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Research Article

The human masseter muscle revisited: First description of its coronoid part

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ABSTRACT

Introduction: The masseter muscle is considered to be bilayered, consisting of a superficial and a deep part. However, a few historical texts mention the possible existence of a third layer as well, but they are extremely inconsistent as to its position. Here we performed an anatomical study to clarify the presence and morphological characteristics of a distinct third layer of the masseter muscle.
Materials and methods: We dissected 12 formaldehyde-fixed human cadaver heads, analysed CTs of 16 fresh cadavers, evaluated MR data from one living subject and examined histological sections using methyl methacrylate embedding of one formaldehyde-preserved head.
Results: An anatomically distinct, deep third layer of the masseter muscle was consistently demonstrated, running from the medial surface of the zygomatic process of the temporal bone to the root and posterior margin of the coronoid process. Ours is the first detailed description of this part of the masseter muscle.
Conclusions: To facilitate discussion of this newly described part of the masseter, we recommend the name M. masseter pars coronoidea (coronoid part of the masseter) as a further reference. The arrangement of its muscle fibers suggest it being involved in stabilising the mandible by elevating and retracting the coronoid process.

1. Introduction

The masseter muscle is the most prominent masticatory muscle. Its main function is to elevate the mandible against the maxilla and to exert masticatory force. The masseter also plays a small part in protracting the mandible and in lateral movements. The masseter muscle also has a special significance for facial aesthetics (Almukhtar and Fabi, 2019).

Textbooks of anatomy traditionally describe the masseter as quadrilateral, and distinguish between a superficial and a deep portion (Arnold, 1845; Aumüller et al., 2020; Terminologia Anatomica: International Anatomical Terminology, 1998; Waschke et al., 2019). The superficial part originates by a thick aponeurosis on the temporal process of the zygomatic bone and the inferior side of the zygomatic arch. The fibers run inferior-posteriorly, superficial to the deep part, and insert onto the mandibular angle at the masseteric tubercle, as well as on the inferior portion of the lateral surface of the mandibular ramus. The deep part originates along the entire length - or according to other sources, just the posterior two-thirds (Dauber, 2019) - of the zygomatic arch; the fibers pass inferiorly and converge to insert on the mandibular ramus, superior and deep to the superficial portion. Anteriorly, the deep part is covered by the superficial portion, whereas posteriorly it is shielded only by the parotid gland. Both layers are innervated by the masseteric branch of the anterior trunk of the mandibular nerve.

However, looking at a larger spectrum of anatomical descriptions, a controversy surfaces regarding the two-layered structure of the masseter. In a historical (38th) edition of Gray`s Anatomy, the muscle was described as consisting of a superficial, a middle, and a deep layer (Williams, 1995). By doing so, the author reflected a much older observation by von Haller (1784) who discussed that the masseter muscle may consist of two or three layers. In this case, the middle part arises from the medial aspect of the anterior two-thirds of the zygomatic arch and from the lower border of the posterior third, and inserts into the central part of the mandibular ramus. The deep layer originates along the entirety of the deep, temporal surface of the zygomatic arch and inserts onto its coronoid process. Williams (1995) declared that the middle and deep layers described in Gray`s Anatomy correspond together to the deep part in the modern

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Terminologia Anatomica (1998). However, since the sources referred to by Williams (1995) regarding the third, deep layer investigated different species and are not in accordance with each other, neither with respect to the origin and insertion of the different muscle parts nor the nomenclature (Schumacher, 1961; Yoshikawa and Suzuki, 1969), their results are difficult to interpret, especially in human specimens. More recently, Gaudy et al. (2000) and Brunel et al. (2003) also describe a 3-layered arrangement of the masseter, with a superficial, intermediate and deep plane. In both cases, the superficial and intermediate layers correspond to the superficial masseter and the deep portion is equivalent to the official deep part of the masseter according to the Terminologia Anatomica (1998).

In order to clarify the structure of the masseter and the resulting inconsistency in nomenclature, we performed anatomical dissections and methylmethacrylate embedding of formaldehyde-fixed cadavers, and supplemented this by computer tomography (CT) examinations of fresh cadavers and magnetic resonance (MR) imaging of a live subject.

As a result, we describe and show here for the first time a distinct portion of the human masseter muscle, which we suggest should be called the coronoid part.

2. Materials and methods

2.1. Macroscopical dissection

For the macroscopical dissection study, 12 heads were obtained from formaldehyde-embalmed cadavers (mean age: 78 years; range: 65–91 years; 7 men, 5 women), who had signed their consent during their lifetime for body donation for educational and medical research purposes in accordance with the guidelines of the Swiss Federal Office of Public Health. The signed consents are available on reasoned request. No inclusion or exclusion criteria were defined.

