaptive changes in the presence of this dysfunction (Ohrbach and Sharma, 2024). In the past, occlusion was thought to play a major role in the pathogenesis of TMD and irreversible occlusal treatment was commonly prescribed. Other studies, however, yielded conflicting results and most studies did not verify a direct causal link between malocclusion and temporomandibular disorders (de Kanter et al., 2018). As of today, there are more and more literature suggesting that occlusal factors do not cause dysfunction on their own, but they may play a role together with psychological, neuromuscular, behavioral and postural factors (Ohrbach and Michelotti, 2015). The connection between cervical posture and TMD is also poorly understood. Some studies have found correlations between forward head posture, cervical pain, and temporomandibular dysfunction, but others report that such correlations may be due to compensation (Yao et al., 2023). Furthermore, the available literature has methodological variability, different diagnostic criteria and different assessment protocols, which makes interpretation difficult (Gagnier et al., 2012). The complexity of the controversy does not end there, however, because of the multifactorial nature of CMD. Along with biomechanical factors, psychological stress, parafunctional habits (bruxism), sleep disturbances, genetic predisposition, trauma, and central sensitization mechanisms can all interact and influence the development and progression of symptoms (Fornai, 2023). Therefore, it is difficult to find a single etiological model to explain the whole range of temporomandibular disorders (TMD) (Wan et al., 2025).

Rationale of the Review: Although there is advance literature that stomatognathic alignment is associated with craniomandibular dysfunction, the mechanisms and effectiveness of rehabilitation strategies are still under debate and not synthesized (Militi et al., 2023). The literature discussed is generally concerned with one or two of the many aspects of TMD with little attempt to bring these components together in a clinical context. Moreover, variable results in terms of causality and therapeutic efficacy persist and present a challenge to evidence-based clinical practice (Leketas, 2018). The review of the literature, which integrates the knowledge about the biomechanical, neuromuscular and rehabilitative viewpoints, may help to develop better comprehension of the complex interactions related to CMD. This is especially useful because of the multidisciplinary nature of the TMD problem and the increased awareness of cranio-cervical integration in orofacial pain disorders.

Aim of the Review: This narrative review aims to explore the relationship between stomatognathic system alignment and craniomandibular dysfunction, with particular emphasis on underlying pathophysiological mechanisms, rehabilitation strategies, and associated clinical outcomes. Additionally, the review seeks to critically evaluate current controversies and identify future directions for multidisciplinary diagnosis and management of CMD.

METHODOLOGY / LITERATURE SEARCH STRATEGY

This study was designed as a narrative review to synthesize the existing literature on the relationship between stomatognathic system alignment and craniomandibular dysfunction, with emphasis on underlying mechanisms, diagnostic approaches, rehabilitation strategies, and clinical outcomes. A narrative review design was selected because the topic involves multiple interrelated anatomical, biomechanical, neurological, postural, and psychosocial factors that cannot be fully addressed through a single narrowly defined research question. A comprehensive literature search was conducted using major electronic databases, including PubMed, Google Scholar, ScienceDirect, Scopus, Web of Science, and Cochrane Library. The search focused on studies published between 2010 and 2026, although older landmark references were also included where they provided foundational concepts related to temporomandibular disorders, occlusion, and craniomandibular dysfunction. The main search terms included: craniomandibular dysfunction, temporomandibular disorders, stomatognathic system, temporomandibular joint, occlusion, malocclusion, cervical posture, forward head posture, masticatory muscles, bruxism, trigeminocervical convergence, central sensitization, physiotherapy, manual therapy, occlusal splints, orthodontic rehabilitation, and multidisciplinary management. Boolean operators such as AND and OR were used to combine relevant keywords.

Studies were considered eligible if they discussed the association between stomatognathic alignment and CMD/TMD, mechanisms of temporomandibular dysfunction, diagnostic criteria such as RDC/TMD or DC/TMD, imaging and functional assessment methods, or conservative rehabilitation approaches. Systematic reviews, narrative reviews, observational studies, clinical trials, diagnostic studies, and relevant textbook-based sources were included. Articles were excluded if they were unrelated to CMD/TMD, focused only on dental pathology without functional relevance, lacked clinical applicability, or were not available in English. The selected literature was reviewed and organized thematically. Key findings were synthesized under major themes, including anatomical and biomechanical foundations, occlusal and muscular factors, cervical-postural relationships, neurological pain mechanisms, psychosocial contributors, diagnostic approaches, rehabilitation strategies, and clinical outcomes. Because this was a narrative review, no formal meta-analysis or statistical pooling was performed. Instead, the evidence was critically discussed to provide an integrated clinical understanding of CMD as a multifactorial biopsychosocial disorder.

ANATOMY AND FUNCTIONAL BIOMECHANICS OF THE STOMATOGNATHIC SYSTEM

The temporomandibular joint (TMJ) is the most complex and most functional synovial joint of the human body. It is the primary joint between the mandible and the temporal bone of the skull and plays a key role in mandibular mobility, which is needed for chewing, speaking, swallowing and breathing (Sakul et al., 2018). The TMJ is a bilateral and interconnected joint, and movements on one side always affect the other, unlike most synovial joints. This complex biomechanical coordination plays a role in the predisposition of the joint to functional disturbances and craniomandibular dysfunction (Gupta et al., 2025). Osseous components of TMJ are the mandibular condyle, mandibular fossa and the articular eminence of the temporal bone. The mandibular condyle is an oval-shaped bony prominence found at the top of the mandibular ramus (Domenyuk et al., 2020). It is made up of dense fibrocartilage instead of hyaline cartilage which gives it greater resistance to repetitive mechanical stress and adaptive remodeling. The condyle fits into the glenoid fossa and the articular eminence of the temporal bone to form a ginglymoarthrodial joint that allows for rotational and translational movements (Athanasiou et al., 2022). The articular disc is a biconcave fibrocartilaginous structure located between the condyle and temporal bone which divides the TMJ into the superior and inferior synovial chambers (Sakul et al., 2018). Articular disc acts as a load-distributing unit and stabiliser in articulation during the movement of the mandible. The middle part of the disc is thinner than the anterior and posterior bands, enabling smooth movement between the condyle and temporal bone (Ghosh, 2019). The disc is posteriorly connected to highly vascularised and innervated retrodiscal tissue and anteriorly to the superior head of the lateral pterygoid muscle. Articular disc displacement or degeneration can be a common cause of TMD and cause the jaw to click, lock up, and become painful or difficult to open (Waxenbaum et al., 2023).

There are a number of ligamentous structures that are involved in the stability and restriction of TMJ movements. The temporomandibular ligament (also called the lateral ligament) strengthens the lateral side of the capsule, and prevents the condyle from moving too far posteriorly and inferiorly (Hill et al., 2022). The accessory ligaments are the sphenomandibular ligament and the stylomandibular ligament that provide secondary stabilization and provide some direction of movement of the mandible. The TMJ is surrounded by fibrous joint capsule which is lined by synovial membranes in the superior and inferior compartments (Öz, 2024). Synovial structures of the TMJ are very important in maintaining lubrication, nutrition and biomechanical efficiency of the joint. The synovial membrane is responsible for the production of synovial fluid, which helps minimize friction between articulating surfaces and provides nutrients to the avascular cartilage of the disc and condyle (Gul et al., 2024). This change in synovial fluids can cause synovial changes and/or degeneration that may affect the ability of the TMJs to function and may contribute to the generation of pain in the temporomandibular complex (Kellesarian et al., 2016). The TMJ allows for both a hinge-like rotation and gliding along the translation. The first phase of initial opening of the mouth is achieved through the rotation of the condyle in the inferior joint compartment while the wider opening of the mouth is obtained by the anterior translation of the condyle-disc complex along the eminence of the temporal bone in the superior joint compartment (Benchea-Indrei[1] et al., 2025). This co-ordinated mechanism enables complex movements of the mandible required for an efficient oral function. Any disruption of structural or biomechanical integrity of the TMJ may affect the mandibular dynamics, and cause craniomandibular dysfunction (Vinayak et al., 2024).

Masticatory Muscles: The masticatory muscles are key parts of the stomatognathic system that are involved in the movement of the mandible, generation of the masticatory forces, stabilization of the joints, and functional coordination (Kijak et al., 2017). These muscles are highly synchronized and work under the control of a neuromuscular system that enables chewing and swallowing, speaking, and postural stability. Relationship between masticatory muscles dysfunction or imbalance and temporomandibular disorders and myofascial pain syndromes is strong (Fassicollo et al., 2021). One of the most powerful muscles of mastication is the masseter muscle. The masseter muscle is attached from the zygomatic arch to the lateral surface of the mandibular ramus and angle and is mainly responsible for elevating the mandible and for strong closure of the jaw (Rokaya, 2024). Considering the high demand of the masseter in chewing and clenching movements, the muscle is very susceptible to muscular fatigue, hyperactivity and myofascial trigger points formation in parafunctional habits patients, including bruxism (SENER, 2024). The temporalis muscle is a wide fan-shaped muscle that originates in the temporal fossa and attaches to the coronoid process of the mandible. Its anterior fibers lift the mandible while the posterior fibers help to retract the mandible and stabilize it (Yu et al., 2021). Temporalis is a muscle that has significant function in maintaining the mandibular position at rest and functional activities. Symmetrical or hyperactive temporalis muscle activity is commonly observed in patients with TMD headaches and muscle dysfunction (Yilmaz et al., 2015).

