Role of TMJ, In Relation to Growth & Development of Mandible – A Narrative Review

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ABSTRACT:

Providing successful care in a variety of dental specialities, from orthodontics to prosthodontics, and guaranteeing both functional and attractive results for patients require a thorough grasp of the TMJ's role in mandibular growth and development. Dentists must be well-versed on the temporomandibular joint's (TMJ) function in connection to the mandible's growth and development. As the midface grows, the TMJ aids in the mandible's expansion in height and length. Mandibular growth is influenced by the condylar biomechanical environment, which is controlled by the articular disc in the TMJ. Condylar cartilage alterations may result from TMJ disc displacement. This narrative review aim to discuss the role of Temporomandibular joint (TMJ) in the mandibular growth and development.

KEY WORDS: Temporomandibular joint (TMJ); Adaptive growth; Mandibular Growth.

INTRODUCTION:

The mandible's growth and development depend on the temporomandibular joint (TMJ) in a number of ways which includes role in adaptive growth, the role of articular disc in mandibular growth and the role of various signalling pathways and genes.

I. Adaptive growth

The mandibular condylar cartilage (MCC), which forms late in foetal development, enables the adaptive growth. In the context of the mandible, adaptive growth also known as "remodelling growth" refers to the jaw's ability to alter its growth in response to mechanical pressures, environmental influences, or functional demands. [1]

A biological process known as "adaptive growth" occurs when tissues—especially soft and bone tissues alter their internal structure, size, and shape in response to mechanical loading, environmental stresses, or functional requirements. Through adaptation to shifting circumstances like physical strain, injury, or changes in usage patterns, this development mechanism enables an organism to preserve homeostasis. Adaptive growth, which involves processes like bone deposition (formation) and resorption (breakdown), is a well-studied phenomenon in bone biology. For instance, the adaptation is evident in regions of bone that experience higher mechanical stress, where bone mass and density may rise (Wolff's Law). On the other hand, bone resorption brought on by inactivity or less stress can cause a decrease in bone mass. [2] The amount of mechanical strain that bones encounter affects how they react. While less stress can cause bone thinning (as in the case of astronauts losing bone mass in microgravity), more stress causes bone to expand and strengthen. Depending on their function, muscles and tissues can also expand adaptively. Muscle growth, for example, happens when physical activity increases, whereas disuse atrophy happens when physical activity declines. [1]

Especially when it comes to bone healing following fractures, when the bone rebuilds itself to regain strength and structural integrity, adaptive growth is essential to the healing process. Adaptive growth is important in dentistry in fields like prosthodontics, where implants or dentures can cause changes in bone structure because of changing stress distribution, and orthodontics, where tooth movement can promote bone remodelling. [3]

The following are important facets of the mandible's adaptive growth:

A. Influence of Functional Activity

The forces produced by speaking, chewing, and other functional actions are adjusted by the mandible. The functional matrix theory states that the surrounding muscles and soft tissues exert demands on the bone and joints, which the bone and joints then react to. Mandibular bone and temporomandibular joint (TMJ) remodelling can be triggered by changes in muscle function, such as those resulting from modified chewing habits or patterns (e.g., bruxism, clenching).[4]

B. TMJ's Role in Adaptive Growth

One of the main areas of adaptive growth in the TMJ is the condylar cartilage. The TMJ can react to external stresses and go through endochondral ossification, which is the process by which bone is formed from cartilage. The growth at the TMJ can adjust to changes in the forces acting on the jaw by either accelerating or decelerating in order to reach functional balance.[5]

C. Orthodontic and Orthopaedic Factors

By changing the stresses applied to the mandible, orthodontic appliances—such as braces or functional appliances—can promote adaptive growth. For instance, through adaptive remodelling of the TMJ, functional appliances can promote forward growth of the jaw in situations of mandibular insufficiency (retrognathia). This type of therapy makes use of the mandible's ability to grow adaptively in order to move the bone into a more advantageous position. [6]

D. Response to Trauma or Disease

In addition, the mandible may develop adaptively in reaction to illness or trauma. For instance, the surrounding bone and tissues may remodel in response to trauma to the mandible or condyle, although this could result in asymmetrical or compensatory growth. By altering movement patterns or loading circumstances, temporomandibular joint disorders (TMDs) can impact adaptive growth. Over time, this might result in compensatory alterations in the mandibular structure. [7]

