



Issue Date: November 2005, Posted On: 12/1/2005

An Orthopaedic Approach to the Diagnosis and Treatment of Disorders of the Temporomandibular Joint

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Problems involving the temporomandibular joint (TMJ) have been termed temporomandibular disorders (TMD). Patients with many different disorders are included under the umbrella designation of TMD. It is important to emphasize that TMD is not one disease with one treatment. A lack of a more definitive diagnostic scheme, especially in published research, has led to confusion in terms of therapeutic approach.¹ Patients who have TMD may or may not have damage to joint structures. Clarification of this issue—healthy joint or damaged joint—will be a major step forward in clarifying the clinical management of TMJ problems.

If after evaluating a patient with a painful knee the physician offers the working diagnosis of "knee disorder," one would question the sensitivity of the diagnostic approach. In dentistry, patients routinely present with a previous diagnosis of "TMJ" or "TMD." Telling a patient that he or she has "TMD" is equivalent to a physician telling a patient he or she has "knee disorder." TMJ and TMD are not accurate orthopaedic diagnoses, and clinicians should not use them.

This article will discuss approaches to development of a more specific diagnostic scheme for TMJ disorders.

BASIC ORTHOPAEDIC PRINCIPLES

A joint is 2 bones joined together to allow movement between those bones. Joints are classified as being of 5 types:²

- (1) syndesmosis: a joint in which 2 bones are bound together by fibrous tissue only.
- (2) synchondrosis: a joint in which 2 bones are joined together by cartilage.
- (3) synostosis: a joint that has become obliterated by bony union.
- (4) symphysis: a joint in which the 2 opposing surfaces are covered by hyaline cartilage and joined by fibrocartilage and strong fibrous tissue.
- (5) synovial: a joint in which the 2 opposing surfaces are covered by cartilage (hyaline or fibrocartilage) and joined peripherally by a fibrous tissue capsule enclosing the joint cavity, which contains synovial fluid. Synovial joints allow a greater degree of movement than the other joints but at the expense of providing less stability. Synovial joints have a specialized tissue, the synovium, that produces synovial fluid, which provides lubrication and nutrition to the inner joint tissues.

The TMJ is a synovial joint and is susceptible to the same disease processes as any other synovial joint in the human body. The current standard in orthopaedic medicine is to determine if damage exists to a joint before treatment is rendered.² If damage to a joint is suspected, the next step is to determine the nature and extent of the injury. The hard tissues are evaluated by radiographic imaging, observing the joint in more than one direction; 3 or more radiographic views are preferred. Two radiographic views offset at 90° are the minimum standard for any joint.²⁻⁴ The plane of the views varies by joint.

Therefore, utilizing only panoramic and transcranial radiographs for evaluation of the TMJ is below the medical standard, since these films provide only one plane of view.

Radiographic techniques to view a damaged TMJ include plain radiography, panoramic radiography, computerized tomography (CT), tomography, fluoroscopy, and magnetic resonance imaging (MRI). CT with reconstruction in multiple planes is currently the best technique for viewing the bones of the TMJ. If CT is not available, tomograms or conventional radiographs in 3 views are adequate (submentovertex, corrected sagittal, and corrected coronal), but much detail is lost. The soft tissues are best evaluated with MRI. The medical standard is to utilize MRI if meniscal damage is suspected.³ A useful MRI protocol for diagnosing TMJ damage would include T1 open and closed corrected sagittal views, T2 and proton density closed corrected sagittal views, and T1 corrected coronal views.⁵ MRI scans basically show water and fat in tissue. A T1 image shows more fat than water, whereas a T2 image shows more water than fat. A T2 is useful in identifying inflammation and edema. A proton density image is between a T1 and a T2 and is useful in visualizing the disc of the TMJ. The results of the CT and MRI, in addition to the history and clinical findings, will allow the clinician to develop a specific diagnosis for the damaged joint.

CT and MRI scans are needed to determine the nature and extent of the damage. There are 6 anatomical structures to evaluate for damage: ligaments, disc, articular cartilage, synovium, cortical bone, and cancellous bone/marrow. For example, damage to the synovium and cartilage in a joint is known as osteoarthritis (OA) in orthopaedic medicine. Damage to the bone marrow by compromised condylar blood perfusion resulting in marrow necrosis is known as avascular necrosis (AVN). Both OA and AVN will eventually lead to damage to the cortical bone but are very different disease processes. Determining health, or damage to specific structures, will allow

one to be more specific as to the disease process. This will allow for specificity of treatment.

