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Functional morphology of the masticatory muscles of *Mus musculus* L.

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Abstract. The functional morphology of masticatory muscles of *Mus musculus* L. is described. The study suggests that the Mm. masseter and *pterygoideus internus* act as an adductor of the mandible. The Mm. temporalis works as retractor, *pterygoideus externus* acts as a protractor and digastricus works as an abductor of the mandible. Among the skull components, zygomatic arch is well formed while the temporal fossa is poorly developed. The influence of muscular pull on the skull components is discussed.

Keywords. Functional morphology; muscles; *Mus musculus*.

1. Introduction

The present paper deals with a bone-muscle complex of masticatory apparatus of the house mouse, *Mus musculus* L. and comprises a part of functional anatomical study of the feeding apparatus of rodents.

Numerous authors have made observations on jaw musculature of rodents. Parsons (1896) gave an account on the myology of the Sciuromorphine and Hystricomorphine rodents. Howell (1926) and Vendeloo (1953) described the anatomy of masticatory muscles in the wood-rat (*Neotoma*) and the musk-rat (*Ondatra zibethica*) respectively. Similar anatomical study was conducted on the Chinchilla (Wood and White 1950) and on the squirrel (Das 1955). Green (1955) described the cranial musculature of *Rattus norvegicus*. Agarwal (1962, 1965) gave the brief account of skull-muscle interrelation of cranial region of certain rodents. Dubale and Patel (1972) and Travadi (1972) studied the masticatory muscles of the squirrel (*Funambulus pennanti*) and Guinea pig (*Cavia porcellous*) respectively and correlated the form with their function. The gross anatomy and internal architecture of the jaw musculature in *Rattus norvegicus* has been studied using a combination of gross dissection, thick sectioning and histological techniques by Hiiemae and Houston (1971). The investigation of Weijs (1973) was to establish a morphological basis for study of the functional morphology of the masticatory apparatus in the albino rat (*Rattus norvegicus*). However, the functional anatomy of the feeding apparatus of *Mus musculus* L. has not been investigated so far.

2. Materials and methods

For the present investigation healthy adult species of *Mus musculus* L. were collected

from suburbs of Ahmedabad. They were kept on their natural diet. They were decapitated, keeping intact all the muscles of mastication. The actions of the muscles of such heads were studied in Ringer's solution for mammals. The muscles were stimulated with a 9-volts electrically operated energizer with bipolar electrodes (Weijs 1973; Patel 1977). Few of the heads were preserved in Goodman's fluid for study of their musculature. Skeletal preparation of the skull were made by careful removal of the attached muscles and bleaching the skull with hydrogen peroxide.

The disposition of the muscles and their innervations were studied under a stereo-binocular microscope. The enlarged photographs of the skull and muscles were used for base and detailed drawings.

Mm. masseter, temporalis, *pterygoideus externus*, *pterygoideus internus* and digastricus were studied in detail and their general actions were determined.

3. Results

3.1. *Skull components associated with the masticatory musculature*

The zygomatic arch forms the lateral border of the skull and encloses the orbit (figures 1 and 3). The anterior portion of the arch forms the plate which makes the external surface of the infraorbital foramen and canal. The jugal process is long and forms a large part of the arch. The arch is bent posteroventrally and remains almost parallel to that of the base of the upper toothrows. The glenoid fossa (figure 3) forms an anteroposterior slope. The temporal fossa is formed by the temporal bone (figure 1). The fossa slopes towards the orbit. The parietal bone extends laterally on the temporal bone. The squamosal part of the zygomatic arch extends posteriorly over the temporal bone as a ridge. The temporal fossa is small. The pterygoid fossa is situated ventrally between the last upper molar tooth and the tympanic bulla (figure 3). This fossa is divided unequally by a middle ridge. Due to the presence of this ridge, the fossa is shallow anteriorly and deep posteriorly. The paroccipital process is short and remains closely applied to the tympanic bulla (figures 1 and 3). The coronoid process is small (figure 2). Its tip remains higher than the level of the

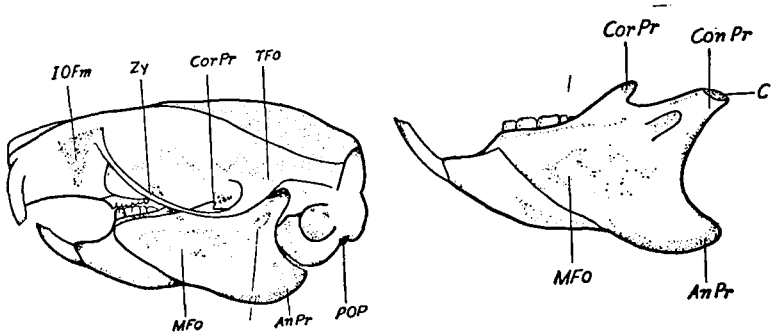

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Figure 1. Lateral view of the skull and the mandible showing skull components associated with the masticatory musculature.