A layered dissection using the outside-in technique was performed: after removal of the skin, subcutaneous fat and the masseteric fascia, the overlying superficial masseter was separated from the deep portion by inserting a pair of forceps between the layers. The diagonally-posteriorly oriented fibers of the superficial masseter were then cut parallel to the zygomatic arch, halfway between their origin and insertion. The superficial muscle layer was then retracted superiorly and inferiorly, exposing the deep masseter. The fan-shaped deep masseter was identified by its longitudinally running fibers originating along the zygomatic arch and converging onto the ramus of the mandible. The deep masseter was then transected again following the same line as with the superficial part. Meanwhile, the branches of the masseteric nerve and vessels were exposed in the opening between the condylar process of the mandible and the deep part of the masseter. At this point, the attachment of the temporal muscle onto the coronoid process also became clearly visible, marking the correct depth for locating the attachment of the third, deepest layer of the masseter, the pars coronoideus. The coronoid part of the masseter was identified by its diagonally-running fibers, which lie underneath the deep masseter, originate posteriorly from the temporal side of the zygomatic arch, and run diagonally-anteriorly towards the coronoid process of the mandible. Following dissection, the length, width and thickness of the coronoid part of the masseter were quantified.

2.2. MMA embedding

For the methylmethacrylate (MME) embedding, one head was used (for detailed methods see Hauser et al. (2015). In short:

Two centimeter-thick transversal sections of a formaldehyde-embalmed head were sequentially dehydrated with 40% ethanol ascending to 100% over a period of 25 days. The initial defatting process was completed with isopropyl alcohol and chloroform. The slices were then infiltrated with MMA for 3 days at 4 °C. The resulting solution was exchanged for pure MMA for the final embedding at 4 °C. The duration of polymerization depended on the size of the sample and lasted approximately one month. All further steps were carried out on the head slices embedded in cured MMA blocks.

Transverse sections were cut using a diamond circular saw with a blade thickness of 400 µm. The resulting 1200 μm thick slices were fixed on white, translucent object holders for further processing. The slides were then ground to a maximum thickness of 250 µm and polished. The following staining methods were used:

i. Toluidine blue epoxy staining (penetration thickness: 3 µm) for basophil structures.
ii. Trichrome Masson-Goldner surface staining (penetration thickness: 3 µm), where mineralized bone and collagen are stained green, calcified cartilage is light green, and muscle tissue and cytoplasm appear in different shades of red.

The resulting histologic slices were documented for inspection (IMS Client software, 20.5: 1 Zoom and FusionOptics Technology Leica M205C; Canon EOS 40D).

2.3. CT analysis

Sixteen fresh cadavers (mean age: 85 years; range: 66–95 years; 4 men, 12 women) were imaged with a CT system (SOMATOM 16, Siemens, Erlangen, Germany, 130 kVolt, axial slices) with a slice thickness of 0.6 mm. Images were acquired using the B31S standard soft tissue convolution kernel. For further analysis, the DICOM axial image series were transformed into 3D reconstructions of the head using Slicer (version 4.10.2), with global thresholding defined for bone and muscular elements. A region in the temporal and infratemporal fossa defined by the zygomatic arch and the temporal bone, the coronoid and condylar process was reconstructed and the presence of the muscle was observed.

2.4. MR analysis

The MR imaging was performed on one research subject (age: 40 years, female) using a Siemens MR system, slice thickness: 4, magnetic field strength: 1.5 T. The resulting images were reconstructed and analysed for the presence of the muscle using Slicer (version 4.10.2).

2.5. Quantitative measurements

Muscle length, width and thickness were measured directly on formaldehyde-embedded cadavers with the jaw fully closed. MR and CT images were analysed using ImageJ (version 1.53c) for the presence of the muscle.

3. Results

The results of our macroscopical and radiological investigations have proved the consistent existence of a third, distinct layer of the masseter muscle in humans. This deepest layer of the masseter, which we call the coronoid part (suggested latin name: *M. masseter, pars coronoidea*), originates posteriorly on the inner, temporal side of the zygomatic process of the temporal bone, with the muscle fibers running diagonally anteriorly, the muscle attaching at the base and along the posterior margin of the coronoid process of the mandible (Figs. 1–3). The coronoid part of the masseter was present in each case studied, indicating that it is a constant architectural element of the masseteric muscle rather than an anatomical variation. The main findings are summarized in Figs. 1–3.

