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Recent Advancements In The Diagnostic Measures And Treatment Modalities Of TMJ Disorders

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Abstract:
The diagnosis and management of the most common cause of non-dental pain in the maxillofacial region, namely temporomandibular disorders (TMD), remains a challenge for clinicians to this day, despite extensive clinical research into the topic. This is because TMD is a broad term comprising of different conditions with complex etiologies, with symptoms that vary in intensity.[1] Numerous treatment modalities have been proposed over the years, with some becoming obsolete while others are gaining in popularity. Nevertheless, it seems that there is no single solution for every case as many different symptoms are included in TMD. Controversies exist in the literature regarding the diagnosis and the management protocol for TMD, hence the selection of treatment modality may often be largely influenced by the expertise of the treating healthcare provider.[1] In general, TMD is believed to affect anywhere between 5 and 15% of adults in the population, yet TMD related symptoms have been reported to be present in up to 50% of adults. TMD represents a significant and complex health problem, with opinions regarding the appropriate course of management often equivocal. In this review, we discuss the current concepts in the etiology and diagnosis of TMD, followed by an up-to-date management approach from a prosthodontist's perspective.[1]

Key Word: *Temperomandibular disorders, diagnosis, Treatment modalities, Recent advances*

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I. Introduction

The diagnosis and management of the most common cause of non-dental pain in the maxillofacial region, namely temporomandibular disorders (TMD), remains a challenge for clinicians to this day, despite extensive clinical research into the topic. This is because TMD is a broad term comprising of different conditions with complex etiologies, with symptoms that vary in intensity. Intriguingly, some signs and symptoms resolve spontaneously even without treatment, whereas others persist for years despite all treatment options having been exhausted. More perplexing is that while some may have a recognizable physical basis, many cases of TMD also involve a significant biopsychosocial component with various associated psychological symptoms, such as depression and anxiety. Numerous treatment modalities have been proposed over the years, with some becoming obsolete while others are gaining in popularity. Nevertheless, it seems that there is no single solution for every case as many different symptoms are included in TMD. Controversies exist in the literature regarding the diagnosis and the management protocol for TMD, hence the selection of treatment modality may often be largely influenced by the expertise of the treating healthcare provider.[1]

In general, TMD is believed to affect anywhere between 5 and 15% of adults in the population, yet TMD related symptoms have been reported to be present in up to 50% of adults. Interestingly, there is evidence that the prevalence of TMD appears to be on the rise in recent years. A recent systematic review and meta-analysis in 2021 concluded that the prevalence of TMD was 31% for adults and 11% for children and adolescence. The fact that TMD encompasses a broad assortment of clinical diseases is partially responsible for the wide range of prevalence rate estimates among studies, as the classification of different types of TMD, the distinction between disease and non-disease, as well as whether to include those with inactive disease as having TMD, may all be subject to the partialities of the assessing clinical researchers. In addition, studies that are questionnaire-based might over-estimate the prevalence of TMD, as the symptoms of many other conditions, such as headache not caused by TMD, dental pain, neuropathic conditions, and otological diseases, can mimic the presentation of TMD.[1]TMD represents a significant and complex health problem, with opinions regarding the appropriate course of management often equivocal. In this review, we discuss the current concepts in the

etiology and diagnosis of TMD, followed by an up-to-date management approach from a prosthodontist's perspective.

II. Temperomandibular Joint Examination

Clinical evaluation begins by observing the patient's natural movements. The evaluation includes the observation of the symmetry of the face and the movements of TMJ as well as when the pain appears (at which articular degree of opening or closing and accessory movements), and the entity of the pain and if a joint sound appears.[2]

The muscles are palpated (internally and externally), the presence of enlarged submandibular lymph nodes is also checked by palpation. Next comes testing the strength of the muscles, individually, and during complex movements. The operator passively moves the jaw, using a glove, to evaluate the TMJ ligament apparatus. We look inside the mouth to check for anatomical anomalies. The fingers are placed on the joint while the patient opens his mouth to evaluate further anomalies. Always with the fingers in support of the TMJ, it is asked to pull out the tongue, turn and flex/extend and incline the neck, during the opening of the mouth; this is to verify any accentuations of TMJ dysfunction, in association with other muscle-joint districts.

Some tools can improve the measurement of the ROM of the mouth, such as the Boley gage and the therabite range of motion scale. These evaluations have their basis in the research diagnostic criteria for temporomandibular disorders (RDC/TMD), updated to 2016. In children with a type II class, they have a higher percentage of TMJ dysfunction; this dysfunction in the growth phase will result in an asymmetry of the mandibular branch begin by inspecting the preauricular area for swelling or erythema. Palpate directly over the joint while the patient opens and closes the mandible, and the extent of mandibular condylar movement can be assessed. Normally, condylar movement is easily felt. Have the patient close slowly, and you will feel the condyle move posteriorly against your finger. Tenderness elicited by this maneuver is invariably associated with articular inflammation. Palpate the superficial temporal artery for nodularity and tenderness.[2]

Palpate the masticatory and cervical muscles and search for areas of tenderness or sustained contraction. Begin with the sternocleidomastoid, trapezius, and posterior cervical muscles. Palpate the masseter at its attachments to the zygomatic arch and angle of the mandible, the temporalis both in the temporal fossa and intraorally along the ascending ramus of the mandible, and the medial pterygoid bimanually, placing one finger externally at the medial aspect of the angle of the mandible and the other finger orally in the lingual vestibule in the retromolar region. The lateral pterygoid is accessible to the examining finger intraorally posterior to the maxillary tuberosity. Areas of identified muscle spasm or tenderness can be injected with local anesthesia, 2% lidocaine or 0.5% bupivacaine without epinephrine, or can be sprayed with fluoromethane or ethyl chloride to determine if these areas are the cause of the patient's symptoms.

Examine the external auditory canal and tympanic membrane with the otoscope and do tuning fork tests to rule out ear pathology, particularly important in patients who complain of hearing changes in association with TMJ symptoms. An audiogram may be indicated if hearing loss is suspected.