Figure 2. Lateral view of the mandible showing various parts associated with the masticatory musculature.

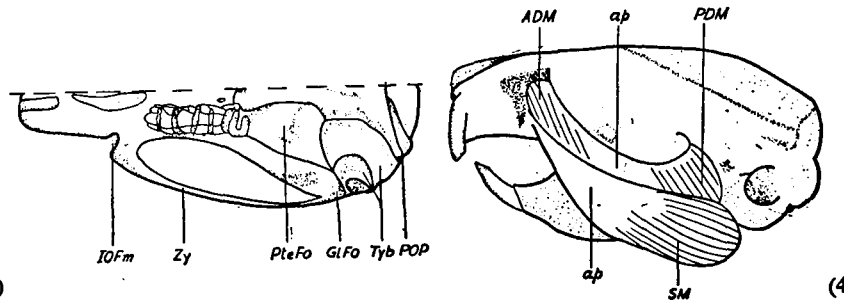


Figure 3. Skull in ventral view (half portion) showing various components of the skull associated with the masticatory musculature.
Figure 4. The M. masseter superficialis and the M. masseter deep.

condyle of the mandible. The condyle is almost pear shaped. The condylar process is moderately long (figure 2). The angular process is wide and well developed (figures 1 and 2). Its posteroventral surface is curved towards the midline. Its inner surface possesses a moderately deep groove. The masseteric fossa is deep anteriorly but shallow posteriorly (figures 1 and 2).

3.2. *Masticatory musculature*

3.2.1. *M. masseter*

It may be divided into superficial and deep masseter, the latter into anterior and posterior parts.

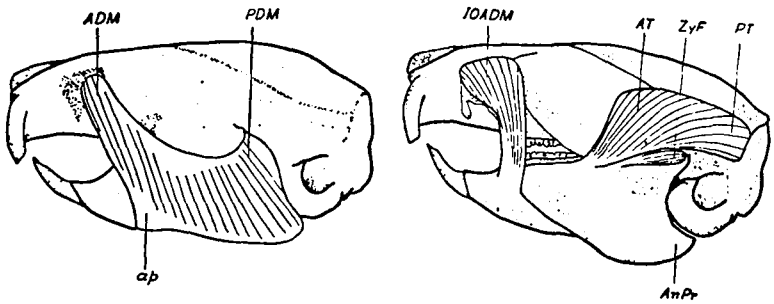
(a) *Superficial masseter* (figure 4): The muscle is situated on the lateral surface of the skull between maxilla and ramus of the mandible. It arises by a flattened tendon on the maxilla, ventrocaudally of the infraorbital fissure and in front of the maxillary part of the zygomatic arch. The tendon extends backward and spreads over the lateral surface of the muscle as an external aponeurosis, covering most of its lateral surface. The fibers run towards the ramus of the mandible and show a unipinnate type of arrangements. The muscle inserts directly on the ventral border of the mandible, and to the caudal tip of the angular process of the mandible.

The contraction of the muscle pulls the mandible forward and upward.

(b) *Deep masseter* (figure 5): This muscle spreads from the zygomatic arch to the ramus of the mandible. The muscle consists of two parts, an anterior and a posterior deep masseter.

Anterior deep masseter: The anterior part of the deep masseter is thick and is situated between proximal part of the zygomatic arch and the mandible. It originates from the infralateral surface of the jugal process of the zygomatic arch. The origin is musculous. An aponeurosis arises posteriorly, below the superior border of the arch. The muscle inserts into the anterolateral surface of the mandible and into the masseteric fossa. This insertion is partly aponeurotic and musculous.

Infraorbital part of the anterior deep masseter (figure 6): The muscle is situated between infraorbital fissure and the anterolateral part of the ramus of the mandioble. The muscle fibres arise directly from the root of the infraorbital foramen. The fibres form a distinct fleshy belly which passes posteriorly through the infraorbital foramen. The muscle turns downward toward the ramus of the mandible. It inserts into its



(5) (6)

Figure 5. The M. masseter deep after removal of the M. masseter superficialis.
Figure 6. The infraorbital part of anterior deep masseter muscle and the fasciculi of the M. temporalis.

tendon and extends to the lateral surface of the mandible above the anterior end of the masseteric ridge and deep to the aponeurotic tendon of anterior deep masseter.