ANATOMY AND PATHOLOGY OF THE TMJ: ARRIVING AT A SPECIFIC DIAGNOSIS

Following is a description of the anatomical components of the TMJ.

Ligaments

Ligaments are bundles of connective tissue that join the 2 bones of the joint. They are composed of collagen and elastin in a 4:1 ratio.⁴ When damaged, ligaments can be stretched, partially torn, or completely torn. In health they serve to hold the joint together when it is not loaded and to define the end points of movement. The TMJ is the only joint in the body in which one of its end points of movement (closing) is solid (teeth). When a joint is loaded, the ligaments play a secondary role in joint stability. Of greater importance to joint stability when the joint is loaded is the shape of the joint surfaces, the shape of the disc, and the position of the muscles.⁴ In synovial joints with discs, ligaments join the disc to the bones and help hold the disc in position when it is not loaded. Under loading, it is the disc shape that stabilizes the disc. A patient cannot have a displaced disc without damage to the discal ligaments. On MRI scans disc position is used to gauge the amount of damage to ligaments. A partially displaced disc will have less damage to the discal ligaments than a fully displaced disc.

Disc

The disc of the TMJ consists of fibrocartilage.^{4,6} The TMJ is the only joint in the body that rotates, slides, and pivots.⁷ Fibrocartilage is more flexible than cartilage, allowing it to conform to both the condyle and eminence during these 3 condylar movements.⁶ When damaged, the disc can be displaced, adhered, atrophied, or perforated. Displacement can occur in any direction, including toward the anterior, anterior medial, anterior lateral, direct medial, and direct lateral. Posterior dislocations are rare but have been reported.⁸ Discs may become damaged from chronic or acute trauma.⁹ Discs may be either partially or fully displaced and may or may not recapture upon opening. A nonreducing displaced disc over time will atrophy and become deformed. A large nonreducing displaced disc is indicative of a more recent injury versus a small atrophic disc.

A classification scheme for displacement of the disc as seen on MRI has been developed by Piper.¹⁰ Piper's disc classification scheme is a modification of a classification scheme by Tasaki and Westesson.⁸ Both are based on MRI interpretation, both identify disc displacements as partial or complete, and both identify in which direction the disc is displaced. While Tasaki and Westesson have 9 categories based on direction of disc displacement, Piper has 5 categories, with several subcategories, based on severity of disc and ligament damage. A Piper Class I has no damage to the disc or discal ligaments while a Piper Class V will have the most. What is not addressed by Tasaki and Westesson, but is by Piper, is whether or not the disc reduces. Also addressed in the Piper classification scheme are joints in which there is bone-to-bone contact (Table).

A Piper I classification indicates that the disc is normal and the ligaments are attached and do not display pathology. Piper II indicates that the disc is in a normal position, but the ligaments are stretched or torn. Piper III indicates that the disc is partially displaced off the condyle; the direction of the displacement is added. Piper IV indicates that the disc is completely displaced with retrodiscal tissue interposed between the condyle and the eminence; the direction of the displacement is indicated. Piper V indicates that there is no longer any tissue between the condyle and the eminence. In Piper III and IV, subclass "a" indicates that the disc recaptures; "b" indicates that it does not. In Piper V, subclass "a" indicates that the bone is in active osteoarthritic breakdown; "b" indicates that the bone has become eburnated (end-stage osteo-arthritis).

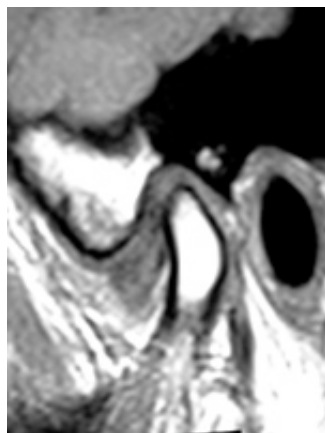


Figure 1. MRI T1 corrected sagittal closed, lateral pole, Piper IVa- anterior lateral. Notice how the majority of the disc is seen in this view indicating an anterior lateral displacement.

