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Temporomandibular joint arthritis: possible etiologic factors and arthritis classification

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ABSTRACT

Aim The aim of this paper was to classify the signs of the various types of arthritis that are related to the TMJ according to the etiologic factors.
TMJ Arthritis classification is presented according to the levels of inflammation, in order to summarize current knowledge about the inflammatory theory, with emphasis on recent research on pathophysiology and radiographic differential diagnosis of TMJ arthritis types: Osteoarthritis (low- inflammatory arthritic condition), results from increased pressure on a particular joint or fragility of the cartilage matrix and represents a destructive process by which the bony articular surfaces of the condyle and fossa become altered. Osteoarthrosis (non-inflammatory arthritic condition) is an adaptive stage, involving morphologic changes of the articular structures, not associated with significant alterations in the mechanical joint function. Altered articular surfaces of the TMJ may be considered as normal adaptive responses to increased loading, rather than pathological degenerative changes. Polyarthritis or polyarticular arthritis (high–inflammatory arthritic conditions), present similar symptoms and clinical findings as osteoarthritis but have different causes. The classic type of high-inflammatory arthritis is rheumatoid arthritis.
Conclusion The clinician must be aware of the various systemic conditions that may affect the TMJ and the stomatognathic system as a whole. In this way the proposed dental treatment plan can and should be adjusted to the needs of the patient taking under consideration the manifestations of the disease in the stomatognathic system.

INTRODUCTION

Joint arthritis represents a group of disorders in which destructive bony changes are seen (1). Arthritis is a very common, although not completely understood disease causing inflammation of the articular surfaces of the joint. There are more than 100 different types of arthritis and related conditions. People of all ages, sexes and races could suffer from it (2). Symptoms mainly include joint pain and stiffness, redness, warmth, swelling, and decreased range of motion of the affected joints. Several types of arthritis can affect the temporomandibular joint (TMJ) (2).
The aim of this paper was to present the etiologic factors of TMJ arthritis and to classify the various types of arthritis according the inflammation level in the joint.

Temporomandibular Joint Arthritis

According to the American Academy of Orofacial Pain, TMJ arthritis is categorized into primary and secondary. Primary TMJ arthritis is characterized by the absence of any distinct local or systemic factor. Secondary TMJ arthritis is associated with a previous traumatic event or disease (3). Consequently, when no precipitating cause is apparent, it is primary arthritis and secondary when a related or preexisting conditions may lead to its development (4).

ETIOLOGIC FACTORS: HOST REMODELING CAPACITY

Autoimmune disorders

Autoimmune diseases have been associated with condylar resorption. The immune response may be

directed against specific molecules found in the extracellular matrices of articular tissues in the TMJ (5).

Rheumatoid arthritis

Rheumatoid arthritis (RA) is an autoimmune multisystem disease characterized by chronic inflammation and synovial hyperplasia which usually affects multiple joints. It is considered the main inflammatory joint disorder, with a prevalence of 0,5-1% in the general population (6). RA predominantly affects women, and it has therefore long been thought that hormones such as prolactin (PRL) and estrogen might play an important role as cofactors in the pathogenesis of RA (7). More than half of the patients with RA present clinical evidence of TMJ involvement, often bilaterally (8), resulting in condylar degeneration and, less commonly, acquired apertognathia. (9). The most common TMJ clinical signs and symptoms are arthralgia, swelling, stiffness during mouth opening and upon waking, weakness of the masticatory muscles with decreased bite force, joint noises and limited joint function (10, 11). Cone beam computed tomography of RA in TMJ demonstrates high prevalence of reduced joint space and serious erosion of cortical and subchondral bone. Bone sclerosis, osteophytes and subcortical cysts may also occur (12). Condylar destruction and flattening with anterior positioning of the condyle are very common radiographic signs. There may be flattening of the articular eminence and erosion of the glenoid fossa (13) (Fig. 1). RA acts as a systemic etiological factor with major impact on the development of temporomandibular disorders. However, since its clinical manifestations are often silent, the TMJ involvement has been ignored (10).

Psoriatic arthritis

Psoriatic arthritis (PsA) is an inflammatory seronegative arthritis that affects 5-8% of patients with psoriasis (14). The diagnosis is made on mainly clinical grounds based on the findings of psoriasis and inflammatory joint arthritis (15). The etiology is multifactorial and results in an autoimmune mechanism with inflammatory and destructive features. Joint involvements are typically asymmetrical and mainly refer to the distal interphalangeal finger joints. (16, 17). TMJ involvement correlates with the severity and duration of the systemic disease. The missed early diagnosis results in severe TMJ damage (15). Dervis (2005) found 60% prevalence of TMJ symptoms in PsA patients, on clinical examination (18). Psoriatic TMJ lesions were defined as mainly of erosive type, while arthralgia is a clinical sign for generalized PsA. Crepitus is associated with structural changes in the joint and bilateral ankylosis is an uncommon late finding (10). Radiographic features of the disease include: condylar head erosion, with osteoporotic lesions, osteophyte formation, joint space narrowing, condylar head flattening and subchondral sclerosis in later chronic disease (19).

