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Physical and anatomical characteristics of the masticatory muscles in camels (*Camelus dromedarius*)

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Abstract

The current study aims to understand the dynamics of the masticatory muscles during closure and opening actions and assess the functional architecture of the various chewing muscles in camels. Twelve healthy adult camel heads of different sexes and ages (2-3 years) from the typical slaughterhouses in Iraq and the Kingdom of Saudi Arabia. A comparative anatomical examination and masticatory muscle linear measurements were performed on the head of the slaughtered camel. These included the masseter, temporalis, pterygoideus, and digastricus muscles. This study included recording the values of each fiber length, weight of the muscle, the mass of muscle, volume of muscle, density, Physiological cross-sectional area (PCSA), force, maximum isometric force, torque, and kinetic energy of the masticatory muscles. According to this study, the masseter and temporalis muscles closed the camel's jaw, while the digastricus and pterygoideus muscles opened the mandible. This study showed that the group of muscles that closed the jaw had greater PCSA values, maximum isometric force, force, torque, and kinetic energy than those that opened the mandible. It is believed that jaw closure is regarded as the muscles' heightened activity that closes the jaw. This study proved that each muscle has its own physical characteristics that differ from others.

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Introduction

Purposeful macroscopy of mammalian chewing muscles is vital for chewing throughout food. It provides information about the health status of the animal (1-6). Understanding the mechanics of masticatory function requires a functional anatomical examination of camel muscles. Many studies have looked into the relationship between feeding habits and the morphology of the musculoskeletal system (7-10). Despite this, very little research has been done on the masticatory muscles (MMs) structure of camels, which generate the forces of bite. There is limited research on the physical features of camel MMs; however, PCSA of masseter muscles (MasM) was not quantified. They are essential for animal health and breeding success, which can explain their mechanism (11,12). Getty *et al.* (13) and Dyce *et al.* (14) provided detailed descriptions of the MMs of ruminants and horses, while Sasaki *et al.* (15) described the morphological anatomy of MMs in giraffes in detail. Added Greaves (16) Ungulates generally have huge masseter and pterygoideus muscles. Janis (17) found that the function of MMs was consistent with the natural diet of sheep and deer in the skull and mammals and the composition of masticatory devices in a variety of mammals (17-19). Currently, there is no extensive explanation of masticatory mechanics for camels. Patil and Bindra (20) recorded that the masticatory system acts as one unit and is completed by adding a digastricus muscle to the opening of the mandible (21).

The jaw opening and closing process is complex (22,23). The digastricus muscle is one of four MMs and exists as a pair (24,25). Lateral pterygoideus muscles make a unique contribution to control mandible movement. Superficial and deep parts of the muscle are defined as functional roles. The superficial portion contributes to mandible closing, while the deep portion of MasM contributes primarily to jaw opening (26). PCSA of MMs is reported in primates (27-29), rabbits (30), and pigs (31). quantification of muscle PCSA is serious in evaluating bite powers in animals, and additional buildup of information on masticatory muscle (MM) PCSA is required (32). Crompton (33) reported that the mandibular joints of all animals migrate into a vertical and horizontal phase during occlusion, as well as a horizontal phase. Still, Muscle number involves the level of activity associated with each phase, which varies considerably according to the type of feeding (34,35).

Thus, the present study is targeted to examine some physical characteristics of MMs, such as weight, length fibers, volume, PCSA of MMs, force, and maximum isometric force for the muscles, to understand their action strategy better. The current research aims to understand the dynamics of MMs during closure and opening actions and assess the functional architecture of the various chewing muscles in camels.

Materials and methods

Animal model

Twelve healthy adult camel heads of different sexes and aged between 2-3 years were obtained from the typical slaughterhouses in Iraq and the Kingdom of Saudi Arabia. They were cut up to get structural information on MMs, the masseter, the temporalis, the medial and lateral pterygoideus, and the digastricus muscles.

Experimental design

Muscles and their tendons at the points of origin and ins ertion were removed. All heads were dissected using standard tools. The morphology of MMs was studied by injecting 10% formalin into the external carotid arteries of five heads. The five camel heads were used to determine the physical characteristics of all MMs, and various measurements were also used to measure the duration spent by the jaw opening and closing muscles during the chewing mechanism.