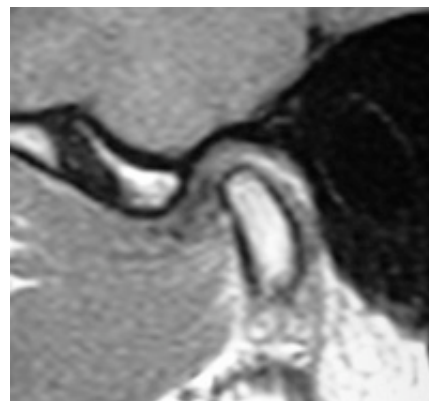


Figure 2. Same joint, more medial view than Figure 1. MRI T1 corrected sagittal closed, medial pole, Piper IVa—anterior lateral.

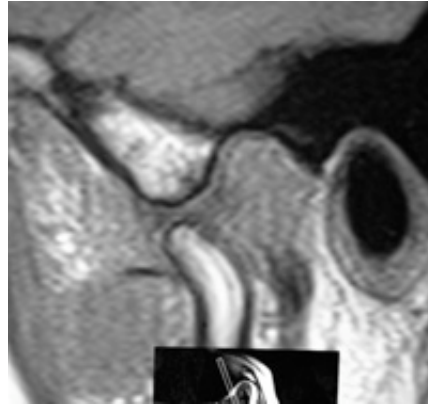


Figure 3. Same joint as Figures 1 and 2 —open view. MRI T1 corrected sagittal open, midcondyle, Piper IVa- anterior lateral.

As examples, a Piper IIIb-anterior medial indicates a partially displaced disc off the lateral pole of the condyle. The disc is displaced in an anteriomedial direction. The medial portion of the condyle is still covered by the disc. Upon opening, the disc does not recapture on the lateral pole. A Piper IVa anterior lateral indicates the disc is completely off both the lateral and medial poles and sits anterior lateral to the condyle. Upon opening the disc is recaptured (Figures 1 to 3).

Articular Cartilage

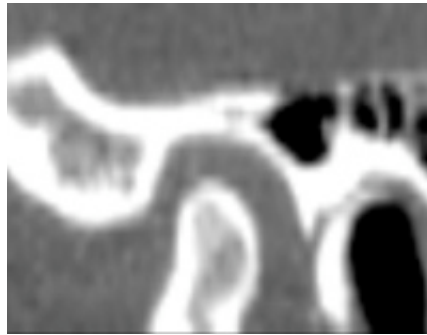


Figure 4. CT corrected sagittal reconstruction. Good size and shape of condyle. MRI indicated Piper I.

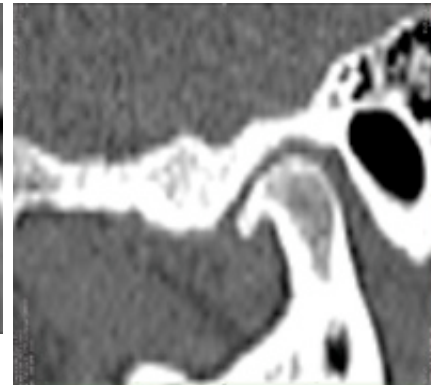


Figure 5. CT corrected sagittal reconstruction. Moderate OA with cyst on superior aspect. MRI indicated Piper V.

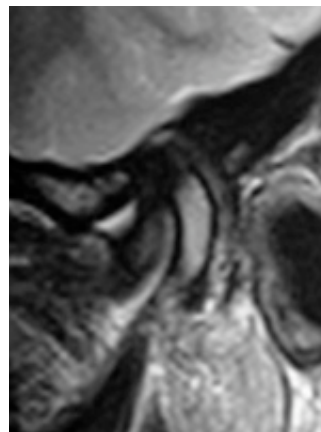


Figure 6. MRI T2 corrected sagittal closed, Piper IVa. Note effusion (white area) in anterior superior joint space.