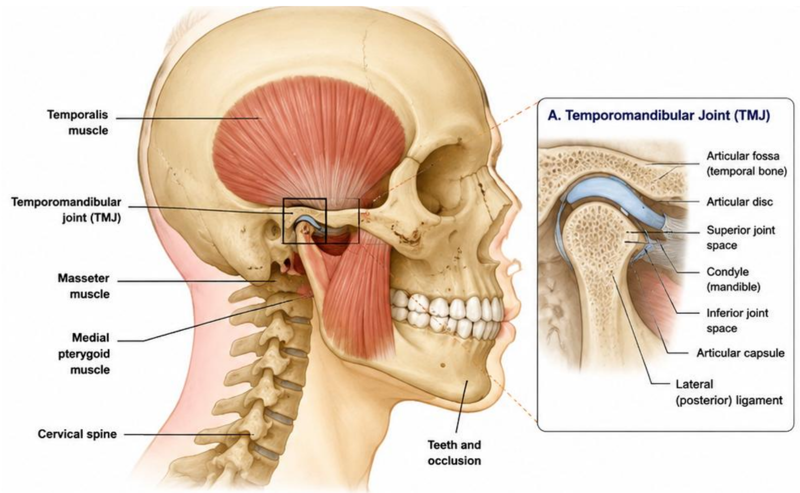

Figure 1: Anatomy of stomatognathic system

The medial and lateral pterygoid muscles are deep in the infratemporal fossa, and play an important role in complicated movements of the mandible. Medial pterygoid is involved in the elevation and mediolateral movement of the mandible in synergy with the masseter (CORNEILLE, 2023). The lateral pterygoid, on the other hand, has a very important function in the protrusion, translation and disc-condyle coordination of the mandibule. The superior head of the lateral pterygoid attaches to the articular disc and capsule of the TMJ and plays a role in its stability during movement. The lateral pterygoid has been associated with disc displacement disorders and joint instability (Pintea et al., 2023) when it is dysfunctional or there is excessive tension. The stabilization of the mandible and the cranio-cervical posture is not only achieved by the primary masticatory muscles, but also by accessory cervical and suprahyoid muscles. These muscular groups must function together to preserve functional harmony of the stomatognathic system. Muscular balance disturbances can change force distribution in TMJ, increase the loading of the joints and play a role in the development of chronic pain (Matías Ambiado-Lillo, 2025) (Papini, 2025).

Neuromuscular Coordination: The stomatognathic system is a functional unit that depends on neuromuscular coordination. Efficient mandibular movement relies on the accurate interaction of sensory receptors, peripheral nerves, central nervous pathways and muscular effectors (Michalakis et al., 2024). This is a very integrated control system that allows adaptation to changes in occlusion, posture, and mechanical loading. The trigeminal nerve is the major neural element of the stomatognathic system. It is the fifth cranial nerve, which gives both sensory and motor innervation to the facial region and motor innervation to the muscles of mastication (Wu et al., 2023). The trigeminal nerve has sensory branches that convey proprioceptive, tactile, nociceptive, and mechanoreceptive information from the periodontal ligament, TMJ structures, muscles, and oral mucosa to the CNS. This is sensory input that is critical for controlling bite force, positioning of the mandibles, and coordinated movement (Perry and Emrick, 2024). The control of mandibular function by motor command is a complex process that relies on communication among the trigeminal motor nucleus, the brainstem central pattern generator, the cerebellar pathways, and the cortical centers (Hong and Park, 2026). These neural networks control the rhythmic chewing movements and the adaptive muscle changes during functional activities. Changes in neuromuscular control can result in inappropriate muscle recruitment, joint overload and impaired mandibular movement (Samulski, 2020). Proprioception has a significant role in the functional stability of the stomatognathic system, especially in relation to the lower jaw.Proprioception has a particularly important role in the lower jaw's functional stability in the stomatognathic system. The mechanoreceptors in periodontal ligament, masticatory muscles and tissues within the TMJ constantly monitor the position of the jaw, the tension of the masticatory muscles, and the occlusal contact (Bejoymony et al., 2015). This sensory feedback enables quick changes in muscle activity to keep the body at biomechanical efficiency and to minimise the stress on the joint structures (Piancino et al., 2017). Neuromuscular abnormalities are often seen in patients with craniomandibular dysfunction. Electromyographic (EMG) measurements have shown that the cervical and masticatory muscles experience changes in their activation patterns, either adaptively or pathologically, which indicate that motor control is altered (Fassicollo et al., 2021). Chronic pain and central sensitization can also alter neuromuscular regulation by altering central processing of sensory information and hyperactivity of muscles. As such, neuromuscular dysfunction is increasingly acknowledged as an important mechanism to the onset and maintenance of TMD (Nijs et al., 2021).

Cranio-Cervical Relationship: Cranio-cervical relationship is an important part of stomatognathic biomechanics and has gained significant interest in current research on temporomandibular disorders (TMD) (Armijo-Olivo, 2016). The head, mandible, cervical spine and its musculature are a single biomechanical unit, and changes in one of its elements can affect the whole craniofacial system (Barzaghideanu et al., 2025a). The position of the cervical spine is a key factor in ensuring the proper alignment and balance of the mandible. Anterior head posture is often accompanied by temporomandibular dysfunction (Zokaitė et al., 2022). This change in posture can cause compensatory retrusion of the mandible, increased tension in the cervical muscles and changes in TMJ loading patterns. A long period of postural imbalance can lead to fatigue in the muscles, limited mandibular movement, and chronic pain development (Sambataro et al., 2019). The occlusal relationship and masticatory muscle activity are greatly affected by head position. Any alterations in cervical alignment may alter the resting position of the mandible and its position during function (Omar et al., 2023). Mandibular kinematics and the subsequent increase in tenderness in the masticatory muscles are typical findings in patients with cervical dysfunction, indicating close functional interdependence between the cervical spine and stomatognathic system (Hölzl et al., 2019). Additional biomechanical integration is provided by muscle chains from the cervical region to the craniofacial structures. The sternocleidomastoid, trapezius, suboccipital and suprahyoid muscles interact closely with masticatory muscles in stabilizing the head's posture and moving the mandible (Ren, 2016). A dysfunction or hyperactivity in these muscle chains can lead to abnormal muscle stresses and compensatory movement patterns, which can lead to symptoms of CMD (Pandey et al., 2022).

In addition, fascial connections are crucial in cranio-cervical biomechanics. The deep cervical fascia and related myofascial links create structural connections between tissues of the cervical and craniofacial areas, enabling mechanical tension to travel throughout the tissue system. As a result, cervical posture and mandibular function could be modified by fascial restrictions or asymmetries (Pilat and Castro-Martín, 2018). Trigeminal and upper cervical nerves converge at the trigeminocervical nucleus as a convergence center in the central nervous system. This neural integration is why there is a common association of cervical pain, headache and temporomandibular symptoms (Malhab et al., 2025). Cervical structures can refer pain to the craniofacial region and vice versa, making it difficult to diagnose and important to thoroughly assess the clinical situation (Basu and Perry, 2021). An insightful implication of the recognition of cranio-cervical interactions is in the development of rehabilitation strategies for patients with craniomandibular dysfunction. Nowadays, the management strategies adopted have a greater focus on the correction of the position, cervical rehabilitation and a multidisciplinary approach in order to restore the general biomechanical balance of the stomatognathic system (Barzaghideanu et al., 2025b). Increased awareness of the mechanisms involved in the relationship between alignment and craniomandibular dysfunction.Raised understanding of the patho-physiological mechanisms between alignment and craniomandibular dysfunction.

PATHOPHYSIOLOGICAL MECHANISMS LINKING ALIGNMENT AND CRANIOMANDIBULAR DYSFUNCTION

Craniomandibular dysfunction (CMD) is a multifactorial disorder with complex interactions between biomechanical, neuromuscular, neurological, postural and psychosocial factors (Militi et al., 2023). The stomatognathic system is a dynamic, interdependent system; changes in occlusion, muscular balance, cervical posture and neural regulation can impact temporomandibular joint biomechanics and play a role in dysfunction. While the exact cause of CMD is still under debate, there is considerable evidence that alignment-related mechanisms are involved in the initiation, progression and chronicity of symptoms. If these pathophysiological pathways are to be understood, then these strategies can be developed to provide a comprehensive rehabilitation plan that will enhance clinical outcomes (Kreisel et al., 2007).