The fibers were stately at 6 diverse positions of a specific muscle, with calipers (N20, Mitutoyo, Japan); the length of the fascicles and the angle of the pennation were recorded for each muscle as measured linearly (cm) (36). The volume of the muscles was calculated using the water displacement method. Masticatory Mass = Volume X Gravity (9.8g). Muscle density is calculated by the mass/volume (37). The weight of muscles was measured using a digital weighing scale (UX420H, Shimadzu Co., Japan). The physiological cross-sectional area (PCSA) refers to the area of a muscle's cross-section that is perpendicular to its fibers, typically at its widest point. This term is usually employed to refer to the contractile characteristics of pennate muscles. PCSA was calculated as follows: PSCA= (muscle mass*pinnation angle cos)/(muscle density*fiber length) (32,38). Masticatory forces were measured by (force = Gravity (g x 9.8) x Mass). The extreme isometric force-generating capability of the muscle is 2 x PCSA (39). Muscular torque (T)= F*d, where (F) is the force intensity and (d) is the distance between the line of influence and the perpendicular space from the force midpoint to the rotation axis.

The muscular Kinetic energy = KE = ½.M* v^2;
where m (muscle mass) and v (muscle speediness) = d*t m/s) (Based on the data of the physical properties of human muscles, especially muscle speed, it was considered the standard in this work. Where considerable muscle speed is concerned, the physical property that relates force and rate of shortening is power (which is force multiplied by velocity). Suppose you make a muscle contract at a force and speed that maximizes power. In that case, it only contracts with a force of about one-third of the maximum that it is capable of producing. The rotation angle of each MasM is numerically expressed by sin θ.

Abbreviations and units of measurement

PCSA: Physiological cross-sectional areas; cm^2, M: Mass of muscle, V: muscle velocity, Muscle mass, g, Volume, cm^3, Density, g/cm^3, F: Force, N, T: Torque, Nm Nm: Newton meter is a unit of torque. and K: Kinetic energy; J is ok. The unit of energy is joule. Finally, to facilitate interspecific comparisons. In the end, individual muscle mass and PCSA were split by the corresponding entire PCSA and total muscle mass.

Results

Camels have a completely functioning masticatory system composed of muscles, mandible bones, tendons, arteries, and nerves. MMs are identified through three different functions: opening, closing, or contracting, which elevate the mandible bone and bilateral muscles (medial and lateral). This study focused on the morphological and physical characteristics of the closed, opened, and unilateral direction mastication muscles. These consist of the masseter and temporalis muscles, which function to close the mandible; the pterygoideus muscles, which facilitate the closing and lateral motions of the mandible, and deviation to either side, whereas the digastricus muscle is in charge of lateral and medial motions. The muscles of mastication close the mandible (closing the jaw) and facilitate the chewing of the masseter and temporalis muscles. While muscles were opening the jaw, namely the digastricus and pterygoideus muscles.

Masseter muscle (MasM)

MasM is the main and largest MM, with a thick tendinous aponeurosis covering it and a rounded-cornered triangle with its apex facing the caudal direction. It occupies the majority of the lateral surface of the face (Figures 1 and 2A). It is composed of three layers: superficial, intermediate, and deep. MasM originates in the rostral part of the zygomatic arch. This muscle divides into three distinct, separate layers through two tendinous laminae, specifically the superficial, middle, and deep MasMs. Fibers of the superficial layer direct caudodorsally, in the superficial portion at an angle of around 30° degree to the parallel line, the middle layer has strings that direct vertically-ventrodorsally, while the fibers of the deep layer also direct vertically to create a tendon that inserts into the masseteric fossa and the vertical ramus to coronoid process of the mandibular bone. The direction of the superficial layer fibers pulls the mandible to close. Because of the alignment of these fibers, this portion is accountable for drawing the lower jaw down to open the oral cavity. The strands of the intermediate and deep layers of MasM are directed vertically, rendering them to the perpendicular line, and these parts are responsible for closing the mouth. The torque, measuring the turning force on muscle, was 28Nm (which is calculated by the formula mentioned in the methods, which is T= F.d) because of the fiber's orientation, which enhances the movement's torque through locking the mandible. KE activates MasM of the oral cavity, whether in a vertical or horizontal direction, approximately 1.05 Joule, which reflects the effort required to shift muscle mass from a resting position to a restricted expanse to the new location. The similar KE utilized for effort is employed through the muscle to revert from its altered location to a resting formal.