Ankylosing spondylitis

Ankylosing spondylitis (AS) also known as Bechterew's or Marie-Strumpell disease is a chronic inflammatory disorder affecting predominantly the axial skeleton, although peripheral joint involvement can also occur (20). TMJ is involved in about 10–24% of cases. The commonest clinical symptoms are pain, tenderness and limited jaw opening, while radiological examination reveals erosions or massive condyle deformity in combination with joint-space narrowing (21). Patients with TMJ involvement have evidence of more extensive spinal disease and peripheral joint involvement (22). Difficulty in opening the mouth may be correlated to

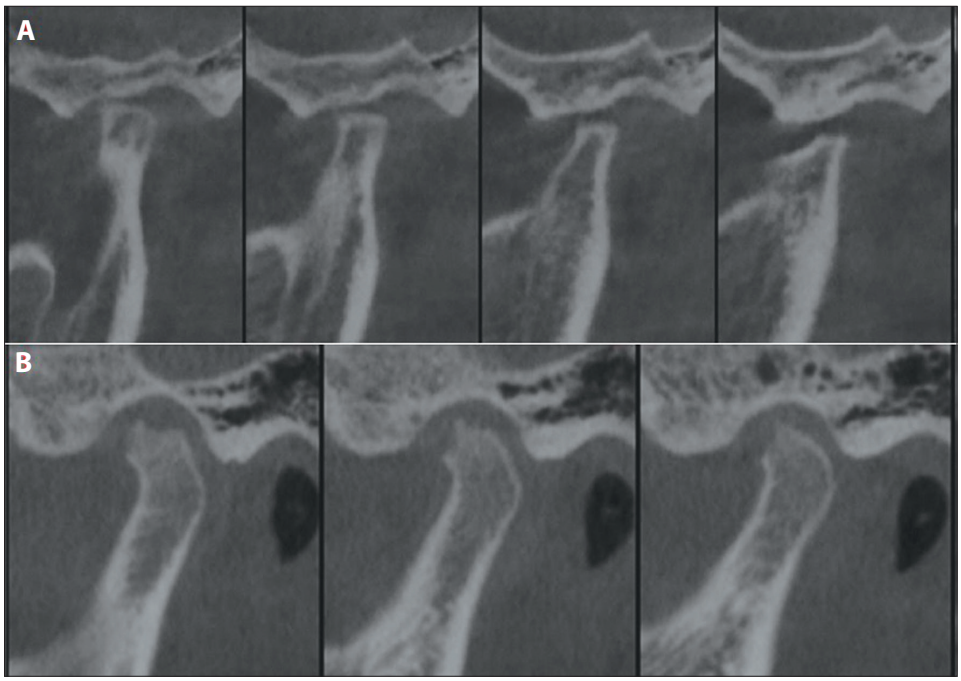

FIG. 1 Temporomandibular joint cone beam computed tomography.
A. Complete flattening of the condylar head and the articular eminence. Anterior positioning of the condyle.
B. Erosion of the cortical and subcortical bone.

the flattening and erosions of the mandibular condyle (21), to elongation of the mandibular coronoid process (23) or due to the approximation of the mandible to chest, which is predominantly affected by AS (22).

Metabolic arthropathy, crystal arthropathy, Calcium Pyrophosphate Deposition Disease (CPPD)

Metabolic or crystal arthropathies represent a heterogenic group of skeletal diseases associated with the deposition of mineralized material within joints and periarticular soft tissues, especially in the articular cartilage and fibrocartilage. Gout is the most common and pathogenetically best understood crystal arthropathy. These crystals are responsible for different rheumatic syndromes, including acute or chronic synovial inflammation (24).

The spectrum of TMJ involvement ranges from asymptomatic disk calcification to a masked joint destruction with erosive condyle and adjacent skull base changes. Common symptoms include pain and preauricular swelling with occasional hearing loss. Chewing can exacerbate the pain. Other less common symptoms include TMJ clicking, tinnitus and malocclusion. The erosions may extend into the skull base and into the middle cranial fossa. Involvement of other joints with chondrocalcinosis is a clue to the diagnosis. (13). CPPD, however is unusual in this site. Authors of several large case series failed to report any acute attacks affecting this joint (25) and only infrequent reports of TMJ CPPD have been published (26, 27, 28, 29, 30).

