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Structures and Functions of Masticatory System

1.1 Introduction

The masticatory system consists of teeth, muscles, ligaments, bones, and joints, which are responsible for functions of the masticatory system, i.e. mastication, speech, swallowing, and speaking. The system also assists in breathing. It is regulated and coordinated by the neurologic controlling system. The musculature aids in specific motion of the mandible and effective teeth movement during function. To study occlusion, explicit knowledge of biomechanics and functional anatomy of mastication is crucial.

1.2 Structures and Functions of Temporomandibular Joint

The temporomandibular joints (TMJs) are synovial joints and movable articulations in the skull [1, 2]. The muscles of mastication along with the suprahyoid and infrahyoid move the TMJ and play a crucial part in jaw movements. The basic components of the TMJ include (Figures 1.1 and 1.2) the mandible (head of the condyle), disc, temporal bone (glenoid fossa and articular eminence), and the capsule surrounding the TMJs.

1.2.1 Articular Surfaces

Each TMJ is formed by the mandible's condylar head and squamous temporal bone's articular surfaces. Mostly, the synovial joints are shielded by the hyaline cartilage; however, the articular surfaces of TMJs are shielded by fibrocartilage (predominantly collagen accompanied by few chondrocytes), which makes them atypical [3, 4]. During jaw movements, the condyles translate forward onto the convex articular eminence.

1.2.2 Ligaments

The ligaments are mainly built from collagenous connective tissue fibers of distinct lengths. Normally, they are nonstretchable, but they can be elongated if extensive forces are applied. Ligaments control the movements of the border. The three major functional ligaments of

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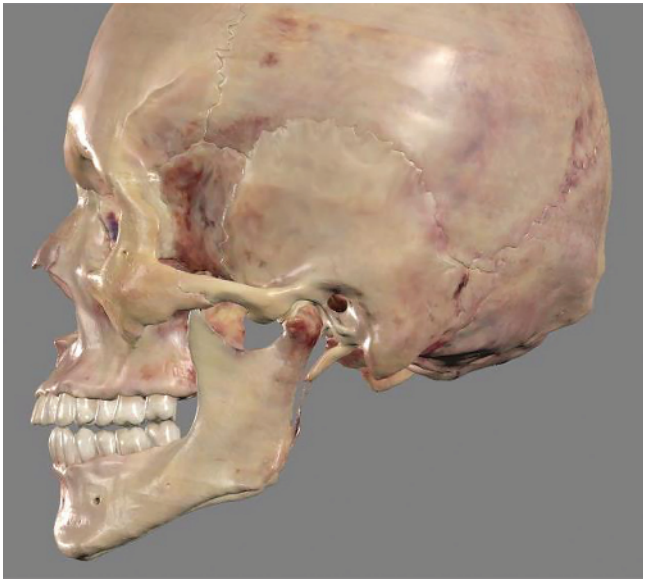

Figure 1.1 Left temporomandibular joint (TMJ) showing the condyle, disc, glenoid fossa, and articular eminence of the temporal bone. Image taken from the Anatomage Table (Anatomage Inc., California, USA).

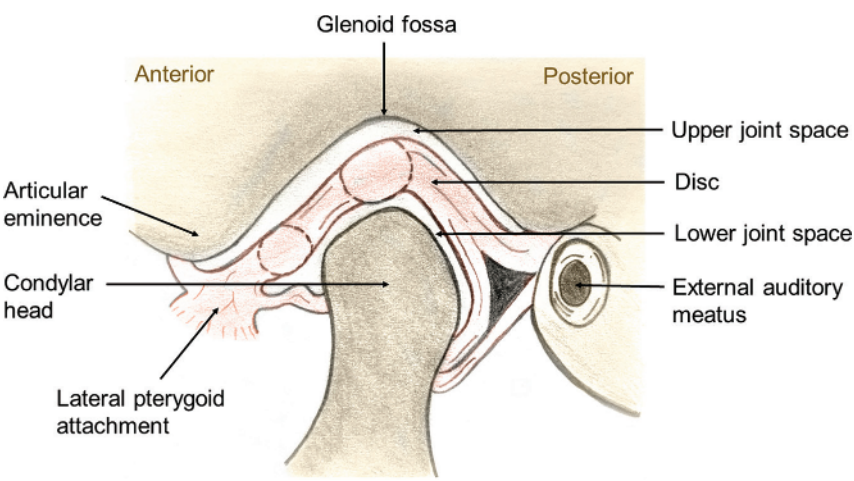

Figure 1.2 Diagram of the right temporomandibular joint (TMJ) sagittal section showing the various components.

the TMJ are the collateral, capsular, and temporomandibular ligaments (TMLs) [1, 5]. The accessory ligaments are two in number: sphenomandibular and stylomandibular.

1.2.2.1 Collateral (Discal) Ligaments

The other name for collateral ligaments is discal ligaments. These are the true ligaments that comprise fibers of collagenous connective tissue and are nonelastic. These ligaments divide

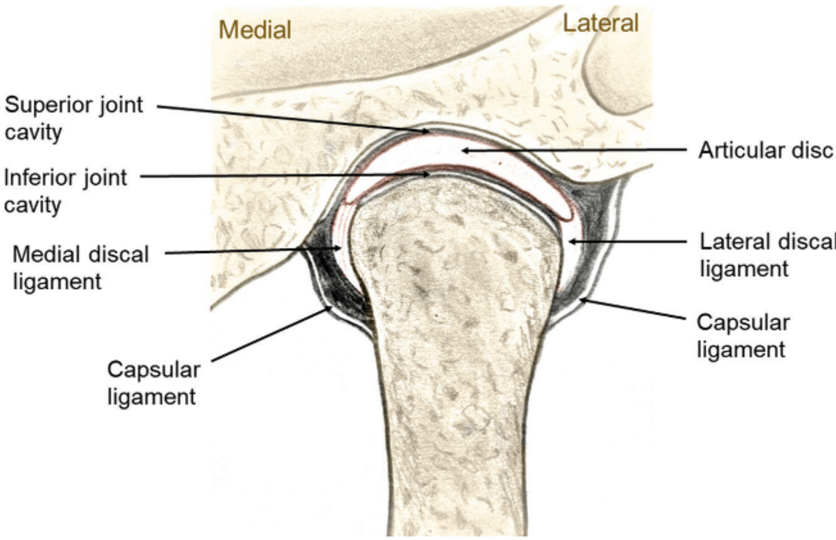

Figure 1.3 Anterior view of the temporomandibular joint (TMJ). Adapted from Reference [1]; chapter published in Management of Temporomandibular Disorders and Occlusion, 7th edition, Okeson J.P., Functional Anatomy and Biomechanics of the Masticatory System, page 10, Copyright Elsevier (2013).

the joint mediolaterally into the inferior and superior joint cavities. The articular disc (lateral and medial borders) is linked to the condyle by the collateral ligaments. The medial discal ligament connects the medial pole of the condyle from the medial edge of the disc, and the lateral discal ligament connects the lateral pole of the condyle from the lateral edge of the disc (Figure 1.3) [1]. During glides of the condyle anteriorly and posteriorly, passive movement with the condyle is permitted by them. Moreover, the anterior and posterior disc rotation on the condyle's articular surface is allowed by them. Hence, they are beneficial for the hinge motion of the TMJ that happens between the articular disc and the condyle.