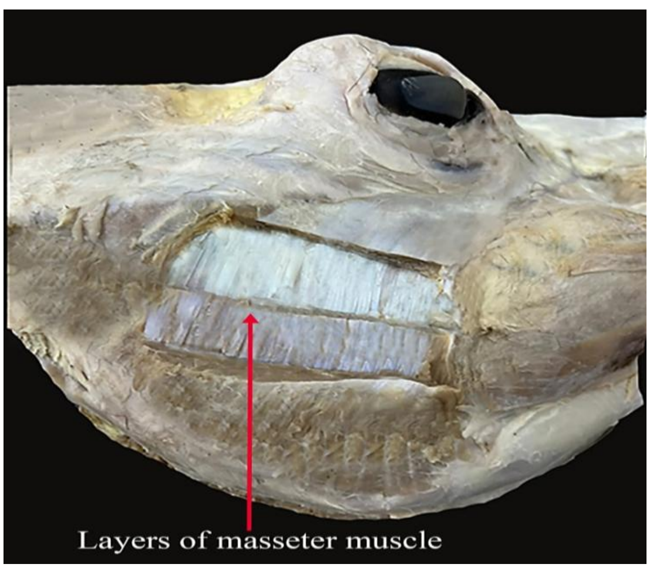

Figure 1: Macrophotography of the camel head (lateral view) shows the position and the shape of MasM.

Temporalis muscle (TM)

It is situated in the temporal fossa of the temporal bone, fan-shaped, smaller, thinner, and spherical compared to MasM. The temporalis muscle ranked as the second largest in terms of mass among all muscles. It begins at the temporal fossa and the medial aspect of the zygomatic arch, inserting into the coronoid process of the mandible. The rostral fibers are oriented in a rostrocaudal manner (from front to back (in the head region)). These fibers function to open the lower jaw, while the caudal fibers of TM are directed caudoventrally to close the mandible (Figure 2). They are in authority to raise the mandible to lock the oral cavity and push it caudally. The estimated torque is roughly 8.64 Nm because of the direction used to increase the torque of the movement by locking the lower jaw together. The KE of TM, which is responsible for its movement in either a vertical or horizontal direction, is approximately 0.79 Joule. The muscle exerts the same KE during the process of transitioning from the open position to the closed position of the lower jaw. The primary role of the temporalis muscle is to raise (close) the lower jaw via the perpendicular motion of the mandible.

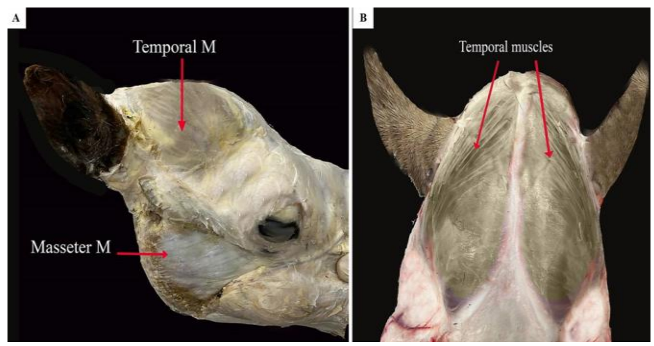

Figure 2: Macrophotography of the camel head (A: lateral view & B: dorsal view) shows the position and the shape of MM and TM.

Pterygoideus muscle (PM)

is located on the medial surface of the perpendicular rami of the mandible. The pterygoideus muscle arises on the medial aspect of the pterygoid bone, whose fibers are directed ventrodorsally to act opening and closing of the mandible. It is inserted into the pterygoid fossa located medially on the ramus of the mandible and the condylar process of the mandible (Figure 3). The torque was 30.72 Nm, while the KE of medial and lateral pterygoideus muscles was 0.90, allowing them to move in both vertical and horizontal directions. It explains how much energy a muscle needs to get from an opening to a shutting motion. The muscle uses the same amount of KE for movement, closing, and opening of the mandible. The chief role of this muscle is to close and raise the jaw. The PCSA of the pterygoideus muscle of 4 (cm^2) was higher than that of all MMs in spite of their relative dominance in mass values.