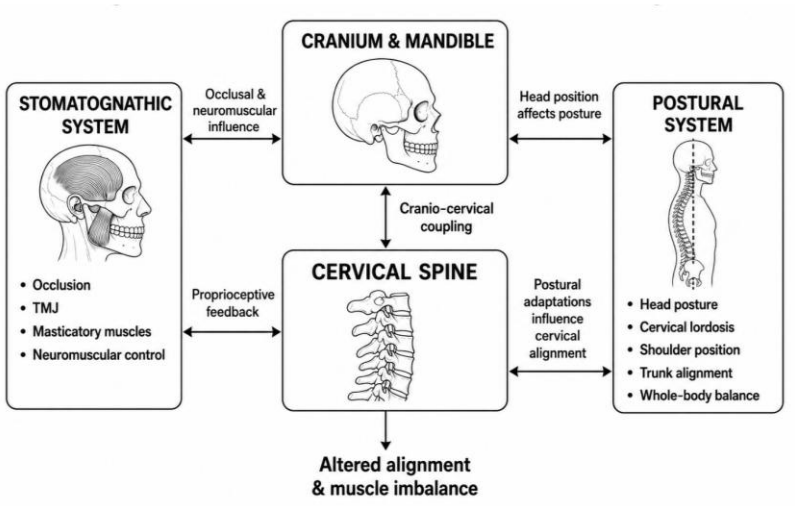

Figure 2: Cranio-cervical postural interaction diagram

Occlusal Factors: Occlusal factors have been an integral part of theories on the development of TM disorders and craniomandibular dysfunction for years. Occlusion, the static and dynamic relationship between the teeth of the maxillae and the teeth of the mandibles in functional and resting activities of the mandibles. Appropriate occlusion ensures even distribution of forces, mastication efficiency, and smooth muscle coordination (Fornai, 2023). In contrast, the biomechanics of the mandible can change with occlusal abnormalities, and the temporomandibular joint and associated musculature is subject to mechanical stress. Malocclusion is a very broad term that refers to a multitude of dental and skeletal discrepancies, such as spacing, crowding, asymmetry, sagittal discrepancies, and changes in vertical dimensions. Various malocclusions have been studied as possible factors associated with CMD (Saghiri et al., 2021). Of these, posterior crossbite is common and is often accompanied by asymmetric movement of the mandible and unilateral overactivity. During posterior crossbite, abnormal transverse relationships of the upper and lower dentition can lead to deviation of the lower jaw on closure, which can create unequal forces across the temporomandibular joints (TMJ). Imbalanced loading of the joints over time can then lead to disc displacement, remodeling of the joints, and muscular imbalance (Iodice et al., 2016). A temporomandibular dysfunction is also frequently accompanied by another occlusal condition called anterior open bite. Loss of anterior tooth contact can affect incisal guidance and affect functional mandibular trajectories in chewing and speaking. Patients with open bite often exhibit enhanced muscular activity during chewing, tongue posture changes and compensatory neuromuscular activity (Broberg et al., 2017). These adaptations can be a cause for mucous fatigability of the masticatory muscles and overloading of the TMJ with time (Broberg et al., 2017; Seligman and Pullinger, 1991). Another factor, deep bite, has been suggested to contribute to changes in the biomechanics of the TMJ. If the anterior teeth are too vertically overlapping, it can hinder mandibular movements and potentially cause greater compressive forces on the temporomandibular joint (Lundberg, 2016). Posterior displacement of the condyle within the glenoid fossa under deep bite conditions could cause posterior pressure on retrodiscal tissues and related neural structures. Moreover, changes in the vertical dimension can affect the loading of the muscles and aggravate the parafunctional loading (Albert et al., 2024).

Another important factor in the pathophysiology of CMD is occlusal instability, which can manifest as premature contacts and/or an imbalanced distribution of occlusal forces. Premature occlusal contacts can disrupt the normal movement of the mandible toward closure and require for maximal intercuspation (Fornai, 2023) compensation by the muscles of the tongue, teeth, and lips. Chronic compensatory activity can lead to long-term muscle tension, fatigue and abnormal joint loading. Occlusal discrepancies can also affect the rest position of the mandible, which puts additional stress on the other muscles that move the jaw (Demerjian et al., 2018). Occlusion changes can alter the distribution of functional forces in the stomatognathic system and lead to a disturbance of the biomechanical equilibrium. Occlusal contacts may not be balanced, which can result in masticatory forces being localized in certain areas of the TMJ. An increase in joint loading can lead to the development of cartilage wear, synovial inflammation, and adaptive remodeling within the TMJ. The repetitive overload can also exacerbate disc displacement and/or degenerative joint changes (Peck, 2016).

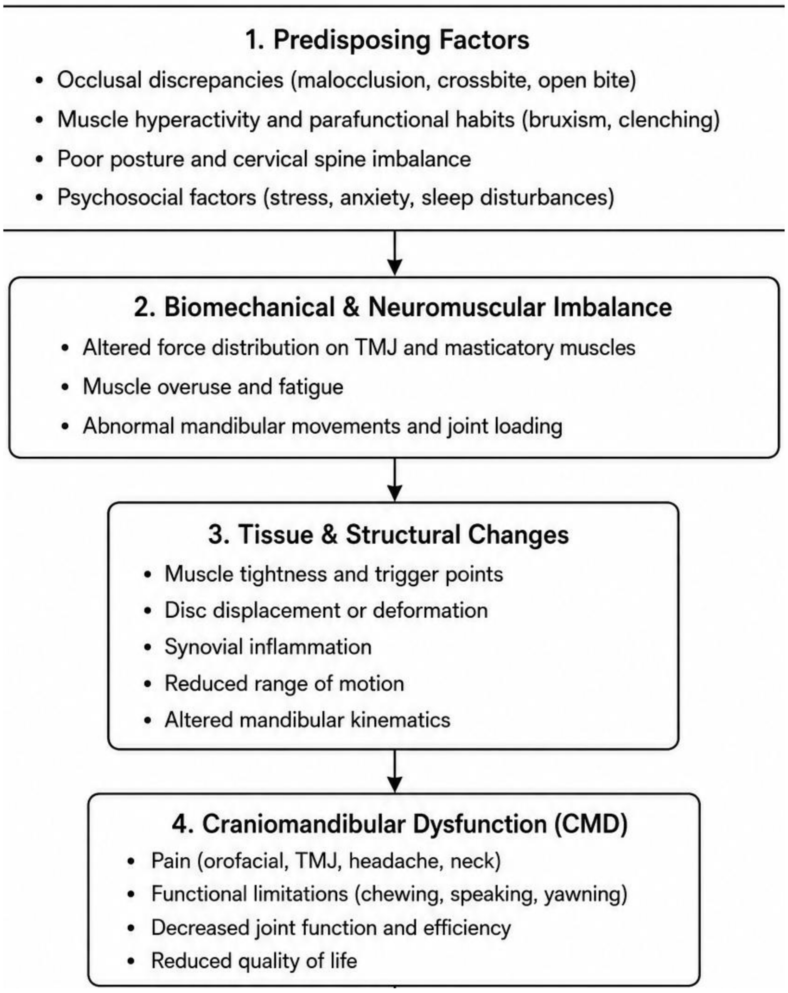

Figure 3: Pathophysiological mechanisms flowchart

Simplified flowchart illustrating the pathophysiological mechanisms linking stomatognathic alignment disturbances with craniomandibular dysfunction, including biomechanical imbalance, tissue changes, and clinical outcomes.

Muscular Dysfunction: Muscular dysfunction is one of the most important pathophysiological mechanisms involved in craniomandibular dysfunction. Yamada et al. (2020) noted that the masticatory muscles are highly active structures that are repetitively under functional loading during chewing, swallowing, speech and parafunctional activities. Muscular coordination disturbances, tone or activation pattern disturbances can impair stomatognathic balance and aggravate pain production and functional difficulties. Patients with CMD are also frequently characterized by muscular hyperactivity, which is also often accompanied by parafunctional habits like clenching and bruxism (Buvinic et al., 2021). Continued high muscle tone causes a decrease in blood flow and buildup of metabolic waste products in the muscle. The physiological changes can sensitise nociceptors and help to develop the myofascial pain syndromes. Masseter and temporalis muscle hyperactivity are especially prevalent in people who suffer from chronic stress and/or occlusal instability (Joyner and Casey, 2015). Another important aspect of muscular dysfunction in CMD is myofascial trigger points. TPs are hyperirritable nodules found within taut bands of dry, skeletal muscle fibres that elicit localized and referred pain on palpation (Zhai et al., 2024). The trigger points are often found in the masseter, temporalis, sternocleidomastoid and trapezius muscles in the context of the temporomandibular disorders. These trigger points can cause referred pain, which can be misdiagnosed or lead to incorrect conclusions about the diagnosis, such as odontogenic pain, headache or otologic symptoms (Zieliński et al., 2021). Bruxism is a significant behaviour and neuromuscular cause of muscular dysfunction. Bruxism can happen while awake or asleep and involves recurrent teeth grinding or clenching (Ella et al., 2017). Bruxism places high levels of parafunctional loading on the masticatory muscles as well as the TMJ structures. The chronic bruxism can cause tooth wear, muscular hypertrophy, and increase the risk of joint inflammation and disc displacement. Psychological stress, anxiety and sleep disturbances are known factors that contribute to muscular dysfunction associated with bruxism (Smyczek et al., 2025).

Another significant mechanism that helps determine the symptoms of CMD is muscular fatigue. Fatigue can be caused by repetitive use of the masticatory muscles, which can affect muscle endurance and coordination, leading to pain, stiffness, and decreased functional efficiency (Al Sayegh, 2021). Fatigued muscles can also show delayed muscle relaxation and reduced muscle output, which also affects mandibular stability and loading during function (Ono and Yonemitsu, 2025). Electromyographic (EMG) studies have been helpful in understanding the changes in neuromuscular function in CMD. Patients with temporomandibular disorders often exhibit heightened activity in the masseter and temporalis muscles and a lack of relaxation (Ono and Yonemitsu, 2025; Shandiz et al., 2025). EMG analyses have also shown the existence of asymmetrical activation patterns of the muscles, delayed activation of the muscles and differences in coordination between the masticatory muscles and the cervical muscles. This provides further evidence in favour of the idea of the involvement of a widespread dysregulation of the neuromuscular system, rather than a singular joint involvement in CMD (Yonekawa and Nishino, 2015). In addition, a chronic muscle dysfunction may play a role in the mechanisms of peripheral and central sensitization. Overactive or tired muscles may cause a persistent nociceptive input that could change pain processing in the CNS, making one more sensitive to pain and thus maintaining chronic symptoms (Clauw, 2015). Therefore, the dysfunction of the muscles is another local biomechanical issue and it plays a role in the neurophysiological development of chronic CMP.