SAPHO syndrome

SAPHO (Synovitis, Acne, Palmoplantar Pustulosis, Hyperostosis, Osteitis) syndrome is a rare disease of unknown origin (31) associated with bone and skin abnormalities (32). The fundamental component of SAPHO syndrome is an inflammatory, pseudoinfectious, sterile osteitis (33). TMJ involvement has rarely been described (34, 35). The mandible is affected in about 10% of SAPHO cases, with the most commonly affected sites being the ascending ramus and posterior mandibular body. Typical clinical symptoms are limitation of mandibular motion, swelling (often associated with erythema and edema), pain and crepitation. TMJ involvement in SAPHO is associated with mandibular asymmetry (34, 36, 37). Typical radiologic TMJ findings are marginal erosions, flattening, and cortical sclerosis of the condyle (38, 39), leading to a deformity of the mandible in the end stage. TMJ tomography shows areas of osteitis and sclerosis of the alveolar bone, reactive cortical thickening, ankylosis and degenerative condyle changes (34, 40).

Septic arthritis, reactive arthritis

septic arthritis is a serious infection, characterized by pain, fever, swelling and even loss of function in one or more affected joints (41). It is considered to be a medical emergency resulting of either the hematogenous spread of micro-organisms through the highly vascularized synovial membrane or the direct extension of a contiguous infection (42). Septic TMJ arthritis results in significant morbidity if diagnosis is delayed (41). The most common pathogens, of the reported cases, have been Staphylococcus aureus, Neisseria, Haemophilus influenzae and Streptococcus (43).

Reactive arthritis (ReA), or seronegative spondylo-arthropathy, is an inflammatory disease that can occur in the TMJs commonly with displaced discs, with or without condylar resorption usually related to bacterial and/or viral pathology. ReA commonly develops in the midteens through the 4th decade, predominant in females, and can cause TMJ pain, arthritis, and condylar resorption. Systemic symptoms of ReA may include joint pain, fever, fatigue, back pain, degenerative joint disease, polyarthritis and dysfunction of the immune system (44).

Hormones, endocrine disorders

Homeostasis during inflammation is achieved by a balance between cytokines and endocrine hormones with the latter playing a significant role in auto-immune diseases. However, the molecular basis for this crosstalk between neuro-endocrine and immune systems is not fully understood (7). Hormonal factors may have a marked influence on condylar remodeling. Females may be predisposed to dysfunctional TMJ remodeling due to loading, suggesting a potential role of sex hormones as modulators of this response (45).

Estrogen

Estrogen is the primary female sex hormone (46) and is increasingly receiving attention for its potential role in condylar resorption. Primate TMJs have been examined for estrogen and progesterone receptors. Female baboon TMJs have estrogen receptors while male baboon's do not. This fact suggests a potential relationship between estrogen-mediated cellular activities and the majority of TMJ female problems (5). Although estrogen is known to play an important role in the etiology of postmenopausal osteoarthritis or RA (47), little information has been available regarding the relationship between estrogen and the etiology of TMJ remodeling (48). In regard to condylar resorption, more relevant pathways related to low estradiol are likely to be the intercellular communication ones (cytokines). There is a great interest about the balancing act between 2 cytokines:

- Receptor Activator of NFκB Ligand (RANKL), membrane-bound ligand expressed on osteoblasts. Binding of RANKL to its receptor RANK, induces osteoclastogenesis and activation of mature osteoclasts (49). Estrogen has been shown to suppress RANKL-induced osteoclast differentiation *in vitro* (50).
- Osteoprotegerin (OPG), a soluble tumor necrosis factor receptor is a naturally occurring RANKL inhibitor. OPG

