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Internal Derangements of the Temporomandibular Joint: Diagnosis and Management

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Additional information is available at the end of the chapter

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Abstract

Millions of individuals worldwide suffer from temporomandibular joint (TMJ) disorders and are characterized by pain and joint dysfunction. TMJ internal derangement (ID) is the most frequent type of temporomandibular disorders (TMDs). The ID of TMJ is defined as a joint dysfunction associated with an abnormal disc position. Identification and elimination of the causes of tissue breakdown of the TMJ that lead to ID are the key factors for successful treatment. The common causes for TMJ ID are trauma and parafunctional habits which lead to joint overload and degenerative changes in the articular structures, increased friction, and gradual disc displacement. Local and systemic inflammatory/degenerative arthropathies may also affect TMJ and cause ID. The aim of this chapter is to give comprehensive knowledge about the contemporary perspective of TMJ ID including diagnostic and therapeutic developments and innovations. Clinicians should establish the correct diagnosis and cause of the disease for appropriate management so that patients do not suffer from ineffective treatments. As an innovative development, TMJ replacements with alloplastic joint prosthesis and tissue-engineered structures hold promise for the future of management of TMJ ID.

Keywords: internal derangement, temporomandibular joint, TMJ, conservative treatment, TMJ surgery

1. Introduction

Millions of individuals worldwide suffer from temporomandibular joint (TMJ) disorders and are characterized by pain and joint dysfunction. TMJ internal derangement (ID) is the most frequent type of temporomandibular disorders (TMDs), including 41.1% of patients with TMD [1]. The ID of TMJ is defined as a joint dysfunction associated with an abnormal disc position [2]. Identification and elimination of the causes of tissue breakdown of the TMJ that lead to ID are the key factors for successful treatment. The common causes for TMJ ID are

trauma and parafunctional habits which lead to degenerative changes in the articular structures, increased friction, and gradual disc displacement [2]. Systemic degenerative arthropathies may also affect TMJ and cause ID. Moreover, some kind of infections and tumors can cause the nonspecific symptoms and may mimic TMJ ID.

The natural course of TMJ ID without treatment was shown that some patients heal spontaneously and the length of time for symptoms to resolve is variable, but generally 1 year. This is thought to be associated with the adaptation capacity of the joint and the healing capacity of the individuals. However, it is not possible to predict the patients who are likely to have a return to asymptomatic condition. The older patients, the patients with longer time of disease onset, and those with magnetic resonance imaging (MRI) evidence of advanced TMD are at a higher risk for not improving spontaneously [3].

This chapter gives comprehensive knowledge about the contemporary perspective of TMJ ID including diagnostic and therapeutic developments and innovations with an emphasis on tissue engineering strategy for joint reconstruction.

2. Definition of the internal derangement of the temporomandibular joint

The most popular definition of ID of TMJ can be explained as the joint dysfunction associated with an abnormal disc position and damage to the internal structures of the joint [2]. The signs and symptoms of ID are nonspecific and can be caused by multiple etiologic factors.

For the diagnosis and management of TMJ ID, updated guidelines and classification systems such as Wilkes staging [4] and Diagnostic Criteria for TMDs (DC/TMD) [5] are available. The Wilkes staging system for ID of TMJ is frequently used by oral and maxillofacial surgeons to provide a guide for treatment based on the severity of the joint damage (**Table 1**). The DC/TMD classification system underwent extensive testing (in terms of sensitivity and specificity) and validated for different languages (the validated translations of DC/TMD into different

Stage	Clinical findings	Radiological findings
I (Early)	Painless clicking, no limitation of motion	Slight disc displacement with early reduction, normal disc morphology
II (Early/intermediate)	Occasional painful clicking, intermittent locking, related headache	Moderate disc displacement with late reduction, mild disc deformity
III (Intermediate)	Frequent pain, joint tenderness, restriction of motion, closed locks	Disc displacement without reduction, deformity of disc, no hard tissue changes
IV (Intermediate/late)	Chronic pain, restriction of motion	Severe disc displacement (without reduction), Severe deformity of disc, degenerative changes
V (Late)	Variable and episodic joint pain, chronic restriction of motion, crepitus	Gross deformity and/or perforation of disc, degenerative arthritic changes, osteophyte deformity subcortical cyst formation

Table 1. Wilkes classification for internal derangement of temporomandibular joint [4].

languages are available at <http://www.rdc-tmdinternational.org>). The current update of DC/TMD was released in 2014 [5]. This diagnostic system has AXIS 1 for classification of the physical categories of the TMDs, and AXIS 2 for classification of psychosocial behavioral aspects of patients with TMDs. According to the last update of DC/TMD Axis 1, TMJ ID is defined in four stages: disc displacement with reduction (DDwR), disc displacement with reduction with intermittent locking, disc displacement without reduction (DDwoR) with limited mouth opening, and disc displacement without reduction without limited mouth opening. The weakness of these classification systems is that there is no causative information associated with the corresponding stages. However, understanding the true cause of damage to the joint structures is essential for proper treatment. Without useful categorization of cause and pathogenesis, treatments often fail because causative factors persist.

In a physiologically normal joint, the disc is positioned between mandibular condyle and the posterior slope of articular eminence when the jaw is closed. When the jaw is opened, the disc slides into a position between condyle and top of the eminence. The attachments of the disc prevent its displacement during opening. The ID of TMJ can be divided into two subgroups basically: disc displacement with reduction and disc displacement without reduction (**Figure 1**). In the DDwR case, disc has slight deformation and forward displacement when the jaw is closed. The displaced disc reduces to normal position at maximal mouth opening (first click noise appears). When the jaw is intended to close, the disc displaces forward again (second click noise—reciprocal click—appears). The patient with DDwR has symptoms of TMJ pain with clicking, intermittent locking, and orofacial pain without limitation on mouth opening. The disc displacement and reduction can be observed in open- and closed-mouth MRI examination (**Figure 2**). In the DDwoR case, disc has moderate to severe deformation and forward displacement when the jaw is closed. During mouth opening, the disc cannot return to its normal position and is compressed between condyle and eminence so as the disorder progresses (**Figure 3**). The patient with DDwoR