1.2.2.2 Capsular Ligament

The capsular ligament incorporates the entire TMJ (Figure 1.4) [1]. Superiorly, the capsular ligament's fibers are connected to the temporal bone through the mandibular fossa's articular surfaces and the articular eminence. Inferiorly, the capsular ligament's fibers are connected to the condylar neck. The function of this ligament is to withstand all the forces arising medially, laterally, or inferiorly, which might result in the separation or dislocation of the articular surfaces. This ligament also helps retain the synovial fluid.

1.2.2.3 Temporomandibular Ligament

The strengthened capsular ligament builds the temporomandibular (TM) or the lateral ligament with the help of strong tight fibers. The TML consists of an inner horizontal portion and an outer oblique portion (Figure 1.4A) [1]. The inner horizontal portion stretches from the zygomatic process and articular tubercle horizontally to the condyle's lateral pole and the articular disc's posterior part. The outer oblique portion stretches from the articular tubercle and zygomatic process to the neck of the condyle.

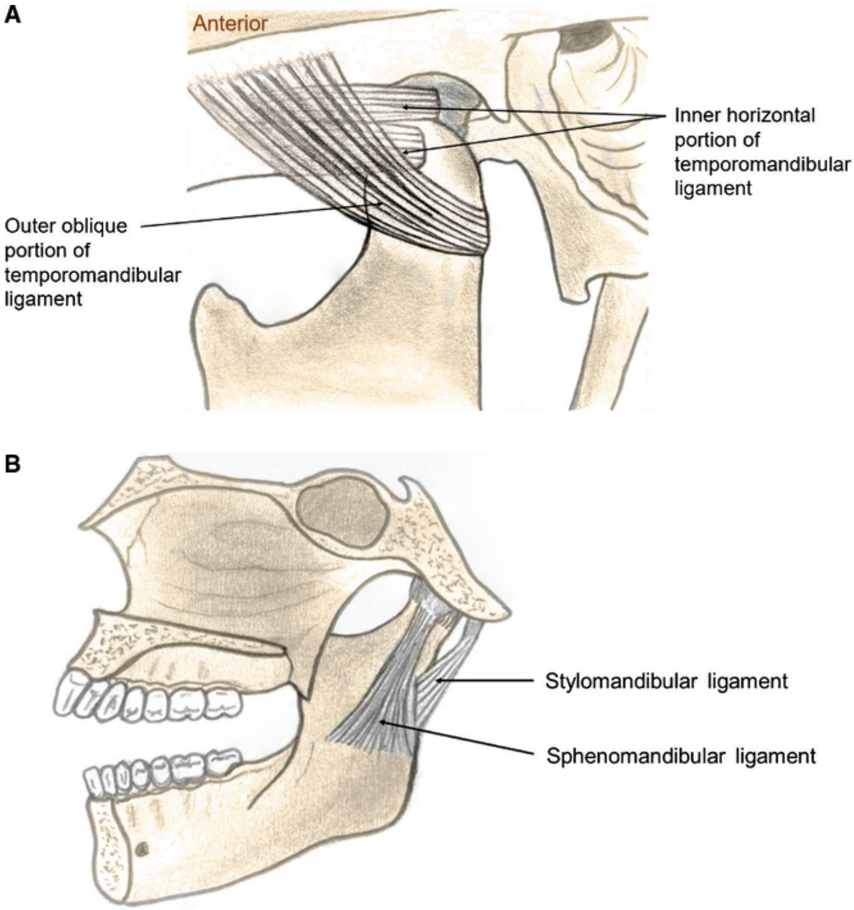

Figure 1.4 Ligaments of the temporomandibular joint. A, Temporomandibular ligament showing the outer oblique portion and the inner horizontal portion. B, Stylomandibular ligament and sphenomandibular ligament. Adapted from Reference [1]; chapter published in Management of Temporomandibular Disorders and Occlusion, 7th edition, Okeson J.P., Functional Anatomy and Biomechanics of the Masticatory System, page 10–11, Copyright Elsevier (2013).

1.2.2.4 Sphenomandibular Ligament

The sphenomandibular ligament is one of the accessory ligaments of the TMJ (Figure 1.4B) [1], which emerges from the sphenoid bone's spine and descends to the mandibular ramus' lingula [6]. This ligament has no crucial function in mandibular movement limitation.

1.2.2.5 Stylomandibular Ligament

The stylomandibular ligament is another accessory ligament of the TMJ (Figure 1.4B) [1], which emerges from the styloid process and descends downward and forward to the mandibular angle and posterior border of the ramus. The uncontrolled protrusive mandibular motions are limited by the stylomandibular ligament. This ligament becomes tense while protruding the mandible and relaxes while opening the mandible.

1.2.3 Nerve Innervation of the Temporomandibular Joint

The trigeminal nerve innervates the TMJ and supplies sensory and motor innervation to the muscles that regulate it. The afferent innervation is supplied by the mandibular nerve branches. Most of the innervation is supplied through the auriculotemporal nerve while it branches off the mandibular nerve. Masseteric and deep temporal nerves provide supplemental innervation [7].

1.2.4 Blood Supply of the Temporomandibular Joint

The principal arteries of the TMJs are composed of the middle meningeal artery anteriorly, the superficial temporal artery posteriorly, and the internal maxillary artery inferiorly. The deep auricular, ascending pharyngeal, and anterior tympanic arteries are the additional crucial vessels. The "feeder vessels" that by a direct route get into the head of the condyle both anteriorly and posteriorly and the inferior alveolar artery through marrow spaces are the routes through which the condyle acquires its vascular supply [8].

1.2.5 Functions of the Temporomandibular Joint

The function of the TMJ is based on the articular design, neuromuscular control, and integrity of soft tissue elements that comprise the anatomy [9]. The prime function of the TMJ is to facilitate movements of the lower jaw. This joint allows a range of movements of the lower jaw, i.e. translational movements (protrusion, retraction, and lateral deviation) and rotational movements (elevation and depression) [2, 9].

1.2.6 Clinical Evaluation of the Temporomandibular Joint

The clinical evaluation of the TMJ includes the observation of the symmetry of the face and the various movements of TMJ. In patients with TMJ dysfunction, it will result in an asymmetry of the mandibular branch.

Pain and clicking are recorded at specific degrees of articular opening or closing, along with accessory movements. The muscles are palpated (externally and internally) and the presence of enlarged submandibular lymph nodes is also checked by palpation. The jaw is slowly moved to evaluate the TMJ ligament apparatus. The fingers are placed on the joint while the patient opens his mouth to evaluate the TMJ. The maximum opening of the mouth should also be evaluated [10].