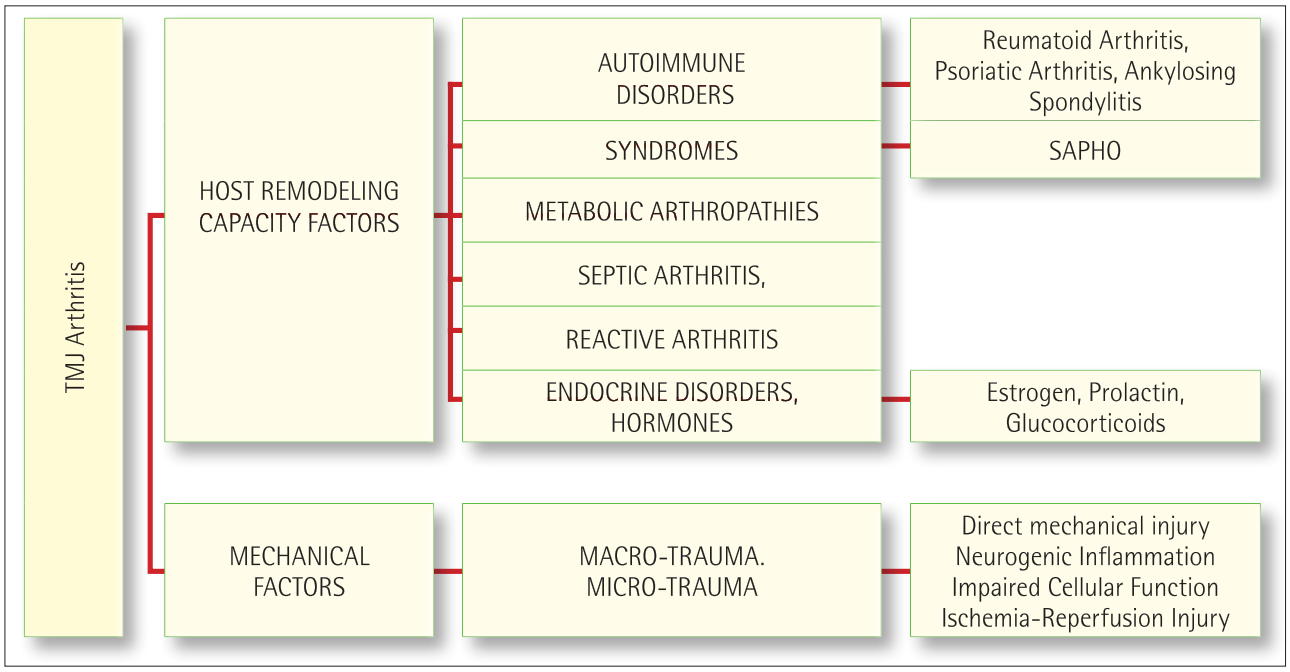

FIG. 2 Temporomandibular Joint Arthritis: possible etiologic factors.

competitively binds RANKL to inhibit the action of the receptor RANK both *in vivo* and *in vitro*, which prevents osteoclastic bone resorption (51).

The balance between these two cytokines is important for bone integrity. Estrogen has been shown to protect bone from local or systemic inflammatory factors by increasing the expression of OPG via estrogen receptors (52). When estrogen is deficient, OPG is not promoted, allowing the inflammatory factors to inhibit new bone formation or promote resorption of bone mass (53). In addition to the RANKL/OPG effect, women with consistently low circulating estrogen levels have increased inflammatory cytokines and resultant increases in arthritic symptoms and decreases in bone mineral density (54). Estrogen might also protect against bone loss, ensuring a low-regulation of the matrix metalloproteinase (MMP) transcription. MMP elevation has been identified in patients with aggressive condylar resorption following degradation of the condyle's extracellular matrix (54).

Prolactin

Prolactin (PRL) is a neuroendocrine hormone, mainly secreted by the anterior pituitary gland and by cells in many extra-pituitary sites, including immune cells (7). PRL protects against osteoclastogenesis and bone loss in inflammatory arthritis by inhibiting cytokine-induced expression of RANKL in joints and synovial fibroblasts (55). PRL also inhibits the apoptosis of cultured chondrocytes in response to a mixture of proinflammatory cytokines. The survival effect of PRL becomes apparent in the context of inflammation. While PRL is not essential for normal immune system development and function, it is a major stress-related hormone, balancing immune system homeostasis in the context of stress, trauma, and inflammation (56).

Glucocorticoids

Glucocorticoids (GCs) are central steroid hormones on endocrine stress response modulation and whole-body homeostasis in vertebrates. In addition to well-known effects on glucose metabolism, immune system, reproduction, feeding, circadian rhythm, behavior, and cognition, GCs also regulate bone metabolism (57).

Endogenous GCs

Endogenous GCs have dual metabolic effect on bone development and metabolism. (58). Physiological levels of GCs are vital for normal skeletogenesis and bone mass accrual highlighting an important anabolic role. However, an increase of GCs over the basal levels causes reduced bone growth, bone resorption and bone mineral loss. GCs levels are rapidly increased in the blood, during an acute stress, before returning to basal levels via negative feedback mechanisms, while chronic stress results in high GCs levels which remain elevated leading to several pathological conditions including bone mineral loss. (57). GCs stimulate the production of RANKL in osteoblasts and osteocytes. OPG production is also regulated by GCs but in this case negatively so RANKL/OPG ratio balances in favor of RANKL. Additionally, GCs cause an increase in macrophage colony-stimulating factor, another essential factor in osteoclastogenesis (58).