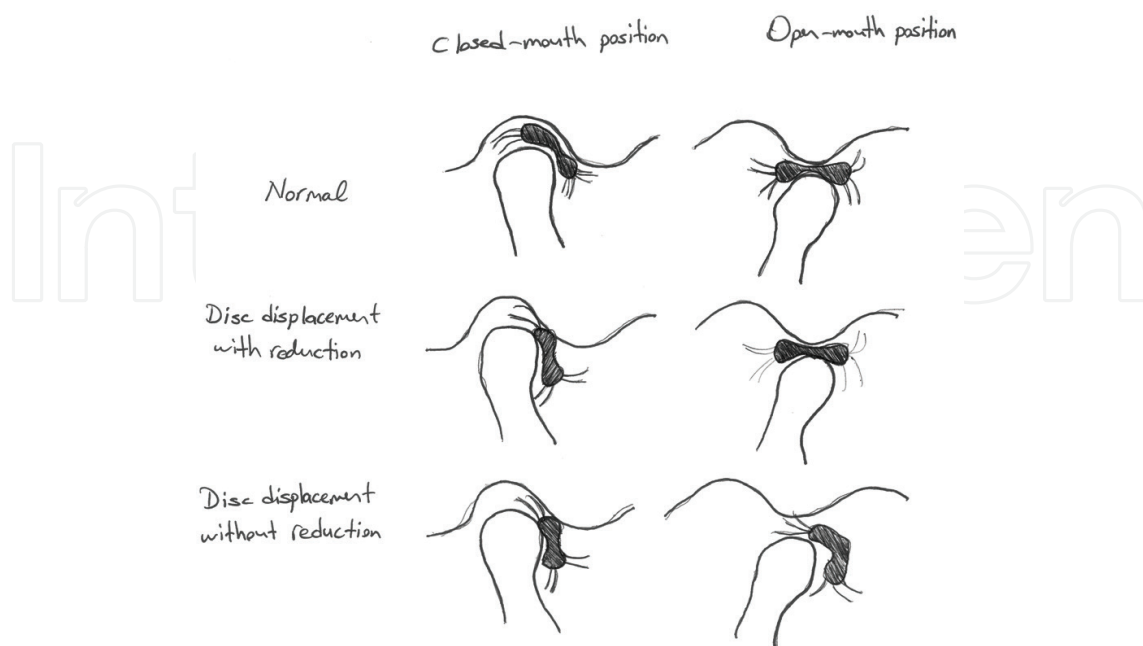


Figure 1. The hand-sketch TMJ figure showing normal condyle-disc relationship, disc displacement with reduction, and without reduction in closed- and open-mouth positions.

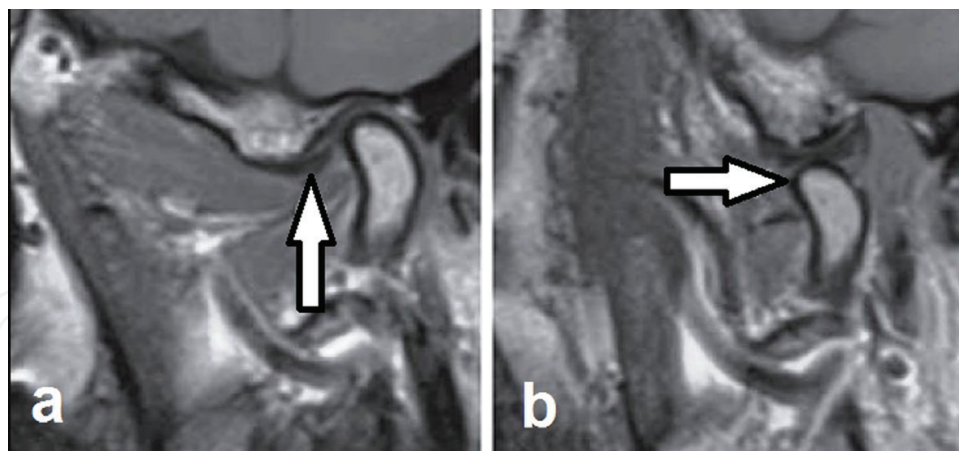


Figure 2. T1-weighted MRI of a TMJ showing anterior disc displacement with reduction; (a) closed-mouth position (anterior displacement of the disc) and (b) open-mouth position (reduction of the disc). White arrow shows articular disc.

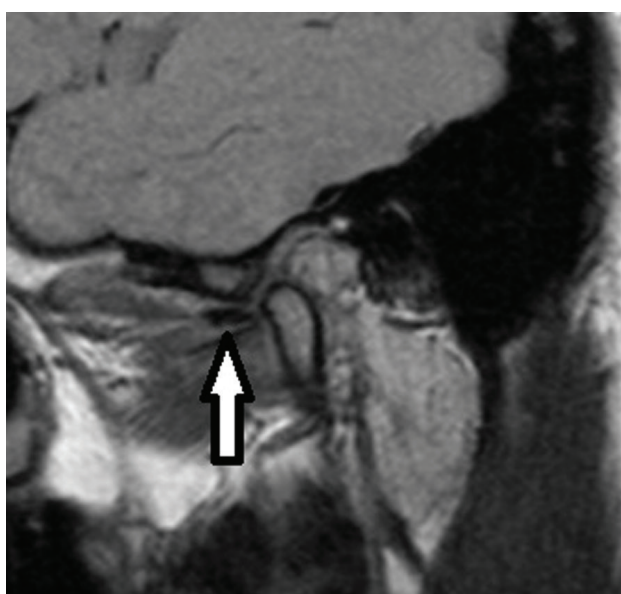


Figure 3. T1-weighted MRI of a TMJ showing anterior disc displacement without reduction in an open-mouth position. Note that the disc is still in a displaced position. White arrow shows articular disc.

has symptoms of increased TMJ and orofacial pain with restricted mandibular motion. The click noise disappears, however; in advanced cases, crepitation noise appears as a result of degenerative changes. In unilateral case, the patient shows restricted contralateral jaw movement while ipsilateral movement is normal. In advanced stages of DDwoR, increased degenerative changes including disc perforation and abrasion of the underlying bone occur.

3. Pathogenesis of internal derangement of temporomandibular joint

The displaced disc can degenerate, become misshaped, perforated, or even torn. If the patient cannot achieve proper treatment, ID gets progressively worse with time, inflammation accompanied, and osteoarthritic changes (abrasion of articular cartilage and underlying bone,

flattening of articular surfaces, less pronounced articular eminence, osteophyte formation, subchondral cyst, and resorption of the condyle) occur [5, 6]. Several inflammatory mediators (such as tumor necrosis factor- α , interleukin 1- β , prostaglandin E2, etc.) play crucial roles in the pathogenesis of ID [7, 8]. The more detailed explanations about the inflammatory mediator background of the ID were discussed in another chapter of this book.

The challenge for clinicians is to diagnose the accurate condition that causes the ID. Once identified, the basis for the treatment is to relieve the patient's symptoms and to improve healing while simultaneously removing the causal factors. The following causal factors or diseases may lead to ID and should be addressed carefully: the excessive loading of the joint, and systemic and localized arthropathies may cause ID of TMJ [2].

3.1. Excessive loading

Joint overload is the most common cause of ID. The joint overload (often caused by stress-mediated parafunction, acute or chronic trauma, unstable occlusion, and increased joint friction) deteriorates cartilage metabolism. This pathologic process causes the fibrillation of cartilage and ultimately leads to biomechanical failure impairing the sliding of the articular surfaces. Clinically, joint noise (clicking) is detected in this stage. The individuals who have persistent parafunction continue to overload articular structures beyond their adaptive capacity leading to pain, synovitis, intra-articular adhesions, osteoarthritis, and disc perforation [2]. Thus, the key principles in the management of ID caused by joint overloading are the reduction of joint loading and inflammation, maximizing joint mobility, and relieving pain. If the patients with ID have the signs of joint overload and if all other causal factors are ruled out, these patients should be managed by an intense 2–3 week regimen of conservative therapies as described below. If the symptoms begin to resolve, then conservative treatment should be continued. However, if the symptoms persist, minimally invasive surgical interventions should be considered. The advanced stages of ID leading to fibrosis, disc deformation or perforation, and TMJ ankylosis require arthrotomy.

3.2. Systemic arthropathy

A number of systemic and rheumatoid disorders play a role of causal factor and can contribute to inflammatory/degenerative arthropathy and ID. Since systemic disorders affect the structure and function of articular tissues, TMJ of the patients with systemic arthropathy may fail under normal joint loads. Thus, clinicians should be aware of this issue when considering patient management. The examples of systemic disorders, which can cause ID, include rheumatoid arthritis, psoriatic arthritis, juvenile idiopathic arthritis, pseudogout, ankylosing spondylitis, polymyalgia rheumatica, chondrocalcinosis, Ehler-Danlos syndrome, Lyme disease, lupus erythematosus, and other connective tissue disorders [2, 9, 10]. For these patients, management of systemic disorders is essential for the treatment of TMJ ID and requires coordination between a maxillofacial surgeon and a rheumatologist. Conservative therapies and arthrocentesis or arthroscopy can relieve symptoms. Moreover, arthroscopic biopsy led to the diagnosis.

