



Functional anatomy and biomechanics of temporomandibular joint and the far-reaching effects of its disorders

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Abstract

The temporomandibular joint (TMJ) is pivotal in the normal functions such as mastication, speech, esthetics, and overall wellbeing. However, a thorough knowledge of this joint, its anatomy and functional biomechanics is essential for the correct analysis of several of its disorders. It is important to understand the far-reaching effects of any disorder in its anatomy, function, and the psychological impact on the patients. This article takes us through the normal anatomy and functions of the joint and a brief review of its far-reaching effects which at times may sound very vague; however, such knowledge will help to look into a new arena of managing disorders of the TMJ.

Introduction

The temporomandibular joint (TMJ) is one of the most important and complex joints in the body which provides the articulation between the movable mandible and the fixed temporal bone of the cranium. The TMJs are bilateral, diarthrodial, ginglymoid, synovial, and freely movable. The term diarthrodial is used because the joint has two articular bone components – The mandibular condyle inferiorly and the articular eminence and glenoid fossa of the temporal bone superiorly. The term ginglymoid is used because the joint has a hinge-like movement component. The joint is lined by the synovial membrane and is freely movable.

It has certain unique features: (1) The articulating surfaces are covered not by hyaline cartilage but by fibroelastic tissue, (2) the condylar cartilage is considered a growth center that significantly contributes to the overall growth of the mandible, (3) the TMJ functions bilaterally and can be influenced by dental occlusion, and (4) it has an intact disc that is movable during all joint movements and functions as a shock absorber.

The dentists must understand the functional anatomy of TMJ before they can effectively diagnose and treat diseases of the TMJ.

Developmental Anatomy

The TMJ begins to develop by the 10th week of intrauterine life from two separate blastemas (mesenchymal condensation) – one for the temporal bone component and one for the condyle. Superior to the condylar blastema, a band of mesenchymal cells develop that will eventually differentiate into the disc. In the center of the condyle, cartilage develops. This will become the secondary cartilage contributes to the subchondral bone formation. The developing disc is highly cellular and vascular in nature. It continues with the developing lateral pterygoid muscle anteriorly and by a ligament with the superior end of the Meckel's cartilage posteriorly, in future, this cartilage will develop into malleus of the middle ear [Figure 1]. The developing TMJ shows all the components of the mature joint by the 14th week of gestation. At the peripheries of the fetal disc is found to contain more nerve fibers and blood vessels.^[1,2]

Clinical Anatomy and Physiology of TMJ Components^[1]

The following are the components of TMJ: Capsule, extracapsular ligaments, articular eminence, glenoid fossa, condyle, disc, disc ligaments, and synovial membrane [Figures 2 and 3].

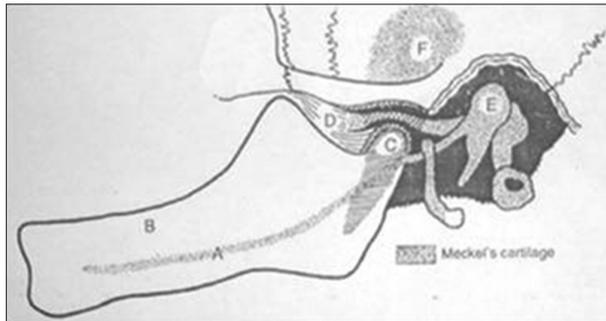


Figure 1: Development of temporomandibular joint, Meckel's cartilage, (A) The developing mandible, (B) developing condyle, (C) lateral pterygoid and fibrous attachment extending to the malleus, (D) malleus, (E) developing temporal component

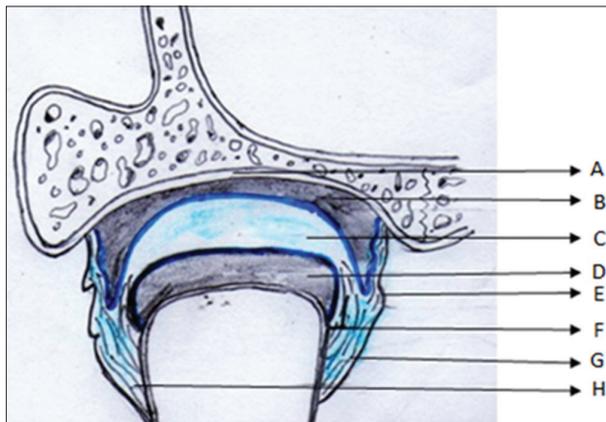


Figure 2: Coronal view of temporomandibular joint, (A) Articular cartilage, (B) superior joint space, (C) articular disc, (D) inferior joint space, (E) synovial membrane, (F) collateral (discal) ligament, (G) medial capsular ligament, (H) lateral capsular ligament