Exogenous/therapeutic GCs

Therapeutic GCs are powerful anti-inflammatory agents that can be administrated orally or injected directly into the joint space (59). GC therapy has been

	Osteoartritis	Osteoarthrosis	Polyarthritis/Rheumatoid Arthritis
Inflammation level	Low-inflammatory, local arthritic condition	Non-inflammatory arthritic condition	High-inflammatory, generalized arthritic condition
Factors	Age-related disorder, increased joint pressure or fragility of the cartilage matrix. Excessive or sustained physical stress to articular structures exceeding normal adaptive capacity or exceeding a decreased adaptive capacity	Normal adaptive response to increased loading	Autoimmune diseases, such as RA, genetic predisposition, viral infections, microbiological, hormonal and environmental factors.
Potential Clinical Characteristics	Pain and loss of joint function. Limited mandibular opening. Soft end feel unless OA is associated with anteriorly dislocated disc. Crepitation especially at chronic OA. Increasing pain with lateral palpation. Symptoms may pre-exist 6 months prior the radiological findings.	No significant alterations in the mechanical function of joint or occlusion No clinical symptoms of pain are reported, except crepitation	Arthralgia, swelling, stiffness during mouth opening and upon waking, weakness of the masticatory muscles with decreased bite force, joint noises and limited joint function
Potential Radiological signs	In early cases radiographs may appear normal. Dysfunctional TMJ remodeling. Acute or early changes – destructive stage: Erosive lesions and joint space narrowing Late changes – tissue repair stage: sclerosis, flattening, subchondral cyst and osteophyte	Functional joint remodeling morphological changes of the articular structures	More diffuse degeneration on imaging. RA: Reduced joint space, erosion of cortical and subchondral bone, sclerosis, osteophytes, subcortical cysts, condylar destruction, flattening with anterior condyle positioning. Possible articular eminence flattening & erosion of the glenoid fossa.
Histological characteristics Laboratory findings	Inflammatory Theory: release of toxic cellular mediators, tissue injury promotion, classical signs of inflammation, loss of function. OA cartilage: rich source of inflammatory mediators Synovitis: (inflammation of the synovial membrane) surrogate marker of pathologic severity. Mechanosignaling and Inflammation: Biomechanical stress activates parallel and converging signals for hypertrophy and apoptosis.	Stable condition, absence of histological inflammatory characteristics, yet the bony morphology remains altered.	Chronic inflammation, synovial hyperplasia. Initial phase: synovial hyperemia, lymphocyte infiltration, fibroinoid degeneration, pannus formation. Cartilage distortion and granulation tissue in the joint cavity. Final stage: Fibrous ankyloses
Affected joints	One or more joints	One or both the TMJs	Four or more joints

TABLE 1 Summary of the potential characteristics for each type of TMJ Arthritis. At the category of Polyarthritis, RA characteristics are mentioned.

shown to be effective at temporarily alleviating joint symptoms associated with osteoarthritis and other inflammatory disorders (60). However, sustained exposure to exogenous GCs is responsible for the so-called GCs-induced osteoporosis, as a consequence of long-term GC therapy (57). The beneficial effects of corticosteroids occur at low doses and short culture duration (60). Changes in GC levels may, in some individuals, initiate mandibular condylar resorption and attendant progressive Class II malocclusion (5). Local injection of GC increases the risk of infection and the destruction of the articular cartilage, tendons or ligament attachments. Repeated intra-articular GC injections have been implicated in the "chemical condylectomy" phenomenon in the TMJ (61). Likewise, oral GC use should be limited to no more than 2 weeks because of the well-known risks of decreased resistance to infection, elevations in blood glucose, osteoporosis and suppression of the hypothalamic-pituitary-adrenal axis (62).

ETIOLOGIC FACTORS - MECHANICAL STRESS

Mechanical stress provokes molecular, soft tissue and osseous adaptive remodeling responses in the normal TMJ. Healthy TMJs maintain homeostasis when subjected to normal and episodal excessive stress. When compromised biochemically or biomechanically, the joint may break down when subjected to normal or abnormally elevated mechanical stimulations.

Micro-trauma and macro-trauma

Micro-trauma refers to any small force, repeatedly applied to the joint structures over a long period of time. If however, loading exceeds the functional limit of the tissue, irreversible changes or damage can result (1). In the case of normal and abnormal TMJ function, the effects of direct and free radical damage are unknown (5).

Macro-trauma is any sudden force to the joint which can result in structural alterations and can be subdivided into two types.

- Direct trauma: The condyle can be suddenly displaced from the fossa, when the teeth are separated, elongating the ligaments and compromising the normal condyle-disc mechanics. Closed mouth trauma is less injurious to the condyle-disk complex, however articular surfaces could certainly receive sudden traumatic loading (1). A direct trauma to the joint can produce both direct and free radical damage to joint molecules and tissues (5). Direct trauma could be iatrogenic, every time the jaw is overextended (1).
- Indirect trauma: refers to injury that may occur to the TMJ secondary to a sudden force, but not directly to the mandible. The most common type of indirect trauma is associated with cervical extension/tension flexion injury (1).

It has been postulated that mechanical stresses at the TMJ lead to oxidative stress of articular tissues (63). It is also hypothesized that excessive mechanical stress to the TMJ may be of a magnitude sufficient to damage tissues directly (direct mechanical injury) or indirectly (neurogenic inflammation and hypoxia-reperfusion injury) (64).