The joint is auscultated during mandibular motion. The normal joint functions relatively quietly. Listen for crepitus or grinding and clicking or popping sounds[2] .The degree of mandibular opening is measured using the distance between the incisal edges of upper and lower anterior teeth. Opening of less than 35 mm is considered abnormal in an adult. There is no upper limit of normal, but few patients can exceed 60 mm comfortably. Observe the opening pattern for deviation. The mandible often deviates toward the affected side during opening because of muscle spasm or mechanical locking by a displaced meniscus.

Examine the hands for signs of systemic disease (e.g., Heberden's modes of osteoarthrosis, ulnar deviation of rheumatoid arthritis), which may also involve the TMJ. Laboratory tests (e.g., complete blood count, erythrocyte sedimentation rate, rheumatoid factor, antinuclear antibody, serum uric acid) are helpful when a systemic cause for TMJ disease is suspected. Radiographs provide useful information about bony architecture of the joint and movement of the condyles during mandibular opening. Lateral transcranial films display the anteroposterior contour of the bony joint structures, whereas transpharyngeal or transorbital x-rays show mediolateral condylar anatomy. Tomograms or a computed tomographic scan determine the extent of a joint ankylosis or tumor. Arthrography or magnetic resonance imaging (MRI) is helpful in determining the position, movement, and integrity of the meniscus.

Instrumental assessments are critical to a safe diagnosis and are necessary before taking a therapeutic approach to a TMJ in dysfunction. Panoramic radiography. Allows evaluation of the mandibular condyles corresponding glenoid fossa relationship. Multi-slice computed tomography or cone-beam computed tomography. To evaluate the morphology of the components that make up TMJ, as well as bone position and pathologies. Magnetic resonance image. It is possible to observe the condition of the articular disk, anatomy, function, and form.[2]

III. Conventional Diagnosis Methods

Most clinicians who treat orofacial pain believe clinical examination is the most crucial process of diagnosing TMD. The location of pain, and whether the pain is localized, remains within or spreads beyond the confines of the muscle, should be confirmed with palpation, which is done at rest and during mandibular function. Clicking or crepitus upon mandibular function might be quite obvious in some cases, and the detection might be aided by the use of a stethoscope. Intriguingly, the presence or location of clicking detected by the clinician might be different from that reported by the patient, and this should be documented. The range of mouth opening measured should include pain-free maximum mouth opening, maximum unassisted mouth opening, and maximum assisted mouth opening. Any deviation of the mandible may indicate differential obstruction of the movement of the mandibular condyle in rotation and/or translation. An intra-oral examination is performed to rule out any mucosal pathologies of the oral cavity and oropharyngeal region, as well as to assess the state of the dentition.[1]

1.History and physical

The clinician should perform a thorough medical and dental history emphasizing the location, onset, and characteristics of pain, aggravating and relieving factors, past treatments, and history of other pain disorders.

Recommended Systematic and Psychological Assessment

Temporomandibular disorder symptoms include pain, TMJ clicking and crepitation, and different levels of mandibular limitation. The pain is typically provoked by function; spontaneous pain in the TMJ area suggests a different etiology. Pain can refer to the neck and scalp and tends to be exacerbated by masticating, yawning, or talking for long periods. A click, crepitus, or pop when opening or closing the mouth may be associated with anterior disc displacement or osteoarthritis. Patients with TMD also report headaches and otological symptoms – otalgia, tinnitus, vertigo, aural fullness, and subjective hearing impairment. However, otological symptoms are more common in myofascial disorder, which is believed to be due to the shared embryological origin of some middle ear structures and masticatory muscles. [1]The physical examination should also search for signs of tooth wear, bruxism, abnormal mandibular movements, tenderness of muscles of mastication, neck, and shoulder, pain with dynamic loading, and postural asymmetry. A neurological examination rules out cranial nerve abnormalities. Careful palpation of masticatory muscles and surrounding neck muscles helps identify trigger points, myospasm, and referred pain syndrome.

2.Pain

Pain from the TMJ and muscles of mastication is a common symptom. It can be a constant or periodic dull ache over the joint, the ear, and the temporal fossa. It is more commonly observed during mandibular movement or palpating the affected regions. The pain can be myogenic, caused by mechanical trauma and muscle fatigue. Articular pain arises from overloading, trauma, or degenerative changes of articular and periarticular tissues.

3.Joint Sounds

A clicking, crepitus, or locking of the TMJ may accompany joint dysfunction. A single click during opening of the mouth may be associated with an anterior disk displacement. A second click during closure of the mouth results in recapture of the displaced disk; this condition is referred to as disk displacement with reduction. When disk displacement progresses and the patient is unable to fully open the mouth i.e., the disk is blocking translation of the condyle), this condition is referred to as closed lock. Crepitus is related to articular surface disruption, which often occurs in patients with osteoarthritis

4.Limitation of Mandibular Movement

Movement limitation can occur in opening, closure, protrusion, and lateral excursion of the mandible. It can be due to muscular or ligamentous restriction or disc displacement.

5.Dislocation

It is the condyle displacement from the fossa, and the patient may be unable to close the mouth. The patient can reduce the dislocation himself or report to the clinician for reduction

6.Otologic Symptoms

TMJ pain in the auricular regions is more noticeable posteriorly. Tinnitus, itching in the ear, and vertigo are other symptoms associated with articular pain.

7.Recurrent Headaches

Patients perceive the pain and tenderness of masticatory muscles along the temporal region as headaches. It can correlate with other headaches, such as migraine pain.

8.Imaging investigations

Imaging is considered to be a useful adjunct in the diagnosis of TMD. Although the diagnostic information provided by plain radiographs like orthopantomogram is limited, they are convenient, simple and serve to rule out some of the differential diagnoses of the bony TMJ, such as fractures, ankylosis, growth disturbances, as well as neoplasms. For the most common types of TMD which clinical presentation is typical, many units might not routinely employ additional imaging. This is due to availability and cost, and that additional imaging might not alter the initial management plan. However, when further information is desired, magnetic resonance imaging (MRI) is the gold standard for TMJ imaging, and is useful in assessing the status of the osseous, as well as the non-osseous structures of the TMJ, such as the masticatory muscles, ligaments and the cartilaginous disc. Classification systems, such as Wilkes, combine clinical and MRI findings to stage the extent of internal derangement in order to guide treatment protocol. MRI is therefore considered mandatory prior to any surgical intervention.[1]

IV. Recent Advances In Diagnostic Measures

Computed tomography

Computed tomography (CT) plays a valuable role in the evaluation of temporomandibular joint (TMJ) disorders, particularly for assessing bony structures and adjacent soft tissues.

