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MORPHOLOGY AND FUNCTIONAL ABILITIES OF THE TEMPOROMANDIBULAR JOINT

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The mandible and the cranium are integrated by a unique joint juncture which is a special structure in the human body for most of its characteristics. From the other joints, it differs in morphology, the potential of the variability of all of the structures related to the joint, special functions, vast freedom of movement, and the close relationship between the joint and vital organs. Articular surfaces are covered by a special type of fibrous tissue which consists of four different zones: the articular zone, the zone of the fibrous cartilage, and the zone of the calcified cartilage. The fibrous capsule of the joint is covered by the synovial membrane. The inside of the joint cavity is filled by the synovial fluid that serves as the metabolic medium and ensures lubrication. The articular disc inserted between the articular surfaces has a complex structure and very important roles ensuring the vast mobility of the joint and the physiological pressure transfer. It divides the joint into two different portions that serve as a uniform functional unit. Morphologically it has a biconcave shape and can be divided into three portions. The intermedial zone is the thinnest, while the posterior, bilaminar, zone has the most complex structure containing the well vascularised retrodiscal tissue between its laminae. Disc constantly changes its shape according to the new configuration inside of the joint which is ensured by a specific alignment of the collagen fibers but also the presence of elastic and oxytalan fibers.
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Key words: *temporomandibular joint, morphology, articular disk, histology*

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Introduction

Starting with the histology, going over the anatomical landmarks and the physiology of the oral cavity, we will explain the function of the temporomandibular joint which participates in our ability to chew, swallow, and speak (1).

The mandible and the cranium are integrated by a unique joint juncture which is a special structure in the human body for most of its characteristics. The fact that the two temporomandibular joints (TMJ) are connected by the same bone complicates the function of the whole masticatory apparatus since the action in one joint results in a reaction in the other (2).

From the other joints, it differs in morphology, the potential of the variability of all of the structures related to the joint, special functions, vast freedom of movement, and the close relationship between the joint and vital organs. The binding tissue of the joint is not the hyaline cartilage but instead a dense fibrous tissue while the secondary condylar cartilage is persisting on the head of the condyle until adolescence (3).

Due to the position of the articular disc, the TMJ is divided into two parts which in the sense of functionality operate as a single functional unit:

- The lower joint space is defined by the condylar processes of the mandible and the articular disc. The disc is firmly bonded to the condyle by the lateral and medial discal ligament which only allows for the rotational movement of the disc over the surface of the condyle;
- The upper joint space is defined by the articular disc as the lower border and the mandibular fossa as the upper. In this space, the only possible movement is gliding since the disc is not that firmly bonded to the mandibular fossa (2, 4).

Histology of the articular surfaces of the TMJ

The tissue that covers the bone surfaces of the joint consists of four different zones:

- the articular zone,
- the zone of the fibrous cartilage, and
- the zone of the calcified cartilage.

The first zone that opposes the articular space is named the articular zone and it represents the outer functional surface. It is built of dense fibrous connective tissue. Most of the collagen fibers in this zone are tightly packed in binds and aligned almost parallel to the surface. Due to this specific structure, the articular surface of the TMJ has many advantages over the hyaline cartilage, aging, and degenerative disorders progress much more slowly and the potential for regeneration is much larger. All of these structures serve the purpose in a joint that is highly mobile and constantly participating in some functionality, whether it comes to chewing, speaking or some parafunction such as grinding of the teeth during the night (5).

The second zone in order is the zone of proliferation and is built of non-differentiated mesenchymal tissue which produces cartilage cells based on the functional requirements or the stress on the joint.

The third zone is the zone of fibrous cartilage. In this zone, the binds of collagen are mostly crossed while some are radially aligned which creates a special kind of tri-dimensional net that counteracts compressive and lateral forces (6-8).

The deep zone is the zone of calcified cartilage. This zone contains chondrocytes and an extracellular matrix. Chondrocytes produce collagen, proteoglycans, glycoproteins, and enzymes. Proteoglycans are complex molecules that consist of the protein core and glycosaminoglycan chains. Proteoglycans are bonded to the hyaluronic acid chains which create matrix protein aggregates. These aggregates are intercrossed throughout the whole collagen net and due to their hydrophilic traits, the matrix is expanding while the pressure inside of the fibers protects from the expansion pressure of the proteoglycan aggregates. Hydrophilic traits are of high importance when it comes to nutrient delivery and maintaining the healthy articular cartilage (2, 9).