Direct mechanical injury

Excessive mechanical stress can lead to direct physical disruption of molecules in affected tissues leading to cell death and tissue volume decreases (5). A significant increase in the number of apoptotic cells was observed in response to mechanical loading. This injury induces chondrocyte apoptosis, sensitive to pharmacologic inhibition (65). Mechanical disruption of specific molecules in a tissue can also lead to the production of free radicals (5).

Mechano-signaling and inflammation

Biomechanical stress activates multiple parallel and converging signals for hypertrophy and apoptosis. Considering for example the physiopathology of disc displacement, the mechanical stress generated in jaw movement during mouth opening and closing prompts the activation of apoptosis in these areas (66). Any abnormal mechanical stress applied on a joint can be converted into activated intracellular signals in joint cells by mechanoreceptors present at the surface of joint cells. These signals may eventually lead to the overexpression of inflammatory soluble mediators when a certain threshold is reached (67). This endogenous reaction phenomenon aims to restore homeostasis and/or tissue remodeling. Therefore, this apoptotic event might work as a protective mechanism to overcome the progression of disease (68).

The term "osteoarthritis" (OA) consequently, has been defined as a low-inflammatory arthritic condition either primary or secondary to trauma or other acute or chronic overload situations, characterized by erosion of the articular cartilage. Pain and loss of joint function may result (61). The TMJ differs from other joints in that the bone of the mandibular condyle is located just beneath the fibrocartilage, making it particularly vulnerable to inflammatory damage (69). Classic types of low-inflammatory arthritis are the degenerative joint disease, produced by intrinsic degeneration of articular cartilage, typically the result of age-related functional loading, and post-traumatic arthritis (11).

Neurogenic inflammation

Neurogenic inflammation and increased sympathetic tone may contribute to net tissue loss following biomechanical TMJ stresses. Traction or compression of peripheral nerve terminals in the joint may evoke a release of neuropeptides, able to initiate inflammatory response. Inflammatory cytokines can increase the synthesis of these neuropeptides in a positive feedback mechanism (5).

The Inflammatory theory

The Inflammatory theory was mainly based on the observation that chondrocytes, the only cell type present in the cartilage, are characterized by slow metabolism activity with no repairing ability (67). Due to this unique architecture of the cartilage, when it is inflamed at the molecular level, it does not qualify for the typical definition of inflammation (70).

Progress in molecular biology profoundly modified this theory. The morphologic changes are frequently accompanied by the superimposition of secondary inflammatory changes (11). Apoptosis of chondrocytes is the prominent characteristic of the early phase of cartilage degeneration and the cytokines released by the apoptotic cartilage chondrocytes may contribute to the destruction of subchondral bone (71). The presence of soluble mediators, such as cytokines or prostaglandins, can increase the production of MMPs by chondrocytes leading to the first steps of the Inflammatory theory (67). Possibly the activated chondrocytes observed in

OA may not only be a target, but also an instigator in the disease process, based on the autocrine production of inflammatory mediators, which promote tissue injury, resulting in some, but not all, of the classical signs of inflammation (70).

Impaired cellular function

Excessive or prolonged mechanical loading of articular tissues of the TMJ may also adversely affect nutrient supply to local cell populations and may perturb certain vital cellular functions. The balance between catabolic and anabolic biologic processes may be disturbed, leading to a net loss of articular tissue (5). Metabolic or mechanical factors contribute to the early cartilage damage (3). For example, according to Maydana et al., the articular disc protects the underlying tissues, and its displacement could expose these tissues to excessive additional pressure with resulting degenerative changes (72). This initiates a series of biomechanical changes in the hard and soft tissues of the joint, triggering the immune response (3).

Synovitis

Synovitis is a surrogate marker of pathologic severity and is strongly associated with an increased risk of radiographic evidence of disease progression (67). Molecules from degraded hyaline cartilage are released into the synovial cavity and react to the foreign bodies by producing inflammatory mediators found in synovial fluid (73). These mediators are able to activate the superficial cartilage layer chondrocytes, leading to the synthesis of metalloproteinase, increasing further cartilage degradation. The mediators can lead also to an increased synthesis of inflammatory cytokines and MMPs by synovial cells themselves, by inducing synovial angiogenesis, perpetuating the cartilage degradation. Another theory supports that synovial tissue is the primary trigger of the OA process (67, 74).

Hypoxia – reperfusion injury

Cellular effects of ischemia

loading pressures that exceed capillary perfusion pressure can impair blood flow to intracapsular tissues leading to ischemia. Cell populations in ischemic tissues adjust their metabolic pathways to accommodate lower oxygen tensions (5). Oxygen homeostasis is fundamental to human physiology, therefore prolonged ischemia results in multiple cellular metabolic and ultrastructural changes (75), inducing a pro-inflammatory state that increases tissue vulnerability to further injury on reperfusion (76).