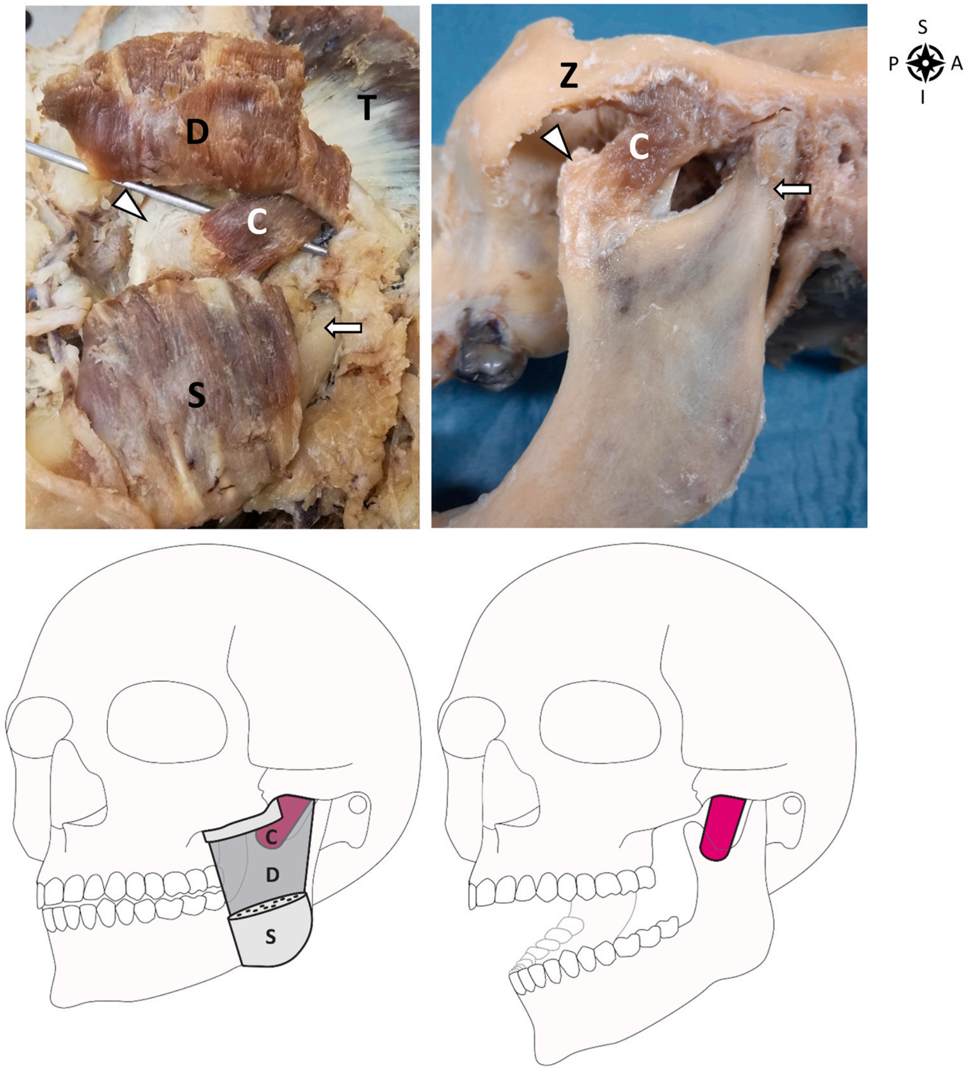

Fig. 1. Macroscopical dissection and schematic drawing representing the coronoid part of the masseter. C = coronoid part of masseter; S = superficial part of masseter; D = deep part of masseter; T = temporal muscle; Z = zygomatic arch; arrow head = coronoid process of mandible; arrow = condylar process of mandible. (S: superior, I: inferior, P: posterior, A: anterior).

3.1. Origin

The origin of the fibers of the coronoid part is different from that of the deep part of the masseter. The coronoid part takes its muscular origin from posterior to the temporozygomatic suture of the zygomatic arch, anteriorly from the temporomandibular joint. The muscle arises from the medial surface of the zygomatic process of the temporal bone, and in some cases from the deep layer of the temporal fascia close to its attachment on the zygomatic arch, thus forming the deepest layer of the masseter. On the other hand, the origin of the deep part of the masseter extends along the entire inferior part of the zygomatic arch, bridges over the temporozygomatic suture, and attaches to both the zygomatic process of the temporal bone and the temporal process of the zygomatic bone. The enthesis is of a muscular form.

3.2. Fiber orientation

The orientation of the muscle fibers is specific for the coronoid part of the masseter. The fibers run parallel and diagonally, from a postero-lateral-superior origin on the zygomatic arch, towards an antero-medial-inferior insertion on the coronoid process. The muscle is thus elongated and quadrangular, with an average anterior length of 22.8 mm, an average posterior length of 20.7 mm, an average anterior width of 9.2 mm, an average posterior width of 12.7 mm, and an average thickness of 2.0 mm (Table 1). The fibers consistently run parallel to the axis of force generation. Thus, the physiological and anatomical cross-sectional area coincide, and are on average 44.6 mm^2. On the other hand, fibers of the deep part of the masseter run longitudinally, along the shortest path from the zygomatic arch, converging on the lateral side of the mandibular ramus, shaped like a fan. Fibers of the coronoid part are oriented perpendicularly to those of the superficial part. Thus, the three layers of the masseter form a network of diagonally arranged muscle fibers, resulting in a cruciate architecture.