Cervical Spine and Postural Dysfunction: There is a close anatomical, biomechanical, neurological interdependence between the cervical spine and craniofacial region. There is growing evidence of the role of postural abnormalities and cervical dysfunction in the pathogenesis of craniomandibular dysfunctions (CMDs) (Ramieri et al., 2022). Changes in cervical alignment can affect mandibular position, muscular activity and loading of the temporomandibular joint, contributing to the onset and chronicity of symptoms (Demerjian et al., 2018). One of the most common postural deviations with CMD is "forward head posture". It is a condition with anterior translation of the cephalic spine towards the cervical spine with often rounded shoulders and thoracic kyphosis (Ashok et al., 2020). The anatomical position of the mandible and cervical musculoskeletal system is changed by FHP, which may exert greater stress on the TMJ and chewing muscles. The head posture forward position is often associated with posterior rotation of the cranium and retrusion of the mandible, which results in a change in the relationship between the teeth and an increase in muscular tension (Omar et al., 2023). Another important postural factor related to the temporomandibular dysfunction is altered cervical lordosis. Normal cervical curves that flatten or reverse will affect load distribution in the biomechanical areas of the cervical spine and craniofacial region (Ren, 2016). The changes can also create increased mechanical tension on the cervical muscles, ligaments and neural structures, resulting in referral of pain to the jaws and facial areas (Frugone Zambra et al., 2026). In many patients with CMD, they have a tendency to overactivate their cervical muscles. Muscles like upper trapezius, levator scapulae, suboccipital and sternocleidomastoid are commonly found to be tense and tender along with temporomandibular disorders (Aoyama, 2021). Excessive cervical muscle activation can result as a compensatory mechanism to maintain head posture stability when there is mandibular dysfunction or occlusal imbalance. On the other hand, neck dysfunction can also impact mandibular kinematics and lead to abnormal recruitment of masticatory muscles (Costescu et al., 2024).

The relationship between posture and CMD is further explained by muscle chains that connect the cervical spine to stomatognathic system. For functional activities a coordinated activity among the cervical and masticatory muscles is a must for maintaining craniofacial stability (Armijo-Olivo, 2016). Failure of any of these systems within this integrated system may thus lead to compensatory alterations throughout the whole cranio-cervical complex (Yin et al., 2025). Biomechanical interaction of the cervical region and temporomandibular structures is also achieved by fascial continuity (Fernandes et al., 2020). In the cervical and craniofacial region, the fascial tissues carry mechanical tension between inter-related anatomical regions. Restriction or asymmetries in fascial networks can thus affect the postural function of the mandible as well as its function (Kitamura, 2018). Importantly, cervical dysfunction can cause mechanical changes, as well as pain sensitization (Peng et al., 2021). A recurrent cervical muscle tension and joint irritations can lead to an increase of nociceptive inputs to trigeminocervical neural pathways, thereby enhancing craniofacial pain perception. The assessment and rehabilitation of cervical posture and muscle function have gained significant importance in the comprehensive evaluation and rehabilitation of patients with CMD (Kielnar et al., 2021).

Neurological and Pain Mechanisms: Neurological mechanisms are important in the development and maintenance of craniomandibular dysfunction, especially chronic pain patients. Modern knowledge of CMD is increasingly focused on neural sensitization, changes in pain modulation, and central nervous system involvement, as well as local biomechanical abnormalities (Kielnar et al. 2021). One of the most significant neurological theories that relates cervical dysfunction and craniofacial pain is called the trigeminocervical convergence theory. The trigeminocervical nucleus in the brainstemc(Malhab et al., 2025) is an area where sensory afferents from the trigeminal nerve and upper cervical spinal nerves converge. This convergence can have nociceptive signals from cervical structures perceived as facial or temporomandibular pain and vice versa. As such, cervical spine and stomatognathic system dysfunction can be responsible for diffuse craniofacial pain patterns (Demerjian et al., 2018). Another significant mechanism which is involved in chronic CMD is central sensitization. A chronic load of nerve fibers from muscles, joints or occlusal structures can cause neuroplastic changes in the central nervous system which can increase pain sensitivity and amplify nerve signals (Monaco et al., 2017). Central sensitization may lead to hyperalgesia, allodynia, and pain that is widespread beyond the area of tissue damage.

Some people can still have pain even though their peripheral structure is resolved, which may be a role for central sensitization (Woolf, 2018). The multidimensional experience of pain associated with CMD is mediated by nociceptive pathways through peripheral nerves, spinal cord neurons, thalamic structures, and pain-processing centers of the cortex (Woolf, 2018). The chronic activation of these pathways can lead to a disruption of emotional processing, stress responses and autonomic regulation, continuing to exacerbate symptomology and functional impairment (Kolacz and Porges, 2018). Chronic pain adaptation refers to physiological and/or behavioral adaptations that reduce pain sensation. Persistent CMD can lead to changes in movement patterns of the mandible, guarding of the muscles, and decreased functional activity (Kolacz and Porges, 2018). These adaptations are initially protective, but over time can lead to muscle stiffness, loss of joint mobility, and additional biomechanical dysfunction.

Table 1. Proposed Mechanisms Linking Stomatognathic Alignment to Craniomandibular Dysfunction

Mechanism	Alignment-Related Factor	Pathophysiological Effect	Potential Clinical Manifestations
Altered Occlusal Force Distribution	Malocclusion, crossbite, deep bite, occlusal instability	Uneven loading of TMJ structures and masticatory muscles	TMJ pain, joint clicking, muscle fatigue
Increased Joint Loading	Premature occlusal contacts and mandibular asymmetry	Increased compressive stress on condyle and articular disc	Disc displacement, joint inflammation, restricted motion
Muscular Hyperactivity	Bruxism, clenching, occlusal interference	Sustained muscle contraction and reduced circulation	Myofascial pain, trigger points, muscle tenderness
Neuromuscular Compensation	Occlusal imbalance and altered mandibular positioning	Adaptive changes in muscle recruitment patterns	Functional asymmetry, abnormal mandibular movement
Cervical Muscle Overactivation	Forward head posture and cervical imbalance	Increased tension within cervical and masticatory muscles	Neck pain, headaches, postural fatigue
Cranio-Cervical Biomechanical Dysfunction	Altered cervical lordosis and poor posture	Impaired cranio-cervical stability and mandibular mechanics	Reduced mandibular mobility, postural instability
Trigemino-Cervical Convergence	Cervical dysfunction and chronic nociceptive input	Shared neural pain pathways between cervical spine and trigeminal system	Referred facial pain, chronic headache
Central Sensitization	Persistent muscular and joint pain	Amplification of pain processing within CNS	Chronic pain, hyperalgesia, allodynia
Fascial Tension Transmission	Myofascial imbalance and postural asymmetry	Altered force transmission through fascial chains	Muscle stiffness, reduced flexibility
Impaired Proprioception	TMJ dysfunction and cervical instability	Abnormal sensory feedback and motor control	Movement incoordination, functional limitation
Psychological Stress Response	Anxiety, emotional stress, sleep disturbances	Increased sympathetic activity and parafunctional habits	Bruxism, muscular tension, pain exacerbation
Behavioral Overloading	Nail biting, unilateral chewing, gum chewing	Repetitive mechanical strain on TMJ and muscles	Fatigue, joint irritation, muscular dysfunction

Psychosocial and Behavioral Factors: The etiopathogenesis and the progression of craniomandibular dysfunction are now seen to be closely influenced by psychosocial and behavioral factors. Currently, CMD is known in a biopsychosocial model, in which psychological stressors, emotional distress, and behavioral patterns interact with biomechanical and neurological parameters to affect symptom development (Upton, 2020). Stress is one of the most important psychosocial factors contributing to TMD. Psychological stress activates the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system, which also increases muscular tension, leading to the development of parafunctional behaviors, such as clenching and bruxism. Chronic stress can thus increase the hyperactivity of muscles, sensitization of pain and fatigue in the stomatognathic system (Le Roux, 2019). Other conditions that are very common among patients with chronic TMD include anxiety and depression. Emotional distress could affect how pain is experienced, how one copes, sleep quality and responsiveness to treatment (Le Roux, 2019). Patients with high levels of anxiety often exhibit greater pain sensitivity and higher muscular tension than do patients without anxiety (Arango-Dávila and Rincón-Hoyos, 2018). Sleep disturbances are strongly linked with CMD, and can mediate exacerbation of symptoms in several ways. Inadequate sleep leads to sub-optimal tissue repair, higher pain sensitivity and increased parafunctional activity during sleep. Sleep bruxism in particular, represents repetitive mechanical stress on the TMJ and masticatory muscles (Duo et al., 2023).