Fibrocartilage covers the articular surface of the condyle and the articular surface of the eminence. The disc is composed of this fibrocartilage. Being resilient, it will act as a shock absorber for longitudinal force. It consists of living chondrocytes, collagen,

proteoglycans, and water. The chondrocytes produce the collagen and proteoglycans. Collagen is the major structural protein of cartilage. The proteoglycans attract and hold the aqueous component, which is 80% by weight. Covering the cartilage is a layer of surface-active phospholipids (SAPL).⁹ The interaction of the SAPL and lubricin, a glycoprotein added to synovial fluid by synovial cells, keeps the 2 joint surfaces from actually contacting during normal loading by maintaining a fluid layer between the surfaces. This results in a very low coefficient of friction. A healthy joint's coefficient of friction is one fifth that of ice sliding against ice.² Cartilage can be damaged by compression or tearing, and the result can be fibrillation, necrosis, proliferation, or adhesion.² Once cartilage is damaged, there will be an increase in friction and an increase in wear of the joint. Cartilage covering the bone is not easily seen with either MRI or CT scans. It is not until the damage has progressed to the subchondral bone that it is radiographically evident (Figures 4 and 5). On MRI T2 images, inflammation to the synovial tissue or joint effusions are clues that the cartilage is breaking down (Figure 6).

Synovium

There are no blood vessels in a healthy joint. The synovium is the tissue that provides nutrition and lubrication to the internal aspect of the joint. Synovial tissue lines the inner walls of the joint and produces a filtrate of blood. Synovial cells in the synovial tissue then contribute to the plasma by adding lubricin and hyalu-ronic acid and removing fibrinogen.² Movement of the joint distributes the synovial fluid, which is critical to health of the cartilage. A significant decrease in synovial fluid flow into the joint or a decrease in the movement of the joint will lead to cartilage damage.

When damaged, the synovium can be inflamed or fibrosed and display proliferation or adhesions. When a disc is displaced, the condyle will rest on the retrodiscal tissue and a portion of the synovium, preventing it from functioning. The synovium and retrodiscal tissue usually will become fibrosed and form what has been termed a pseudo disc.² A significant percentage of synovium is lost when a disc is displaced, thereby compromising the health of the cartilage. If a disc is displaced and the condyle is sitting on the synovium, it can be inferred that the synovium is damaged.

Cortical Bone

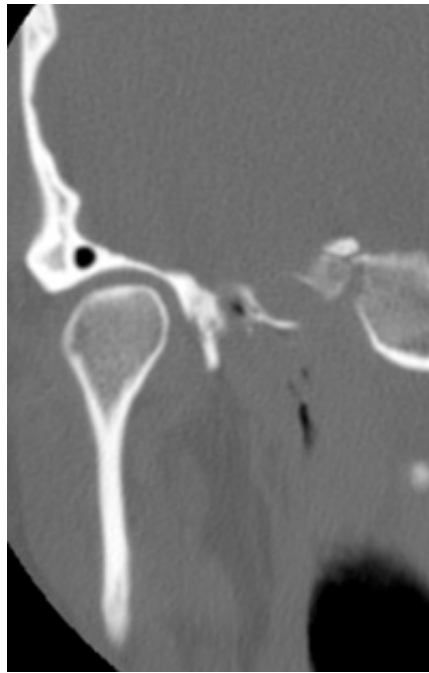


Figure 7. CT coronal view, normal size and shape. Note intact cortical bone shell around the cancellous bone. Slight hypercalcification is seen superiorly.

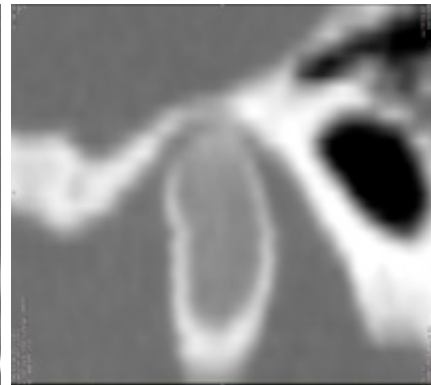


Figure 8. CT corrected sagittal reconstruction. Good size and shape of condyle. Condylar position in fossa indicates disc is displaced. There is no room for a disc. MRI indicated Piper IVa.

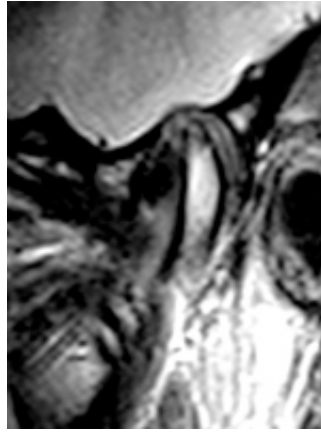


Figure 9. MRI T2 corrected sagittal closed, Piper IVb. Marrow edema is seen in the condyle. Compare this to the marrow in Figure 6. The unevenness of the marrow signal indicates that the superior portion of the marrow has necrosed. The cortex eventually collapsed post surgery (discectomy).