Evaluation of bony elements: CT is well-suited for assessing the bony components of the TMJ, including the condyle, mandibular fossa, and articular eminence. It provides detailed information about fractures, degenerative changes, erosions, and congenital anomalies of the TMJ.[3]

Soft tissue assessment: In addition to bony structures, CT can also visualize adjacent soft tissues, such as the disc, muscles, and ligaments surrounding the TMJ. This can be helpful in detecting soft tissue abnormalities, such as disc displacement or inflammation. CT allows for three-dimensional reconstructions of the TMJ, which can provide additional information for assessing congenital anomalies, fractures, and postsurgical changes. These reconstructions offer enhanced visualization and understanding of complex anatomical structures. CT is often recommended when there is a suspicion of bony involvement based on clinical assessment or when primary bony pathologies are suspected. It may be performed following MRI to complement the assessment of bony structures.

CT offers several advantages over MRI in TMJ imaging, including superior visualization of bone details and the ability to perform detailed 3D assessments of congenital, traumatic, and postsurgical conditions. However, it's important to consider factors such as radiation exposure and the need for contrast agents when choosing between imaging modalities. Overall, CT is a valuable tool in the evaluation of TMJ disorders, providing essential information about bony and soft tissue abnormalities to aid in diagnosis and treatment planning.[3]

Cone beam computed tomography [CBCT]

CBCT offers superior diagnostic quality, reduced radiation dose, and cost-effectiveness compared to conventional CT when imaging the maxillofacial region. Its focused imaging capabilities and isotropic voxel resolution make it an invaluable tool for clinicians in the field of dentistry and maxillofacial surgery. CBCT is widely used in dentistry and maxillofacial surgery for various diagnostic and treatment planning purposes, including the assessment of dental implants, evaluation of TMJ disorders, detection of dental pathology, and surgical guidance for orthognathic surgery and implant placement.[4]

Magnetic resonance imaging [MRI]

MRI provides excellent soft tissue contrast, allowing for detailed visualization of both the bony and soft tissue components of the TMJ. This high resolution enables clinicians to assess the joint's anatomy, including the articular disc, cartilage, ligaments, and surrounding muscles. MRI allows imaging in multiple planes, which is particularly advantageous for evaluating the complex anatomy of the TMJ. Clinicians can obtain images in sagittal, coronal, and axial planes, enabling comprehensive assessment of the joint and surrounding structures. Dynamic MRI sequences, such as cine MRI or functional MRI, allow visualization of the joint in motion during activities like opening and closing the mouth.MRI is particularly useful for detecting and characterizing soft tissue pathology in and around the TMJ, such as disc displacement, joint effusion, synovitis, and muscle abnormalities.[5]

Jaw bone scan using radionucleotide

Radionuclide bone imaging has been a cornerstone in nuclear medicine departments for diagnosing various bone pathologies. Over the years, the choice of tracer for bone imaging has evolved, with different radiopharmaceuticals offering unique advantages.evaluation of bone metastases, assessment of skeletal disorders such as Paget's disease and osteomyelitis, and monitoring response to therapy in conditions like bone tumors and osteoporosis.Overall, the evolution of bone imaging tracers from ^87mSr to ^99mTc-polyphosphate and, more recently, to ^18F-fluoride reflects advancements in nuclear medicine technology and the ongoing quest for improved diagnostic accuracy and patient care in the evaluation of bone disorders.[6]

Bite force and tooth contact measurement sensors

Various sensitive electronic devices are utilized to measure bite force accurately. These devices rely on pressure sensors to convert the force exerted during biting into electrical signals.

Strain gauge transducers: Strain gauge transducers are one of the most common types of pressure sensors used in bite force measurement devices. These sensors consist of thin metal foil or wire grids that deform when subjected to force, resulting in changes in electrical resistance. The amount of resistance change is proportional to the applied force, allowing for accurate measurement of bite force.

Piezoelectric transducers: Piezoelectric transducers utilize piezoelectric materials that generate an electrical charge when subjected to mechanical stress or pressure. When a force is applied to the sensor, it generates a voltage signal proportional to the applied force. Piezoelectric transducers offer high sensitivity and fast response times, making them suitable for dynamic bite force measurements.

Piezoresistive transducers: Piezoresistive transducers are made of materials whose electrical resistance changes in response to applied pressure. When a force is exerted on the sensor, the resistance of the material changes, resulting in a corresponding change in electrical output. Piezoresistive transducers are known for their high sensitivity and low noise performance, making them suitable for precise bite force measurements.

Pressure transducers: Pressure transducers, also known as capacitive pressure sensors, utilize changes in capacitance to measure pressure. These sensors consist of two parallel plates separated by a dielectric material. When a force is applied to the sensor, the distance between the plates changes, resulting in a change in capacitance. This change in capacitance is converted into an electrical signal proportional to the applied force.[7]

Computerized electro diagnostics

Computerized electro-diagnostics have indeed emerged as a sophisticated approach in the assessment and management of temporomandibular joint (TMJ) disorders (TMD). By harnessing advanced technologies, these techniques offer several advantages in accurately defining, diagnosing, and treating TMJ-related conditions.

Mandibular jaw tracking: Mandibular jaw tracking, first introduced in 1971, involves the use of computerized systems to monitor and record the movement of the mandible in three dimensions. This technique allows clinicians to analyze parameters such as range of motion, condylar path movements, and mandibular trajectory deviations, providing valuable information for diagnosing TMJ disorders and evaluating treatment outcomes.

Surface electromyography (sEMG): Surface electromyography, introduced in the 1980s, is indeed a valuable tool in maxillofacial orthopaedics for diagnosing and treating patients with temporomandibular disorders (TMD) and assessing stomatognathic system dysfunctions in individuals with malocclusions.It involves the placement of electrodes on the surface of the skin to measure the electrical activity of masticatory muscles during rest and functional activities. sEMG provides objective data on muscle activity patterns, muscle imbalances, and muscle fatigue, helping clinicians assess muscle function and identify abnormalities associated with TMJ/TMD.