Other parafunctional behaviors include nail chewing, gum chewing, unilateral chewing, teeth grinding, and teeth clenching, which also add to the excessive loading of the stomatognathic system. Chronic parafunctional activity can maintain the state of muscular fatigue, inflammation of the joints, and structural degeneration (Leketas, 2018). The psychosocial and behavioral factors work together and play a significant role in the initiation and maintenance of craniomandibular dysfunction. Their interplay with biomechanical and neurological factors underscores the need for a multidisciplinary evaluation and management approach that addresses both structural abnormalities and emotional and behavioral factors that drive chronic pain and dysfunction (Polonowita et al., 2024).

Table 2. Major Studies Evaluating the Relationship Between Stomatognathic Alignment and Craniomandibular Dysfunction

Author/Year	Study Design	Population	Main Alignment Factor Evaluated	Key Findings	Clinical Relevance
Okeson (2013)	Narrative review	Literature-based	Occlusion and neuromuscular factors	Occlusion may contribute to TMD in susceptible individuals but is not the sole etiological factor	Emphasized conservative management approaches
Armijo-Olivo et al. (2011)	Systematic review	Adults with TMD	Cervical posture	Significant association between TMD and forward head posture was observed	Highlighted importance of cervical rehabilitation
Manfredini et al. (2017)	Systematic review	TMD populations	Occlusal factors	Weak evidence supporting direct causality between malocclusion and TMD	Challenged traditional occlusion-centered theories
Ferreira et al. (2014)	Cross-sectional study	Female TMD patients	Head posture and cervical alignment	Forward head posture correlated with increased muscular pain and dysfunction	Suggested postural correction as adjunct therapy
Schiffman et al. (2014)	Diagnostic criteria validation study	TMD patients	Functional and psychosocial factors	Established DC/TMD as reliable diagnostic criteria	Improved diagnostic standardization
Wieckiewicz et al. (2015)	Review study	Bruxism and TMD patients	Bruxism and muscular hyperactivity	Bruxism contributes to muscular overload and temporomandibular symptoms	Reinforced role of parafunctional habits
Costa et al. (2015)	Electromyographic study	Patients with CMD	Muscle activity patterns	Altered EMG activity observed in masseter and temporalis muscles	Supported neuromuscular dysfunction theory
Silveira et al. (2015)	Clinical study	TMD patients	Cervical posture and mobility	Reduced cervical mobility associated with TMD severity	Suggested combined cervical and TMJ rehabilitation
Michelotti et al. (2020)	Experimental study	Healthy individuals	Occlusal interference	Artificial occlusal interferences increased muscular activity in some subjects	Demonstrated adaptive neuromuscular responses
La Touche et al. (2018)	Systematic review	TMD and neck pain patients	Cervical-muscular relationship	Strong association between neck disability and TMD symptoms	Supported multidisciplinary rehabilitation
Ohrbach & Dworkin (2016)	Review article	Chronic pain/TMD patients	Psychosocial mechanisms	Psychological distress significantly influences TMD chronicity	Reinforced biopsychosocial model

DIAGNOSTIC APPROACHES

Accurate diagnosis of craniomandibular dysfunction (CMD) and temporomandibular disorders (TMD) is critical for proper treatment planning and long-term management. These disorders are multifactorial and heterogeneous and require a comprehensive and multidisciplinary approach for diagnosis that includes clinical examination, imaging modalities, functional assessments and standardized diagnostic criteria (Seidel et al., 2025). The current diagnostic approaches seek to define the structural abnormalities of the temporomandibular joint (TMJ) and evaluate the muscular dysfunction, postural changes, neuromuscular coordination and psychosocial factors involved in the development of symptoms (Fong et al., 2018). A complex nature of CMD may lead to simultaneous disorders of the temporomandibular joint, masticatory muscles, cervical spine and craniofacial structures. Thus, a series of diagnostic tests is required to complete the picture of the disorder (Fornai, 2023). Clinicians, however, use a combination of subjective symptom evaluation and objective clinical findings to make an accurate diagnosis and determine the mechanisms underlying dysfunction (Rosendal et al., 2017).

Clinical Examination: Clinical examination is the backbone of the diagnosis of CMD and is the most important source of information regarding the involvement of muscles, the integrity of the joints, characteristics of pain, and function of the mandible. Systematic Examination protocol can help the clinician identify functional abnormalities, reproduce symptoms and differentiate between muscular and intra-articular origins of pain (Schindler et al., 2022). Assessment of jaw movement is an essential part of the clinical assessment. Mouth opening, lateral excursions and protrusive movements are used to evaluate the range of motion of the lower jaw (mandible) (Svechtarov et al., 2015). Normal maximal mouth opening is approximately 40 to 60 mm, but this can also depend on the age, sex and craniofacial morphology. Limited opening of the mandible can be caused by muscle spasms, disc displacement without reduction, joint degeneration or capsular fibrosis. Unilateral deviation or deflection of the mandible on opening may indicate either unilateral dysfunction of the muscles or internal derangement of the TMJ. The assessment of movement quality, smoothness and symmetry is a key component to elucidate functional abnormalities as well (Golanska et al., 2021). Palpation of the TMJs and associated musculature helps to obtain information on tenderness, hyperactivity of the muscles and myofascial trigger points. The clinician usually examines the masseter, temporalis, medial pterygoid, sternocleidomastoid and trapezius muscles for symptoms of pain, tightness and referred symptoms (Kalladka et al., 2021). Elevation of the mandible may cause tenderness to be felt in the lateral pole of the condyle or retrodiscal tissues, which can be a sign of inflammation or joint dysfunction. Muscle tenderness in myogenous TMDs is a condition that is commonly experienced and can play a large role in chronic pain complaints (Khan et al., 2023). Another key area of clinical examination is assessment of joint sounds. The jaw can make clicking, popping or crepitus sounds when moving the jaw back and forth. Joint clicking is often related to disc displacement with reduction, which occurs when the displaced articular disc temporarily returns during the translation of the mandible (Kemp, 2018). Coarse grating sounds are described as crepitus, and are associated with degenerative joint disease and osteoarthritic changes of the articular surfaces. While some joint sounds might be present in asymptomatic patients, if they are combined with pain and/or functional limitation they may be indicative of clinically significant dysfunction (Pereira, 2018).

Assessment of pain is important for CMD diagnosis because of the chronic nature of many TMDs. Clinicians assess the characteristics of pain, such as location, intensity, duration, frequency and aggravating factors, by performing a patient history and physical examination. The sources of pain can be muscular, articular, cervical or neuropathic and can radiate to the head, neck, ears or shoulders (Klasser et al., 2023). There are common scales (like the Visual Analog Scale (VAS) and the Numeric Rating Scale (NRS)) that are used to measure symptom severity and track treatment effectiveness. Additionally, psychosocial characteristics, sleep disorders and parafunctional behaviors that can affect pain and chronicity are often evaluated (Karcioglu et al., 2018). A thorough clinical examination also involves assessment of occlusal relationships, cervical posture, mandibular symmetry, and other parafunctional habits like clenching or bruxism. However, it is important to carry out a comprehensive clinical evaluation to reach a diagnosis and plan a rehabilitative approach that is personalised to the patient when CMD is often a combination of anatomical and functional systems.

Imaging: Imaging modalities are a very important part of diagnosis and evaluation of TMDs because they allow detailed visualization of the osseous structures, position of the TMJ articular disc, soft tissues, and relationships between the cranium and the mandible. The choice of imaging modality is determined by the underlying pathology, clinical presentation and the diagnostic goals (Talmaceanu et al., 2018). Magnetic resonance imaging (MRI) is considered the gold standard for evaluation of soft tissue structures in the temporomandibular joint. Unlike x-rays and CT scans, MRI uses a powerful magnet to produce a strong magnetic field that is used to generate images of the articular disc, retrodiscal tissues, synovial membranes and joint effusions with no exposure to ionizing radiation (Orhan et al., 2017). This is a very useful modality for the diagnosis of internal derangements such as a disc displacement with or without reduction. MRI can also evaluate inflammatory changes, effusion of the joint and degenerative changes in the TMJ. Dynamic MRI techniques could also be used to assess the coordination of disc and condyle movement during mandibular motion to improve the diagnostic accuracy in functional abnormalities patients (Young, 2015). More recently, cone-beam computed tomography (CBCT) has played an important role in the assessment of osseous structures of the TMJ and craniofacial complex. The CBCT can give a three-dimensional view of the mandibular condyle, glenoid fossa, integrity of the cortical bone and joint morphology, and the radiation dose, although high, is relatively low compared to the radiation dose of conventional computed tomography (Caruso et al., 2017). This modality is very helpful in the diagnosis of degenerative changes, condylar resorption, osteophyte formation, fractures, ankylosis and asymmetrical skeletal relationships. CBCT also has the ability to assess craniofacial morphologic and occlusal relationships relevant to orthodontic and prosthodontic treatment planning (Caruso et al., 2017). Cephalometric analysis is a vital diagnostic tool that assesses craniofacial skeletal relationships, position of the mandible and cervical posture. Lateral cephalometric radiographs can be used to assess sagittal and vertical skeletal discrepancies, head posture, airway size and shape, and mandibular alignment (Opris et al., 2022). Structural abnormalities related to malocclusion and temporomandibular dysfunction, such as retrognathia, higher mandibular plane angle, and altered cranio-cervical relationships (Kui et al., 2024), may be seen in the cephalometric parameters. Cephalometric analysis is not a direct examination of the soft tissues in the TMJ, but it does give important information on the overall craniofacial balance and postural alignment (Sambataro et al., 2019).