The contraction of anterior deep masseter elevates the mandible forward.

Posterior deep masseter: It is large and extends from the zygomatic arch to the mandible. The muscle has a mixed origin. Some of the fibers arise directly from the bone and other by an internal aponeurosis, originating close from the lower border of the arch and covering the greater part of its length. All the fibres of the deep masseter pass medially as well as slightly posteriorly to spread in wide area of the lower lateral surface of the mandible. The muscle inserts partly aponeurotically and partly musculously into the ramus and angle of the mandible where many of the deeper fibres of the superficial measseter are attached. Thus the fibre arrangement is of a pinnate type.

The contraction of the muscle pulls the mandible upward.

3.2.2. *M. temporalis* (figure 6)

It consists of three fasciculi, viz. anterior, posterior and zygomaticus fasciculus. The muscle is covered by a temporal fascia.

(a) *Anterior fasciculus:* This part is separated from the posterior fasciculus by loose connective tissues. The fibres arise from the temporal ridge behind the orbit. The fibres converge to the orbit and inserts fleshily into the retromolar fossa of the mandible.

(b) *Posterior fasciculus:* This large fasciculus occupies the squamous temporal bone behind the orbit. It originates from the temporal bone posterior to the anterior fasciculus. The fibers extend to the orbit and insert onto the anterior border of the coronoid process by the aponeurosis.

(c) *Zygomaticus fasciculus:* It is a small fasciculus and lies below the squamosal part of the zygomatic arch. It arises from the root of the squamosal part of the zygomatic arch. It inserts musculously external to the ramus of the mandible, below the coronoid process.

The contraction of the anterior fasciculus elevates the mandible upward and backward while that of the posterior retracts it backward.

3.2.3. *M. pterygoideus* (figure 7)

The muscle comprises 2 parts, viz. *M. Pterygoideus externus* and *M. pterygoideus internus.*

(a) *M. pterygoideus externus:* It lies between the lateral surface of the skull and the inner surface of the mandible. It originates from the rostral border of the basis-

phenoid and the rostral half of the lateral surface of the outer pterygoid lamina. Its origin is mostly musculous and partly aponeurotically. The fibres run laterocaudally and slightly dorsally along otic region to the skull of the medial side of the condylar process. All the fibers converge to the condyle of the mandible. The fibers insert to the articular capsule which remains attached on the condyle of the mandible.

The contraction of the muscle pulls the condylar process forward from the glenoid fossa.

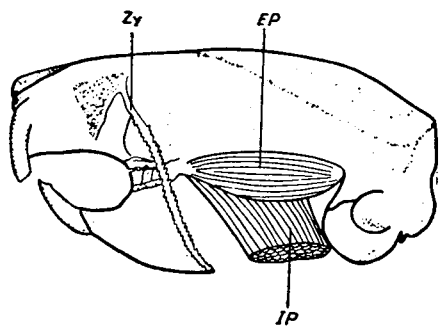
(b) *M. pterygoideus internus:* The muscle is situated between the pterygoid fossa and the inner surface of the angular process of the mandible. It arises partly aponeurotically and partly musculously from the pterygoid fossa and its lamina. The fibers run downward and inward to the angle of the mandible. The fibers insert mostly musculously and partly aponeurotically on the inner surface of the angular process of the mandible.

The contraction of the muscle pulls the mandible forward, upward and medially.

3.2.4. *M. digastricus* (figure 8)

It is a composite muscle situated between symphysis of the mandible and occipital bone. It consists of 2 bellies, an anterior and posterior belly. The posterior belly arises from the paroccipital process of the occipital bone. The origin is mostly fleshy and partly aponeurous. The belly passes forward and medially and forms a short tendon. Two tendons of the posterior bellies join to the aponeurous arcade. This aponeurous arcade attaches to the hyoid apparatus. The anterior bellies originate from the anterior convex margin of the aponeurous arcade and pass as flat and continuous mass of the muscle between the rami of the mandible. The bellies diverge anteriorly into 2 and arch inserts by a flat aponeurosis into the anterior and lateral margins of a shallow fossa on the lower border, a little behind the symphysis of the mandible.