Role of reactive oxygen species

it has become apparent that re-perfusion, the blood flow reestablishment in the joint after a period of ischemia (i.e. reduced intracapsular pressure following relaxation of jaw muscles), can place ischemic organs at risk of further cellular necrosis and thereby limit the recovery of function because oxygen tension rapidly rises in affected tissues (77). Reperfusion of ischemic tissues with altered metabolic pathways still functioning, results in formation of toxic reactive oxygen species (76), affecting various molecular TMJ species (78). Figure 2 presents a layout of the possible etiologic factors of TMJ arthritis.

TMJ ARTHRITIS CLASSIFICATION

TMJ Arthritis classification is presented, in the following paragraphs, according to the levels of joint inflammation, in order to summarize current knowledge about the inflammatory theory, with emphasis on recent research on pathophysiology and radiographic differential diagnosis of TMJ arthritis types (Table 1).

Osteoarthritis, low-inflammatory arthritic condition

One of the most common types of TMJ arthritis is osteoarthritis (OA) (or degenerative joint disease) (79), an age-related disorder, which results of increased joint pressure or fragility of the cartilage matrix (67) and represents a destructive process by which the articular surfaces of the condyle and fossa become altered (1). Classically OA, unlike RA, was considered an inherently, non-inflammatory disorder of movable joints characterized by deterioration of articular cartilage and formation of new bone at the joint surfaces and margins. Moreover, OA is not a systemic disease, in comparison with the systematic character of RA, but a disorder in which an "inflammatory component" seems to be restricted in the cartilage and bone (70).

Joint remodeling

Joint remodeling is a biological homeostatic procedure of normal functional adaptation (80, 11). A certain amount of loading is necessary to survive, because loading forces drive synovial fluid in and out of the articular surfaces, passing with it nutrients coming in and waste products going out (1). Hyaline cartilage of the load-bearing joints is more resistant to compression, but the TMJ fibrocartilage better withstands shear forces (81). Under normal physiological conditions, a balance exists in synovial joints between tissue breakdown and repair. When the balance is disturbed by biomechanical or inflammatory insult, the discal fibrocartilaginous remodeling system may fail, resulting in accelerated tissue breakdown (82). Consequently, two distinct categories of TMJ remodeling can be observed: 1) Functional remodeling, an ongoing, continuous process characterized by moderate morphologic changes of the articular structures, not associated with any significant alterations in the joint function or the occlusion and 2) dysfunctional remodeling which adversely affects the joint and the occlusion and is distinguished by excessive TMJ morphologic changes (5, 45).

Idiopathic condylar resorption

Idiopathic condylar resorption (ICR), also known as

progressive condylar resorption, is described by Arnett and colleagues (1996) as a dysfunctional remodeling of the TMJ (5). Whether the pathology of ICR is a form of osteoarthritis is still debated. Considering that the clinical features of ICR are comparable to those found in other low-inflammatory arthritic TMJ conditions, until the etiology of this entity is completely elucidated, it will be included in the same context of osteoarthritic disease (61).

Post-traumatic arthritis – Cheerleader's syndrome

Post-traumatic arthritis is a form of osteoarthritis. When the condyle receives sudden macrotrauma, a secondary arthritic condition can develop. (1). It could also be referred to as "cheerleader's syndrome," because it frequently occurs in teenage girls participating in sports activities which, through minor or major trauma to the jaws, can initiate or exacerbate the host tolerance (83). However, post-traumatic arthritis can also occur after the development of chronic inflammatory arthritis (84).

Primary features of TMJ osteoarthritis

TMJ OA usually affects both mandibular condyle and articular eminence (4). Common characteristics are limited mandibular opening with a soft end feel, crepitation, increasing pain with lateral condyle palpation, similarly to manual joint loading (1). The radiographic signs of the disease are cortical bone erosion, joint compartment flattening, with productive bone changes such as sclerosis and osteophyte (85). These signs represent different stages of the disease process. Erosive lesions and joint space narrowing indicate acute or early change, whereas sclerosis, flattening, subchondral cyst and osteophyte may indicate late changes (86). Osteophyte formation typically occurs at a later stage in the disease and can stabilize and broaden the surface area of the joint in an attempt to better withstand axial loading forces (13) (Fig. 3). Changes in the architecture of the subchondral trabecular bone due to accelerated bone turnover can form subchondral cysts (Ely's cysts). In symptom-free individuals, radiographic evidence of TMJ OA occurs in 14% to 44%. However, clinical evidence of the disease occurs in only 8% to 16% of the population (4). The changes seen on imaging do not always correlate with symptoms, therefore many patients may be pain-free despite advanced osteoarthritis and the only complaint is of joint noises or grating (87).