3.3. Attachment

The attachment of the coronoid portion of the masseter on the coronoid process of the mandible can be clearly separated from the tendinous attachment of the temporal muscle. The tendon and muscle fibers of the coronoid part of the masseter run

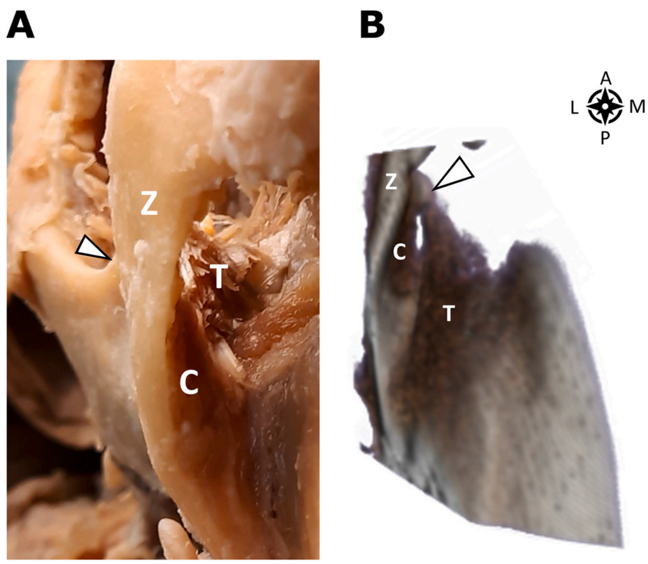

Fig. 2. A Postero-superior view of the temporal fossa on a dissected specimen. B 3D-CT reconstruction of the temporal fossa, postero-superior view. C = coronoid part of masseter; S = superficial part of masseter; D = deep part of masseter; T = temporal muscle; Z = zygomatic arch; arrow head = coronoid process of mandible. (A: anterior, P: posterior, M: medial, L: lateral).

posterolaterally from the coronoid process of the mandible towards the posterior third of the zygomatic arch. Fibers from the tendinous attachment of the temporal muscle run medially and superiorly from the coronoid process, towards the zygomatic bone and the squamous part of the temporal bone.

From a histological perspective, the attachment of the tendon of the coronoid part of the masseter forms a fibrous enthesis, similar to the periosteal-diaphyseal attachment of long bones, with the fibres passing through the periosteum into the bone (Fig. 4.).

Table 1
Summary statistics of the dimensions of the posterior part of the masseter muscle in formaldehyde-fixed specimens. (Measurements rounded to the nearest whole millimeter.).

Measure (mm)	Average	Minimum	Maximum
Length			
posterior	20.7	13	30
anterior	22.8	15	32
Width			
posterior	12.7	10	15
anterior	9.2	5	15
Thickness	2.0	2	2

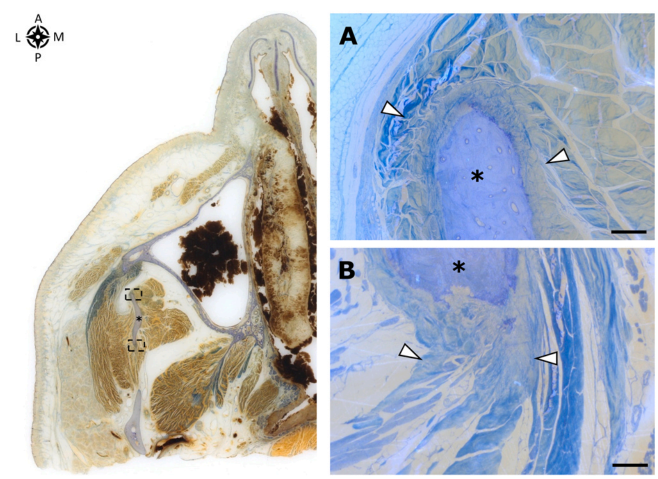

Fig. 4. A Inferior view of an MMA-embedded transverse section, showing the entheses of the temporal muscle and the coronoid part of the masseter on the coronoid process. A Attachment of the temporal muscle tendon (arrowheads) on the anterior part of the coronoid process (*) via the periost. Scalebar: 200 µm. B The fibrous enthesis of the cornoid part tendon (arrowheads), with fibres passing through the periost (*). Scalebar: 100 µm. (A: anterior, P: posterior, M: medial, L: lateral).