Capsule

The joint capsule is a fibroelastic, highly vascular and highly innervated dense connective tissue [Figure 4]. The lateral aspect of the capsule attaches to the zygomatic tubercle, the lateral rim of the glenoid fossa and the post-glenoid tubercle. Medially, the capsule attaches to the medial rim of the glenoid fossa. Posteriorly, the capsule attaches to the petrotympanic fissure and fuses with the superior stratum of the posterior bilaminar zone. Between the posterior capsule and posterior glenoid tubercle, a highly vascular tissue called the vascular body is found. The capsule attaches inferiorly to the periosteum of the neck of the condyle.

Extracapsular ligament

The main extracapsular ligaments that provide stability to the joint are the lateral temporomandibular and sphenomandibular ligaments. The sphenomandibular ligament originates from the anterior process of the malleus, the lips of the petrotympanic fissure, and the spine of the sphenoid above and inserts into the lingual of the mandibular foramen below. Two other

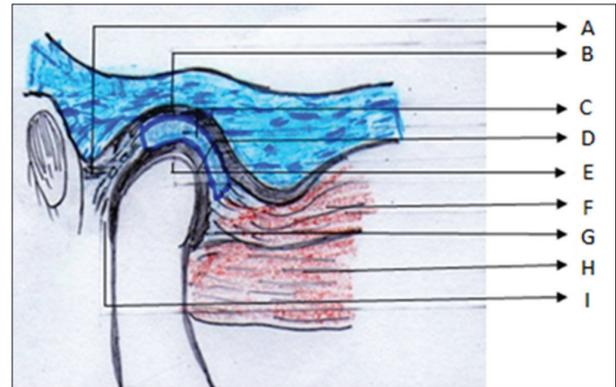


Figure 3: Lateral view of temporomandibular joint, (A) Superior retrodiscal lamina, (B) superior joint space, (C) articular disc, (D) inferior joint space, (E) articular cartilage, (F) superior lateral pterygoid muscle, (G) anterior capsular ligament, (H) inferior lateral pterygoid muscle, (I) inferior retrodiscal lamina

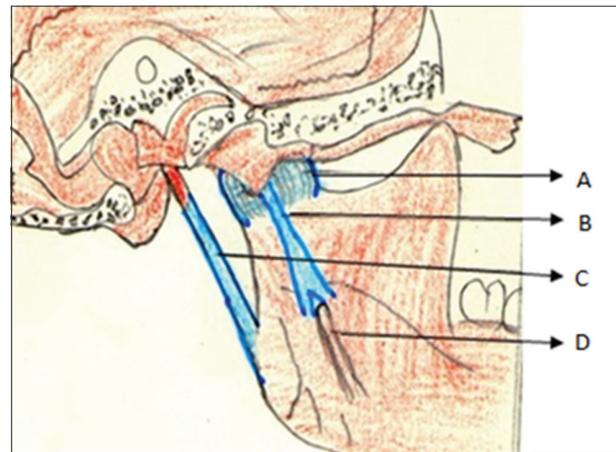


Figure 4: Capsule and ligaments of temporomandibular joint, (A) Fibrous capsule, (B) sphenomandibular ligament, (C) stylomandibular ligament, (D) mylohyoid groove

accessory ligaments are the stylomandibular ligament and the pterygomandibular raphae. The stylomandibular ligament attaches to the styloid process above and the angle and posterior border of the mandibular ramus below. The pterygomandibular raphae attach to the pterygoid hamulus above and to the posterior end of the mylohyoid ridge of the mandible below.

Articular eminence

The articular eminence consists of two slopes. One is descending slope, formed by a transverse ridge that is a medial extension of the zygomatic tubercle and another one is ascending slope. The superior slope of the anterior bilaminar zone inserts on the ascending slope of the eminence and, therefore, limits the anterior superior recess of the joint cavity. The articular eminence is covered by dense, compact fibrous tissue that consists primarily of collagen with a few elastic fibers. Underlying the fibrous tissue covering is chondroid bone and then compact bone.