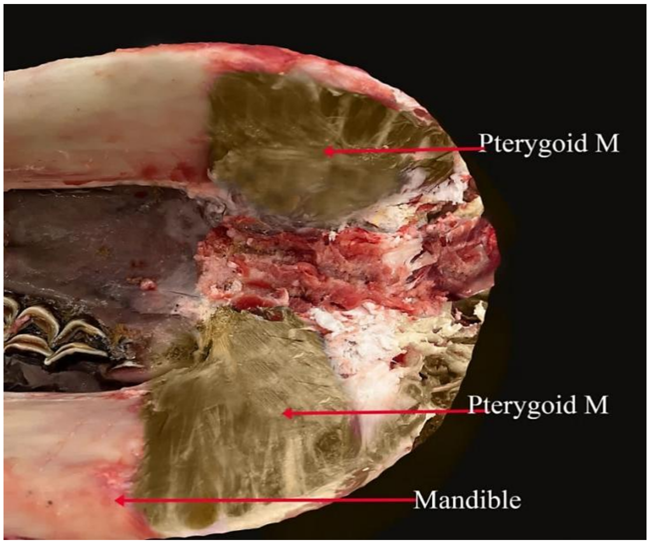

Figure 3: Macrophotography of the camel head (medial view) shows the position and the shape of the pterygoideus muscle.

Digastricus muscle (DM)

It takes up a large portion of the medial surface of the lower jaw behind the ramus of the mandible. The digastricus muscle comprises two muscle bellies connected by an intermediate tendon. The rostral belly is a fusiform bundle flattened, twice as long; it arises from a depression on the medial side of the lower edge of the mandible; it extends downward and backward to join the caudal belly in a middle tendon, while the caudal belly is shorter than the rostral belly, arises from digastricus fossa close to the midline of the mandible (Figure 4).

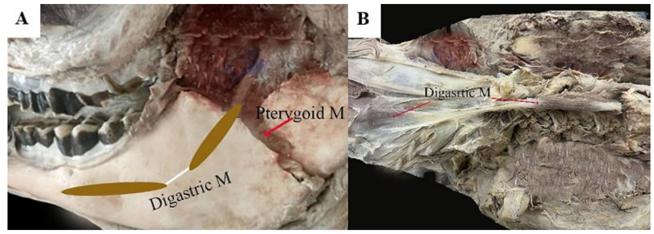

Figure 4: Macrophotography of the camel head (medial view) shows the position and the shape of the digastricus muscle.

KE of digastricus muscle is necessary for the body of muscle from the closed to the open state. The rated torque is approximately 12.38 Nm because the orientation of the fibers enhances the torque generated by the action of locking the mandible. The calculated KE related to the movement of the digastricus muscle in the mouth, whether moving vertically or horizontally, is 0.52 Joule, necessary for shifting the muscle mass from locking to opening the mandible. DM functions in jaw opening by depressing the mandible (Tables 1-3 and Figures 5-13).

Table 1: Results of measuring the physical properties of MMs, including weight (Average±S.D), volume (Average±S.D), weight %, and volume% of all muscles, are summarized

Muscle	Weight (g)	Weight %	Volume (cm^3)	Volume %
Masseter	75±5.7	37	60±7.5	34
Temporalis	55±6.7	27	45±9.1	25
Pterygoideus	44±5.8	21	40±8.8	22
Digastricus	26±5.2	13	30±8.8	17
Total	200		175	

Table 2: Results of measuring the physical functional properties of MMs, including fiber length, muscle weight, the mass of muscle, volume of muscle, density of muscle, PCSA, force, maximum isometric force, torque, and KE are presented (Average±S.D)

Measurement	Masseter M	Temporalis M	Pterygoideus M	Digastricus M
Fiber length (cm)	12±1.9	14±1.9	10±1.9	12±2.3
Weight (g)	75±5.7	55±6.7	44±5.8	26±5.2
Muscle mass (g)	588±46.3	440±57.9	392±69.9	294±43.9
Volume (cm3)	60±7.5	45±9.1	40±8.8	30±8.8
Density (cm^3)	9.8±1.9	9.8±1.9	9.8±1.9	9.8±1.9
PCSA (cm^2)	2.5±0.2	3.2±0.4	4±0.5	2.1±0.1
Force (N)	5.76±0.7	4.32±0.5	3.84±0.5	2.88±0.3
Maximum isometric force (Ncm^2)	5±0.8	6.4±0.75	8±1	4.2±0.6
Torque (N. m)	28.8±3.8	8.64±1	30.72±4	12.38±2.4
KE (J)	1.05±0.2	±0.790.1	±0.700.1	±0.520.05