1.2.7 Radiographic Examination of the Temporomandibular Joint

Various instruments are used in the assessments of the TMJs, and they play a vital role in the diagnosis. Hence, it is necessary to do a proper assessment using instruments before taking a therapeutic approach to a TMJ in the dysfunction [11]. Various imaging techniques for the TMJ include panoramic radiography, plain radiography (transcranial projection), computed tomography or cone-beam computed tomography, and magnetic resonance imaging (Figure 1.5) [12–14]. Panoramic radiography (Figure 1.5A) is important in the

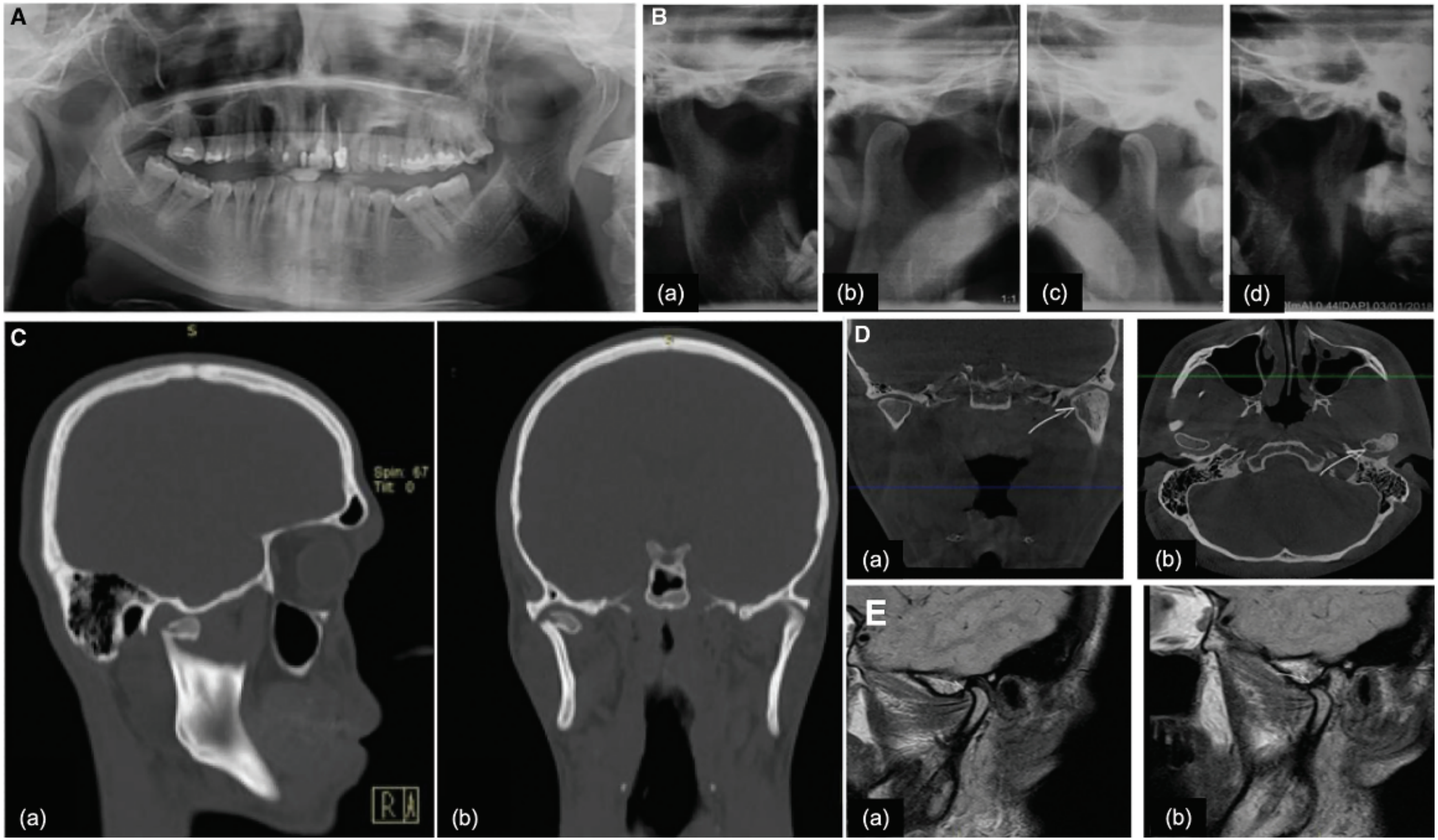

Figure 1.5 Various imaging techniques for the temporomandibular joint. A, Panoramic radiography. B, Plain radiography (transcranial projection) [(a) and (d) Closed-mouth, (b) and (c) Open-mouth]. C, Computed tomography [(a) Saggital plane, (b) Coronal plane]. D, Cone-beam computed tomography [(a) Coronal plane, (b) Axial plane]. E, Magnetic resonance imaging [(a) Closed-mouth, (b) Open-mouth]. Reproduced from [12] / with permission of Kathmandu University Medical Journal (KUMJ) Kathmandu University.

evaluation of the mandibular condyles to the glenoid fossa relationship. Plain radiography of the TMJs (Figure 1.5B) using transcranial projections is useful in the evaluation of the TMJ. The images can be taken at various angulations (lateral oblique transcranial projections, anterior–posterior projections, submental-vertex projection, transpharyngeal view) to avoid the superposition of the temporal bone and the opposite TMJ [13]. Computed tomography or cone-beam computed tomography (Figure 1.5C,D) is done to evaluate the morphology of the components that make up TMJ as well as bone position and pathologies [14]. Magnetic resonance imaging of TMJ (Figure 1.5E) helps observe the condition of the articular disk, anatomy, function, and form.

1.2.8 Clinical Considerations of the Temporomandibular Joint

Loss of teeth results in the subsequent loading of the TMJ, and it can lead to histomorphological and pathophysiological changes in the TMJ joint (the articular disc, articular cartilages, the synovium, and the articular bony components) [15]. The severity of the changes increases with increasing age and is aggravated by impaired occlusal stabilization and existing arthritis of the joint.

Various pathologies can affect the TMJ and potentially cause varying degrees of dysfunction [16]. Damage or disease in the joint area adversely affects masticatory function and speaking, affecting the quality of the life of the patient. Common conditions and diseases of the TMJ include joint pain, muscular pain, rheumatoid arthritis, ankylosing spondylitis, psoriatic arthropathy, fibromyalgia syndrome – myalgia, and multiple sclerosis.

Effective treatment options for patients suffering from severe TMJ disorders are in high demand because surgical options are restricted to the removal of damaged tissue or complete replacement of the joint with prosthetics. Surgical procedures for TMJ are performed for various medical reasons: local and/or systemic disease, trauma, alteration of joint morphology, and loss of function. The long-term outcome of TMJ arthroscopic surgery is acceptable and stable compared with other surgical procedures [17]. Total joint reconstruction using alloplastic joint replacement is done to treat the end-stage disease and has good post-surgical results in the presence of idiopathic condylar resorption [18].

1.3 Structures and Functions of Masticatory Muscles

Muscles are composed of several muscle fibers varying between 10 and 80 μm in diameter [1]. A single nerve ending innervates each fiber, which is situated close to the center of the fiber. The end part of the muscle fiber gathers into bundles forming the muscle tendon which inserts into the bone. Actin and myosin present in muscle fiber are polymerized proteins that have an important function in muscle contraction. Each one of the muscle fibers consists of several myofibrils. These myofibrils comprise approximately 3000 actin filaments and 1500 myosin filaments, situated side by side.