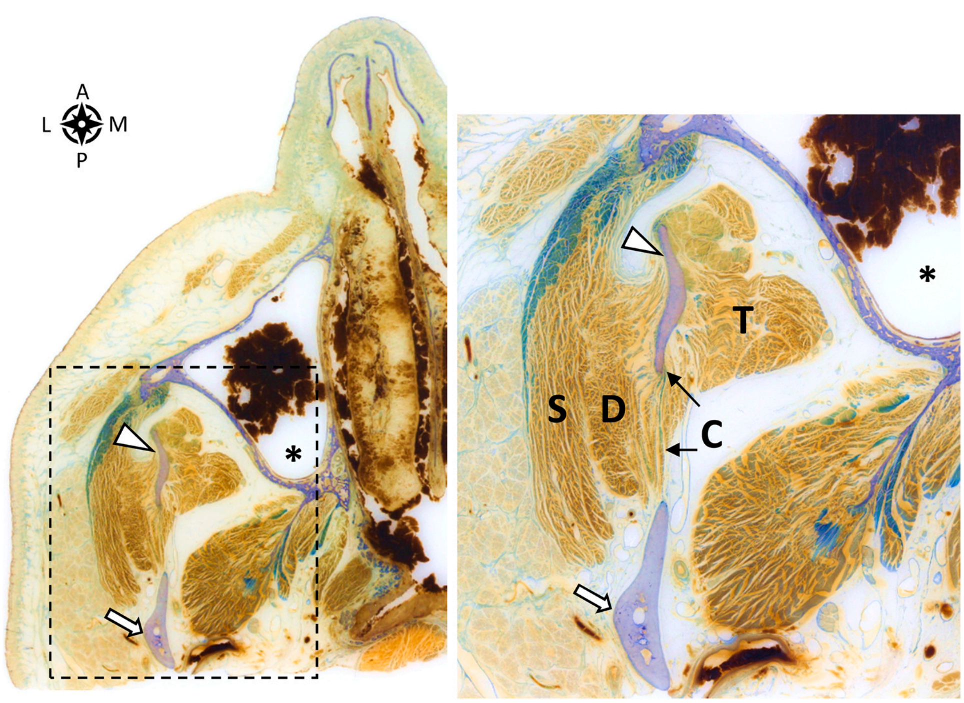

Fig. 3. Inferior view of an MMA-embedded transverse section. C = coronoid part of masseter; S = superficial part of masseter; D = deep part of masseter; T = temporal muscle; Z = zygomatic arch; arrow head = coronoid process of mandible; arrow = condylar process of mandible; * = maxillary sinus. (A: anterior, P: posterior, M: medial, L: lateral).

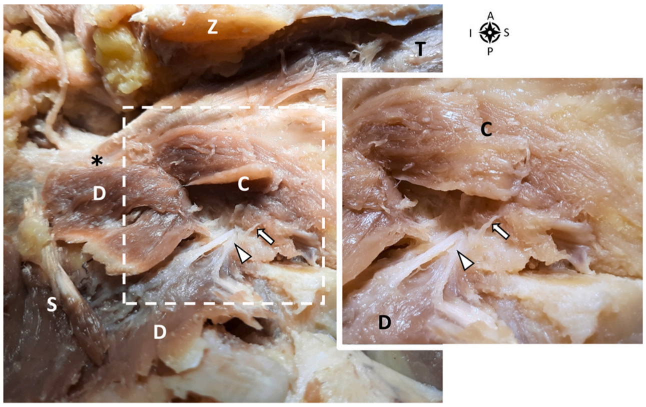

Fig. 5. Lateral view of a the coronoid part of the masseter, showing an innervating muscular branch (arrow) branching off the masseteric nerve (arrowhead). CP: coronoid part of masseter, D: deep part of masseter, S: superficial part of masseter, Z: anterior end of zygomatic arch (the rest removed) (A: anterior, P: posterior, I: inferior, S: superior).

3.4. Innervation

The main innervation of the coronoid part of the masseter are branches of the masseteric nerve (Fig. 5.). The mandibular nerve passes through the gap between the posterior border of the coronoid part and the condylar process of the mandible and reaches the deep part of the masseter through the mandibular incisure.

4. Discussion

We here describe a new, third subdivision of the masseter, the coronoid part, which forms the deepest layer of the masseter muscle. Our anatomical analysis of the direction of the muscle fibers implies that the coronoid part is involved in the retraction of the mandible, and specifically in the stabilization of the mandibular coronoid process.

4.1. Development

The development of the muscles of mastication and their supporting skeletal elements involve an interlaced network of processes in which the formation of each distinct unit reciprocally influences the development of all other associated units. Thus, the development of the zygomatic arch, mandible, and masseter & temporal muscles are intricately intertwined. The zygomatic arch is built as a response to forces originating from the masseter muscle, which moves the lower jaw and shapes parts of the temporal and zygomatic bones into processes that meet at the zygomaticotemporal suture (Hylander and Johnson, 1997; Katsube et al., 2021; Rafferty et al., 2000; Shimizu et al., 2018; Spyropoulos, 1977).

The coronoid process of the mandible, which is a common insertion point shared by both the newly-described coronoid part of the masseter and the temporal muscle, develops from a separate ossification centre, distinct from the main body of the mandible. It is integrated into the mandibular ramus only later in development, at about the 8th-9th gestational week (CRL 56 mm) in humans (Radlanski et al., 2003; Spyropoulos, 1977). During this first developmental phase, the coronoid process of the mandible develops endochondrally from a primary ossification centre separate from Meckel's cartilage (Lee et al., 2001; Radlanski et al., 2003). Later on, however, the tip and the anterior part of the coronoid process is also shaped by secondary cartilage formation driven by forces originating from the temporal muscle (Anthwal et al., 2015; Velasco et al., 2009). By the 14th week of gestation, this second phase of development is complete and the newly formed bone is being fully incorporated into the coronoid process (CRL 117 mm) (Radlanski et al., 2003). This biphasic development of the coronoid process can also be observed by the different attachment types of the coronoid part of the masseter and the temporal muscle. Stronger pulling forces by the temporal muscle result in secondary cartilage formation and a fibrocartilaginous attachment, whereas weaker forces exerted by the coronoid part of the masseter enable a less robust, fibrous entheses.