Osteoarthrosis, non-inflammatory arthritic condition

When structural changes in the subarticular bone are seen on radiographs, but no clinical symptoms of pain are reported by the patient, except crepitation, a stable adaptive phase of osteoarthrosis is represented. The past history may reveal a period of time when symptoms where present (OA) (1). The term "osteoarthrosis", is a synonym for osteoarthritis in the medical orthopedic literature (61) and is identified in the dental TMJ literature as a non-inflammatory arthritic condition (70). When bony changes are active, the condition is called osteoarthritis. As remodeling occurs the condition can become stable, yet the bony morphology remains altered. This adaptive stage is osteoarthrosis (1). Apparently the description of osteoarthrosis is similar to functional joint remodeling (5), emphasizing the lack of overt inflammation (70). A new term, adaptive remodeling instead of osteoarthrosis, is suggested by Türp et al., supporting

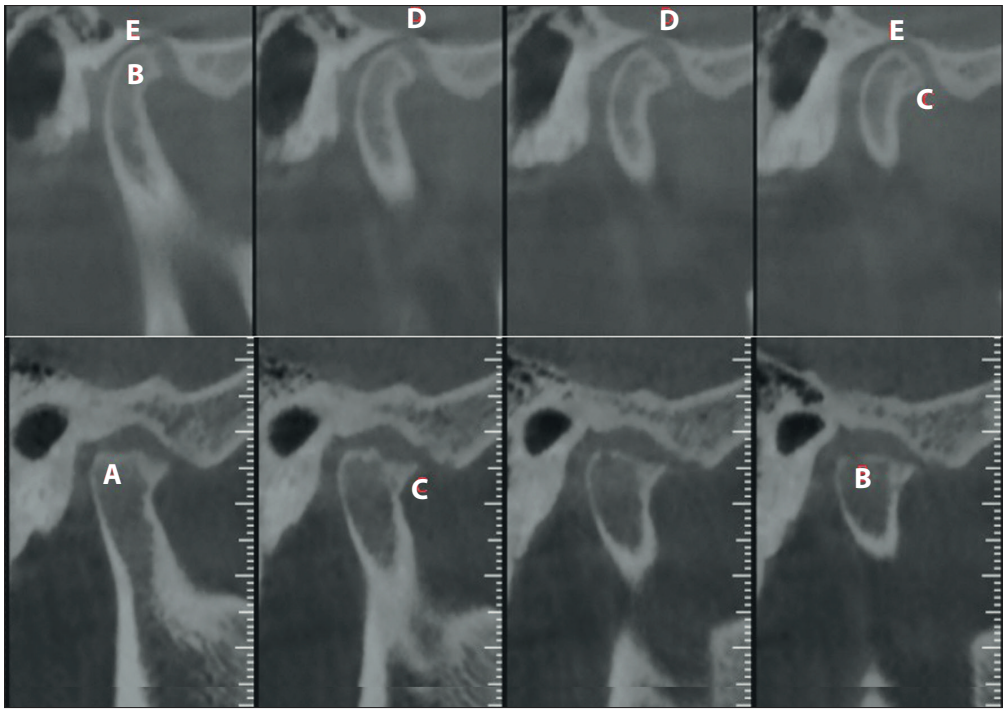

FIG. 3 Temporomandibular joint cone beam computed tomography.
A: Bone sclerosis of the condylar head.
B: Flattening of the condylar head.
C: Osteophytic formation.
D: Erosion of the glenoid fossae.
E: Reduced joint space.

that altered articular surfaces may be considered as normal adaptive responses to increased loading, rather than pathological degenerative changes (88).

Polyarthritis, high–inflammatory arthritic conditions

Polyarthritis represent a group of arthritic conditions, less common in the TMJ (1). They are also known as polyarticular arthritis and are defined as arthritis affecting four or more joints simultaneously (89). They present similar symptoms and clinical findings as OA but have different causes (1). High-inflammatory arthritic conditions primarily involve the synovial cells and joint bone. The classic type is RA while other include infectious or viral arthritic conditions, metabolic arthropathies, such as gouty arthritis, psoriatic arthritis, lupus erythematosus, ankylosing spondylitis, Reiter's syndrome and arthritis associated with ulcerative colitis. In all instances TMJ can be involved and individuals show a more diffuse degeneration of the involved joints on imaging (11).

DISCUSSION AND CONCLUSION

The clinical relevance of this study was to present an overview of the etiology of TMJ arthritis and a classification of the various types according to the inflammation level in the joint. The clinician must be aware of the various systemic conditions that may affect the TMJ and the stomatognathic system as a whole. In this way the proposed dental treatment plan can and should be adjusted to the needs of the patient taking under consideration the manifestations of the disease in the stomatognathic system.

Contributions

MA, IR, SK, DK, MM data collecting and analyzing, manuscript writing, references search; ML and NP manuscript reviewing and references search.

Conflict of interests

All the authors declare no potential conflict of interests.

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