Glenoid fossa

The glenoid or mandibular fossa is limited posteriorly by the petrotympanic fissure, which provides attachment to the posterior capsule and limits the boundary of the posterior superior recess of the joint cavity. The fossa has lateral and medial rims. The medial rim is just lateral to the spine of sphenoid and the foramen spinosum with its middle meningeal artery. The lateral rim continues anteriorly into the zygomatic tubercle and posteriorly into the post-glenoid tubercle.

Condyle

The condyle is broad mediolaterally and narrow anteroposteriorly. It has a lateral tubercle, joint capsule, and medial tubercle. The tubercles provide attachments to the lateral and medial collateral ligaments. The articular surface of the condyle is covered by a thick layer of fibroelastic tissue. The condylar covering is sometimes called as fibrocartilage. The condyle is roughly ovoid in shape. It is approximately measuring about 15-20 mm mediolaterally and 8-10 mm anteroposteriorly.

Disc^[3]

The disc fills the space between the condyle and the temporal bone. It is biconcave in shape. It consists of three parts - anterior band, intermediate zone, and posterior band. It is described as avascular non-innervated fibrocartilage. The disc ligaments consist of the anterior and posterior bilaminar zones or ligaments, the lateral and medial collateral ligaments, and the discomalleolar ligament. All these ligaments are vascular, innervated, and fibroelastic in nature. The anterior ligament has a superior stratum that inserts on the ascending slope of the articular eminence and an inferior stratum that inserts inferiorly at the anterior aspect of the condyle. The anterior ligament is supported by the superior and inferior heads of the lateral pterygoid muscle. The posterior ligament or the bilaminar zone consists of a highly elastic superior stratum that inserts on the lips of the petrotympanic fissure and an inferior stratum that also contains elastic fibers that inserts on the posterior aspect of the condyle below. The posterior bilaminar zone stretches considerably while jaw opening to allow the disc to continue to cover the condyle at all ranges of motion.

The medial and lateral condylo-discal or collateral ligaments are collagenous and firmly attach the disc to the lateral and medial poles of the condyle, respectively. They are vascular and highly innervated. The most medial portion of the disc is connected to the discomalleolar or Pinto's ligament.

Synovial membrane^[4,5]

The inside of the TMJ capsule and the non-articulating surfaces of disc ligaments are lined with synovial membrane. Synovial villous projections can be seen grossly as hyperemic tissue in the anterior, posterior, medial, and lateral recesses of the joint cavities. Histologically, the synovial membrane consists of intimal and subintimal layers. The intima is one to four layers

deep. Two types of cells exist – one cell type appears such as fibroblast and secretes subintimal collagen and proteoglycans and the glycoproteins of the synovial fluid. They are referred to as Type B or S-cells. The second type of cell is macrophage-like. These cells are active in phagocytosis and are referred to as Type A or M-cells.

The volume of synovial fluid in the superior joint compartment is 1.2 ml, whereas the inferior joint compartment contains 0.9 ml. The fluid exists under negative intra-articular pressure. The surface tension of the synovial fluid allows the spread of fluid over the articular surfaces as a capillary film that permits the lubrication of the joint during condylar movements. It contains a glycoprotein known as lubricin, which serves to lubricate and minimize friction between articular surfaces of synovial joints.

Vascular supply of TMJ

The external carotid artery is the main blood supply to the joint. The artery sends two important branches, the lingual and facial arteries, to the region. At the level of the condylar neck, the external carotid bifurcates into the superficial temporal artery and the internal maxillary artery. These two arteries supply the muscles of mastication and the TMJ. The arteries within the temporal bone and mandible also send branches to the capsule.

Innervation of TMJ

The TMJ receives innervations primarily from the auriculotemporal nerve branch of the mandibular nerve (V3 of the trigeminal nerve) and also innervated by masseteric and deep temporal nerves. The joint capsule, disc ligaments, and synovium are innervated, whereas the disc proper and the fibrous coverings of the articulating surfaces and condylar cartilages are non-innervated. In addition to the nerve fibers, the capsule contains three types of mechanoreceptors: Ruffini receptors, Golgi tendon organs, and Pacinian corpuscles. Free nerve endings are also present.

Age Changes in TMJ

TMJ comprises the mandibular condyle, its articulation with glenoid fossa of the temporal bone, the interposing meniscus and associated muscle and ligamentous attachments. Since the disc is composed of fibrocartilage and possesses no regenerative capacity, perforation is an end stage abnormality. Discal thinning and perforation may be part of the normal aging process and not pathological. Deterioration and notching of the cortical plate were seen routinely after the seventh decade.