The formation of both the zygomatic arch and the coronoid process represent a response to the differentiation and active presence of the masseter & temporal muscles (Katsube et al., 2021; Shimizu et al., 2018). Thus, the different developmental origins of the zygomatic process of the temporal bone and the coronoid process of the mandible provide the embryological basis for the integration of a unit into the masseter that is separate from the main muscular elements connecting the entire zygomatic arch to the mandibular ramus.

4.2. Comparative anatomy

From a comparative perspective, the presence of the coronoid part of the masseter is difficult to establish in other mammalian species, as the deep part of the masseter is often described separately and referred to as the zygomaticomandibular or maxillomandibular muscle, or the suprazygomatic part of the temporal muscle (Cox and Jeffery, 2011; Schumacher, 1961; Yoshikawa and Suzuki, 1965). The literature mentioned by Williams (1995) when discussing the three layers of the masseter (Schumacher, 1961; Yoshikawa and Suzuki, 1965) involves several mammalian species, including humans. The squirrel monkey (*Saimiri sciurea*) and the Yezo brown bear (*Ursus arctos yezoensis*) present muscles that may correspond to the coronoid part in humans (Yoshikawa and Suzuki, 1965). In the squirrel monkey, the muscle is classified as the posterior deep part of the masseter. Here, however, the authors did not address the exact origin and insertion of this muscle part, so these can only be deduced from the figures and do not provide sufficient evidence. Furthermore, a muscle part with similar origin and insertion is missing in the chimpanzee (*Pan troglodytes*), making the evaluation and the comparison of the results difficult. In the Yezo brown bear, a muscle similar to the coronoid part in humans is referred to as the zygomaticomandibular muscle (Yoshikawa and Suzuki, 1965) or the suprazygomatic part of the temporal muscle (Schumacher, 1961), which arises from the posterior half of the zygomatic arch and attaches to the lateral surface of the coronoid process. However, a similar muscle has not been found in the phylogenetically closely related Japanese black bear (*Selenarctos thibetanus japonicus*). Thus, a careful analysis of the literature suggests that the presence of the coronoid part of the masseter in other mammalian species cannot be ruled out and requires further investigation.

4.3. Perspectives in humans

Schumacher (1961) divides the masseter muscle into two segments, superficial and deep, corresponding to the currently recognised superficial and deep parts, respectively. He also describes in detail 5 separate tendinous layers, 3 of which he assigns to the superficial and 2 to the deep layer. The description of the deep segment of the muscle includes a division that may correspond to the coronoid part. It originates on the inner side of the zygomatic arch and inserts on the mandibular insicure and the lateral side of the coronoid process. Unfortunately, there is no clear illustration to support this statement or clarify exactly which segment of the zygomatic arch this muscle segment originates from, but from the description it can be surmised that it is the entire length of the arch. Thus, the coronoid part was probably either overlooked or simply classified as part of the deep portion.

Brunel et al. (2003) also describe three planes of the masseter, all of them attaching on different aspects of the mandibular ramus. The superficial and the intermediate planes together correspond to the modern superficial masseter. The deep plane is divided up into an anterior and a posterior part, which together make up the deep masseter according to the Terminologia Anatomica (1998). Although the posterior part of the deep masseter in this case must have also contained the coronoid portion, there is no mention of the muscle attaching onto the coronoid process, and thus the functional relevance of the retractor part of the masseter has been, until now, overlooked.

4.4. Innervation and blood supply

The masseteric nerve and the masseteric branches of the maxillary artery reach the masseter muscle posterior to its coronoid part, or as a variation, also anteriorly, passing between the muscle and the condylar and/or the coronoid process of the mandible (Kaya et al., 2014; Pinheiro et al., 2020), at the same time giving off branches to innervate and supply the coronoid part of the masseter.

Since the coronoid part of the masseter inserts onto the coronoid process, a possible source of innervation could come – as an anatomical variation described for the attachment of the temporal muscle – from a recurrent branch of the inferior alveolar nerve via the retromolar canal and its openings, alternatively from the long buccal nerve, (Schejtman et al., 1967). Further investigations are needed to clarify whether the innervation of the small area at the attachment of the coronoid part of the masseter on the coronoid process originates – at least to some extent – from the inferior alveolar or the long buccal nerve.