3.3. Localized arthropathy

This term describes an articular disorder that is atypical and not caused by joint overloading or systemic disease. A localized atypical arthropathy usually affects one joint only. The clinical

signs and symptoms are nonspecific and include joint pain, noise, limited function, and changes in the occlusion. The imaging techniques and arthroscopic biopsy show unusual findings (multiple loose calcifications or synovial effusions) and confirm the diagnosis. The localized arthropathy of TMJ can be summarized as follows: osteochondroma, synovial chondromatosis, crystal deposition disease, and synovial cyst. The localized arthropathies may cause or mimic TMJ ID. The secondary inflammatory component from neighboring regions (otitis, tonsillitis, and maxillary sinusitis) can affect TMJ and cause ID [2, 11]. The correct diagnosis is crucial in these kinds of disorders and treatment usually includes arthroscopy or arthrotomy.

4. Diagnosis of internal derangement of temporomandibular joint

4.1. History and physical examination

Complete medical history, clinical, and radiological examinations are essential for correct diagnosis. The most frequent signs and symptoms related to ID are pain on TMJ region, decrease in mouth opening (the normal values of maximum inter-incisal mouth opening are between 35 and 50 mm) and laterotrusive movements (the normal values of the ipsi- and contra-lateral movements of the joint are between 5 and 10 mm), TMJ noise (clicking and crepitation), intermittent lock of the joint, deflexion or deviation of the mandible during mouth opening [5]. The tenderness of the masticatory muscles may accompany.

4.2. Imaging methods

Imaging of TMJ is necessary to establish the proper diagnosis, to select the appropriate treatment, and to assess the treatment results. For imaging purposes, the following contemporary techniques are frequently used.

4.2.1. Panoramic radiography or arthrography

Orthopantomography (OPG) and/or arthrography are used to assess hard tissues of TMJ including condyle, glenoid fossa, and articular eminence. For detailed examination, computed tomography (CT)/cone-beam computed tomography (CBCT) is preferred.

4.2.2. Computed tomography or cone-beam computed tomography

CT or CBCT is useful to assess bone abnormalities such as ankylosis, degenerative changes, osteoarthritis, growth abnormalities, fractures, and tumors. A stereolithographic model of a patient's TMJ skeleton can be prefabricated using three-dimensional (3D) technology for reconstructive purposes.

4.2.3. Magnetic resonance imaging

MRI is the standard imaging technique for visualization of TMJ. It is used to assess retrodiscal tissue, disc position and morphology, displacement and reduction of the disc, bone marrow

changes, degenerative involvements, and joint effusion [12]. Recently, the potential use of MRI-CBCT image fusion technique was introduced in order to improve the reliability and accuracy of assessment of disc positions [13]. Contemporarily, real-time MRI imaging of TMJ allows comprehensive data about the dynamics of all articular structures during jaw movement and offers more reliable diagnosis for ID of TMJ [14]. MRI is contraindicated in claustrophobic patients and those with pacemakers.

4.2.4. Single photon emission computed tomography

This technique is used to detect metabolic activity and inflammation on the joint structures. The single photon emission computed tomography (SPECT) can be used for conventional evaluation of osteoarthritis of TMJ (which is the further stage of ID) [15].

4.2.5. Electromyography

This method is used to assess masticatory and cervical muscles' activities when bruxism or muscle-mediated joint overload is suspected as a causal factor for TMD [16].

4.2.6. Ultrasonography

The ultrasonography (USG) is used as an alternative imaging technique for the diagnosis of TMD. On USG images, condyle and glenoid fossa are hyperechoic (high reflection of sound waves) and appear white, bone marrow is hypoechoic (low reflection of sound waves) and appears black, connective tissues (joint capsule and retrodiscal tissue) and muscles (lateral pterygoid and masseter muscles) are isoechoic (intermediate reflection) and appear heterogeneously gray, and the disc appears as a thin area of hyperechogenicity surrounded by a hypoechoic halo [17]. Diagnostic accuracy of USG was reported to be 54–100% for disc displacement, 72–95% for joint effusion, and 56–93% for osteoarthrosis [17]. The USG can be used to assess the thickness of the masticatory muscles in order to evaluate their causal effects for TMD [18]. Moreover, USG can also be used as an image guide for injection into the superior and lower joint space [19, 20].

4.2.7. Other methods

If the clinician suspects systemic involvement (such as rheumatoid arthritis or juvenile idiopathic arthritis), appropriate tests including human leukocyte antigen-B27, anti-nuclear factors, and rheumatoid factors should be ordered [10].

4.3. Differential diagnosis

Some kinds of extra-articular disorders may mimic clinical signs and symptoms of TMJ ID and should be considered as differential diagnosis. These pathologic entities can be summarized as headache, neuralgia, migraine, atypical orofacial pain, ear disorders, coronoid process hyperplasia, trismus following inferior alveolar nerve anesthesia or muscle trauma, deep-space infections of maxillofacial region, radiation fibrosis, myositis ossificans, and metastasis of other regions' cancer [2, 5].

5. The treatment methods of internal derangements of temporomandibular joint

The most frequently used diagnostic classification system in order to decide proper management for ID of TMJ is Wilkes classification (**Table 1**) [4]. Wilkes defined five stages with clinical and radiographic features of ID and offered different treatment methods according to the stages of the disorder [4]. The treatment methods of TMJ ID can be basically divided into two subgroups: conservative and surgical. According to Wilkes classification [4], early stages of ID can be managed with conservative or minimally invasive methods; however, advanced stages (IV or V) might require open joint surgery. The principle of treatment consists of removal of the factors which can cause ID, reduction of symptoms, and also promote the healing of the articular structures. The disc displacement does not always cause mechanical obstruction. In the literature, MRI studies [21, 22] showed a high percentage of disc displacement in asymptomatic patients (about 32–38%) and thus it is controversial whether repositioning the disc into normal position should be a treatment goal or not.

The conservative and surgical treatments should never be considered separately. The two therapeutic options should always be taken into account. The lack of control of causal factors such as joint overload usually causes failure of the treatment.

5.1. Conservative methods

The conservative treatment is a fundamental therapeutic element. Mostly, it is also the first-line therapeutic step (except for the ankylosis, tumor diseases and cysts. For the corresponding diseases, the primary treatment method is the open surgery). The basis of the conservative therapy is the reduction of the joint loading and pain and also improvement of healing. If the causal factor of ID is diagnosed as excessive joint loading, most of these patients can be successfully managed with conservative methods. The conservative therapy includes a number of different treatment methods:

5.1.1. Patient education

The most important aspect of conservative treatment is to inform and educate the patients about the natural course, etiology, and pathogenesis of the ID. The diet modification, improved sleeping, and awareness of mandibular parafunction should be established by patient education. Patient education is the first and essential part of the management and makes the patients important partners for their care. The education of patients is crucial for control of all causal factors (especially excessive loading) leading to ID.

5.1.2. Drug treatment

This therapy includes several groups of drugs:

- a. **Analgesic drugs:** They are used to reduce pain (most often non-steroidal anti-inflammatory—NSAI—drugs). NSAI drugs are also used to reduce inflammation.