Bone is a calcified living matrix that is composed of 70% inorganic material (mineral), 25% organic matrix and cells, and 5% water. The cells are osteocytes, osteoblasts, and osteoclasts. The organic matrix is primarily composed of collagen, and the mineral component is primarily hydroxyapatite. Blood vessels and nerves are also present. Cortical bone, the dense outer shell, covers the inner multichannelled cancellous bone (Figure 7). When damaged, bone can experience osteolysis, necrosis, hypercalcification, adaptation (modified shape), atrophy, and hypertrophy.^{2,4} The blood supply to the cortical bone is derived from the periosteum on the outside of the bone and from the marrow on the inside. Periosteum terminates at the periphery of a joint and does not continue into the joint to cover the subchondral bone. This means that cortical bone underneath cartilage (subchondral bone) has a limited blood supply dependent on the marrow. CT scans are best for determining the health of the cortical bone. A normal condyle should have a noncongruent oval shape with respect to the fossa with no flattening or lipping. Flattening, lipping, and cysts are signs of OA. On a corrected sagittal view, midcondyle should be approximately 70% of the size of the fossa. The cortex should be intact with no cyst and no hypercalcification present. The condyle should be centered in the fossa anterior-posteriorly with room for the disc noted on the CT (Figure 4). If there is no room for a disc, it is likely displaced and can be verified on the MRI scan (Figure 8).

Cancellous Bone/Marrow

Cancellous bone is inside the outer shell of cortical bone. It consists of thin trabeculae of bone with bone marrow filling the multichannelled spaces. Bone marrow consists of blood vessels, nerve fibers, fat cells, and hemopoietic tissue. Hemopoietic cells (mainly in the spine, shoulder, and pelvis of adults) produce red blood cells, white blood cells, and platelets.²

The vascular supply of the mandibular bone is derived from the inferior alveolar artery centrally and from penetration of arteries and veins through the periosteum peripherally. Since periosteum does not continue into a joint, the superior portion of the condylar head does not have this collateral vascularity into its marrow. The penetrating vessels into the marrow end at the joint periphery. Vessels at the level of the joint periphery (the last opportunity to enter the marrow) come from the anterior medial, posterior medial,

and posterior lateral directions.^{11,12} A disruption of this vascularity will lead to a decrease in condylar marrow blood perfusion. Decreased blood perfusion into the marrow will lead to hypoxia, edema, and/or necrosis. An anteriorly displaced disc that results in a distalization of the condyle in the fossa will exert pressure in the areas of the blood supply to the condylar head. It can be suggested that AVN, which occurs in the TMJ condyle, is a result of both pressure on the anterior tissues by the disc and pressure on the posterior tissues by the distalization of the condyle.¹³ The resultant compromised condylar perfusion is what may lead to hypoxia, edema, and necrosis. The T2 images of the MRI scan are used to detect marrow edema and marrow necrosis. Healthy marrow will produce a low-intensity signal on the T2 image, inflamed marrow will produce a high-intensity signal, and necrotic bone will produce no signal (Figure 9).

A PROPOSED ORTHOPAEDIC DIAGNOSIS OF TMJ DISORDERS

A proposed approach to orthopaedic diagnosis of disorders of the TMJ consists of 3 phases:

Phase 1

(1) History of the problem.

(2) Physical examination:

•joint palpation

- muscle palpation
- movement analysis of joint under both unloaded and loaded conditions
- analysis of muscle coordination of joint movement
- auscultation
- Doppler auscultation¹⁴
- joint vibration analysis (Bioresearch).¹⁵

(3) Develop differential diagnosis.

The TMJ is suspected of being either healthy or damaged. If damaged, then go to phase 2.

Phase 2

(4) Radiological imaging:

- CT scans with axial and coronal views of the TMJ. (If CT scans are not available, plain radiographs should be taken [at least 2 views 90° to each other, 3 views are preferred].)
- Multiplanar reconstruction of the sagittal view, MRI: (a) T1 open and closed corrected sagittal views, T1 corrected coronal views; (b) T2 and proton density corrected sagittal views.