4.5. Relationship to the temporal muscle

The tendinous attachment of the coronoid part of the masseter on the posterior edge and at the root of the coronoid process is similar in structure to the insertion of the temporal muscle along the inferior-anterior edge of the coronoid process, in that it is anchored into the bone via the periosteum (Fig. 4.). At the tip and along the superior-anterior edge of the coronoid process, however, the temporal muscle is inserted into the bone with a fibrocartilaginous attachment, formed by secondary cartilage formation due to the strong mechanical forces invoked by the muscle (Hems and Tillmann, 2000; Kasahara et al., 2020). The fibrous entheses of the coronoid part along the posterior edge of the coronoid process resemble those of periosteal-diaphysary attachments on long bones suggesting that the coronoid masseter portion exerts less force on the bone than the temporal muscle and thus does not induce the formation of secondary cartilage (Hems and Tillmann, 2000; Kasahara et al., 2020).

The common attachment of the temporal muscle and the coronoid part of the masseter could imply that the coronoid part of the masseter is a segregated part of the temporal muscle. This, however, considering the distinct and separate innervation of the muscles, is unlikely.

4.6. Functional relevance

The force exerted on the coronoid process of the mandible by the coronoid part of the masseter is directed laterally and posteriorly, stabilizing and retracting the anterior-superior part of the mandible.

Since the coronoid, deep and superficial part of the masseter are all innervated by the masseteric branch of the mandibular nerve, the three muscle layers are able to form a functional unit that stabilizes and closes the jaw. The coronoid and posterior parts of the deep portion can work together synergistically to raise the mandible. At the same time, the direction of the fibers of the coronoid portion is almost perpendicular to the fibers of the superficial masseter, creating a cruciate muscle, where the two layers are able to function antagonistically by either retracting or protracting the jaw, respectively. From all portions of the masseter muscle, however, it is only the coronoid part that is able to selectively retract the mandible. Further physiological studies can in the future support the anatomical findings and lead to a more detailed analysis of the function of the coronoid part of the masseter.

5. Conclusions

The specifications of the coronoid part of the masseter muscle are as follows:

1. It has its muscular origin on the medial, temporal surface of the zygomatic process of the temporal bone and the deep layer of the deep temporal fascia, clearly separated and distinguishable from the temporal muscle and from the deep part of the masseter.
2. The muscle fibers have a diagonal orientation, starting posterior and supero-lateral on the zygomatic process of the temporal bone, running medially and anteriorly towards the root and posterior edge of the coronoid process.
3. The coronoid part has a slightly tendinous insertion at the root and along the posterior edge of the coronoid process.
4. It has a narrow, elongated, rectangular shape.
5. The mandibular nerve and vessels reach the deep and superficial masseter from the temporal fossa, passing through the mandibular incisure both anteriorly and posteriorly from the coronoid part of the masseter.

We would like to stress that the significance of the newly described coronoid part of the masseter is not only anatomical. Our measurements suggest that the coronoid part of the masseter muscle we describe here has distinct orientation and attachment, and we propose that this could be sufficient to provide further functional stabilization of the lower jaw. Precise knowledge of the architecture of the masseter muscle may also be important in a clinical context, with regard to the management of temporomandibular disorders or surgical interventions in the zygomatic arch region. Knowledge of normal muscle mass and location can facilitate minimally-invasive procedures and optimal patient therapy.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Almukhtar, R.M., Fabi, S.G., 2019. The masseter muscle and its role in facial contouring, aging, and quality of life: a literature review. Plast. Reconstr. Surg. 143, 39E–48E. https://doi.org/10.1097/PRS.0000000000005083

Anthwal, N., Peters, H., Tucker, A.S., 2015. Species-specific modifications of mandible shape reveal independent mechanisms for growth and initiation of the coronoid. EvoDevo 6 (61), 1–14. https://doi.org/10.1186/S13227-015-0030-6

Arnold, F., 1845. Handbuch der Anatomie des Menschen, mit Rücksicht auf Physiologie und praktische Medicin. Herder'sche Verlagshandlung, Freiburg im Breisgau.

Aumüller, G., Aust, G., Conrad, A. (Eds.), 2020. Duale Reihe Anatomie, 5th ed. Thieme, Stuttgart.

Brunel, G., El Haddioui, A., Bravetti, P., Zouaoui, A., Gaudy, J.F., 2003. General organization of the human intra-masseteric aponeuroses: changes with ageing. Surg. Radiol. Anat. 25, 270–283. https://doi.org/10.1007/s00276-003-0125-y

Cox, P.G., Jeffery, N., 2011. Reviewing the morphology of the jaw-closing musculature in squirrels, rats, and guinea pigs with contrast-enhanced MicroCt. Anat. Rec. 294, 915–928. https://doi.org/10.1002/ar.21381

Dauber, W. (Ed.), 2019. Feneis`Bild-Lexikon der Anatomie, 11th ed. Thieme, Stuttgart.

Gaudy, J.F., Zouaoui, A., Bravetti, P., Charrier, J.L., Guettaf, A., 2000. Functional organization of the human masseter muscle. Surg. Radiol. Anat. 22, 181–190. https://doi.org/10.1007/s00276-000-0181-5

von Haller, A., 1784. Grundriss der Physiologie für Vorlesungen. Konrad F. Uden, Berlin.