- b. Anti-spasmodic and muscle relaxants:** They are used to reduce muscle spasm accompanying a number of painful conditions (in addition to reducing the skeletal muscle tone, it is also effective to reduce emotional stress).
- c. Chondroprotective drugs:** These drugs are capable of restoration of the metabolic balance in articular cartilage cells; their anti-inflammatory and analgesic effects are also described [8]. In our previous study [8], we concluded that glucosamine-chondroitin combination, which are structural molecules of joint cartilage and necessary for proteoglycan and glycosaminoglycan synthesis, significantly increases the mouth opening and decreases the inflammatory cytokine levels of synovial fluid in ID of TMJ. Moreover, this chondroprotective combination provides efficient pain relief as well as narcotic analgesics.
- d. Antidepressant drugs:** High prevalence of stress, depression, and anxiety is associated with TMD. Antidepressant medications are used to solve stress-related causal factors of TMD. These drugs have adjunct effects in improving sleep quality and reducing stress-related parafunctional habits including bruxism and clenching [23]. Low doses of antidepressant drugs have also analgesic effects.
- e. Antibiotics:** These drugs are only indicated in the event of accompanying infectious diseases of the joint (septic arthritis).

5.1.3. Physiotherapy

This is one of the basic therapeutic methods. The indications include discopathy and the hypermobility of the joint. The position of the dislocated disc can be improved by physiotherapy in discopathy cases. In hypermobility cases, the physiotherapy supports the strengthening of the ligaments of the articular capsule, thus reducing the excessive movement in the joint. Physiotherapy techniques are also used to improve the mobility in the masticatory and cervical spine muscles [6]. During physiotherapy, following cautions should be applied: the exercises should be performed at short time intervals (three to five times in a row) and multiple times in a day, which is better than exercising once a day for a longer time period (which can lead to the overload of the joint and occurrence and/or progression of the pain). Moreover, the exercise should always be done to the pain limit—avoid trying to overcome the pain by the movement. Aside from the reduction of joint loading, it is crucial to perform passive-motion exercises for a minimum of 2 months after surgical interventions [2]. The basis of the physiotherapy consists in

- a. Isometric exercises:** Exercises against palm resistance during which the active muscle groups are strengthened, strengthening the muscles and ligaments of the articular capsule.
- b. Post-isometric relaxation exercises:** Relaxation of muscle groups for the treatment of the increased muscle tone due to the emotional stress.
- c. Repositioning exercises:** These exercises are indicated for the alignment of the dislocated disc and mobilization of the joint (restoration of the jaw motion, indicated for the luxation of the jaw—the *Hippocrates maneuver* as well as for the acute dislocation of the disc).
- d. Massages of the chewing muscles:** These exercises are used to improve muscle blood flow, thus enhancing functions of the muscles and reducing their pain; they contribute to

the movement coordination and to the stretching of spastic muscle fibers. These exercises are also used for rehabilitation of the opening, the most often used method in the post-operative care. It is divided into the passive one (when patients open their mouths using some aids or fingers) and the active ones (when the mouth opening is accompanied with the actual activities of the muscles).

5.1.4. *Thermotherapy*

Thermal stimuli—cold or heat—can be used in the treatment of ID. Cold causes reduction in passing of nerve impulses on nerve endings, thus reducing perception of pain. Furthermore, it causes local vasoconstriction and it acts as an anti-inflammatory agent. Cold is indicated mainly for bacterial inflammations. The use of cold may include compresses or the application of cooling sprays. The application of heat effects pain receptors in muscles and synovium, thus reducing the pain accompanying aseptic inflammations (such as arthritis and osteoarthritis). Heat is most often used in the form of hot compresses.

5.1.5. *Bio-stimulating laser therapy*

Low-level laser therapy (LLLT) supports reparation processes; it acts as the analgesic and anti-inflammatory agent (it stimulates mitochondria, supporting the production of adenosine triphosphate, increasing the blood flow in tissues, and increasing the lymphatic drainage). Moreover, the laser application stimulates blood microcirculation and reduces muscle contraction [24]. The bio-stimulation laser is indicated especially for aseptic arthritis and degenerative changes. The advantages of LLLT for the management of ID are that it provides aseptic, noninvasive, painless, non-pharmaceutical therapy without postoperative discomfort [24]. However, long-term effectiveness of LLLT for the management of TMD is limited [25].

5.1.6. *Occlusal splint*

This is a removable appliance of plastic material (most often resin) with a thickness of 1.5–3 mm. The splint can be made on the superior or inferior dental arch, while the splint on the inferior dental arch is preferred as it is better hidden and patients consider it better (**Figure 4**). The splints can be partial (covering only a part of the dental arch) or total (covering the dental arch completely). The treatment effect consists in the reduction in intra-articular pressure (thus reducing overload and pain), balancing of the occlusion, relaxation of the muscle spasm, and creation of the environment for easier alignment of the dislocated disc. It should be kept in mind that continuous and/or long-term use of an appliance may develop a malocclusion and must be avoided. An occlusal splint must meet several conditions:

- It must ensure a symmetrical, bilateral articulating contact of dental arches.
- It must be strong enough, with smooth edges and good retention.
- It should cover only the teeth; it must not irritate the periodontium.
- It must not be a functional obstacle, restrict the movement of the tongue, phonation, and swallowing.

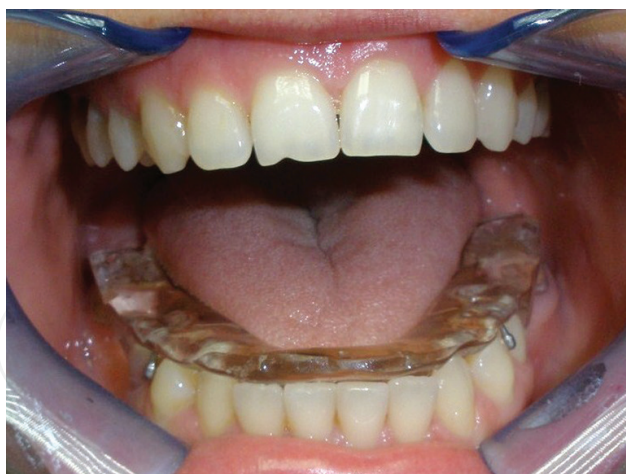


Figure 4. Clinical view of occlusal splint therapy used for conservative treatment of ID of TMJ.

The indications for the occlusal splint include the discopathy as well as inflammatory and degenerative changes. The splint is also used for patients with para-functional activities (night guard). In our previous clinical study [26], we observed that stabilization splint therapy provided significant improvements in pain relief, joint mobility (mouth opening and laterotrusive movements), disability, and psychological status of the patients with DDwoR after 6 months of treatment. However, the success rate of splint therapy was shown to be 60% for DDwoR. Splint therapy can be used alone or in combination with arthrocentesis. Our recent study showed that simultaneous splint application following arthrocentesis (success rate was 95%) has no significant additional effect on arthrocentesis alone (success rate was 92.5) for the treatment of DDwoR [26].

5.1.7. Inter-maxillary fixation

It is used to restrict the jaw motion, thus soothing inflammatory affections of the joint, leading to the reduction of pain. The inter-maxillary fixation (IMF) is most often used in the form of inter-maxillary screws and elastic bands. The indications for the IMF include, in particular, septic arthritis. Another application consists in a conservative treatment of articular eminence fractures, and it is further used for non-cooperating patients with recurrent luxations of the TMJ.