Electrosonography: Electrosonography, developed in 1987, combines ultrasound imaging with electromyography to evaluate the TMJ and surrounding structures. This technique allows for real-time visualization of joint morphology, disc position, and muscle activity during jaw movement, providing valuable diagnostic information for TMJ/TMD assessment.[8]

Jaw vibration analysis

Joint Vibration Analysis (JVA) is indeed a valuable diagnostic tool used in the assessment of temporomandibular joint (TMJ) function and health. This computerized process involves recording vibrations bilaterally from the TMJs and analyzing these vibrations using specialized software to provide insights into the TMJ's condition. Here's an overview of how JVA works:

Recording of vibrations: During a JVA assessment, sensors are placed bilaterally over the TMJs to record vibrations emitted during jaw movement. These sensors may be in the form of accelerometers or piezoelectric sensors, which detect and measure the vibrations generated by the TMJs.

Processing of vibrations: The recorded vibrations are then processed using specialized software to analyze their frequency, amplitude, and other characteristics. This processing helps to identify any abnormal patterns or deviations in the TMJ vibrations that may indicate dysfunction or pathology.

Diagnostic indicators: JVA software typically provides diagnostic indicators based on the analyzed vibrations. These indicators may include parameters such as vibration energy, frequency spectrum, and symmetry between the left and right TMJs. Deviations from normal values or patterns in these indicators can suggest TMJ dysfunction or damage.

Integration with clinical assessment: JVA is often used in conjunction with other clinical assessments, such as physical examination, medical history, and imaging studies, to provide a comprehensive evaluation of TMJ health. The information obtained from JVA helps clinicians make informed decisions regarding diagnosis and treatment planning for TMJ disorders.

Range of motion measurement: As part of the JVA assessment, the range of motion (ROM) of the jaw is typically measured. Any deflection observed during maximum opening, such as 3 mm or more, may indicate joint dysfunction or pathology. This measurement provides additional information about TMJ function and helps to identify abnormalities that may warrant further investigation. Overall, Joint Vibration Analysis (JVA) is a valuable tool in the assessment of TMJ function and health, providing objective data that can aid in the diagnosis and management of TMJ disorders. By recording and analyzing TMJ vibrations, JVA helps clinicians identify abnormalities and deviations from normal function, allowing for more targeted and effective treatment strategies.[9]

Ultrasound

Ultrasonography (US) has emerged as a valuable diagnostic tool for evaluating temporomandibular joint (TMJ) effusion, with several studies demonstrating its efficacy compared to MRI, which is considered the gold standard technique. Specifically, this method has been found to be particularly reliable when measuring capsular width, especially when it exceeds approximately 1.950 mm in the adult population. Studies have identified a critical TMJ capsular width of around 2 mm, which serves as a threshold for detecting effusion using US. This critical width is important for ensuring interobserver reliability among clinicians performing US examinations of the TMJ. Furthermore, research has shown that capsular width is not only useful for diagnosing effusion but also serves as a risk factor for TMJ pain when adjusted for other confounding factors. This underscores the clinical significance of accurately measuring capsular width using US and correlating it with patient symptoms and outcomes. Overall, US is an effective and reliable tool for diagnosing TMJ effusion, particularly when assessing capsular width. Its ability to provide accurate measurements and its correlation with clinical symptoms make it a valuable asset in the evaluation and management of TMJ disorders.[10]

T-SCAN

The T-scan occlusal analysis system is a quantitative tool that provides objective measurements of occlusal parameters, allowing for a more comprehensive assessment of occlusion compared to qualitative methods. Unlike traditional qualitative indicators such as articulating paper or silk, which rely on visual inspection of marks left on the teeth, the T-scan system utilizes electronic sensors and software to precisely record the timing, force, and distribution of occlusal contacts during various functional tasks such as chewing and biting. The T-scan system consists of a thin sensor pad that is placed between the patient's dental arches. As the patient bites down, the sensor records the occlusal forces and timing of contacts, which are then displayed graphically on a computer screen. This information allows clinicians to identify premature contacts, occlusal imbalances, and areas of excessive force, which may contribute to occlusal instability or TMJ dysfunction.[11]

Novel artificial neural network

AI technology has shown great promise in various areas of medicine, particularly in the diagnosis and management of life-threatening conditions such as cardiovascular disease and cancer. AI algorithms can analyze complex medical data, including imaging studies, laboratory results, and patient history, to assist healthcare professionals in making more accurate and timely diagnoses, predicting disease progression, and personalizing treatment plans. The integration of AI into TMD care has the potential to enhance diagnostic accuracy, improve

treatment outcomes, and optimize patient management strategies. By leveraging advanced computational techniques and analyzing diverse datasets, AI can provide valuable insights into TMD pathophysiology, guide personalized treatment approaches, and ultimately improve the quality of life for TMD patients.[12]

Thermovision

Thermography has emerged as a potential diagnostic tool in temporomandibular joint dysfunction (TMD), although research in this area has been relatively limited. In a study by Wozniak et al. [35], conducted between 2014 and 2019, the sensitivity, specificity, and accuracy of thermography in identifying the degree of dysfunction in TMD patients were assessed. Here's a summary of the methodology employed in the study: Thermal Imaging Procedure: Facial and neck thermograms were captured using a thermal imaging camera, with projections taken from both the right and left sides under constant test conditions.

Automatic Calibration Tools: The study utilized automatic calibration tools during the tests to optimize the level and range of displayed temperatures, as well as the color palette and contrast in all image areas. This ensured consistency and accuracy in thermal image capture.

Quantitative Analysis: Quantitative analysis of thermograms was performed in selected areas of the face and neck, which were marked with tools in a 1 cm diameter circular area. This allowed for precise measurement and comparison of temperature variations in specific regions of interest.

Individual Image Analysis: Due to the possibility of displacement of individual thermograms of the examined subjects, each image was analyzed individually. Corrections were made as necessary to ensure accurate interpretation of temperature data.