Based on the quantity of myoglobin pigment present in muscle fibers, they can be distinguished into two forms: Type I (slow) and Type II (fast) [19]. Type I fibers consist of a greater quantity of myoglobin and have a deep red color. They can maintain slow yet sustained contraction, are resistant to fatigue, and undergo aerobic metabolism. Type II fibers consist of less quantity of myoglobin and have a whiter color. They have a small number of mitochondria and depend more on anaerobic metabolism for activity. These fibers undergo rapid contraction; however, they fatigue quickly compared to slow fibers. A combination of slow and fast fibers is present in all the skeletal muscles in a diverse quantity that reflects the function of the muscle. Those muscles that must react promptly are mainly composed of white fibers. Slow fibers are present in those muscles that are chiefly utilized for continuous and slow activities. The primary muscles of mastication consist of four muscle pairs: temporalis, masseter, and medial and lateral pterygoids.

The features of masticatory muscles are that [20] (i) they develop from the mesoderm of the first pharyngeal arch, whereas the trunk and limb muscles develop from the somites; (ii) they have a wider range of myosin-heavy chains in adulthood, such as neonatal and cardiac isoforms; (iii) they have a greater number of hybrid fibers by which they have high force in a fatigue-resistant mode; (iv) their morphology of the fibers is unusual, with type II fibers smaller in diameter compared to type I; and (v) the velocity of shortening of their type I and type II fibers (slower and faster) as explained earlier [19, 21] and shown in Figure 1.6 [20]. In addition, the masticatory muscles are moldable based on environmental and genetic factors [21].

Besides, the jaws that are involved in mastication present some unique developmental and morphological features compared to the postcranial skeleton (the trunk and limbs) as shown in Figure 1.7) [20]. The features of the mandibular bone are that (i) they are developed from the embryonic neural crest cells instead of the embryonic mesoderm, (ii) they support teeth, (iii) they have some pathologies that are not present in other bones (some are related to the teeth), (iv) they contain more red bone marrow than yellow bone marrow, (v) their regeneration capacity is greater than that of the other bones, and (vi) they are under constant movement and mechanical loading from chewing, swallowing, and speech [22–25]. In addition, the muscle–bone functional relationship is involved in bone biomechanics, i.e. loading and movement affect its shape through the remodeling process [20].

The origin and insertion of various primary muscles of mastication (temporalis, masseter, and medial and lateral pterygoids) with their functions are shown in Table 1.1. Each of the muscles is discussed in detail, focusing on the direction, attachment, and function of the muscle fiber.

1.3.1 Temporalis

The temporalis is a broad fan-shaped muscle that emerges from the temporal fossa and the lateral surface of the skull. The temporalis fibers combine as they merge down between the zygomatic arch and the skull's lateral surface, making a tendon that inserts into the coronoid process and anterior border of the ramus of the mandible. The temporalis can be divided into three distinct areas (Figure 1.8A) [1]: the anterior portion (vertically directed fibers), the middle portion (obliquely directed fibers across the lateral surface of the skull), and the posterior portion (horizontally directed fibers running over the ear forward to merge with the other fibers of temporalis while they course below the zygomatic arch). The mandible is elevated as there is a contraction of the temporal muscle. Contraction of the anterior portion results in vertical elevation of the mandible, the middle portion results in

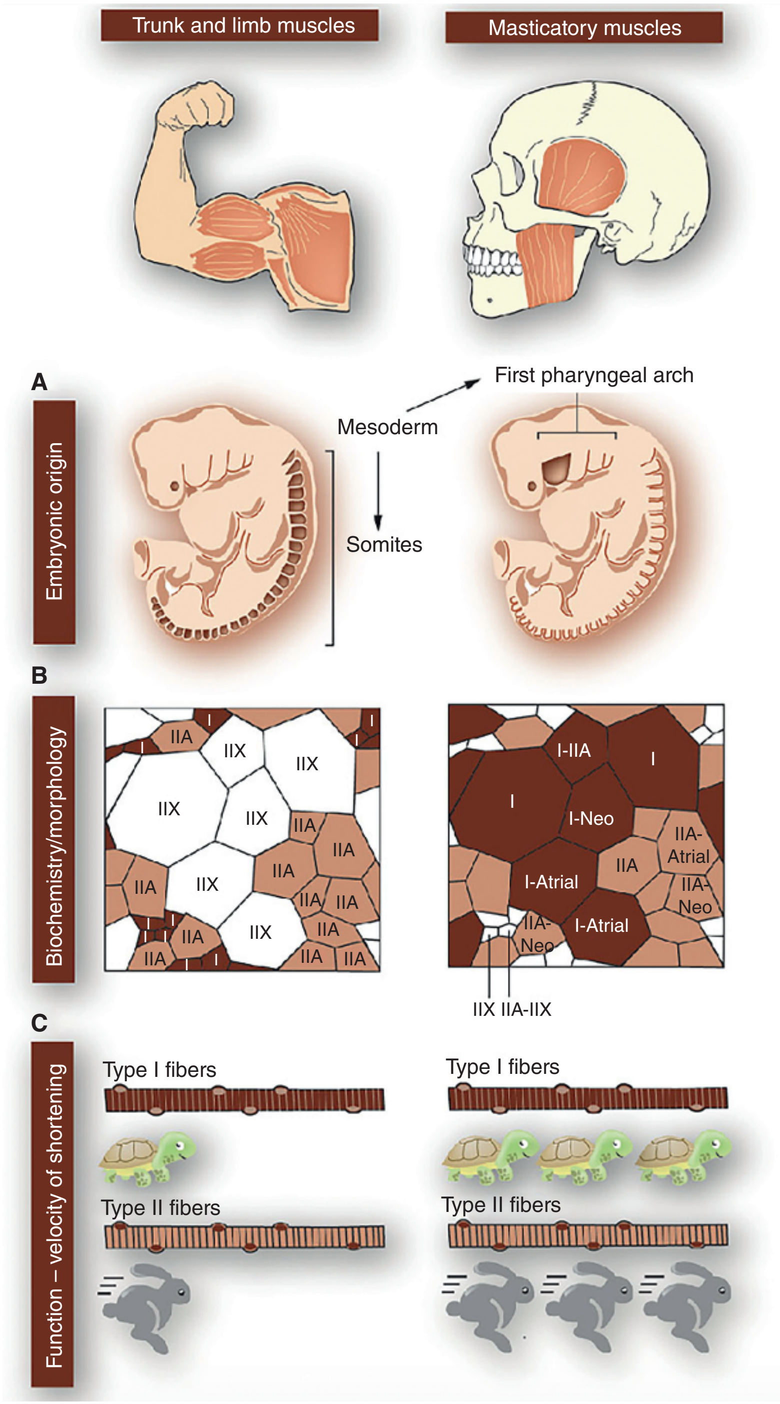

Figure 1.6 Features of masticatory muscles compared to the trunk and limbs. Reference [20] / Frontiers Media S.A. / CC BY 4.0.