5.2. Surgical methods

The surgical treatment is provided in the event when the conservative treatment does not have any effects (the painful symptoms as well as joint dysfunctions still persist) for a period of 3–6 months. The risk of surgical intervention is the injury to the surrounding anatomic structures (in particular the facial nerve). The surgical treatments for ID consist in the following:

5.2.1. Arthrocentesis

This is the mini-invasive surgical method in order to perform the lavage of the superior joint space [27]. The intervention is performed directly into the joint structures; however, the operation input is limited to the injection needle only (**Figure 5**). It can be performed under local



Figure 5. Clinical view of TMJ arthrocentesis used as a minimally invasive surgical treatment method of ID.

anesthesia alone or in combination with conscious sedation. The procedure can be performed in two different ways:

- a. **Single-needle technique:** This is also called pumping arthrocentesis. The irrigation fluid is introduced into the joint with a single needle and subsequently removed through it.
- b. **Two-needle technique:** One needle is used to introduce the fluid into the joint, whereas through the other needle the fluid escapes from the joint cavity.

The aim of the lavage is to flush out inflammatory mediators and loose particles from the joint space (to reduce pain), lysis of the adhesions in the joint, expand the joint cavity (to facilitate the alignment of the dislocated disc), change negative intra-articular pressure to positive pressure (to release the adhering disc), and irrigate micro-particles of the degenerative-changed cartilage (which otherwise irritate the joint synovium and lead to the development of inflammatory changes). Ringer's solution is used as the irrigation fluid (100–400 ml). Arthrocentesis requires less surgical skill and is an economic treatment method, but does not permit direct visualization and removal of pathologic intra-articular tissues and is less effective for lavage and removal of adhesions compared to arthroscopy. At the end of arthrocentesis, intra-articular application of the therapeutic drugs (corticosteroids, sodium hyaluronate, platelet-rich plasma (PRP), etc.) is also possible. It was reported that arthrocentesis was reliable for treating Wilkes II and III stages of ID, and the treatment results were better in patients with advanced stage [28].

5.2.2. Intra-articular application of drugs

The application of a number of medications directly into the superior synovial joint cavity (the space between the disc and glenoid fossa) is a treatment method. The following medications may be used for intra-articular application:

- a. **Glucocorticoids:** These medications are used for their anti-inflammatory effects. They reduce the synthesis of prostaglandins and the production of antibodies, thus decreasing joint effusion and pain. After arthrocentesis, about 1 ml betamethasone can be used for anti-inflammatory purpose. The indications include osteoarthritic symptoms, rheumatoid arthritis, and inflammatory degenerative joint disease.
- b. **Sodium hyaluronate:** This is a buffered solution of hyaluronate acid sodium salt, which is an essential component of the cartilage and the synovial fluid. It acts against the disintegration of the extracellular matrix. It activates reparation processes of the cartilage, improves the condition of chondrocytes, and the viscosity of the synovial fluid (it reduces friction), and it features an anti-inflammatory effect (through the inhibition of inflammatory cytokines). The hyaluronate has chondrotropic and lubrication effects. It is indicated for the treatment of osteoarthritic symptoms, inflammatory degenerative joint disease, and discopathy.
- c. **Platelet-rich plasma (PRP):** The blood platelets obtained by centrifugation of the venous blood can be applied intra-articularly. The principle of the treatment consists in the growth factors contained in the blood platelets that cause changes in the cell proliferation, regulate the cellular metabolism, and affect chondrogenous activities. The indications of PRP in the TMJ include inflammatory degenerative diseases [29].

5.2.3. Arthroscopy

This is a method, in which the endoscope is introduced into the joint cavity; the endoscope allows examination of the intra-articular cavity through the transmission of the intra-articular image to the display (**Figure 6**). The endoscopes intended for the TMJ arthroscopy usually have a diameter of 1.9–2.7 mm. Typically, only the arthroscopy of the superior synovial cavity (the cavity between the disc and glenoid fossa) is performed; the arthroscopy of the inferior joint space (the cavity between the disc and condyle) is carried out less often due to the difficult access. The arthroscopy technique yields superior efficacy compared to arthrocentesis in removing articular adhesions, increasing joint function, and decreasing pain for the management of ID [30]. According to the performed intervention, the following is carried out:

- a. **Diagnostic arthroscopy:** It consists in the visualization of each part of the joint space, while lysis of the adhesions and joint lavage are also carried out during the arthroscopy. In addition

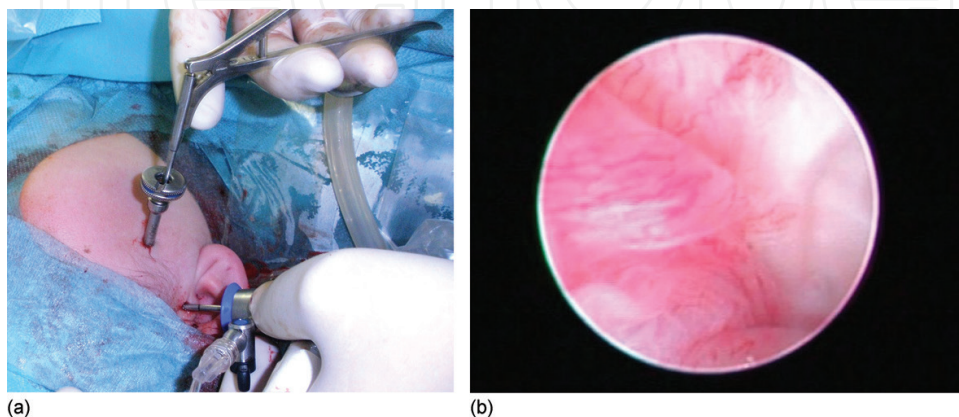


Figure 6. TMJ arthroscopy: (a) clinical view and (b) endoscopic view of the joint.

to the endoscope, the needle used to release the irrigation fluid is introduced into the joint during the diagnostic arthroscopy. Through arthroscopic joint visualization, diagnosis of ID stage and identification of osteoarthritic changes can be established. The needle can also be used for the direct injection of medications into the inflammatory-changed synovial tissue and the retrodiscal tissue. In our previous clinical study [31], we observed that patients with a longer duration of symptoms of DDwoR had more advanced levels of fibrous adhesion and inflammatory and degenerative changes of the articular structures under arthroscopic view. The patients with a shorter duration of ID benefit more from arthroscopic lysis and lavage than those with longer duration of disease onset [31].

- b. Surgical arthroscopy:** It consists in the surgical intervention in the joint under arthroscopic view. In addition to the endoscope and the needle for releasing, the working (surgical) input for surgical tools (hook, probe, scissors, forceps, laser fiber, and shaver) is also introduced into the joint. The surgical arthroscopy is used to remove adhesions and to align and fix the disc, for synovectomy, discectomy (surgical removal of herniated disc material), or eminectomy (removal of the articular tubercle) procedures [32]. As shown in our recent technical note, hand-made alternative mini-instruments, which are made from stainless steel wire of 0.5 mm in diameter, can be used for the removal of adhesions during arthroscopic surgery [33]. It is also possible to obtain specimens for histopathologic examinations.