Assessment of Sensitivity, Specificity, and Accuracy: The sensitivity, specificity, and accuracy of thermography in identifying the degree of dysfunction in TMD patients were evaluated based on the quantitative analysis of temperature data obtained from thermal images. By employing standardized imaging protocols, automatic calibration tools, and quantitative analysis techniques, researchers were able to assess the utility of thermal imaging in identifying TMD-related temperature variations in the facial and neck regions. Further research in this area may help elucidate the role of thermography in TMD diagnosis and treatment planning.[13]

3D electromagnetic articulography technique

3D electromagnetic articulograph is utilized to record mandibular border and functional movements. This device is designed to accurately capture the movements of the mandible in three-dimensional space using electromagnetic sensors. The recording protocol applied in the study was based on the methodology developed by Fuentes et al., which likely includes specific instructions for sensor placement, calibration, and data acquisition to ensure accurate and reliable measurements. The mandibular border movements recorded during the study were based on the classifications proposed by Okeson, a renowned expert in temporomandibular disorders (TMD). Okeson's classifications categorize mandibular movements into various types, such as protrusion, retrusion, lateral excursions, and opening and closing movements, which are essential for evaluating jaw function and diagnosing TMD.

It's important to note that each clinical examination and experimental procedure was carried out by the same researchers (M.F.L., P.C.), ensuring consistency and reliability in data collection and interpretation. This practice helps minimize potential variability and bias in the study results, enhancing the validity of the findings. Overall, the use of the 3D electromagnetic articulograph and adherence to standardized recording protocols and classifications contribute to the rigor and precision of the study's methodology, providing valuable insights into mandibular movements and their relationship to temporomandibular disorders.[14]

V. Treatment/Management

Only 5% to 10% of patients require treatment for TMD, and 40% of patients have spontaneous resolution of symptoms. In a long-term follow-up study, 50% to 90% of patients had pain relief after conservative therapy. A multidisciplinary approach is successful for the management of TMD. Initial treatment goals should focus on resolving pain and dysfunction. [46]

Conservative treatment

Therapeutic exercises

The most important stage of a treatment protocol is education with cognitive awareness training and relaxation therapy as well as self-observation that should be completed by patients with masseter hypertrophy, tension-type headaches or bruxomania (the grinding of teeth occurring as a neurotic habit during the waking state). It is important to explain to the patient the background of the disorders (especially the role of one's emotional stress) and warn about habitual parafunctional activities (e.g., nonfunctional tooth contacts or oral mucosa biting). The patient should be aware of what he or she does with their teeth, and when they fall into bad

habits, try to eliminate that habit. Muscular training is the primary mode to achieve muscle restoration, especially after traumas and injuries. It is thought to be the most conservative treatment as well as the simplest and most non-invasive method of TMD treatment. In patients with severely expressed asymmetries and symptoms, exercises to restore the muscular equilibrium seem to be the only proper route of treatment. Muscular therapy must be restrictive; it should be carried out moderately, and the intensity should be increased with time to avoid aches and patient discouragement from the suggested treatment. In this situation, muscular therapy is effective in 70 % of suffering patients.[15]

In some cases, such as patients with muscular or joint (muscular or arthritis pain) pain, the mouth opening is limited, and therefore, therapy is less effective. The exercises can require stretching, relaxation and isometric movements that should be performed routinely to eventually lead to a shortening of the excessively expanded muscles or to a restoration of the full length of the shortened muscles. Additionally, the natural tension and symmetric jaw movement can be restored. The training is underdone to correct the mobility of the mandible. To strengthen the muscles and to acquire balance between the left and right sides, opening the mouth along a straight line in front of the mirror is recommended. The resistance is acquired from the gentle pressure of the patient's fingers to the mandible. The exercises are repeated in sets of 15 to 20 repetitions, 2 to 3 times a day. The improvement should be observed after 6 weeks. Research from Bae and Park showed that active and relaxation exercises could improve the limited range of motion, deviation and pain in masticatory muscles. For muscle relaxation, they recommend putting the front one-third of the tongue on the anterior part of palate and applying a light force to the tip of the tongue so it does not touch the teeth, having the patient maintain this position as long as he/she can withstand (3 times over a period of 4 weeks, 10 min each time). In case of too wide of a mouth opening, or excessive mobility of the jaw and mandible deviation during opening (with excluded suspicion of subluxation), the exercises are limited, and straightening of the opening pathway are recommended. The exercise involves opening the mouth with the tip of the tongue touching the palate (usually near the A-H line) in front of a mirror, along the straight line. It is recommended to maintain the contraction of the tongue muscles for two seconds during mouth opening. The exercises should be repeated 2 to 3 times a day, 15 to 20 repetitions each.[16]

Occlusal splint therapy

To achieve the proper relation of the jaw, centric relation (CR) should be restored. It is easily performed by occlusal splints. An occlusal appliance is any removable artificial occlusal surface used for diagnosis or therapy affecting the relationship of the mandible to the maxillae. Occlusal appliances may be used for occlusal stabilization, for the treatment of temporomandibular disorders, or for the prevention of dentition wear. Occlusal splints are used in a vast majority of patients with TMDs to restore the static and dynamic symmetry of the stomatognathic system. Most commonly, they are used in cases with disc displacement. The splints are fabricated individually by an experienced team consisting of a dentist and technician. One of the most popular occlusal splints is the Michigan-type bite splint, precisely described by Ramfjord and Ash Jr. This splint could be used in both dental arches, but preferably in the maxilla. The mandibular splint is used when the posterior area is missing teeth in the mandible and unwanted tooth movement must be avoided.[16]

The main purpose of this device is to disengage the occlusion, place the condyle in the centric position, relax the masticatory muscles and prevent further tooth wear due to nocturnal parafunctional activity. The main features of this splint are freedom in centric and canine guidance. It is important to note that the relation of the maxillary and mandibular arches may differ after the treatment when compared to the initial state, especially when partial coverage splints are used. After the Wieckiewicz et al. The Journal of Headache and Pain (2015) 16:106 Page 3 of 12 replacement of the mandible, the condyles are replaced, and consequently, the mandible is positioned properly and the pain is reduced. Walczynska-Dragon and Baron have proven that occlusal splint therapy using the SVED (Sagittal Vertical Extrusion Device) appliance decreases not only aches in the head and all parts of the spine but also disc displacements within 3 weeks of treatment. The next decrease in frequency of unwanted, unfavorable symptoms was observed after 3 months of treatment with splints. When properly performed, these splints also unblock a limited mouth opening. The occlusal splints are also used in the initial phase of treatment in patients with mouth overclosure caused by a pathologic deep bite. Before the prosthetic rehabilitation of the severe tooth wear, one should remember that initially, splint therapy should be applied to adapt the stomatognathic system to the new occlusion. Beside occlusal splint therapy subsequently selective grinding of the teeth to restore physiological and/ or proper and /or balanced occlusal support is required in some cases.[16]