Age Changes in the Mandible

The morphology of the mandibular condyle varies considerably both in size and shape greatly among different age groups and individuals. This is due to developmental variability as well as remodeling of condyle to accommodate malocclusion,

trauma, endocrine disturbances, radiation therapy, and other developmental abnormalities and diseases.

The most prevalent morphologic changes are detected in the TMJ of elderly persons due to the onset of joint degeneration. The shape of the condyle may be categorized into five basic types: Flattened, convex, angled, rounded, and concave.^[6]

At birth

The angle is obtuse (175°), and the condyloid portion is nearly in line with the body. The coronoid process is of comparatively large size and projects above the level of the condyle.

Childhood

The angle becomes less obtuse, owing to the separation of the jaws by the teeth; about the 4th year, it is 140°.

The neck of the condyle is more or less bent backward in old ages. Disc displacement, perforation, disc deformation, and arthrosis seem to increase with age.

Age Changes in Disc

At the age of 9-10 weeks, the articular disc has a more cellular structure with an irregular arrangement of fibers. At the 11th week, the disc consists of fusiform cells, which are located mainly on its surface and densely arranged collagenous fibers. At the 12th week, the shape of disc changes into a thinner central part and a thickened peripheral part. The histological study shows avascular anterior part of the disc and is composed of woven fibrous tissue, whereas the posterior part is of looser texture and may be subdivided into an upper zone rich in elastic tissue and a lower zone, which has many large blood vessels.^[7-9] As age advances, there is a progressive decrease in cellularity and an increase in collagen fibers in the disc.^[10] The disc becomes thinner and shows hyalinization and chondroid changes.

Age Changes in Synovial Fluid

Become fibrotic with thick basement membrane changes in blood vessels and nerves in TMJ:^[11]

- Walls of blood vessels thickened
- Nerves decrease in number.

Biomechanical Properties of TMJ

Mandibular motions result in static and dynamic loading in the TMJ. During natural loading of the joint, combinations of compressive, tensile, and shear loading occur on the articulating surfaces [Figure 5].

The disc is composed of variable amounts of cells and an extracellular matrix. The matrix consists of macromolecules (15-35%) and fluid (65-85%). These macromolecules consist mainly of collagen (85-90%) and proteoglycans (10-15%).

The TMJ disc behaves as a viscoelastic structure; it can function as a stress absorber and stress distributor thereby reduce stress concentration and excessive stress in the disc, cartilage, and bone components of the joint like disc perforation and thinning, osteoarthritis (condylar deformation with erosive and/or proliferative changes). Normal TMJ - position of disc,^[7] posterior band - 12'o clock, and intermediate zone - 1'o clock.

The compressive elastic modulus of the disc is smaller than its tensile one because the elasticity of the disc is more dependent on the collagen fibers than on the proteoglycans.

When dynamic loading occurs, the disc is likely to behave less stiffly than under static loading because of the difference of fluid flow through and out of the disc during loading.

The normal position of TMJ in cone beam computed tomography images in both sagittal and coronal view are shown in Figure 6.

Mechanics of the Healthy Joint

The joint is a bilateral articulation. Movement involving the joints has been divided into different phases - Occlusal, retruded opening, early protrusive, late protrusive, early closing, and retruded closing phases.

Occlusal phase

Involves a static jaw position with the teeth in maximum intercuspation. The posterior band occupies the deepest part of the mandibular fossa. The intermediate zone and anterior band lies between the condyle and posterior slope of the eminence.

Retruded opening phase

The condyle rotates and moves 5-6 mm inferior to the intermediate zone, which now becomes the articulating surface. The medial pole of the condyle moves anterosuperiorly and lateral pole moves posteroinferiorly. The shape of the inferior

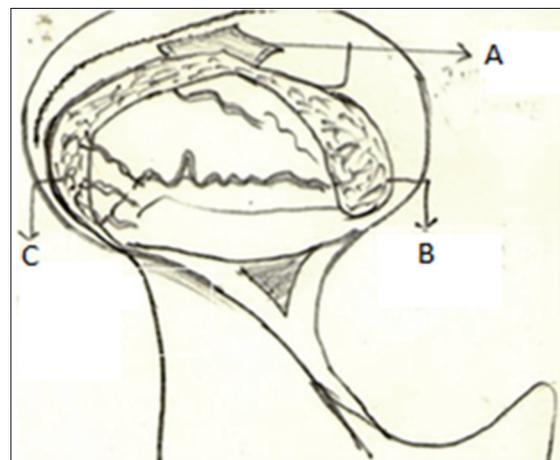


Figure 5: Antero-lateral view of disc with various orientations, (A) Intermediate zone, (B) anterior band, (C) posterior band