In certain cases, further imaging techniques like panoramic radiography and ultrasonography can be used to aid evaluation of CMD (Kinalski et al., 2020). The panoramic radiographs can be useful for initial screening of gross osseous abnormalities, dental pathology and asymmetry, whereas ultrasonography is a non-invasive and cost-effective tool for superficial joint structures and muscular conditions. In general, these methods have lower completeness in the diagnosis of TMJ than MRI or CBCT (Shi et al., 2022). The use of advanced imaging modalities in the diagnosis of CMD has greatly enhanced the knowledge of temporomandibular pathology. In spite of this, imaging results should be interpreted in the context of clinical symptoms and structural abnormalities can also occur among patients without clinical symptoms (Zhao et al., 2025).

Functional Assessment: Functional assessment techniques are employed to objectively assess the activity of muscular system, occlusal force distribution, mandibular dynamics and postural alignment in patients with craniomandibular dysfunction (Sambataro et al., 2019). Clinical assessment and imaging are complemented with these assessments, and they provide a way to detect functional impairments that could be involved in symptom development and persistence (Leddy et al., 2021). Electromyography (EMG) is a common method of assessing the electrical activity of the masticatory muscles and the cervical muscles. Surface electromyography can be used to assess muscle recruitment patterns, resting muscle activity, coordination and fatigue, non-invasively (Szyszka-Sommerfeld et al., 2023). Increased resting activity of masseter and temporalis muscles, and asymmetrical muscle activity and/or altered muscle coordination during mandibular movements are often observed in patients with temporomandibular disorders. EMG can also detect hyperactivity related to parafunctional activities like bruxism and clenching. Moreover, an electromyographic assessment could help in assessing the progress of the rehabilitation after occlusal therapy, physiotherapy or neuromuscular interventions (Fassicollo et al., 2021; Mapelli et al., 2016). Bite force analysis quantifies occlusal loading patterns and masticatory efficiency. With digital occlusal analysis systems, like T-Scan technology, it is possible to assess occlusal contacts, timing and force distribution during the mandibular closure (Röhrle et al., 2018). An abnormal bite force pattern can be a factor in uneven TMJ loading, compensation by muscles, and occlusal instability. The maximal bite force is usually diminished in patients with CMD, which may be caused by pain inhibition, fatigue of the muscles, or dysfunction of the jaw. Analysis of bite force is, therefore, useful to provide information about the functional adaptation and biomechanical imbalance of the stomatognathic system (Fornai, 2023).

Posture analysis has become a more important part of assessing CMD as there is a known connection between cervical posture and TM dysfunction. Evaluation of head posture, cervical curvature, shoulder symmetry, and spinal posture can help to detect postural abnormalities that could be related to altered mandibular mechanics (Minervini et al., 2023). The assessment of cranio-cervical relationships is commonly performed using techniques like photogrammetry, computerized posture analysis and 3D motion analysis. Patients with chronic TMD often have a forward head posture, with cervical muscle imbalance being a significant factor both in the severity of symptoms and the effectiveness of treatment (Barzaghideanu et al., 2025a). Additionally, the mandibular movement pattern, velocity and trajectory in functional activities could be analyzed using mandibular kinesiography and jaw tracking systems. These evaluations can be used to identify deviations, limitations and asymmetries in movement patterns that are associated with internal derangements and/or muscular dysfunction (Wintergerst et al., 2026). Functional assessment methods add to the picture of a more complete understanding of the biomechanical and neuromuscular factors that underlie CMD. These integrated into clinical evaluation improve diagnostic accuracy and aid individual rehabilitation planning (Kumar and Dwivedi, 2025)

Diagnostic Criteria: TMDs were historically heterogeneous, presenting significant problems in diagnosis and research consistency. Recognizing the need to overcome these shortcomings, there are standardized diagnostic classification systems in existence to increase the reliability, validity, and reproducibility of clinical practice and scientific research (Ohrbach and Dworkin, 2016). In 1992, a new, broadly accepted, and standardized framework for evaluating TMDs, known as the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), was developed. The RDC/TMD used a dual axis model, which included both physical and psychosocial components of the temporomandibular disorders (Ohrbach and Dworkin, 2016). Axis I identified clinical diagnoses such as muscular disorders, disc displacement or arthralgia/degenerative joint disease. Psychological status, pain-related disability, depression and somatization were assessed in Axis II. This biopsychosocial approach played an important part in the understanding of the multidimensional nature of CMD and a greater consistency in the methodology used in research (Hietaharju, 2023). Although it has been widely used, its diagnostic sensitivity and specificity were inadequate, leading to the creation of a new DC/TMD classification system. The DC/TMD was introduced in 2014, and updated diagnostic algorithms and enhanced clinical applicability with keeping the dual-axis biopsychosocial model (Warzocha et al., 2024). The DC/TMD offers validated clinical examination protocols for the diagnosis of common temporomandibular disorders related to pain and intra-articular temporomandibular disorders. The implementation of the DC/TMD framework has led to increased reliability and standardized assessment procedures, which has increased its acceptance and use internationally (Steenks et al., 2018).

The DC/TMD highlights the importance of a full assessment of pain characteristics, mandibular function, joint sounds, psychosocial status and functional impairment. Using a standardized symptom questionnaire and examination procedures enhances the consistency in diagnosis across different clinicians and research contexts (Warzocha et al., 2024). Importantly, psychosocial assessment is incorporated, as there is increasing awareness that psychosocial mechanisms significantly impact symptom severity and treatment outcomes of chronic pain (Driscoll et al., 2021). Standardized diagnostic criteria have played a crucial role in advancing CMD research and clinical management. Nevertheless, temporomandibular disorders remain highly heterogeneous conditions requiring individualized assessment that integrates clinical findings, imaging results, functional evaluation, and psychosocial considerations. Consequently, contemporary diagnostic approaches increasingly emphasize multidisciplinary assessment aimed at identifying the multifactorial contributors underlying craniomandibular dysfunction (Kang et al., 2015).

REHABILITATION STRATEGIES

Craniomandibular dysfunction (CMD) and temporomandibular disorders (TMD) should be treated by a comprehensive and personalized rehabilitation plan that involves restoring functional balance in the stomatognathic system, relieving pain, enhancing mandibular mobility, and addressing contributing biomechanical and psychosocial factors (Militi et al., 2023). Because of the multifactorial nature of CMD, there is no one therapeutic modality that works for everyone. However, modern rehabilitation approaches focus on conservative, reversible, and multidisciplinary management focusing on the pathophysiological mechanisms of dysfunction (Tarihci Cakmak and Sen, 2025). The rehabilitation strategies for CMD address multiple components of the stomatognathic system such as occlusion, muscular activity, neuromuscular coordination, cervical posture, and behavioral adaptation. The incorporation of dental, physiotherapeutic, orthodontic, and psychological treatment in a combined approach is supported by increasing evidence with the aim of optimizing the long-term clinical outcome. However, there is still considerable debate about whether individual therapies are more significant and if structural correction has any impact on symptom resolution (Sandoval-Munoz and Haidar, 2021; Zapata-Soria et al., 2022).

Occlusal Therapy: The use of occlusal therapy has been a long-standing principle of treatment for TMD. The first step of occlusal therapy is to achieve biomechanical stability in the stomatognathic system through the optimization of occlusal contacts, low marginal and low muscle activity, and the reduction of abnormal loading on the joints. Depending on the clinical condition, occlusal interventions can range from stabilization splints to occlusal adjustment procedures to comprehensive bite rehabilitation (Manfredini, 2018). One of the most frequently prescribed conservative treatments for CMD is a stabilization splint, which can also be called an occlusal splint or bite guard. They are usually made of hard acrylic material and are inserted into the mouth, either as a whole or in fragments, to ensure the even occlusal contact of the teeth. The purpose of stabilization splints is to redistribute occlusal forces, decrease parafunctional activity, facilitate muscular relaxation, and protect dental structures from excessive loading caused by bruxism(Kinalski et al., 2020). Several mechanisms have been proposed to explain the therapeutic effects of stabilization splints. The splints provide a more normal occlusal relationship, minimizing abnormal muscle recruitment and stress on the TMJ. Furthermore, splints can also modify the proprioceptive input from periodontal receptors and muscle receptors, which contribute to neuromuscular relaxation and less pain. Some clinical studies have shown that certain patients with myogenous TMD or mixed TMD presentations have a clinical benefit from a stabilization splint, including increasing the intensity of pain, increasing mobility of the mandible, and improving sleep quality (Kitamura, 2018; Klasser et al., 2023).