Massage therapy

Myofascial pain is a common symptom of TMD – it is often associated with the clenching of teeth, grinding and stress. TMD myofascial pain occurs in 31 to 76 % of the population; it can be relieved by massage therapy, which leads to re-establishing the proper flexibility and muscular length and relieves pain. The

massage therapy for TMD might be divided into effleurage, kneading, friction, stretching and petrissage, leading to the permanent adaptation of the muscles. Massage reduces tissue swelling as well as pain in TMD patients. The pressure used during massage must not be too intense and should increase over time at each therapeutic session because therapy performed too strongly may lead to increased muscular tonus. Massages should be performed twice a week, with a minimum of 30 min for each session. It takes at least 8 therapeutic sessions to receive true relief. In addition to the local influence, massage leads to the relaxation of the entire body and reduces stress, thus improving the patient's mood; it reduces tension headaches and muscle aches, restores equilibrium between the masseter tension, and improves mastication. The physiotherapist may also recommend heating or cooling of the affected muscles. To restore the accurate function of the TMJ, changes in daily habits is important. The change of food consistency (eating softer foods), applying cold or heat, and avoiding extreme movements of the mandible (chewing gum, wide yawning or loud singing) might be enough to decrease TMD symptoms. In this situation, counselling, behavioural therapy and stress management should also be applied to decrease muscle hypertension and bad habits.[16]

Manual therapy

Manual therapy is similar to massage therapy, but the procedure performed by the physiotherapist is different; it refers to stimulation of the so-called "trigger points". There are two main methods of treatment by applying manual therapy: mobilization and the muscle energy technique. The mobilization technique is most commonly used in disc displacements; it involves repeated traction or sliding movements at a slow speed and with increasing amplitude. The desirable effect is to increase the limited range of motion within the joint and reduce pain. The movements are carried out perpendicularly or parallel to the plane of the treated joint, oscillating, and typically repeated 8 to 10 times in 3 sets. The procedure is performed in a seated position with the patient's head stabilized on the chest of the physiotherapist who holds the patient's head and mobilizes the mandible with one hand. Traction consists of 3 stages: relaxation (abolition of forces acting on joint), tension (remotion of the articular area) and stretch (increase in remotion of articular area).

The muscle energy technique (MET) is used when limited movements of the mandible are observed and caused by soft tissue (muscles and connective tissue) damage. The treatment involves repeating 3 phases: the first phase is making a movement that is possible due to limited tissue elasticity; in the second phase, the patient slightly tightens the muscles trying to make a move in the opposite direction of the force created by the physiotherapist and should last approximately 10 s; in the last phase, the patient relaxes the muscles. The technique can be performed both in a seated or lying position.[16]

Other physiotherapeutic techniques

Physiotherapy involves many techniques of treatment. The most common massage and manual therapies were previously described, but for TMD treatment, also other techniques are used. Among them, **biofeedback, lamp exposure, iontophoresis, ultrasound and transcutaneous electrical nerve stimulation (TENS)** are used. The purpose of biofeedback is to stimulate the muscles to work properly and achieve maximal relaxation of the muscles in a short period of time. The therapy involves electromyography to train the adequate neuromuscular tension of the patient and develops the ability to alter a physiological response. The surface electrodes are placed on the muscles (typically masseter) uni- or bilaterally; other muscles (e.g., anterior temporalis) may also be included. SEMG biofeedback may include muscle tension discrimination. The treatment protocol involves teaching the patient how to open their mouth properly to strengthen the tension of the tongue and protrude the mandible. Only after this are the electrodes applied in line with the muscle fibers (usually upon the midsubstance of the masseter muscle belly). The measurements of the minimal muscular tension are performed when the patient rests with all their muscles relaxed; this is used as a reference in the follow-up. Observing the movements and muscular tonus the patient exercises help to restore the appropriate muscular activity.[16]

Transcutaneous Electrical Nerve Stimulation (TENS) is another well-known method of pain relief for TMDs. The method is based on electrical stimulation of pain areas via surface electrodes and is considered safe and non-invasive. TENS helps to relieve chronic and acute pain in joint and/or muscle disorders. Unfortunately, due to the small number of studies (especially randomized trials), TENS cannot yet be considered a standard treatment for TMDs, as its effectiveness is still uncertain. In addition to the therapeutic value of electric potential, a tool called electromyography (EMG) is used for establishing muscular function and and is the most reliable and objective technique.[16]

For pain release, especially in subacute arthropathies and inflammatory rheumatic diseases, heat treatment is applied; it alleviates strong pain, although the result is typically short-therm. Heat is supplied either by means of Solux lamps (ca. 15 min from 20 cm distance) or through a thermophor filled with water at a temperature of 158 to 176 °F (70 to 80 °C) and wrapped with a towel. Other recommendations to decrease pain are sulfur and iodide baths**. Cryotherapy** is another form of temperature related therapy but applies cold instead

of heat. **Cold packs, cold spray or air, and ice compresses** are used as analgesic agents. The application of cold is used immediately prior to kinesiotherapy and helps fight muscle hypertension and tendinopathies as well as rheumatic diseases. One should remember that there is a high risk of frostbite (skin damage due to low temperature) with this form of therapy. The cold compresses should be applied for 10–15 min. Cryotherapy leads to the attenuation of pain, reduces stiffness in the TMJ and increases mandibular mobility.