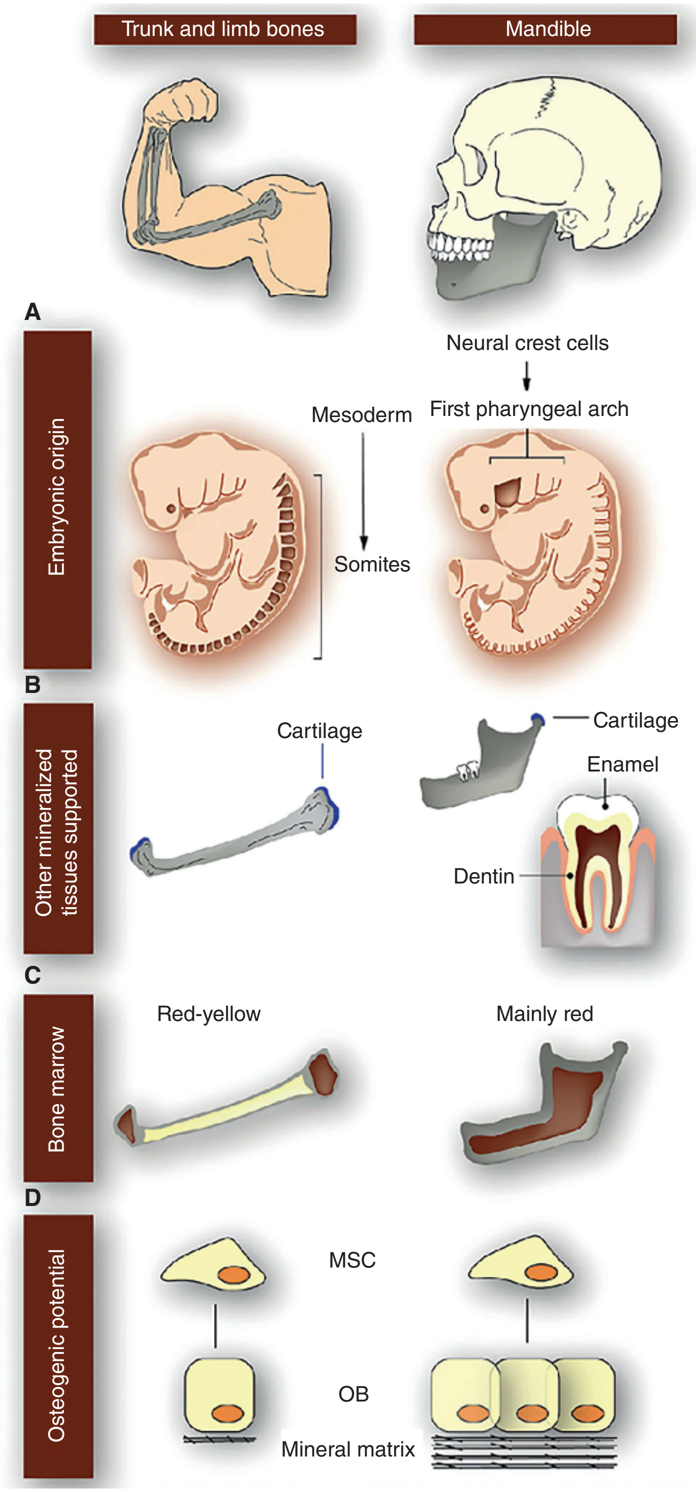

Figure 1.7 Features of mandibular bone compared to the trunk and limbs. Reference [20] / Frontiers Media S.A. / CC BY 4.0.

Table 1.1 Origin and insertion of various muscles of mastication.

Muscles	Origin	Insertion	Functions
Masseter	Zygomatic arch	Angle of the mandible Ramus of mandible	Closing the mouth Protrusion (superficial head) Retrusion (deep head) Ipsilateral excursion
Temporalis	Temporal fossa	Coronoid process Ramus of the mandible	Closing the mouth Retrusion (posterior fibers) Ipsilateral excursion
Medial pterygoid	Superficial head: maxillary tuberosity Deep head: Medial surface of the lateral pterygoid plate	Angle of the mandible Ramus of mandible	Closing the mouth Protrusion Contralateral excursion
Lateroid pterygoid	Superficial head: Infratemporal fossa Inferior head: Lateral surface of the pterygoid plate	Capsule of the temporomandibular joint The neck of the condyle	Opening the mouth Protrusion Contralateral excursion

elevation and retrusion of the mandible, and the posterior portion results in retrusion of the mandible (Table 1.1). This muscle also helps in the ipsilateral excursion of the mandible. The temporalis is innervated by the deep temporal branch of the mandibular nerve of the trigeminal nerve, and the blood is supplied by the anterior, posterior, and superficial temporal arteries [1].

1.3.2 Masseter

The masseter muscle is rectangle-shaped and it arises from the zygomatic arch and descends to the angle of the mandible and the lateral aspect of the lower border of the mandibular ramus (Figure 1.8B) [1]. It consists of two portions: the superficial portion (pass downward and a bit backward) and the deep portion (pass chiefly in a vertical direction). Elevation of the mandible happens when the fibers of the masseter muscle contract (Table 1.1). This is a strong muscle that aids in supplying the required force for efficient chewing. The superficial portion helps in the protrusion of the mandible. The masseter is innervated by the masseteric nerve from the mandibular branch of the trigeminal nerve, and the blood is supplied by the masseteric artery [1].

1.3.3 Medial Pterygoid

The medial surface (deep or internal) of the pterygoid originates from the pterygoid fossa and stretches downward, backward, and outward; it then inserts along the medial surface of the angle of the mandible (Figure 1.9A) [1]. The superficial head of the medial pterygoid