Figure 6: Normal position of temporomandibular joint (TMJ) in cone beam computed tomography image. Sagittal and coronal view of TMJ shows uniform joint space and centrally positioned condyle within the glenoid fossa

compartment changes the most. The movement continues with an opening to about 18 mm.

Early protrusive opening phase

The condyle moves inferiorly and anteriorly approximately 6-9 mm beneath the intermediate zone. The movement stretches the bilaminar zone. More space develops posteriorly as the condyle translates anteriorly. This change shifts the posterior band posteriorly.

Late protrusive opening phase

The condyle moves inferiorly and anteriorly beneath the anterior band. More space develops in the superior compartment posteriorly than in the inferior compartment during rotation. Blood enters spaces of the posterior attachment.

The superior retrodiscal lamina contains elastic connective tissue. Apparently, during forward translation, the lamina exerts posterior traction on the disc. This action limits anterior dislocation of the disc.

Early closing phase

The condyle translates posteriorly, about 6-9 mm to the intermediate zone. There is a simultaneous reduction of space posteriorly in the superior compartment.

Retrusive closing phase

Superiorly, the condyle rotates but remains inferior to the posterior band. This movement reduces the space in the inferior compartment, tightens the mandibular attachment, and forces blood from the posterior attachment. The condyle return near the occlusal phase. The limitations of specific ligaments and the lateral pterygoid muscle restrict movements of the condyle.^[9]

All these movements of mandible occur by two movements of the condyle. One is the gliding movement which takes place between the disc and temporal surface of articulation. The second is the rotator or hinge movement which takes place between the disc and head of the condyle. These movements help in mastication and other functions of the mandible.

Normal functional movement of the condyle and disc during the full range of opening and closing. The disc is rotated posteriorly on the condyle as the condyle is translated out of the fossa. The closing movement is the exact opposite of opening.

The normal functioning of the TMJ is affected not only by several biological but also psychological factors; hence, a bio-psycho-social role is thought to be played out in temporomandibular disorders (TMD). The effect of these disorders have far-reaching effects, some of which do not seem to be appropriate at all, nevertheless, when reversed seem to reverse the signs and symptoms of the TMD. The other names previously given are a craniomandibular disorder or craniofacial disorder; however, the name TMD seems to have adequately and relevantly indicates the group of disorders. Patients with TMD may have visited various centres to try to identify their problem and had many tests done on them, but with not much relief and hence may many a time present with a psychological disturbance too, which may present as bruxism, this may have an impact on their social life too, one needs to look at such patients holistically and plan appropriate measures.

The manifestations in the head include pain such as in the forehead, temples, a "migraine" type of a headache, sinus headaches, shooting type of pain in the back of the head, the scalp, and hair may be painful to touch.

The ears may present with aches, ringing sounds, stuffiness with itching and even vertigo.

TMD can present with eye changes such as pain behind the eyes, photophobia, bulging out, or bloodshot eyes. The joint itself may present with clicking or grating sounds, pain in the cheek muscles and abnormal jaw (deviation or locking), and tongue movements with no apparent obvious cause. Such patients may also have a limited mouth opening or inability to open the mouth. The patient may not be able to chew properly and may have soreness especially in the posterior teeth. The other features of TMD could be swallowing difficulties and may extend

to produce laryngitis, a sore throat, with need to often clear their throat and presence of voice irregularities. The changes could lead to a nagging cough, feeling of something in the throat constantly, one other effect could be sleep disturbances.

TMD can produce pain and tiredness in the neck muscles with stiffness, extending to painful shoulders, and numbness of the fingers. Other joints could also be involved when a systemic disease needs to be ruled out. There can be far-reaching effects like change in posture and overall feeling of un-wellness, without an apparent cause to justify, at these times the dentist can play a major role in not only identifying but also relieving the agony of patients with such vague symptoms, hence the importance of knowing the normal anatomy and functional characteristics of this very vital joint.^[12,13]

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