A new method of rehabilitation with the aim of TMJ stabilization and increased jaw stability is taping, or Kinesio Taping (KT). KT also decreases drooling and provides mouth closure. To increase jaw stability, one piece of tape in a "Y"-shape cut should be prepared and placed proximal to the joint; the superior tail is shorter than the inferior tail. The superior tail should be applied diagonally along the upper jaw and directed towards the lower cheek with "paper-off" tension. The tape width should be 1.5 to 2 inches (3.8 to 5 cm). The mandible cannot subluxate at the movement. To decrease the hypermobility of the joint and release TMJ pain, two tape pieces (1 inch wide and 2 inches long each) should be placed diagonally to each other over the joint, forming an "X". To improve jaw stability, tape is usually applied to both sides. The balance in head position and body posture usually leads to a decrease in hypertension of not only the masticatory muscles but also the neck, arms and spine [58, 59]. The method is quite new but has become increasingly popular [60, 61]. The special therapeutic tape adheres to the skin with adequate flexibility and consists of a polymer elastic strand wrapped by 100 % cotton fibres. The tape allows for a normalization of muscle tone and increases the process of self-healing. KT stimulates an endogenous analgesic system and changes the subjective feelings of the patient. Alignment of muscular tone is possible by improving proprioception. KT could be applied for myofascial pain therapy in a range of masticatory muscles, especially the masseters. The clinical technique has been described by Kase et al .[16]

Pharmacotherapy and minimally invasive and invasive procedures

Pharmacotherapy for TMD is not commonly used. It is only used when other somatic symptoms, such as sleep disorders, chronic pain, arthralgias, inflammatory diseases, myalgias or neuropathies are associated with TMD. As TMD may manifest from different systemic diseases (e.g., arthritis, inflammatory bowel diseases, Parkinson disease), it is important to diagnose the patient properly and implement treatment for the underlying disease, especially when depression is a suspected diagnosis. One has to remember that pharmacotherapy has its goal in decreasing pain and inflammation within the joint and/ or muscles. This therapy improves function and inhibits the progression of the disease. [16]

Pharmacotherapy can be considered as a complementary therapy rather than a treatment itself. The exceptions are systemic diseases with TMJ involvement. For TMD release, the most commonly used medications are myorelaxants, nonsteroidal anti-inflammatory drugs (NSAIDs), analgesics, tricyclic antidepressants, benzodiazepines and corticosteroids. The first medication of choice for moderate pain relief is acetaminophen (average daily dose of 325–1000 mg). NSAIDs and analgesics help to relieve pain (including radiating pain) in the head, jaw muscles, face, neck or shoulders. A high efficiency of TMD pain relief is shown with ibuprofen* and meloxicam** (average daily dose of 400–800 mg* and 7.5–15 mg**). In this particular situation, pharmacotherapy is considered a supportive therapy that supplements other therapies. Used by itself, pharmacotherapy is considered for palliative therapy. NSAIDs decrease pain and stop the inflammatory process.

Muscle relaxants (baclofen, tizanidin, cyclobenzaprine), opiates (morphine), anticonvulsants (e.g., gabapentin), ketamine, and TCA (e.g., amitriptyline) have also been used clinically for TMJ management, but there is no evidence for their efficacy. To achieve the myorelaxation effect with low CNS impact, metaxolone is recommended (average daily dose of 800 mg). In specific cases, medications should be used admittedly. During acute spasms (sudden muscular contraction and painful shortening that is maintained over time), anesthetics are advised to block the pain and allow therapeutic stretching. Usually, the analgesic blockage with an infiltration of 1 ml of 2 % lidocaine (without vasoconstrictor) in the involved muscle is applied. A complementary therapy may include dypirone 500 mg (also in association with a myorelaxant, such as orfendrine, if necessary) 3 times a day, for 2 days. In this situation, 90 % of cases require analgesic therapy.

In myositis and other inflammatory disorders, the most appropriate strategy is the administration of one dose of corticosteroid intramuscularly. Another approach is the injection of an analgesic or anti-inflammatory agent. The most common injections contain corticosteroids (with anti-inflammatory action) or hyaluronic acid. In animal models, the use of an inhibitor selective for the inducible COX-2 enzyme may attenuate the neurogenic component of inflammation. COX enzymes are blocked by NSAIDs. Unfortunately, those medications have a high risk of adverse side effects, which may include exacerbation of hypertension or gastrointestinal upset that may lead to ulcerations. COX-2-selective NSAIDs (eg. Celecoxib, Meloxicam) which have less side effects, are not found to be better for the treatment of TMD. There is a hope that lotions containing NSAIDs will not have as many side effects and will have a positive impact on relieving pain.

In chronic facial pain, aside from pain relievers, antidepressants should be used as a supplementary treatment. Antidepressants may be used for chronic pain as a primary analgesic. These medications manage

headaches and neuropathic pain, reducing the feeling of depression caused by pain and improving sleep quality. It had been proven that NSAIDs relieve pain in patients who suffer from arthritis. In this situation, diclofenac at a maximum dose of 50 mg orally 3 times daily or naproxen sodium 500 mg twice a day are recommended, as they improve pain in more than half of the patients. It had been shown that the use of antibiotics, such as doxycycline or other tetracyclines, could help prevent condylar resorption. Regardless of their antibiotic activity, antibiotics inhibit matrix metalloproteinases (MMPs), whose levels are elevated in inflammatory processes involving TMJ. Doxycycline is also a medication of choice in patients who undergo orthognathic surgery to avoid the resorption process.

For anxiety treatment and stress relieve, benzodiazepine (eg. Diazepam 5 mg, Lorazepam 1 mg or Alprazolam 0.5 mg) for 5–10 days should be prescribed. Clinical investigations by Bakke et al. and Emara et al. confirm the possibility of applying botulinum toxin type A (BTX-A) for the treatment of disc displacements using injections in the lateral pterygoid muscles. BTX-A decreases myofascial pain and symptoms in the bruxers by reducing muscle tension. Botulin is a biologic neuromuscular blocking agent that works as a muscle relaxant and therefore relieves pain in the head and neck; it also decreases neuromuscular tonus and bruxing at night. Hypertrophic masseter muscles activity is also reduced. Due to the large scope of BTX-A, it can be used in various temporomandibular disorders, such as bruxism, oromandibular dystonia, myofascial pain (also including TMJ involvement), trismus, hypermobility, masseter or temporalis hypertrophy, headaches and neck pain.[16]