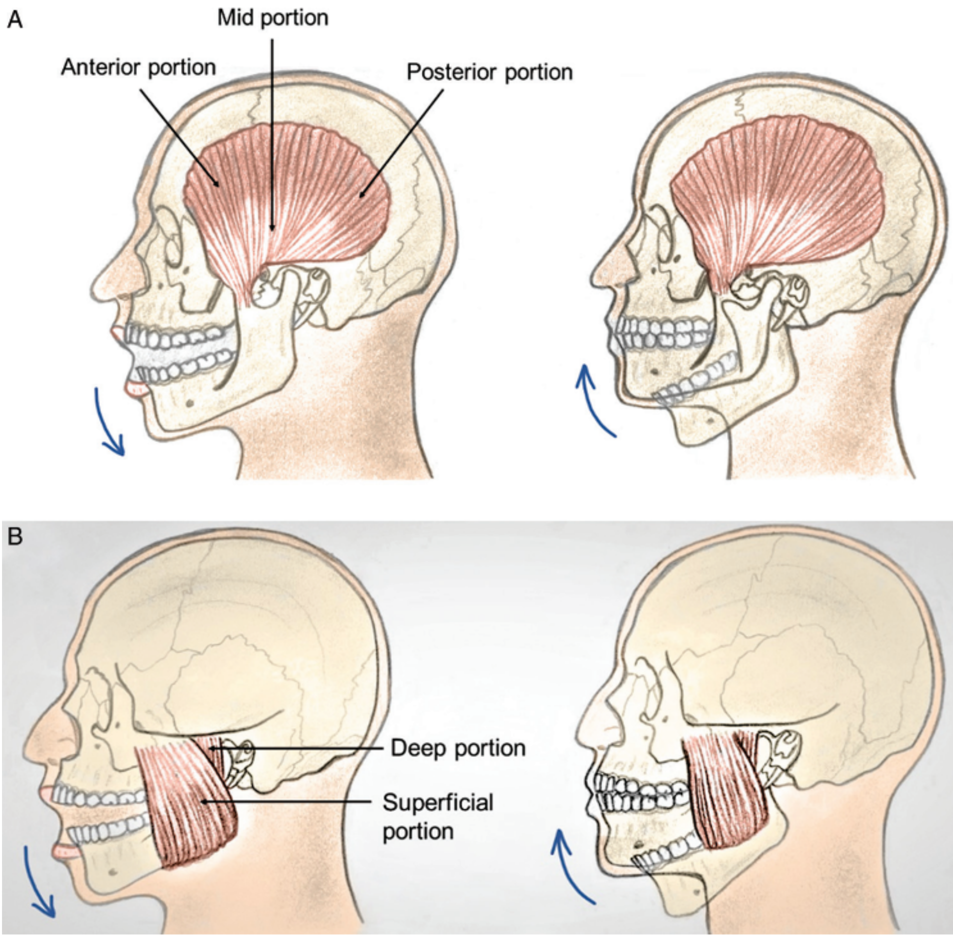

Figure 1.8 Temporalis and masseter muscle in function during opening (depression) and closing (elevation). A, Temporalis muscle in function during opening and closing of the mandible. B, Masseter muscle in function during opening and closing of the mandible. Adapted from Reference [1]; chapter published in Management of Temporomandibular Disorders and Occlusion, 7th edition, Okeson J.P., Functional Anatomy and Biomechanics of the Masticatory System, page 11, 13, Copyright Elsevier (2013).

originates from the maxillary tuberosity, runs along with the masseter muscle, and inserts at the ramus of the mandible. The medial pterygoid results in the elevation of the mandible as a result of the contractions of the muscle fibers (Table 1.1). It is effective in mandibular protrusion as well. Contralateral excursive movement is created by the unilateral contraction of this muscle. The medial is innervated by the mandibular branch of the trigeminal nerve and the blood is supplied by the pterygoid branch of the maxillary artery [1].

1.3.4 Lateral Pterygoid

The lateral pterygoid is divided into two distinct and different muscles: the inferior and superior lateral pterygoids. Their functions are quite different. The superior head of the lateral pterygoid muscle is smaller and originates from the infratemporal surface of the greater

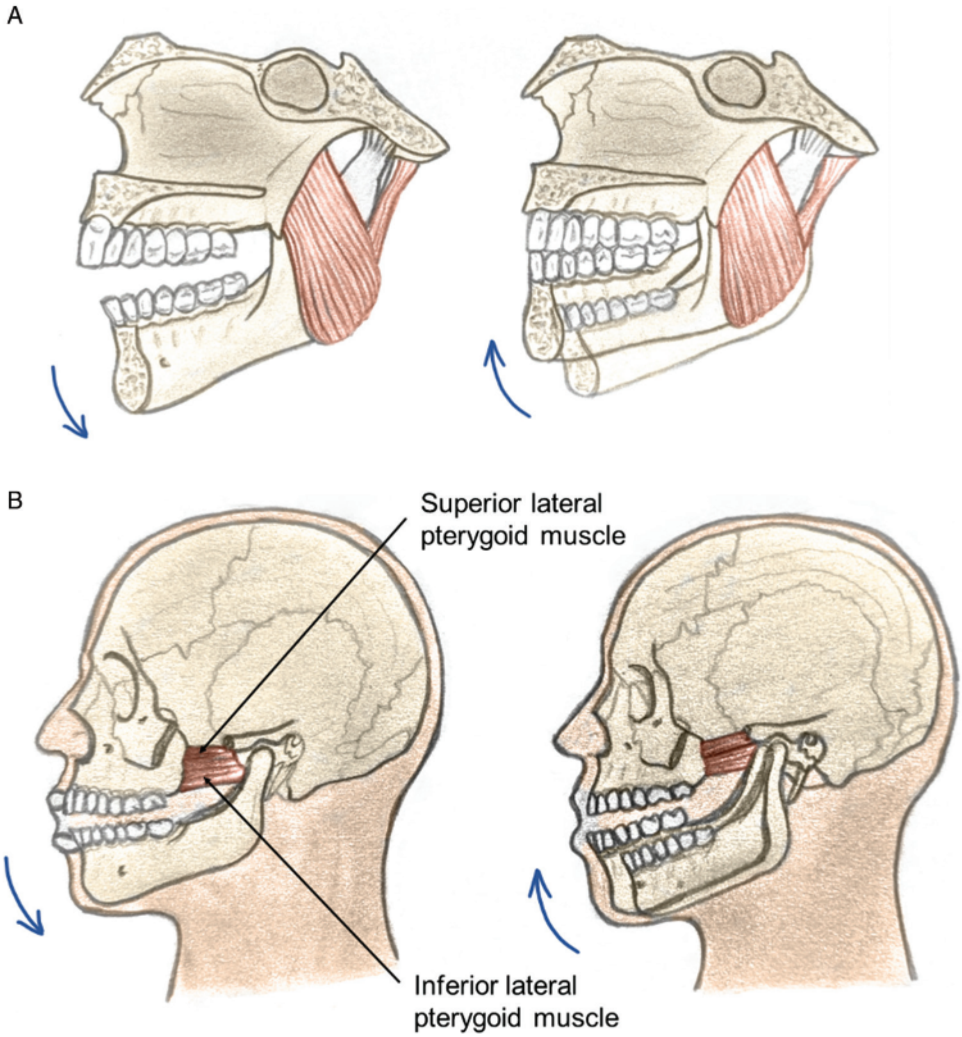

Figure 1.9 Medial, inferior, and superior lateral pterygoid muscles during opening (depression) and closing (elevation). A, Medial pterygoid in function during opening and closing of the mandible. B, Inferior and superior lateral pterygoid muscles in function during opening and closing of the mandible. Adapted from Reference [1]; chapter published in Management of Temporomandibular Disorders and Occlusion, 7th edition, Okeson J.P., Functional Anatomy and Biomechanics of the Masticatory System, page 13–14, Copyright Elsevier (2013).

wing of the sphenoid, stretching quite horizontally, backward, and outward; it then inserts in the articular capsule, the disc, and the condylar neck (Figure 1.9B) [1]. Most of its fibers, i.e. 60–70%, attach to the condylar neck, and just 30–40% attach to the disc [6, 26]. The inferior head of the lateral pterygoid emerges from the outer area of the lateral pterygoid plate and stretches upward, backward, and outward; it then inserts predominantly on the condylar neck (Figure 1.9B) [1]. As the simultaneous contraction of the left and right inferior lateral pterygoids happens, there is a forward pull of the condyles below the articular eminences, resulting in mandibular protrusion. Contralateral excursive movement is created by unilateral contraction and brings about lateral mandibular movement to the opposite side (Table 1.1). During the opening, only the inferior lateral pterygoid becomes active, while the superior lateral pterygoid only becomes active when united with the elevator muscles. It also becomes specifically active in the power stroke and during the moment when teeth are in occlusion. Power stroke indicates the motions of the mandible as opposed to resistance, for instance, chewing/clenching. The lateral pterygoid pulls the condyle and the disc, primarily in an anterior aspect. The medial angulation of the muscles' pull is enhanced when there is forward movement of the condyle. The muscle pull is directed more medially rather than anteriorly when the mouth is widely opened. The superior and inferior lateral pterygoids are innervated by the pterygoid branch of the trigeminal nerve and the blood is supplied by the pterygoid branch of the maxillary artery [1].