(5) Radiographic interpretation:

- What is damaged—ligaments, disc, articular cartilage, synovium, cortical bone, and/or cancellous bone/marrow.

(6) Refine differential diagnosis.

Phase 3

(7) More detailed history:

- Collect and evaluate previous records.

(8) Repeat physical evaluation of the TMJ (see phase 1):

- Correlate with MRI and CT scans.

(9) Comprehensive dental exam:

- teeth—full-mouth radiographs
- periodontal examination
- occlusal analysis: mounted study models.

(10) Photographs.

(11) Diagnostic tests:

- diagnostic blocks
- blood tests.

(12) Analysis of above data to develop a working diagnosis.

If a joint is damaged, adequate radiographic imaging (at least 2 views 90° to each other) is required. After the clinician has determined that specific anatomic structures may be damaged (in the first phase of the diagnostic work-up), CT and/or MRI scans should be ordered if the clinician has access to such imaging. Obtaining CT or MRI scans early in the diagnostic process will provide valuable information. CT and MRI allow assessment of the health of each of the 6 anatomic components. The clinician is seeking to determine not only what structure(s) is (are) damaged, but also the type and extent of damage and whether the pathologic process is still ongoing. Phase 3 of the exam process can then confirm clinically what was found radiographically.

Table. Diagnostic Summation for Temporomandibular Disorders.

Disc/Ligaments

Piper I Normal disc and ligaments

Piper II Normal disc position; ligaments torn or stretched

Piper IIIa Partial displacement of the disc, reduces on opening; ligaments torn or stretched

Piper IIIb Partial displacement of the disc, nonreducing on opening; ligaments torn or stretched
 Piper IVa Full displacement of disc, reduces on opening; ligaments torn or stretched
 Piper IVb Full displacement of disc, nonreducing on opening; ligaments torn or stretched
 Piper Va Bone-to-bone contact; active degeneration
 Piper Vb Bone-to-bone contact; bone has become eburnated

Synovial Damage

- 1 Healthy synovium
- 2 Reversible damage (inflammation)
- 3 Mild irreversible damage
- 4 Moderate irreversible damage—cartilage cells will die
- 5 Severe damage—all cartilage cells will die

Cartilage Damage

- 1 Healthy cartilage
- 2 Reversible damage to cartilage
- 3 Mild irreversible damage—flattening of condyle is seen
- 4 Moderate flattening and lipping—cysts may be present
- 5 End-stage osteoarthritis

Cortical Bone (Condyle)

- 1 Cortex intact—good condylar size and shape
- 2 Reversible early changes to cortical bone
- 3 Mild irreversible damage—changes to the shape of the condyle are seen
- 4 Moderate irreversible damage—bone loss is evident, altered size and shape
- 5 Severe damage to the cortical bone—altered size and shape

Bone Marrow

- 1 Healthy marrow
- 2 Reversible damage—blood perfusion is compromised, but not to the point of necrosis
- 3 Early necrosis present—may or may not lead to collapse of condylar cortex
- 4 Moderate damage—marrow necrosis present, collapse of the cortex highly likely
- 5 Severe damage—marrow necrosis present, collapse of the cortex imminent or has occurred

Mechanical Stability

- 1 Normal—shape and position of condyle/disc/fossa provide stability under load
- 2 Reversible damage—slight joint flexure under load
- 3 Mild irreversible changes to the shape of the condyle/disc/fossa—will subluxate under load
- 4 Moderate irreversible changes to the shape of the condyle/disc/fossa—will subluxate under load
- 5 Severe irreversible changes to the shape of the condyle/disc/fossa—will not tolerate load

Structural Stability (Condyle/Fossa)

- 1 Excellent prognosis—condylar/fossa bone is stable, occlusion will be stable
- 2 Good prognosis—there is a slight risk of future bone loss
- 3 Fair prognosis—bone loss has already occurred, slight risk of ongoing bone loss
- 4 Guarded prognosis—bone loss has already occurred, moderate risk of ongoing bone loss
- 5 Poor prognosis—bone loss of condyle/fossa will continue with changes in occlusion