E. Growth and Remodeling with Age

Although it slows down after adolescence, adaptive growth persists throughout life. The mandible may still undergo remodelling as an adult in response to shifting stresses like tooth loss or occlusion (bite) changes. Although it occurs more slowly, this remodelling plays a role in age-related changes in the jaw and dental arches, including resorption in edentulous patients and changes in the form of the mandible as a result of shifting chewing forces. [8]

II. The articular disc

The temporomandibular joint's (TMJ) articular disc is crucial to the mandible's healthy growth and development, especially for preserving appropriate joint mechanics during development. The articular disc is essential for supporting the healthy operation of the TMJ, a significant mandibular development site, even though it does not directly aid in bone formation. [9]

The articular disc affects mandibular growth in the following ways:

A. Joint Stability and Smooth Movement

The articular disc facilitates smooth movement within the TMJ by serving as a cushion between the temporal bone and the mandibular condyle. As a result, there is less friction and direct bone-to-bone contact, allowing the mandible to move easily in various directions (opening, shutting, and lateral movements). The joint's uniform distribution of mechanical stresses is guaranteed by the articular disc, which permits the mandible to move smoothly and effectively. Normal mandibular development, particularly during growth periods, depends on proper joint function.[9]

B. Shock Absorption and Load Distribution

The forces produced during speaking, chewing, and other jaw movements are distributed via the articular disc. The disc helps shield the condylar cartilage from undue stress or damage by distributing these loads uniformly. The mandibular condyle's regular adaptive growth depends on this balanced load distribution. Balanced mandibular development is possible when the stresses are evenly distributed, allowing for symmetrical growth at the condyle. [10]

C. Condylar damage prevention

One of the main locations for bone formation during growth is the mandibular condyle, which occurs by endochondral ossification. The articular disc serves as a barrier between the condyle and the temporal bone, preventing the condyle from being worn down or damaged. Asymmetrical mandibular development or other abnormalities may result from changed forces on the condyle caused by injured or misplaced discs, which can cause abnormal joint function (as in TMJ disorders). [11]

D. Impact on Growth Patterns of the Mandible

Damage or disc displacement can affect TMJ function, resulting in aberrant mandibular mobility and growth. For instance, a common occurrence in TMJ disorders is anterior displacement of the articular disc, which can cause uneven loading of the condyle and impair condylar development. Depending on the extent and length of the dysfunction, prolonged disc displacement may result in aberrant growth patterns, such as mandibular asymmetry or a retrognathic (underdeveloped) jaw.[12]

E. Role in Orthodontic and Orthopedic Interventions

For mandibular development problems to be successfully treated with orthodontics and orthopaedics, the TMJ, especially the articular disc, must function properly. To guarantee appropriate mandibular growth during orthodontic appliance therapy, it could be important to address disc dysfunction or TMJ disorders. A healthy articular disc is essential for preserving the joint's force balance, and functional appliances that seek to direct mandibular growth frequently depend on the TMJ's capacity for adaptation. [13]

F. Disc Dysfunction's Effect on Growth

The normal biomechanics of the joint can be changed by temporomandibular joint disorders (TMDs) that impact the articular disc's location or integrity. These dysfunctions may disrupt the mandible's normal growth trajectory in children and teenagers.

Condylar resorption or changed joint mechanics, which can result in problems like condylar hypoplasia (underdevelopment) or growth disturbances, which can show up as facial asymmetry or malocclusion, can be caused by chronic disc displacement or dysfunction. [10]

III. Genes and several signalling pathways

Genes and several signalling pathways, interact intricately during the temporomandibular joint's (TMJ) development and growth. Among the most crucial genes in this process are Osterix (Osx), Indian hedgehog (Ihh), Runx2, and Sox9.

These genes are essential for controlling how the tissues in the TMJ, including as the condylar cartilage, bone, and other related structures, differentiate, grow, and mature.