1.3.5 Accessory Muscles of Mastication

Accessory muscles of mastication that are directly associated with mandibular function and assist in jaw opening include the digastric, mylohyoid, geniohyoid, omohyoid, sternohyoid, stylohyoid, sternothyroid, and thyrohyoid muscles. These muscles coordinate the full integration of mandibular movement during opening and closing through their attachments to the hyoid bone, the mandible, and other bones [1, 2].

Accessory muscles that are indirectly associated with mandibular function are in the cervical area and include the sternocleidomastoid and scalenus anterior, scalenus medius, and scalenus posterior muscles. These muscles help in the stabilization of the skull and neck and allow the mandible to move relative to the skull [1, 2].

The digastric muscle is divided into two portions (Figure 1.10) [1]. The anterior belly of the digastric muscle originates at the fossa present on the mandible's lingual surface, exactly over

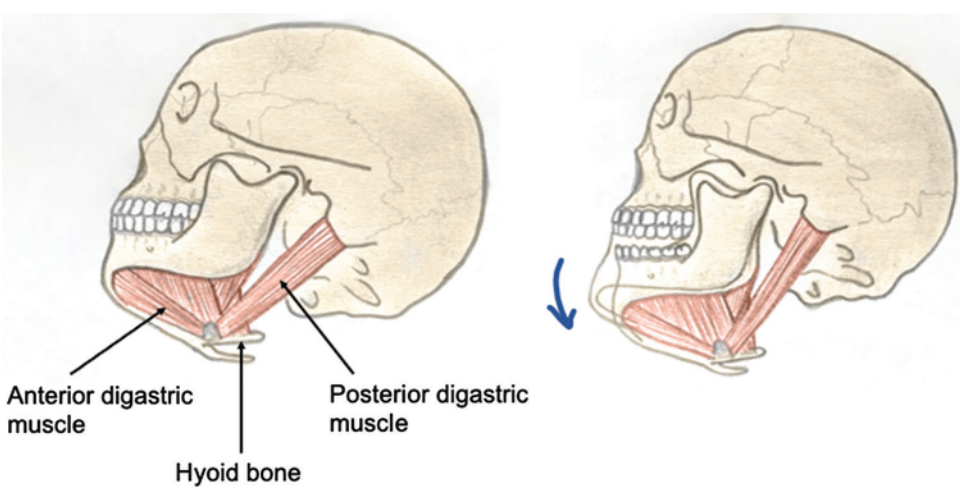

Figure 1.10 Digastric muscle in function during opening (depression) and closing (elevation) of the mandible. Adapted from Reference [1]; chapter published in Management of Temporomandibular Disorders and Occlusion, 7th edition, Okeson J.P., Functional Anatomy and Biomechanics of the Masticatory System, page 15, Copyright Elsevier (2013).

the lower border and near the midline, and the fibers of this muscle pass downward and backward and then insert at the very same intermediate tendon where the posterior belly of the digastric joins. The posterior belly of the digastric muscle arises from the mastoid notch and the fibers of this muscle pass forward, downward, and inward to form the intermediate tendon joined to the hyoid bone. The contraction of the left and right digastric muscles and the fixation of hyoid bone through the support of infrahyoid and suprahyoid muscles results in the lowering and backward pull of the mandible, which separates the teeth from the contact. As the mandible becomes stable, the hyoid bone is elevated by the infrahyoid and suprahyoid along with the digastric muscles, which is a crucial activity in the process of swallowing. The mandibular function is well coordinated by the infrahyoid and suprahyoid muscles. The anterior digastric is innervated by the mandibular branch of the trigeminal nerve and mylohyoid nerve, and blood is supplied by the submental artery [1]. The posterior digastric is innervated by the digastric branch of the facial nerve and the blood is supplied by the facial and lingual arteries. The strap muscles primarily function to raise and depress the hyoid bone and larynx. The strap muscles also assist with depression of the mandible when opening the mouth against an opposing force. The buccinator is a facial expression muscle that helps in mastication by keeping food pushed back within the oral cavity [27].

1.3.6 Clinical Considerations of the Muscles of Mastication

TMJ pain and dysfunction may result from various etiologies. They are commonly seen in nocturnal bruxism, habitual clenching of the mouth, and trauma to the TMJ from injury. Bruxism is a common cause of TMJ dysfunction, secondary to a resultant imbalance in the muscle of mastication forces from excessive grinding of the teeth [28, 29]. Muscle spasms of the muscles of mastication (trismus) can be a symptom of a tumor or infection, which can result in difficulty in opening the mouth. Other infections or inflammation of the muscles may present as myositis or pain during the movement of the jaw [30]. TMJ dysfunction can also result from the imbalance of forces within the muscles of mastication.

Damage or disease in the TMJ area adversely affects masticatory function. Masticatory muscle disorders include myofascial pain and dysfunction, myositis, and neoplasms. The masticator space is enveloped by the deep cervical facia; hence, tumors of TMJ are rare. The tumors of TMJ might have extended from adjacent regions. Mesially, the fascia is attached to the skull base, laterally to the temporalis muscle, anteriorly to the body of the mandible, and posteriorly to the ramus of the mandible [31].

1.4 Structures and Functions of Teeth and Associated Structures

In humans, the dentition comprises 32 permanent teeth as shown in (Figure 1.11). A tooth consists of two parts: crown and root (Figure 1.12). The part that can be seen above the gingival tissue is the crown, and the section of the tooth that is surrounded by and submerged in the alveolar bone is the root. Numerous fibers of connective tissues help in attaching the root to the alveolar bone.

Figure 1.11 Human dentition showing upper, lower teeth, and gingiva.

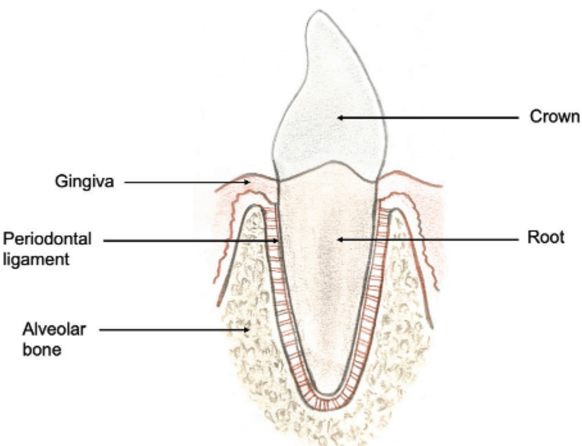

Figure 1.12 The tooth and surrounding structures.

Most of the fibers obliquely begin from the cementum and then to the bone in a cervical direction (Figure 1.12). Collectively, the fibers can be termed the periodontal ligament. In addition to firmly attaching the tooth to the bony socket, the fibers also aid in the dissipation of the forces on the bone, which are applied during the teeth's functional contact (natural shock absorber). The information related to position and pressure is provided by specialized receptors, which are a part of the periodontal ligament.