The contraction of the muscle pulls the mandible downward and backward.



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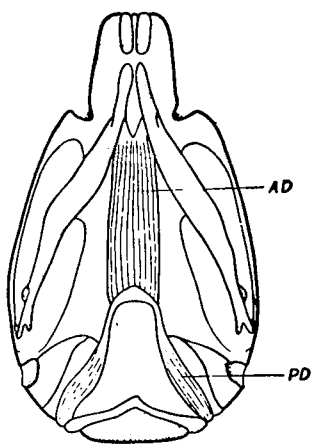

(8)

Figure 7. The external and internal parts of the *M. pterygoideus* after removal of the part of the mandible and part of the zygomatic arch.

Figure 8. The anterior and posterior parts of the M. digastricus.

4. Discussion

It is observed that the *M. masseter* is a relatively large component among the masticatory musculature (figures 4 and 5). Its fiber arrangement is of a pinnate type which provides a shorter but more powerful pull as reported by Grant (1942). During mastication a higher degree of complexity in pinnation helps the muscle to counteract the tensile force created by the food. The infraorbital part of the anterior deep masseter arises from the infraorbital foramen. This kind of arrangement helps to bring the incisors of the lower jaw in close contact with those of the upper jaw and as suggested by Hiiemae (1971b). 'The deep masseter muscles elevate the lower jaw against the resistance of the food during incision'. Agarwal (1962) says, '...Food has modified the dentition and the skull musculature and the latter, in turn, has affected the skull structure'. It seems that due to powerful adduction of the *M. masseter*, the related skull components such as zygomatic arch, infraorbital fissure and canal, masseteric ridge and angular process are well developed. It is further noteworthy that the zygomatic arch is bent posteroventrally and the posterior part of the deep masseter arises from the length of the arch. This may be due to high muscular pull. Slade (1895) has reported that the curvature and strength of the zygomatic arch depend on the energy of the masticatory muscles in mammals.

The Mm. *pterygoideus externus* and *internus* are moderately developed compared to the masseter series of muscles. The condylar process is long and the condyle is encircled by the articular capsule of the *M. pterygoideus externus*. This kind of arrangement of the muscle seems to assist the condyle in the gliding movement of the mandible in the glenoid fossa and prevents the condyle from dislocation during anteroposterior movement of the mandible.

The inward curvature of the angular process of the mandible is noteworthy. According to Hiiemae (1971b) the *M. pterygoideus internus* helps to stabilize the jaw against the tendency of the deep masseter to evert the lower border and the angle of the mandible.

Among the masticatory musculature, the *M. temporalis* is poorly developed. Its area of origin is small and the temporal fossa is least developed. Consequently, the coronoid process is less developed as compared to other processes of the mandible. Such development of the coronoid process was also observed in the squirrel by Dubale and Patel (1972). Further, Alexander (1968) mentioned that the *M. temporalis* is relatively of little use to herbivores and omnivores. However, the posterior fasciculus of the *M. temporalis* retracts the mandible and also nullify the effect of the downward force created by the food. The anterior fasciculus can also augment the action of the posterior fasciculus of the *M. temporalis* in retracting the mandible (Hiiemae 1971b).

The *M. digastricus* is the major abductor of the mandible which occupies most of the ventral surface of the rami of the mandible. Its aponeurous arcade attaches to the hyoid apparatus. Moreover, it inserts on the symphysis of the mandible and therefore as suggested by Miles (1972) it acts with a considerable mechanical advantage in lowering down of the mandible during muscular contraction. The *M. pterygoideus externus* by its protrusive force helps in this abduction of the mandible.

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Abbreviations used in figures

AD–anterior digastricus muscle; ADM–anterior deep masseter muscle; AnPr–angular process; ap–aponeurosis; AT–anterior temporal muscle; C–condyle; ConPr–condylar process; CorPr–coronoid process; EP–external pterygoideus muscle; GlFo–glenoid fossa; IOADM–infraorbital part of anterior deep masseter; IOFm–infraorbital foramen; IP–internal pterygoideus muscle; MFo–masseteric fossa; PD–posterior digastricus muscle; PDM–posterior deep masseter muscle; POP–paroccipital process; PT–posterior temporal muscle; PteFo–pterygoid fossa; SM–superficialis masseter muscle; TFo–temporal fossa; Tyb–tympanic bulla; Zy–zygomatic arch; ZYF–zygomatic fasciculus of the *M. temporalis.*