Acupuncture

A common method frequently used in Asian countries is a needle puncture, also known as acupuncture. This method is also gaining popularity in western countries. Acupuncture originated in China over 3,000 years ago. A skilled acupuncturist restores whole body balance and the flow of energy within it (called Qi) to relieve a patient's pain and to improve the inflammatory process within the joint and decrease hypertension. The method is more successful in patients who change their dietary habits (soft food, avoidance of chewing gum, less saturated fats, coffee and fried foods in the diet). Interestingly, acupuncture is very successful in long-term follow-ups (18–20 years). There are several recommended acupuncture points (e.g., SI-18, GV-20, GB-20, ST-6, ST-7, BL-10 and LI-4) that should be "triggered" weekly, 30 min per session. Needles are inserted within the pain area and around the ear and jaw. In some cases, needles near elbows, knees and the big toe are inserted to relieve pain and inflammatory process within the TMJ. It is recommended to complete 6 sessions of acupuncture treatment, but chronic disorders may require more. Often, acupuncture should be associated with pharmacotherapy. [16]

A modern approach of needle puncture is based on the findings of trigger points in painful muscles. Dry needles are inserted at the trigger points, or taut bands, which are not related to the meridian or Chi points, are placed according to traditional Chinese acupuncture practices. Biochemical differences have been found between healthy muscle fibers, and active and latent trigger points. Therefore, needle puncture at trigger points actually change the biochemical environment of the painful muscles of TMD patients.

Drug therapy and alternatives in rheumatoid disorders

In rheumatoid disorders**,** the TMJ is usually only one of the joints (or only one of the organs) involved in the disease process. Arthritis may be asymptomatic but might be associated with TMJ pain, especially during movement. The disorders may include condylary damage and synovitis. The untreated process may lead to mandibular growth disturbances, leading to laterogenia, malocclusions and micrognathia. The joint involvement would, in this case, impact the treatment decisions. In pharmacotherapy, systemic methotrexate and/or TNF inhibitors are used. Additionally, corticosteroids might be successful for modifying the course of the disease. Splint therapies and functional orthodontic appliances might still be used but are adjuvant to the pharmacologic treatment. The medications themselves may reduce the inflammatory process within the joint.[16]

Surgical procedures

The arthrocentesis that involves draining the joint with a therapeutic substance reduces the inflammatory process, evacuates inflammatory exudate, releases the disc, breaks up adhesions, eliminates pain, and improves joint mobility; this should be performed with the mouth wide open and a protruded mandible. Two needles are used to puncture the joint space to restore normal maximal mouth opening and functioning. This technique has limitations due to low tolerability and difficulties in performing the procedure; therefore, single needle arthrocentesis has become more popular. Randomized controlled trial carried out by Vos et al. tried to determine the effectiveness of arthrocentesis compared to conservative treatment as initial treatment with regard to temporomandibular joint pain and mandibular movement. They showed that arthrocentesis reduces pain and functional impairment more rapidly compared to conservative treatment but in long term observations the effectiveness of both treatment modalities achieved comparable outcomes. The method of

intra-articular injections of platelet-rich plasma (PRP) to patients with persistent pain related to severe temporomandibular joint dysfunction described by Pihut et al. seems to be a valid procedure for decreasing TMD pain. In the most severe cases in who TMJ is too severely damaged by the inflammatory process to be cured in a conservative way, implants are used to replace the TMJ. Examples include the Christensen system, the TMJ Concepts system and the Lorenz (BMF) system. Ciocca et al. showed the regenerative properties of mesenchymal stem cells and CAD-CAM-customized pure and porous hydroxyapatite scaffolds to replace the temporomandibular joint condyle. Previously mentioned articles and other papers have confirmed that tissue engineering and stem cells therapy seem to be a promising alternative to the traditional procedures for the management of pain associated with degenerative TMJ disease.

The main indication for TMJ replacement is pain relief and functional improvement in arthritis (osteoarthritis, psoriatic, rheumatoid arthritis and ankylosing spondylitis). The other situations where the TMJ needs replacement are ankylosis, damage by trauma and complications after earlier joint replacement. In a case of severe malocclusion, dentofacial anomalies and unilateral condylar hyperplasia or hypoplasia complicated by TMJ dysfunction the surgical procedures combined with orthodontic treatment should be considered.[16]

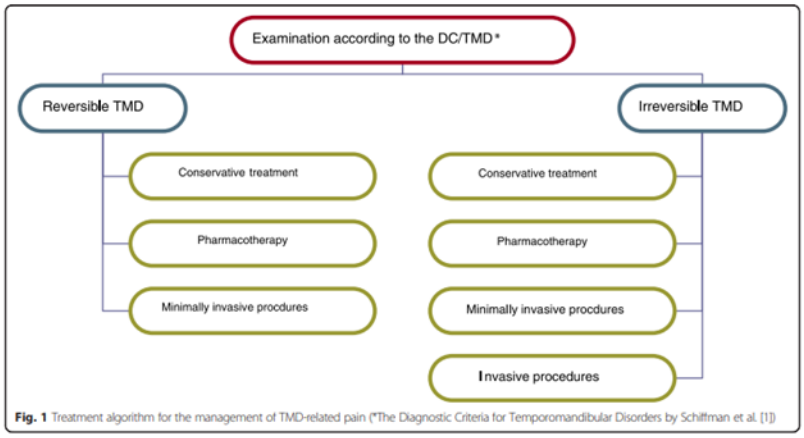

Fig. 1 Treatment algorithm for the management of TMD-related pain (*The Diagnostic Criteria for Temporomandibular Disorders by Schiffman et al. [1])

Table 1Treatment algorithm for TMD management

VI. Conclusion

The diagnosis of TMD involves distinguishing common conditions from clinically significant but uncommon or more serious conditions that require urgent attention. For instance, certain neoplasms like chondrosarcoma of the TMJ may initially present with symptoms similar to common TMD diagnoses, highlighting the importance of thorough evaluation and differential diagnosis. While historically, the focus of TMD diagnosis has been on physical factors, the significant role of psychosocial factors is now well-recognized. As such, a multimodal approach to treatment, which may include counseling and psychological therapy alongside physical interventions, is increasingly advocated. Although many cases of TMD are managed conservatively initially, clinicians should be cautious about prolonged conservative treatment without clear clinical improvement. Early minimally invasive procedures are gaining favor over open joint surgery, which is now reserved for specific situations. Thus, the treatment paradigm for TMD is evolving, emphasizing the importance of early intervention and individualized approaches tailored to each patient's needs and symptoms. Despite ongoing research and advancements in the understanding and management of TMD, challenges persist, and no universal solution exists. Continued efforts in research, education, and clinical practice are essential to improve the diagnosis, management, and outcomes of patients with TMD.

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