The responsibilities of role of Genes and signalling systems

1. Runx2 (Runt-related transcription factor 2)

Role in Bone Formation (Osteogenesis): Runx2 is a master regulator of bone production and osteoblast differentiation. It is necessary for the initial phases of endochondral ossification, which is the process by which bone replaces cartilage at the mandibular condyle as the TMJ grows. Runx2 is produced in chondrocytes and pre-osteoblasts during TMJ development, which encourages mesenchymal stem cells to differentiate into osteoblasts (bone-forming cells). Runx2 is essential for the initial creation of the TMJ as well as the continuing growth and remodelling of the mandibular condyle, as evidenced by the failure in bone development seen in mice with this deficit.[14]

Runx2 also controls a crucial stage in bone formation in the TMJ:

The change from a proliferative to a hypertrophic state of chondrocytes in the condylar cartilage. It ensures appropriate TMJ development by coordinating the interaction between cartilage growth and the condyle's ossification processes. [14]

2. Sox9 (SRY-box transcription factor 9)

Role in Cartilage Formation (Chondrogenesis): Sox9 is a gene that is required for the development of cartilage in the TMJ and for the differentiation of mesenchymal stem cells into chondrocytes, or cells that make cartilage. The formation of the condylar cartilage, the mandible's primary growth zone, depends on Sox9 expression during the early stages of TMJ development. It regulates the cartilaginous growth plate's chondrocyte proliferation. The creation of the extracellular matrix of cartilage, which gives the condylar cartilage in the TMJ its shape and stability, depends on Sox9. [15]

Precursor to Endochondral Ossification: Sox9 indirectly prepares cartilage for ossification while simultaneously promoting chondrogenesis. It regulates the equilibrium between chondrogenesis and subsequent bone formation in the condyle in concert with Runx2. The significance of Sox9 in TMJ growth is highlighted by the severe cartilage development deficits shown in Sox9 knockout mice, which result in TMJ deformities.[15]

3. Indian Hedgehog (Ihh)

Regulation of Chondrocyte Differentiation and Proliferation: Ihh is a signalling molecule that is essential for controlling chondrocyte differentiation and proliferation, especially in endochondral ossification, the mandibular condyle's predominant growth mechanism. Ihh promotes chondrocyte proliferation and controls the development of hypertrophy, or larger chondrocytes, a stage before ossification. This is a crucial step in the TMJ's formation and expansion. Ihh signalling regulates the rate and degree of cartilage formation in the condyle of the TMJ by ensuring that chondrocytes maintain a balance between proliferation and differentiation. [16]

Interaction with Parathyroid Hormone-related Protein (PTHrP): To keep the growth plate in the condyle, Ihh and PTHrP collaborate in a feedback loop. In order to regulate the rate of bone formation, Ihh stimulates chondrocyte proliferation while PTHrP postpones their hypertrophy. Ihh signalling disruption causes chondrocyte differentiation errors, which in turn cause aberrant TMJ growth, including condylar hypoplasia (underdevelopment). [16]

4. Osterix (Osx)

Final Stages of Osteoblast Differentiation: The transcription factor Osterix (Osx) is necessary for pre-osteoblasts to finally differentiate into mature osteoblasts, which are in charge of creating bone in the TMJ. It functions downstream of Runx2 and is essential for the development of bone-forming cells in the mandibular condyle during endochondral ossification. Osx makes sure that during TMJ growth and remodelling, the condylar cartilage is appropriately replaced with bone. [17]

Ossification of the Mandibular Condyle: Osx encourages the creation of bone matrix and mineralisation of the condylar cartilage as the TMJ grows, which is a crucial stage in creating the mandible's mature bone structure. Animals lacking Osterix exhibit significant abnormalities in bone production, indicating that it plays a part in the ossification process required for the development of the TMJ. [17]

Temporomandibular joint disorders (TMD) and condyle trauma are two conditions that can seriously hinder mandibular growth, resulting in facial asymmetry, malocclusion, and functional difficulties. Normal mandibular growth, especially in developing individuals, depends on early identification and treatment of TMJ dysfunction. [18]

CONCLUSION:

Because it serves as a growth centre and a biomechanical regulator, the TMJ is essential to the mandible's development. Maintaining normal jaw mobility and face symmetry depends on the appropriate development of the mandibular condyle, which is ensured by the interplay of mechanical forces, molecular signalling pathways, and genetic variables. Abnormal mandibular growth can result from any disturbance in the TMJ's structure or function, underscoring the joint's crucial role in craniofacial development.

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