5.2.4. Open joint surgery

Open surgery is indicated only in the event that the conservative therapy, arthrocentesis, or arthroscopy does not have effects repeatedly (approximately 5% of the TMD patients) [34]. Generally, it can be concluded that the open surgery is indicated if all possibilities have been exhausted and the patient's condition has not improved or has even deteriorated. The exceptions include ankylosis, dislocated fractures of the articular eminence, tumors, and developmental anomalies (in which the surgical treatment is the first therapeutic step). The open joint surgery operations for TMJ ID can be performed on the soft and/or hard tissues of the joint. The most common for ID, open joint surgery may include discectomy, reshaping of the articular surface, and implementation of autologous or alloplastic materials [35]. Briefly, the following surgical interventions can be performed:

- a. Discopexy:** The open repositioning of the dislocated disc and its fixation in a suitable position related to the condyle (with a suture, pin, screw, and anchor).
- b. Discoplicacy:** This is another method to solve the dislocation of the disc. It is based on the assumption that the dislocation of the disc causes stretching of the retrodiscal tissue. During the discoplicacy, the rear part of the retrodiscal tissue is excised and then the remaining parts are approximated to each other with a suture. Thus, the disc is aligned and fixed back in its physiologic position.
- c. Discoplasty:** The reparation of the disc perforation accompanying degenerative changes consists in closing of small perforations (with a suture or its overlap). It is indicated only for young patients.
- d. Discectomy:** The removal of the disc is indicated for extensive degenerative changes (disc perforation) or if the patients have persistent symptoms after discoplasty treatment

(Figure 7). In ID patients showing no improvement with previous mini-invasive modalities, discectomy offers regaining jaw motion and reducing orofacial pain and may be followed with disc replacement.

- e. **Condyloplasty:** The removal of unevenness from the condyle, grinding, and smoothing. It is indicated for accompanying degenerative changes.
- f. **Condylar shaving:** The removal of 3–5-mm bone tissue from the top of the condyle is indicated for condylar hyperplasia at the active stage of the growth (Figure 8).
- g. **Condylectomy:** The removal of the condyle in the event of extensive degenerative changes (Figure 9).
- h. **Eminoplasty or Eminectomy:** These methods are basically introduced for the treatment of joint hypermobility. However, the osteoplasty or the removal of the articular tubercle can also be performed for the treatment of TMJ ID, for repositioning of the dislocated disc. In the TMJ ID cases, the disc is caught between the condyle and articular eminence; thus, eminectomy procedure expands the space between the bony structures so the disc can be aligned back to its original position.

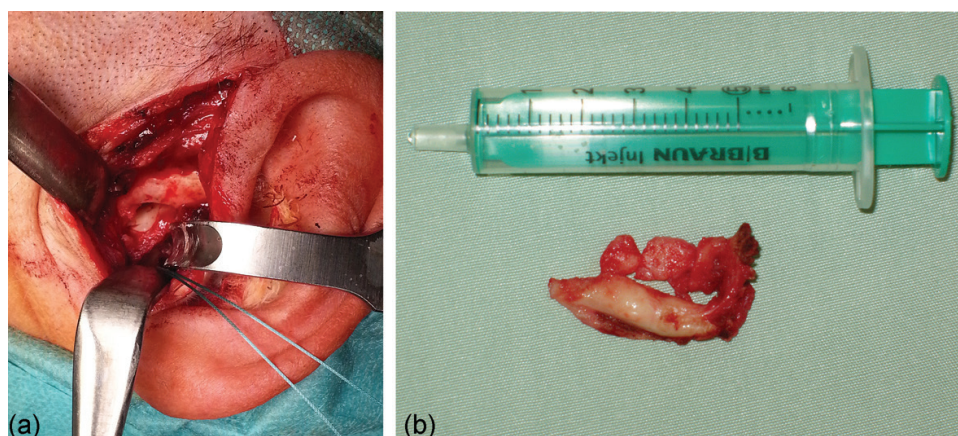


Figure 7. TMJ discectomy as a surgical treatment method of ID; (a) surgical (preauricular) approach, (b) removed articular disc tissue.



Figure 8. Condylar shaving is the removal of 3–5-mm bone tissue from the top of the condyle.

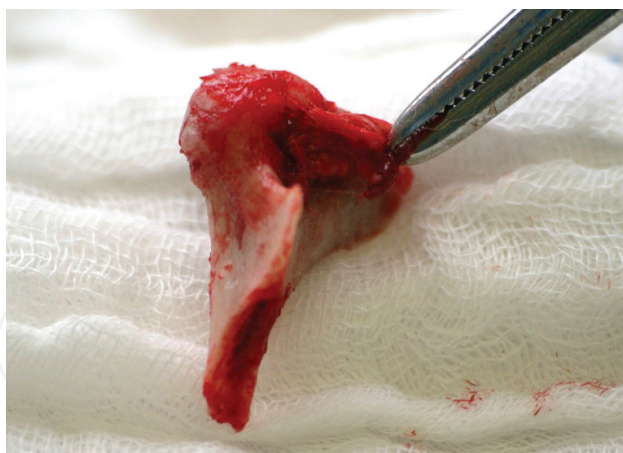


Figure 9. Condylectomy is the removal of the condyle. This technique can be used in the event of extensive degenerative changes caused by advanced stages of ID of TMJ.

i. Reconstruction of the joint: It can be divided into the reconstructions of the disc, condyle, and articular fossa:

- **Disc reconstruction:** The reconstruction of articular disc is performed after the discectomy. The subsequent direct contact of the condyle with the fossa can lead to the progression of the degenerative changes and the occurrence of the ankylosis. This is prevented by the interposition material, which is inserted into the joint cavity. For disc replacement, a variety of tissues and materials are used including abdominal fat graft, auricular cartilage, temporalis muscle or fascia, silastic, and proplast-teflon disc implants [6].
- **Fossa reconstruction:** The reconstruction of the glenoid fossa is performed using fossa prosthesis. The fossa prosthesis is made of metal alloys; the fossa is fixed with mini-screws to the zygomatic arch. It is described for degenerative changes.
- **Condyle reconstruction:** The reconstruction of the condyle is performed after resection of the condyle. The reconstructive materials are fixed to the branch of the inferior jaw. The autologous (costochondral, sternoclavicular, metatarsophalangeal bone grafts, especially indicated for young patients due to the growth activity of graft materials) and alloplastic (made of metal alloys) materials are used for the reconstruction.
- **Total joint reconstruction:** The total joint prosthesis combines the replacement of the fossa and the condyle at the same time. The condyles are made of chromium-cobalt alloy (and they are fixed to the branch of the inferior jaw with mini-screws). The fossa is made of the high-polymerized polyethylene (and it is fixed with mini-screws to the zygomatic arch). The articular prostheses are available in the form of stock prosthesis (where there is a number of fossa and condyle sizes available) and custom prosthesis (which are made individually according to the patient's CT-based stereolithographic model) (**Figure 10**). It is clearly evident that the individual prostheses are more convenient. However, their use is limited by a higher price compared to stock prostheses [36].

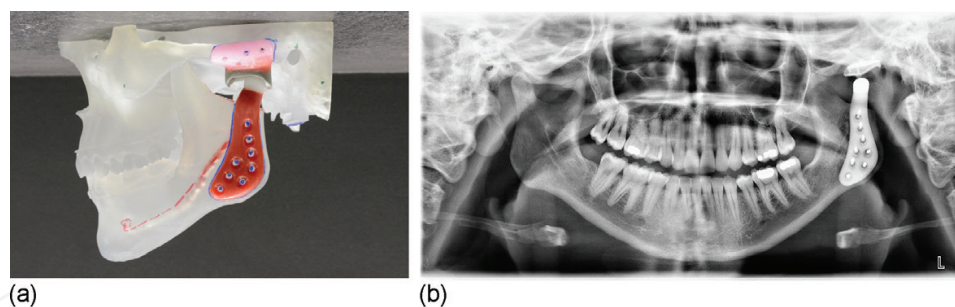


Figure 10. The total joint reconstruction combines the replacement of the fossa and the condyle at the same time; (a) production stage of custom-made TMJ prosthesis which is made individually according to the patient's CT-based stereolithographic model, (b) postoperative OPG of a patient with custom-made TMJ prosthesis.