Synovial membrane

The synovial membrane covers the internal surface of the fibrous capsule and doesn't cover the articular surfaces since it would quickly tear. It is already presented that the TMJ consists of two articular spaces, the upper and the lower. Internal surfaces of these spaces are covered by the specialized endothelial cells which lie over the vascular layer. The cells that build the superficial layer are macrophages and fibroblasts. The upper and the lower articular space are filled by the synovial fluid which is produced by the synovial membrane and the synovial fold on the anterior end of the retrodiscal tissue. The lower articular space is filled with roughly 1 ml of the synovial fluid, while in the upper there is slightly more fluid since it is more voluminous (10).

The main functions of the synovial fluid are as follows:

- The metabolic medium which is needed since the articular surfaces do not have blood vessels,
- Lubrication during the function of the joint (11).

The synovial membrane establishes lubrication in two possible mechanisms. Boundary lubrication is the primary mechanism and relieves the friction inside of a moving joint as the synovial fluid moves throughout the joint cavity covering the articular surfaces (12). Weeping lubrication ensures the exchange of the metabolites. The joint in function creates tensions between the articular surfaces which press on the synovial membrane to excrete a small amount of the fluid inside of the joint cavity ensuring the exchange of metabolites. Important constituents of the synovial fluid that provide the lubrication function are proteoglycans, together with hyaluron which binds to fibronectin and helps keep the surfaces smooth. Surface-active phospholipids together with the glycoprotein lubricin provide friction relief in the joint (13). The synovial membrane also contains pro-inflammatory cytokines such as interleukins and tumor necrosis factor which elevate in concentration in TMJ disorders that are present in all age groups with the prevalence in females (14). The hydrostatic pressure of the synovial fluid is lower than the atmospheric pressure but raises in levels in patients with bruxism since the articular surfaces are under higher pressure during these para functions.

Morphology of the TMJ articular disc

TMJ articular disc transfers the pressure and enables complex mobility of the joint. The biconcave shape gives it the ability to adapt to the morphology of the articular surface on the condyle on one side and the mandibular fossa and the articular tubercle on the other. While in the function the shape of the disc changes and in rest it turns back to normal unless the joint was impacted by non-physiological forces, such as bruxism and trauma (3, 15). Observed in the sagittal plane the articular disc can be divided into three sections based on its thickness. The thinnest is the central section and it is named the intermedial zone. The anterior section is slightly thicker while the posterior zone is the thickest. Based on the transverse cross-section it can be concluded that the intermedial zone is the thinnest and the medial zone is the thickest (3). If the joint is in its normal anatomical configuration the condyle is set up against the intermedial zone.

The posterior portion of the disc can be divided into two laminae:

1) Superior retrodiscal lamina is built out of the fibrous and elastic fibers which are connected with the tympanic plate;

2) Inferior retrodiscal lamina which is built out of collagen with the downwards junction direction to ensure binding to the condyle.

This region is named the bilaminar zone. The retrodiscal tissue between the two laminae contains a large number of nerves and blood vessels. A significant blood flow can be seen in the venous plexus of the disc as the veins enlarge multiple times when the condyle moves to the front when the jaw is open.

The anterior part of the disc also contains two laminae which are connected to the capsular ligament, the superior being connected to the anterior end of the articular tubercle on the temporal bone and the inferior lamina that is connected to the front side of the condylar neck. Both of these laminae consist of collagen fibers. In-between the junctures to the capsular ligament the disc is connected to the lateral pterygoid muscle. The articular disc is not only connected to the capsule in the front and back rather all around the borders dividing that way the joint cavity into two. The synovial membrane covers the surface of these parts (2, 3).

Cells and the extracellular matrix of the articular disc

TMJ disc is rich in cells and vascularization before birth. The vascularization quickly becomes scarce and the only source of nutrients become the retrodiscal tissue and the synovial fluid. The articular disc embodies three types of cells, mostly fibroblasts, but also fibrochondrocytes and chondrocytes. The more rounded the body of the cell is, the more cytoplasm it contains. Fibroblasts contain a certain amount of endoplasmatic reticulum, mitochondria, Golgi apparatus and vesicles. Extracellular collagen fibers surround cellular membranes. Extensions of cellular membranes on the cells inside of the disc that are 100 μm and longer have been observed. The role of these extensions is to supply nutrients from the peripheral blood vessels and transport them to the central portion which is avascular (13, 16). This functionality is ensured by the small transmembrane protein molecules classified as connexins which provide the transport route for the small molecules to go from one end of the cell to the other.