Hauser, N.H., Hoechel, S., Toranelli, M., Klaws, J., Müller-Gerbl, M., 2015. Functional and structural details about the fabella: What the important stabilizer looks like in the central European population. Biomed. Res. Int 2015, 1–8. https://doi.org/10.1155/2015/343728

Hems, T., Tillmann, B., 2000. Tendon entheses of the human masticatory muscles. Anat. Embryol. 201–208. https://doi.org/10.1007/S004290000107. (2023, 202).

Hylander, W.L., Johnson, K.R., 1997. In vivo bone strain patterns in the zygomatic arch of macaques and the significance of these patterns for functional interpretations of craniofacial form. Am. J. Phys. Anthropol. 102, 203–232. https://doi.org/10.1002/(SICI)1096-8644(199702)102:2<203::AID-AJPA5>3.0.CO;2-Z

Kasahara, M., Matsunaga, S., Someya, T., Kitamura, K., Odaka, K., Ishimoto, T., Nakano, T., Abe, S., Hattori, M., 2020. Micro- and nano-bone analyses of the human mandible coronoid process and tendon-bone entheses. J. Biomed. Mater. Res. Part B Appl. Biomater. 108, 2799–2806. https://doi.org/10.1002/JBM.B.34609

Katsube, M., Yamada, S., Utsunomiya, N., Yamaguchi, Y., 2021. OPEN A 3D analysis of growth trajectory and integration during early human prenatal facial growth. Sci. Rep. 1–11. https://doi.org/10.1038/s41598-021-85543-5

Kaya, B., Apaydin, N., Loukas, M., Tubbs, R.S., 2014. The topographic anatomy of the masseteric nerve: a cadaveric study with an emphasis on the effective zone of botulinum toxin A injections in masseter. PRAS 67, 1663–1668. https://doi.org/10.1016/j.bjps.2014.07.043

Lee, S.K., Kim, Y.S., Oh, H.S., Yang, K.H., Kim, E.C., Chi, J.G., 2001. Prenatal development of the human mandible. Anat. Rec. 263, 314–325. https://doi.org/10.1002/AR.1110

Pinheiro, R.P., Gaubeur, M.A., Itezerote, A.M., Saleh, S.O., Hojaij, F., Andrade, M., Jacomo, A.L., Akamatsu, F.E., 2020. Anatomical study of the innervation of the masseter muscle and its correlation with myofascial trigger points. J. Pain Res. 13, 3217–3226. https://doi.org/10.2147/JPR.S265717

Radlanski, R.J., Renz, H., Klarkowski, M.C., 2003. Prenatal development of the human mandible. Anat. Embryol. 221–232. https://doi.org/10.1007/S00429-003-0343-4. (2073, 207).

Rafferty, K.L., Herring, S.W., Artese, F., 2000. Three-dimensional loading and growth of the zygomatic arch. J. Exp. Biol. 203, 2093–2104.

Schejtman, R., Devoto, F.C.H., Arias, N.H., 1967. The origin and distribution of the elements of the human mandibular retromolar canal. Arch. Oral Biol. 12, 1261–IN9. https://doi.org/10.1016/0003-9969(67)90127-6

Schumacher, G.H., 1961. Funktionelle Morphologie der Kaumuskulatur. Fischer, Jena.

Shimizu, M., Narboux-Nême, N., Gitton, Y., de Lombares, C., Fontaine, A., Alfama, G., Kitazawa, T., Kawamura, Y., Heude, E., Marshall, L., Higashiyama, H., Wada, Y., Kurihara, Y., Kurihara, H., Levi, G., 2018. Probing the origin of matching functional jaws: roles of Dlx5/6 in cranial neural crest cells. Sci. Rep. 8, 1–15. https://doi.org/10.1038/s41598-018-33207-2

Spyropoulos, M.N., 1977. The morphogenetic relationship of the temporal muscle to the coronoid process in human embryos and fetuses. Am. J. Anat. 150, 395–409. https://doi.org/10.1002/aja.1001500303

Terminologia Anatomica: International Anatomical Terminology, 1998. Thieme Medical Publishers, New York.

Velasco, J.R.M., Vázquez, J.F.R., Blanco, C.D. la C., López, R.C., Sánchez, M., Velasco, J.A.M., 2009. Development of the mandibular condylar cartilage in human specimens of 10–15 weeks' gestation. J. Anat. 214, 56–64. https://doi.org/10.1111/J.1469-7580.2008.01009.X

Waschke, J., Böckers, T.M., Paulsen, F. (Eds.), 2019. Sobotta Anatomy Textbook, 1st ed. Elsevier, Munich.

Williams, P.L. (Ed.), 1995. Gray`s Anatomy, 38th ed. Churchill Livingstone, New York.

Yoshikawa, Suzuki, 1969. The comparative anatomical study of the masseter of the mammal. Ann. Anat. 125, 363–387.

Yoshikawa, T., Suzuki, T., 1965. Masseter of the mammal (II). Okajimas Folia Anat. Jpn 40, 339–363.