Although commonly used, the exact mechanism and the long-term effects of splint therapy remain debatable. Other investigators believe that symptom improvement is largely due to behavioral changes or to a placebo effect or to symptom variation over time rather than to direct biomechanical correction. Additionally, if this is combined with an overreliance on long-term splint application with no attention paid to other psychosocial and postural factors, therapeutic success may be compromised in the longer term. Occlusal adjustment is the process of selectively reshaping the occlusal surfaces to remove early contacts and correct occlusal harmony (Kreisel et al., 2007). Historically, irreversible occlusal equilibration procedures were often done in patients with TMD with the assumption that occlusal discrepancies were the main etiological factor. Recent findings, however, have questioned this notion, and irreversible occlusal adjustment is no longer regarded as a standard procedure for treating TMDs (Kolacz and Porges, 2018). Present guidelines suggest caution for irreversible occlusal procedures, as evidence of their effectiveness as primary treatment for CMD is lacking. Selective occlusal adjustment can be helpful in carefully selected patients with occlusal interference and/or prosthodontic instability, but indiscriminate use can worsen the symptoms or create further biomechanical imbalance. Therefore, the majority of modern rehabilitation treatments are recommended to be reversible or conservative in nature before proceeding to a permanent occlusal modification. Bite rehabilitation is a wider restorative or prosthodontic approach that seeks to achieve functional occlusion and vertical dimension in patients with extensive tooth wear, missing dentition and/or severe occlusal instability. Treatment for full mouth rehabilitation can include crowns, bridges, implants, or a type of reconstruction to optimize occlusal support and the position of the mandible (Le Roux, 2019). These interventions can include optimizing masticatory efficiency, minimising abnormal loading and optimizing stomatognathic stability. Bite rehabilitation, however, should take care of detailed planning and comprehensive functional assessment because the occlusion and temporomandibular function are complexly related (Kui et al., 2024). One of the most controversial issues in the field of CMD is the role of occlusion. While it is recognized that occlusal abnormalities can contribute to biomechanical stress and muscular compensation in those susceptible, modern evidence is growing to suggest that the occlusion is just one component in a multifactorial model with numerous interacting factors. Thus, successful rehabilitation may require a combination of occlusal therapy, physiotherapeutic, behavioral, and psychosocial interventions (Lee, 2024; Leketas, 2018).

Physiotherapy and Manual Therapy: Physiotherapy has become an essential pillar of the conservative approach to craniomandibular dysfunction (CMD) especially in patients with muscular pain, limited mandibular mobility, cervical dysfunction and postural imbalance. Physiotherapeutic interventions seek to minimize pain, attain functional mobility, normalize cranio-cervical biomechanics, and enhance muscle coordination using non-invasive and evidence-based methods (Öz, 2024; Pandey et al., 2022). The flexibility exercises are very common in order to relieve the tension of the masticatory and cervical muscles. Hyperactivity of the masseter, temporalis, pterygoid, sternocleidomastoid and trapezius muscles may be an area of therapeutic stretching. Stretching exercises could benefit the movement of the mandible, decrease the muscle stiffness and alleviate pain from myofascial dysfunction. Controlled mandibular stretching is also beneficial in patients with limited mouth opening secondary to muscular spasm or disc displacement(Papini, 2025; Pascu et al., 2025). Joint mobilizations are commonly used to re-establish normal temporomandibular and cervical joint mechanics. Passive gliding movements of the TMJ that are intended to increase condylar translation and decrease capsular restriction may be required for manual mobilization. Upper cervical (c1-c2) cervical mobilization techniques can also enhance posture, decrease muscle tension and reduce referred craniofacial pain. Patients who are more likely to benefit from which mobilization therapies are most useful include those with joint hypomobility, movement asymmetry, and functional restriction (Ono and Yonemitsu, 2025; Opris et al., 2022).

The goal of myofascial release therapy is to decrease the tension in the fascia and increase soft tissue mobility in the craniofacial and cervical portions. Fascial restrictions can lead to abnormal force transmission, imbalance of the muscles and pain sensitisation of the stomatognathic system (Peng et al., 2021). Myofascial release techniques: sustained manual pressure to restricted fascial tissues to increase circulation, decrease adhesions and increase tissue extensibility. Pereira (2018) and Pilat and Castro-Martín (2018) found from clinical studies that myofascial therapy can reduce the intensity of pain and enhance functional capacity in patients with myogenous TMD. In recent years, dry needling has been more and more used as an auxiliary procedure for TMD temporomandibular dysfunction-related myofascial trigger points. The insertion of fine needles to decrease local muscle tension and modulate nociceptive activity is a minimally invasive technique.A minimally invasive technique involves inserting fine needles in the hyperirritable muscle points to decrease local muscle tension and modulate nociceptive activity (Seligman and Pullinger, 1991). Dry needling can cause increased movement of blood, decrease peripheral sensitisation and normalise neuromuscular function of the affected muscles. Dry needling has been found to have positive impacts on pain relief and mandibular mobility, especially in chronic muscular TMD patients (SENER, 2024). Another important component of physiotherapy in the management of CMD is the cervical rehabilitation, given the known correlations of cervical posture and temporomandibular dysfunction. Commonly, postural correction exercises, cervical stabilization training, deep neck flexor strengthening and scapular stabilization exercises are incorporated into rehabilitation programs (Pascu et al., 2025). The FHP and cervical muscle overactivation are highly prevalent in TMD patients and could be a contributing factor to chronic pain and abnormal mandibular mechanics (Ohrbach and Sharma, 2024). Exercise treatment to enhance motor coordination and muscular endurance is also commonly used in rehabilitation therapy programs. Specific exercises of the mandible can benefit the regulation of neuromuscular control, decrease abnormal movement patterns and support the functional adaptation of the stomatognathic system (Perry and Emrick, 2024). Importantly, patient education about posture, stress management, and para-functional habit reduction are often combined with physiotherapy interventions with the most beneficial effect (Peng et al., 2021).

Orthodontic Rehabilitation: In some patients with malocclusion, craniofacial asymmetry or structural abnormalities which may be associated with craniomandibular dysfunction, orthodontic rehabilitation may play an important role. Orthodontic treatments have as their goal: to create functional occlusal relationships, improve the positioning of the mandible, and create a biomechanical balance within the stomatognathic system. The connection between orthodontics treatment and TMD, however, is still debatable and there is still some controversy about how much influence the correction of malocclusion has on symptom resolution. (Ono and Yonemitsu, 2025; Piancino et al., 2017). The advantages of clear aligner therapy are aesthetic and allows for controlled tooth movement. Aligners can be used to increase occlusal stability, shift occlusal forces and decrease traumatic occlusal contacts in certain patients. In some studies, aligners have been shown to temporarily alter the activity of the masticatory muscles, and help with neuromuscular coordination. Also, some people may experience less parafunctional loading due to the aligner splinting effect. However, in the absence of significant occlusal or skeletal abnormalities, orthodontic treatment should not be the primary treatment for TMD (Pilat and Castro-Martín, 2018; Sandoval-Munoz and Haidar, 2021). Functional appliances are often used in patients who are growing with skeletal discrepancies involving the position of the mandible and craniofacial development. The purpose of these appliances is to change the growth pattern of the mandible and to help to achieve a better functional occlusion by orthopaedic and neuromuscular adaptation (Ramieri et al., 2022). Functional appliances can improve muscle balance and decrease biomechanical stress with extreme skeletal malrelationships. But the direct role of their prevention or treatment in TMD is still not completely understood (Kijak et al., 2017).

Orthognathic correction may be indicated in patients with severe dentofacial deformities, skeletal asymmetry, and substantial functional impairment of stomatognathic system (Leddy et al., 2021). The surgical correction of skeletal discrepancies can enhance occlusal stability, facial symmetry, airway function and mandibular biomechanics. When the malocclusion is severe and/or condylar displacement is present, orthognathic surgery may alleviate TMD symptoms in certain cases. Surgical procedures, on the other hand, have some risks and require careful multidisciplinary planning, involving orthodontists, maxillofacial surgeons and rehabilitation specialists (Pereira, 2018). Today, the evidence indicates that orthodontics does not cause nor is it always a cure-all for temporomandibular disorders. Rather, treatment should be considered as part of the comprehensive functional evaluation and multidisciplinary care (Barzaghideanu et al., 2025; Mishra, 2020).

Neuromuscular Rehabilitation: The goal of neuromuscular rehabilitation is to restore coordinated muscular activity, optimize motor control, and decrease maladaptive neuromuscular patterns leading to CMD. Neuromuscular interventions are gaining relevance in contemporary rehabilitation treatment because numerous TMD patients demonstrate muscle recruitment imbalance, postural imbalance and chronic muscle tension (Fong et al., 2018; Pandey et al., 2022). A common use for biofeedback therapy is to enhance awareness and control of muscular activity. Surface electromyographic biofeedback enables patients to observe muscle tension and is used to teach them relaxation skills. Patients with bruxism, clenching and stress-related hyperactivity of muscles might benefit from biofeedback especially. Biofeedback therapy can help to minimize pain intensity and enhance mandibular function (Opris et al., 2022; Pereira, 2018). Another key aspect of neuromuscular rehabilitation is posture correction. An abnormal posture of the head and the alignment of cervical spine can influence the position of the mandibles and the strain on the muscles. Rehabilitation programs frequently include exercises to restore balanced cranio-cervical alignment, improve cervical stabilization and correct forward head posture. Better posture can help alleviate abnormal loading on the cervical spine and temporomandibular joint (Omar et al., 2023).

The motor control exercises are aimed at normalizing the movement patterns of the jaw and enhancing coordination between the structures of the masticatory and cervical muscles. Controlled opening and closing exercises, tongue positioning exercises, and proprioceptive training for re-establishing functional neuromuscular balance may be used. Motor control rehabilitation has been shown to be especially beneficial for patients with movement asymmetry, muscular guarding or chronic maladaptive movement patterns (Ohrbach and Dworkin, 2016). Neuromuscular rehabilitation often includes relaxation techniques and breathing patterns because of the relationship between stress and autonomic function and muscle tension. Diaphragmatic breathing and relaxation techniques can help decrease the activation of the sympathetic nervous system and increase general muscle relaxation (Buvinic et al., 2021). Neuromuscular rehabilitation methods are designed to tackle not only the structural abnormalities, but the functional and neurophysiological factors contributing to CMD as a whole.