6. Tissue engineering in temporomandibular joint reconstruction

In the current century, the main topic of new studies searching the contemporary treatment methods of TMJ ID is the repair and replacement of joint structures by using tissue engineering methods. The main objective is to produce joint components (such as mandibular condyle or articular disc) that have the ability to perform functional articulation. The main research areas are cell sourcing, biomaterials for scaffolding, and bioactive stimuli [6]. Using tissue engineering techniques, it is intended to produce joint components capable of adaptation to functional articulation and possessing the biochemical, biomechanical, and geometric properties of healthy TMJ tissues [6].

The possible indications for bioengineered articular structures can be summarized as untreatable condylar trauma, condylar hyperplasia, TMJ pathology in skeletally immature patients, and history of metal hypersensitivity (a contraindication for TMJ alloplastic replacement), and TMJ ID [37]. Bioengineered replacements have the potential to be able to grow with the patients, so tissue engineering technology may particularly offer significant benefits for skeletally immature patients requiring TMJ reconstruction. On the other hand, growth potential of bioengineered tissues should be considered cautiously. In terms of TMJ ID, surgical implantation of bioengineered articular disc may be a promising management for patients with unsalvageable disc (Wilkes stages III–V).

The possible contraindications for bioengineered TMJ reconstruction can be summarized as unresolved causal factors such as parafunctional habits, ankylosis (recurrence of ankylosis may occur in bioengineered articular structures as in autografts), history of multiple-failed TMJ arthroplasty (scar tissue can impede vascularization of bioengineered tissue), and autoimmune diseases (the underlying disease such as rheumatoid arthritis might destroy bioengineered tissue).

7. Conclusion

The TMJ disorders are widespread in population and ID is the most frequent type of TMD. The etiologic factors of ID are joint overload and localized and systemic arthropathies.

The real causal factors and correct diagnosis should be established in order to provide appropriate management. In early stages of TMJ ID, conservative methods are considered. If the derangement becomes more severe or refractory to conservative therapies, and in some special situations, proper surgical techniques should be considered. In these situations, the timing of surgical treatment and performing proper technique is crucial for long-term success. Otherwise, patients require repeat treatments indicating low promise for successful management. In terms of open joint surgery, it should be kept in mind that arthroplasty may be resulted in degenerative changes in the future and the patient may need further surgical treatments including total joint replacement. Currently, contemporary researches focus on replacing the disc or condyle in terms of tissue engineering therapy. However, it seems that there are many steps to solve in order to insert this technology into clinical practice.

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References

- [1] Manfredini D, Guarda-Nardini L, Winocur E, Piccotti F, Ahlberg J, Lobbezoo F. Research diagnostic criteria for temporomandibular disorders: A systematic review of axis I epidemiologic findings. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics*. 2011;**112**:453-462. DOI: 10.1016/j.tripleo.2011.04.021
- [2] Israel HA. Internal derangement of the temporomandibular joint: New perspectives on an old problem. *Oral and Maxillofacial Surgery Clinics of North America*. 2016;**28**:313-333. DOI: 10.1016/j.coms.2016.03.009
- [3] Kurita K, Westesson PL, Yuasa H, Toyama M, Machida J, Ogi N. Natural course of untreated symptomatic temporomandibular joint disc displacement without reduction. *Journal of Dental Research*. 1998;**77**:361-365. DOI: 10.1177/00220345980770020401
- [4] Wilkes CH. Internal derangements of the temporomandibular joint. Pathological variations. *Archives of Otolaryngology – Head & Neck Surgery*. 1989;**115**:469-477. DOI: 10.1001/archotol.1989.01860280067019
- [5] Schiffman E, Ohrbach R, Truelove E, Look J, Anderson G, Goulet JP, List T, Svensson P, Gonzalez Y, Lobbezoo F, Michelotti A, Brooks SL, Ceusters W, Drangsholt M, Ettlin D, Gaul C,

- Goldberg LJ, Haythornthwaite JA, Hollender L, Jensen R, John MT, De Laat A, de Leeuw R, Maixner W, van der Meulen M, Murray GM, Nixdorf DR, Palla S, Petersson A, Pionchon P, Smith B, Visscher CM, Zakrzewska J, Dworkin SF, International RDC/TMD Consortium Network, International association for Dental Research; Orofacial Pain Special Interest Group, International Association for the Study of Pain. Diagnostic criteria for temporomandibular disorders (DC/TMD) for clinical and research applications: Recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. *Journal of Oral & Facial Pain and Headache*. 2014;**28**:6-27. DOI: 10.11607/jop.1151
- [6] Murphy MK, MacBarb RF, Wong ME, Athanasiou KA. Temporomandibular disorders: A review of etiology, clinical management, and tissue engineering strategies. *The International Journal of Oral & Maxillofacial Implants*. 2013;**28**:e393-e414. DOI: 10.11607/jomi.te20
- [7] Ernberg M. The role of molecular pain biomarkers in temporomandibular joint internal derangement. *Journal of Oral Rehabilitation*. 2017;**44**:481-491. DOI: 10.1111/joor.12480
- [8] Damlar I, Esen E, Tatli U. Effects of glucosamine-chondroitin combination on synovial fluid IL-1 β , IL-6, TNF- α and PGE2 levels in internal derangements of temporomandibular joint. *Medicina Oral, Patologia Oral y Cirugia Bucal*. 2015;**20**:e278-e283. DOI: 10.4317/medoral.20242
- [9] Sidebottom AJ, Salha R. Management of the temporomandibular joint in rheumatoid disorders. *British Journal of Oral and Maxillofacial Surgery*. 2013;**51**:191-198. DOI: 10.1016/j.bjoms.2012.04.271
- [10] Kalaykova SI, Klitsie AT, Visscher CM, Naeije M, Lobbezoo F. A retrospective study on possible predictive factors for long-term temporomandibular joint degeneration and impaired mobility in juvenile arthritis patients. *Journal of Oral & Facial Pain and Headache*. 2017;**31**:165-171. DOI: 10.11607/ofph.1656
- [11] Araz Server E, Onerci Celebi O, Hamit B, Yigit O. A rare complication of tonsillitis: Septic arthritis of the temporomandibular joint. *International Journal of Oral and Maxillofacial Surgery*. 2017;**46**:1118-1120. DOI: 10.1016/j.ijom.2017.04.007
- [12] Bertram S, Rudisch A, Innerhofer K, Pümpel E, Grubwieser G, Emshoff R. Diagnosing TMJ internal derangement and osteoarthritis with magnetic resonance imaging. *Journal of the American Dental Association*. 2001;**132**:753-761. DOI: 10.14219/jada.archive.2001.0272
- [13] Al-Saleh MA, Alsufyani NA, Lagravere M, Nebbe B, Lai H, Jaremko JL, Major PW. MRI alone versus MRI-CBCT registered images to evaluate temporomandibular joint internal derangement. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*. 2016;**122**:638-645. DOI: 10.1016/j.oooo.2016.07.024
- [14] Krohn S, Frahm J, Merboldt KD, Wassmann T, Joseph AA, Bürgers R. Diagnosis of disk displacement using real-time MRI: Clinical report of two patients. *Journal of Prosthetic Dentistry*. DOI: 10.1016/j.prosdent.2017.03.022 [Epub ahead of print]
- [15] Park KS, Song HC, Cho SG, Kang SR, Kim J, Jun HM, Song M, Jeong GC, Park HJ, Kwon SY, Min JJ, Bom HH. Open-mouth bone scintigraphy is better than closed-mouth bone