Both the maxillary and mandibular arches consist of the alveolar bone where the distribution of the 32 permanent teeth is equal – alignment of the 16 maxillary teeth is in the maxilla's alveolar process that is firmly linked to the lower anterior part of the skull; the alveolar process of the mandible, the jaw which can move, contains the alignment of the remaining 16 teeth. Usually, the mandibular teeth overlap with the maxillary teeth when in occlusion, both horizontally and vertically, mainly due to the mandibular arch being smaller than the maxillary arch. The reasons for this discrepancy in size are that (i) the mandibular teeth widths are narrower than the maxillary anterior teeth, creating a smaller arch width and (ii) the facial angulation of the mandibular anterior teeth is smaller than the maxillary anterior teeth, which ultimately results in some vertical and horizontal overlapping.

Incisors are the teeth that are situated in the arches' most anterior region. These exhibit a typical shovel shape, also consisting of an incisal edge. Both maxillary and mandibular sections consist of four incisors each. The incisors are responsible for cutting off food in the process of mastication. The canines are posterior to the incisors situated at the arches' corners. In general, they are the longest among the permanent teeth and they consist of a root and a single cusp. Both maxillary and mandibular sections consist of two canines each. As we move further back in position in the arch, we find the premolars. Both maxillary and mandibular regions each consist of four premolars. Since they have two cusps, they are also known as bicuspids. With two cusps present, the biting surfaces of premolars increase greatly. The occlusion of mandibular and maxillary premolars is such that food is caught and crushed in between the teeth. Premolars are mainly responsible for effectively breaking down the substances of food into minute sizes. Molars are the teeth found behind the premolars. Both the mandibular and maxillary sections consist of six molars each. There are either four or five cusps in the crown of each molar. Due to this, a surface that is large and broad is created, which is enough to accomplish the disintegrating and crushing of food. Molars are functionally special in the latter chewing stages. In that stage, the breakdown of food into small particles is suitable for swallowing.

1.5 Biomechanical Interaction Between Masticatory Muscles and Bones

Mechanical stimulation in the orofacial region is an important factor in the determination of bone shape and its development. The mechanical stimulation results in bone strains above the 1500–3000 microstrain range, and the strain results in bone modeling, which increases bone mass [32, 33]. On the other hand, strains below the 100–300 microstrain activate bone resorption and this reduces unnecessary bone. In addition, low strain magnitudes acting at high frequency also result in bone formation [34, 35]. For bone formation to occur, bone cells that are responsible for bone remodeling must sense such changes in mechanical stimuli. During muscle contraction and functional loading, i.e. the deformation of bone tissue, intertrabecular spaces, and movement of interstitial fluids cause mechanical stimuli that osteocytes sense through mechanoreceptors to activate the target molecule within the cell [20].

The masticatory apparatus produces loads of different magnitudes and high frequencies on the jaws and teeth. These loads result in bone remodeling and ultimately shape the mandible to fit mechanically. These loads result in micro deformation because of the different force vectors acting on it.

During the chewing stroke and muscle activity, bone strain occurs and the TMJ acts as the fulcrum; the distance of muscle insertion to the TMJ is the force arm, and the biting force is the resistance arm. The more anterior the biting point, the lower the resulting biting force, and vice versa. As the posterior teeth are close to the TMJ, biting at the posterior teeth reduces the length of the resistance arm and increases bite force. Hence, biting in posterior teeth is more efficient in terms of the use of muscle force. There is also a difference in the TMJ loading vectors for molar and premolar bites due to the bite-point location [36]. The posterior part of the mandible has a thinner cortical bone compared to the anterior part of the mandible, which can absorb the strains during biting [37, 38].

Furthermore, during biting, the TMJ surfaces apart from the forces on the mandible and cranium [36, 39]. The muscle force decomposes at the biting point and the TMJ. Thus, if a large force is generated during contraction, it reduces the reaction force at the TMJ. The resulting forces produced during biting cause the deformation of the mandible in three patterns: bending of the sagittal plane, bending of the transverse plane, and twisting of the body and symphysis [40, 41] as shown in Figure 1.13 [20]. The anterior part of the mandible has a thick cortical bone, and the posterior end of the corpus has more strains during biting [37, 38].

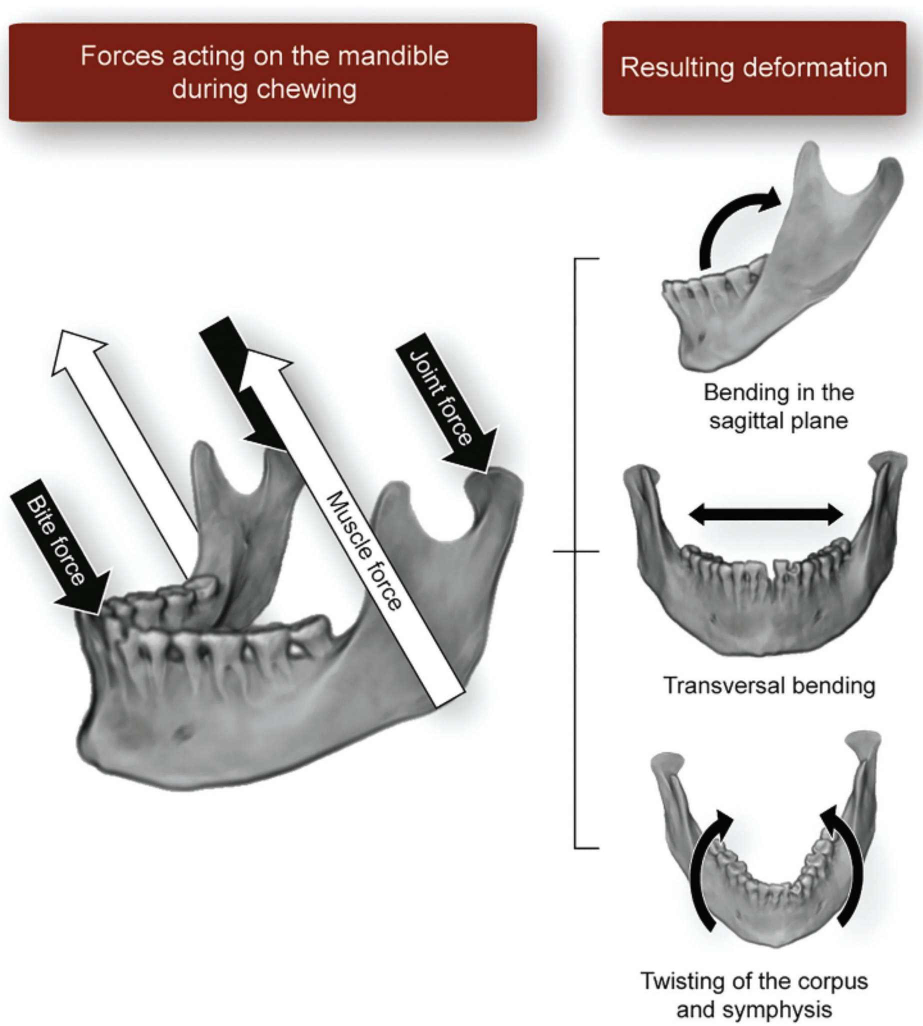

Figure 1.13 Various forces acting on the mandible during biting and bone deformation. Reference [20] / Frontiers Media S.A. / CC BY 4.0.

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