Multidisciplinary Management: Because of the complex and multifactorial nature of craniomandibular dysfunction, multidisciplinary management is more and more seen as the gold standard for the treatment of this disorder (Armijo-Olivo, 2016). CMD is often a combination of biomechanical, neuromuscular, psychological, and behavioural issues that cannot be resolved with any single treatment. Thus, it is crucial to organize collaborative care models that require the participation of several health care providers, to obtain optimal clinical results (Topaloğlu and Poorshiri, 2024). Dentists are a key role in diagnosis, occlusal management and restorative rehabilitation. An occlusal relationship is assessed and stabilization splints are prescribed when needed, parafunctional habits are identified and corrected, and when required, they coordinate restorative treatments to maintain occlusal relationships. Highly-trained prosthodontists and oral medicine specialists can also participate in more complicated rehabilitation planning and pain management. The role of physiotherapists is vital to focus on muscular dysfunction, cervical posture, joint mobility and neuromuscular coordination. Physiotherapists can successfully restore functional movement and alleviate pain caused by musculoskeletal imbalance, using manual therapy, exercise prescription and postural rehabilitation.

Orthodontists play a role in the management of malocclusion and skeletal discrepancies that could affect the stomatognathic biomechanics. For patients with severe dentofacial deformities, orthodontic and orthopaedic treatment can be used to enhance functional occlusion and potential long-term structural stability. As there is a clear link between psychosocial factors and pain perception, psychologists are more and more involved in the management of chronic TMD. Cognitive behavioural therapy, stress management, relaxation and behavioural modification strategies can have significant effects on coping and symptom chronicity. In patients with chronic pain (especially severe chronic pain), central sensitization, or neuropathic pain components, pain specialists may be needed. Pharmacological management, trigger point injections and interdisciplinary pain rehabilitation programs can be useful in managing complex chronic pain mechanisms. Communication between healthcare professionals is essential and treatment planning should be individualized to the patient's functional, structural, and psychosocial needs for effective multidisciplinary management. Recent evidence increasingly points to integrated rehabilitation strategies that involve conservative dental treatment, physiotherapy, behavioural interventions and psychosocial support, in order to achieve the best possible results in patients with craniomandibular dysfunction over the long term.

CLINICAL OUTCOMES

Clinical outcomes are used to assess the effectiveness of rehabilitation strategies for craniomandibular dysfunction (CMD) and temporomandibular disorders (TMD). The goals of successful treatment are to alleviate pain and to achieve a functional, more stable, and high quality of life. Pain level and functionality improvement, mandibular ROM, quality of life, long-term stability, and recurrence rate are common measures used to evaluate outcomes.

Pain Reduction: The main aim of rehabilitation in CMD is to reduce pain. Conservative treatments include occlusal splints, physiotherapy, manual therapy, biofeedback, and behavioral interventions, which all help to decrease muscle tension and improve function to reduce muscular and joint pain. Commonly, pain is measured with the Visual Analog Scale (VAS) or the Numeric Rating Scale (NRS). While there are improvements sometimes reported, results can be different, especially for people with chronic pain and central sensitization.

Functional Improvement: Better jaw function is one of the very important signs of treatment success. Rehabilitation can improve chewing, speaking, mandibular coordination and oral functioning. Physiotherapy, occlusal correction, orthodontic treatment and posture rehabilitation help improve muscular coordination and decrease the functional limitations. Functional outcome is typically evaluated by patient completed questionnaires like the Jaw Functional Limitation Scale (JFLS).

Range of Motion: An important goal in rehabilitation is to increase ROM of the mandible. Common symptoms of CMD patients include limited mouth opening and jaw movement because of pain, muscle spasm or joint dysfunction. Stretching exercises, manual therapy and joint mobilization techniques are an excellent way to increase mandibular mobility. A conservative approach is often associated with clinical findings of an increased opening and better jaw excursions.

Quality of Life: CMD can cause problems in terms of comfort, emotions, sleep and social functioning. Rehabilitation is effective at reducing pain, restoring function and addressing psychological factors (stress and anxiety) that affect quality of life. Oral Health Impact Profile (OHIP) and SF-36 are widely used assessment tools for quality-of-life improvements.

Long-Term Stability: Long-term stability is defined as the maintenance of treatment effects and the prevention of symptom recurrence. Long-term results are usually good when conservative methods and patient education, along with the correction of posture, stress management and self-care strategies are used. Multidisciplinary treatment and early diagnosis are key to the sustained functional improvement

Recurrence Rates; CMD is a multifactorial condition and recurrence of symptoms is common. Risk factors include parafunctional habits, stress, poor posture and psychosocial distress. Recurrence rates are reduced in multidisciplinary rehab programs that incorporate physiotherapy, occlusal therapy, behavioral modification, and patient education. Continuous monitoring and self-management strategies help maintain long-term treatment success.

CURRENT CONTROVERSIES AND LIMITATIONS

There have been a number of controversies and gaps in understanding regarding craniomandibular dysfunction (CMD). The connection between occlusal and postural disorders and temporomandibular disorders (TMD) remains controversial, with some studies suggesting a causal link while others find no evidence. Despite the efforts of diagnostic systems like RDC/TMD and DC/TMD, diagnostic procedures, patient selection, and outcome assessment still differ across studies, which makes it difficult to compare. Treatment outcomes for CMD are variable because it is a heterogeneous condition with muscular, joint, neurological, and psychosocial factors. Several studies are limited by small sample sizes, short follow-up times and poor control groups. In addition, there could be placebo effects and natural fluctuations in symptoms that affect the results of treatment. Available evidence now points to a multifactorial biopsychosocial approach, which implies that structural, neuromuscular, behavioral, and psychological factors interact to produce CMD. Hence, more high quality longitudinal studies are required to better understand the mechanisms of disease and to improve rehabilitation approaches.

FUTURE DIRECTIONS

Advanced diagnostics, precision rehabilitation, and personalized treatment approaches are expected to be future areas of research in CMD. Artificial intelligence (AI) could improve diagnosis by analyzing imaging, occlusion, jaw motion, and patient-reported symptoms, as well as helping to predict treatment outcomes and identify patients who are at risk for chronic pain. New technologies in digital occlusal analysis, such as computerized bite-force assessment and dynamic occlusal mapping, could help with treatment planning and monitoring. Continuous real-world assessment of jaw movement, muscle activity, posture, and sleep bruxism could be facilitated by the use of wearable sensors to assist with behavioral interventions. Rehabilitation in future will likely be individualized, incorporating biomechanical, neuromuscular, psychological and genetic elements. Multidisciplinary strategies that incorporate behavioral therapy, orthodontics, and digital technologies with physiotherapy can enhance long-term treatment success and decrease the likelihood of recurrence by addressing each individual patient's needs. Overall, technological innovation and patient-centered care are expected to shape the future of CMD management.

CLINICAL IMPLICATIONS

This review highlights that craniomandibular dysfunction should be managed as a multifactorial condition rather than as an isolated temporomandibular joint problem. Clinicians should assess occlusion, mandibular movement, masticatory muscle tenderness, cervical posture, parafunctional habits, pain intensity, and psychosocial factors to identify the main contributors to dysfunction. The findings support the use of conservative and reversible treatment as the first-line approach. Occlusal splints, physiotherapy, manual therapy, postural correction, neuromuscular exercises, patient education, behavioral modification, and stress management may help reduce pain and improve mandibular function. The review also emphasizes the importance of multidisciplinary care. Dentists, physiotherapists, orthodontists, psychologists, and pain specialists may need to work together, especially in chronic or recurrent cases. Irreversible occlusal procedures or surgical interventions should be considered cautiously and only after comprehensive evaluation. Overall, effective CMD management should be individualized, conservative, and mechanism-based, aiming to reduce pain, restore jaw function, improve quality of life, and prevent recurrence.

CONCLUSION

Craniomandibular dysfunction (CMD) is a multifaceted disorder with complex interactions that involve the temporomandibular joint, occlusal relationships, masticatory musculature, cervical spine, and the neuromuscular regulatory systems. Recent evidence increasingly suggests that changes in stomatognathic alignment can involve an interrelated, biomechanical, neurological, postural and psychosocial relationship that contributes to the development and progression of temporomandibular disorders (TMDs). The combination of malocclusion, muscular dysfunction, cervical imbalance and parafunctional behaviours can interfere with functional harmony within the stomatognathic system, resulting in pain, limited mobility of the mandible and compromise the quality of life. The relationship between stomatognathic alignment and CMD is still debatable, despite of great research. The etiological significance of occlusal and postural abnormalities remains ambiguous due to conflicting evidence, methodological differences, and differences in diagnostic criteria. Based on this, the current understanding supports a biopsychosocial approach where structural, functional, behaviour, cultural and social factors are considered.

AUTHOR CONTRIBUTION

Author	Contribution
Dr. Taimia Tahir	Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Software, Validation, Supervision, Writing – Original Draft, Writing – Review & Editing.

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