Muscle/CNS Function

- 1 Smooth, harmonious muscle function
- 2 Slight tremors, hesitation in muscle movement
- 3 Mild muscle splinting and slight disharmonious muscle movements
- 4 Moderate muscle splinting and disharmonious muscle movements
- 5 Severe muscle splinting and disharmonious muscle movements

Occlusion (Teeth)

- 1 Normal healthy occlusion—centric relation is equal to maximal intercuspation
- 2 Slight malocclusion, nonpathologic—centric relation is not equal to maximal intercuspation
- 3 Mild pathological malocclusion—damage to teeth, periodontium, TMJ structure and/or muscle occurs as a result of the occlusion
- 4 Moderate pathological malocclusion
- 5 Severe pathological malocclusion

After all 3 phases of the diagnostic process, each area can be rated on a scale of 1 to 5, with 1 being healthy and 5 being the most damaged (Table). Also included in this rating is an estimate of joint structural and mechanical stability, the condition of muscles of mastication, and the status of the occlusion. From this information, a working diagnosis is made. The more common ortho-paedic diagnoses associated with the TMJ are as follows: physical damage to ligaments, disc subluxation, osteoarthritis, hypercalcification of bone, adaptive remodeling of bone, synovitis, joint effusion, marrow edema, avascular necrosis, joint adhesions, and fibrous ankylosis. Certain orthopaedic textbooks^{2,4} are excellent references. The TMJ will undergo the same disease processes as other synovial joints.

Example: A single patient with a clicking joint may present with the following:

- (1) right TMJ disc subluxation—Piper 4a, anterior lateral, large disc (size, mass)
- (2) synovitis
- (3) joint effusion
- (4) partial loss of synovial tissue secondary to disc subluxation
- (5) early OA (active), secondary to synovial damage and load changes to the TMJ
- (6) slight malocclusion secondary to change in condylar position from disc subluxation.

Treatments can be customized for the specific problems uncovered in the diagnostic process.

Conclusion

Not all patients labeled with TMD will have clearly identified damage to the structures of the TMJ. If a joint is damaged, the clinician should determine which structures are damaged (ligaments, disc, articular cartilage, synovium, cortical bone, and cancellous bone/marrow). To obtain a diagnosis 2 radiographic views of a damaged joint, 90° to each other, are the minimal medical standard of care. If meniscal damage is suspected, a MRI scan is required. CT scans combined with MRI scans are ideal to fully evaluate the condition of the TMJ. The clinician should determine not only what is damaged, but also the type and extent of damage. By utilizing the information provided by the CT and MRI scans, a more accurate diagnosis can be obtained. Specific orthopaedic diagnoses for damaged joints will help clinicians who treat these patients provide specific treatments and there-by improve prognosis and treatment outcomes.

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Continuing Education Test No. 71.2

After reading this article, the individual will learn:

- the anatomical structures of the temporomandibular joint that are subject to damage, and
- an orthopaedic approach to diagnosing temporomandibular disorders.

1. The TMJ is what type of joint?

- a. synchondrosis
- b. syndesmosis
- c. synovial
- d. synostosis

2. Soft tissues of the TMJ are best evaluated using _____.

- a. plain radiographs
- b. panoramic radiographs
- c. CT scans
- d. MRI

3. The TMJ is the only joint in the body that _____.

- a. rotates
- b. slides
- c. pivots
- d. all of the above

4. The tissue that provides nutrition and lubrication to the internal aspect of the TMJ is _____.

- a. cartilage
- b. fibrocartilage
- c. synovium
- d. lubricin

5. The minimum standard for radiographically evaluating any joint is _____.

- a. panoramic radiograph
- b. 2 radiographic views offset at 90°
- c. CT scans
- d. cephalometric radiograph

6. On a T2 image of an MRI scan, a low- intensity signal indicates _____.

- a. healthy bone marrow
- b. necrotic bone
- c. inflamed bone marrow
- d. thin cortical bone

7. The blood supply to the cortical bone is derived from _____.

- a. periosteum on the outside of the bone
- b. marrow on the inside of the bone
- c. both a and b
- d. none of the above

8. The following statement is FALSE:

- a. Periosteum does not continue into a joint.
- b. The penetrating blood vessels into the marrow end at the joint periphery.
- c. CT scans are best for determining the health of cortical bone.
- d. Cartilage covering bone is best seen with either MRI or CT scans.

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