The extracellular matrix consists mostly of water (roughly 80%), collagen and oxytalan fibers, glycosaminoglycans and proteoglycans. Collagen fibers serve the purpose of keeping a certain shape of the disc. In the intermedial zone, collagen fibers are stacked in the anteroposterior direction while in the anterior and the posterior zones, which are thicker, fibers are stacked in the superoinferior and transversal directions. Peripheral portions of the disc contain collagen fibers that are arranged circumferentially (17).

While the joint performs its movements, the articular disc constantly adapts to the shape of the mandibular condyle and the fossa. This adaptability stems from the position of the collagen fibers as well as their wavy configuration (18). Elastic fibers are present inside of the disc but their amount lowers with aging except in the superior retrodiscal lamina. Oxytalan fibers are binds of microfibrils and are specific for the intra-articular discs in humans. Primary glycosaminoglycans are dermatan sulfate and chondroitin sulfate as well as a certain amount of hyaluronic acid and heparan sulfate (19). Proteoglycans provide viscoelasticity to the disc as well as the ability to maintain the pressure of the interstitial fluid. Proteoglycans intercross collagen fibers throughout the whole collagen net. Larger molecules of proteoglycans can be found in the intermedial zone of the disc, but also in the anterior and posterior portions where the pressure on the disc is higher (20). In the lateral and medial zones rather small proteoglycan molecules can be found, such as decorin and biglycan (21).

Conclusion

The exceptional specificity of the TMJ stems from the complex structure of all of its constituents. This complexity provides a vast range of motion and the ability to participate in a large number of important functions. Even though the joint is biologically designed to sustain constant function and intense functional pressures, aging causes the lowering of adaptation capacities of the tissues inside of the joint even when physiological relationships among all of the related structures are optimal. Connection with various oral tissues alongside the fact that two joints are connected by the same bone additionally complicates the structure and functions. Severe damage of the joint requests surgical intervention and replacement with implants that in most cases don't satisfy the biological criteria, therefore not improving the quality of the patient's life. Possibilities for inventing new therapeutic procedures are hard due to the complexity of the joint. Many sources state that the hope for the future lays in tissue engineering which accentuates the importance of acquiring knowledge about temporomandibular joint structures for all biomedical researchers in this field.

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GRAĐA I FUNKCIJA TEMPOROMANDIBULARNOG ZGLOBA

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Mandibula i kranijum povezani su kompleksnom zglobnom vezom, koja je po mnogim osobinama jedinstvena u ljudskom organizmu. Od drugih zglobova razlikuje se građom, morfološkom varijabilnošću zglobnih komponenata, specijalizovanim funkcijama, izuzetnom slobodom pokreta i blizinom vitalnih organa. Zglobne površine prekrivene su gustim fibroznim tkivom, koje se sastoji iz četiri histološki različite zone: artikulaciona zona, proliferativna zona, zona fibrozne hrskavice i zona kalcifikovane hrskavice. Fibrozna kapsula zgloba prekrivena je sinovijalnom membranom. Zglobna šupljina ispunjena je sinovijalnom tečnošću, koja ima ulogu metaboličkog medijuma i omogućava lubrikaciju. Temporomandibularni disk ima kompleksnu strukturu i veoma važne uloge, koje omogućavaju širok spektar pokreta u zglobu i fiziološki prenos pritiska. Disk deli zglobnu šupljinu na dva zasebna sprata, koji predstavljaju jednu funkcionalnu jedinicu; morfološki ima bikonkavan oblik. Po debljini, može se podeliti na zone od kojih je intermedijalna najtanja. Najkompleksniju strukturu ima posteriorna, bilaminarna zona, između čijih lamina se nalazi dobrovaskularizovano retrodiskalno tkivo. Disk se u toku funkcije stalno prilagođava izmenjenom položaju zglobnih površina, zahvaljujući specifičnom rasporedu i valovitoj strukturi kolagenih vlakana, kao i prisustvu elastičnih i oksitalanskih vlakana.

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Ključne reči: *temporomandibularni zglob, morfologija, temporomandibularni disk, histologija*