- scintigraphy in the diagnosis of temporomandibular osteoarthritis. *Nuclear Medicine and Molecular Imaging*. 2016;**50**:213-218. DOI: 10.1007/s13139-016-0407-z
- [16] Choi KH, Kwon OS, Jerng UM, Lee SM, Kim LH, Jung J. Development of electromyographic indicators for the diagnosis of temporomandibular disorders: A protocol for an assessor-blinded cross-sectional study. *Integrative Medicine Research*. 2017;**6**:97-104. DOI: 10.1016/j.imr.2017.01.003
- [17] Manfredini D, Guarda-Nardini L. Ultrasonography of the temporomandibular joint: A literature review. *International Journal of Oral and Maxillofacial Surgery*. 2009;**38**:1229-1236. DOI: 10.1016/j.ijom.2009.07.014
- [18] Strini PJ, Strini PJ, Barbosa Tde S, Gavião MB. Assessment of thickness and function of masticatory and cervical muscles in adults with and without temporomandibular disorders. *Archives of Oral Biology*. 2013;**58**:1100-1108. DOI: 10.1016/j.archoralbio.2013.04.006
- [19] Dayisoylu EH, Cifci E, Uckan S. Ultrasound-guided arthrocentesis of the temporomandibular joint. *British Journal of Oral and Maxillofacial Surgery*. 2013;**51**:667-668. DOI: 10.1016/j.bjoms.2013.05.144
- [20] Levorova J, Machon V, Hirjak D, Foltan R. Ultrasound-guided injection into the lower joint space of the temporomandibular joint. *International Journal of Oral and Maxillofacial Surgery*. 2015;**44**:491-492. DOI: 10.1016/j.ijom.2014.12.013
- [21] Larheim TA, Westesson P, Sano T. Temporomandibular joint disk displacement: Comparison in asymptomatic volunteers and patients. *Radiology*. 2001;**218**:428-432. DOI: 10.1148/radiology.218.2.r01fe11428
- [22] Katzberg RW, Westesson PL, Tallents RH, Drake CM. Anatomic disorders of the temporomandibular joint disc in asymptomatic subjects. *Journal of Oral and Maxillofacial Surgery*. 1996;**54**:147-153. DOI: 10.1016/S0278-2391(96)90435-8
- [23] Rajan R, Sun YM. Reevaluating antidepressant selection in patients with bruxism and temporomandibular joint disorder. *Journal of Psychiatric Practice*. 2017;**23**:173-179. DOI: 10.1097/PRA.0000000000000227
- [24] Marini I, Gatto MR, Bonetti GA. Effects of superpulsed low-level laser therapy on temporomandibular joint pain. *The Clinical Journal of Pain*. 2010;**26**:611-616. DOI: 10.1097/AJP.0b013e3181e0190d
- [25] Douglas De Oliveira DW, Lages FS, Guimarães RC, Pereira TS, Botelho AM, Glória JC, Tavano KT, Gonçalves PF, Flecha OD. Do TMJ symptoms improve and last across time after treatment with red (660 nm) and infrared (790 nm) low level laser treatment (LLLT)? A survival analysis. *Cranio*. DOI: 10.1080/08869634.2017.1292176 [Epub ahead of print]
- [26] Tatli U, Benlidayi ME, Ekren O, Salimov F. Comparison of the effectiveness of three different treatment methods for temporomandibular joint disc displacement without reduction. *International Journal of Oral and Maxillofacial Surgery*. 2017;**46**:603-609. DOI: 10.1016/j.ijom.2017.01.018

- [27] Nitzan DW, Dolwick MF, Martinez GA. Temporomandibular joint arthrocentesis: A simplified treatment for severe, limited mouth opening. *Journal of Oral and Maxillofacial Surgery*. 1991;**49**:1163-1167. DOI: 10.1016/0278-2391(91)90409-F
- [28] Ungor C, Atasoy KT, Taskesen F, Pirpir C, Yilmaz O. Long-term outcome of arthrocentesis plus hyaluronic acid injection in patients with Wilkes stage II and III temporomandibular joint internal derangement. *Journal of Craniofacial Surgery*. 2015;**26**:2104-2108. DOI: 10.1097/SCS.0000000000002078
- [29] Hegab AF, Ali HE, Elmasry M, Khallaf MG. Platelet-rich plasma injection as an effective treatment for temporomandibular joint osteoarthritis. *Journal of Oral and Maxillofacial Surgery*. 2015;**73**:1706-1713. DOI: 10.1016/j.joms.2015.03.045
- [30] Al-Moraissi EA. Arthroscopy versus arthrocentesis in the management of internal derangement of the temporomandibular joint: A systematic review and meta-analysis. *International Journal of Oral and Maxillofacial Surgery*. 2015;**44**:104-112. DOI: 10.1016/j.ijom.2014.07.008
- [31] Machoň V, Sedý J, Klíma K, Hirjak D, Foltán R. Arthroscopic lysis and lavage in patients with temporomandibular anterior disc displacement without reduction. *International Journal of Oral and Maxillofacial Surgery*. 2012;**41**:109-113. DOI: 10.1016/j.ijom.2011.07.907
- [32] McCain JP, Hossameldin RH, Srouji S, Maher A. Arthroscopic discopexy is effective in managing temporomandibular joint internal derangement in patients with Wilkes stage II and III. *Journal of Oral and Maxillofacial Surgery*. 2015;**73**:391-401. DOI: 10.1016/j.joms.2014.09.004
- [33] Machon V, Levorova J, Foltan R, Hirjak D, Sidebottom A. Mini-instruments for minimally invasive arthroscopy of the temporomandibular joint: A technical note. *British Journal of Oral and Maxillofacial Surgery*. 2015;**53**:662-663. DOI: 10.1016/j.bjoms.2015.04.015
- [34] Dolwick MF, Dimitroulis G. Is there a role for temporomandibular joint surgery? *British Journal of Oral and Maxillofacial Surgery*. 1994;**32**:307-313. DOI: 10.1016/0266-4356(94)90052-3
- [35] Dolwick MF. The role of temporomandibular joint surgery in the treatment of patients with internal derangement. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics*. 1997;**83**:150-155. DOI: 10.1016/S1079-2104(97)90106-2
- [36] Mercuri LG. Custom TMJ TJR devices. In: Mercuri LG, editor. *Temporomandibular Joint Total Joint Replacement – TMJ TJR. A Comprehensive Reference for Researchers, Materials Scientists, and Surgeons*. Switzerland: Springer; 2016. pp. 91-130. DOI: 10.1007/978-3-319-21389-7
- [37] Salash JR, Hossameldin RH, Almarza AJ, Chou JC, McCain JP, Mercuri LG, Wolford LM, Detamore MS. Potential indications for tissue engineering in temporomandibular joint surgery. *Journal of Oral and Maxillofacial Surgery*. 2016;**74**:705-711. DOI: 10.1016/j.joms.2015.11.008