Table 3: Measuring results of physical functional characteristics of closed and opened mastication groups included mass of muscle (g), volume of muscle (cm3), density of muscle (cm³), PCSA (cm²), force (N), maximum isometric force of muscle (Ncm²), torque of muscle (Ncm2) and KE (J) (the average)

Muscle	Muscles mass	Volume	Density	PCSA	Force	MIF	Torque	KE
Masseter	588±46.3	60±7.5	9.8±1.9	2.5±0.2	5.76±0.7	5±0.8	28.8±3.8	1.05±0.2
Percentage	57.19%	57.14%	50%	43.85%	57.14%	48.07%	76.92%	57.06%
Temporalis	440±57.9	45±9.1	9.8±1.9	3.2±0.4	4.32±0.5	6.4±0.75	8.64±1	0.79±0.1
Percentage	42.81%	42.86%	50%	56.15%	42.86%	51.93%	23.07%	42.93%
Closed	1028	105	19.6	5.7	10.08	10.4	37.44	1.84
Percentage	100%	100%	100%	100%	100%	100%	100%	100%
Pterygoideus	392±69.9	40±8.8	9.8±1.9	4±0.5	3.84±0.5	8±1	30.72±4	0.70±0.1
Percentage	57.22%	57.14%	50%	65.57%	57.14%	65.57%	71.27%	57.37%
Digastricus	294±43.9	30±8.8	9.8±1.9	2.1±0.1	2.88±0.3	4.2±0.6	12.38±2.4	0.52±0.05
Percentage	42.78%	42.86%	50%	34.43%	42.86%	34.43%	28.72%	42.63%
Opened	686	70	19.6	6.1	6.72	12.2	43.1	1.22
Total	100%	100%	100%	100%	100%	100%	100%	100%

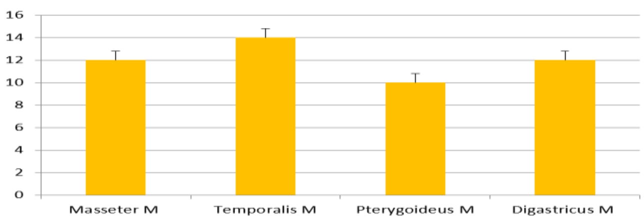

Figure 5: Diagram illustrating the average fiber length of the MM.

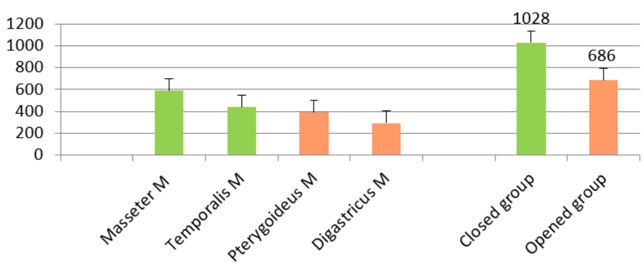

Figure 6: Diagram illustrating the average mass of chewing muscles and a comparison between the mass of two groups of chewing muscles.

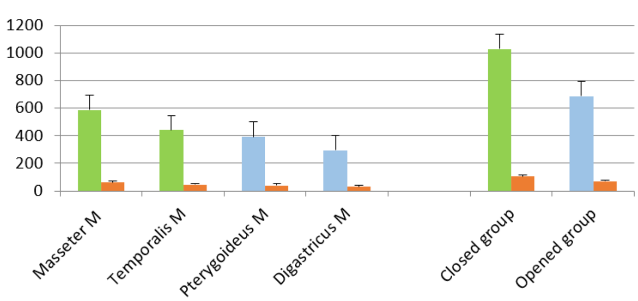

Figure 7: Diagram illustrating the average mass and volume of chewing muscles and comparison between the mass and volume of two groups of MMs.

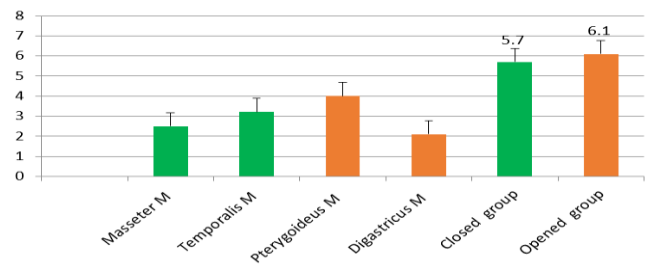

Figure 8: Diagram illustrating the average PSCA of MMs and a comparison between the closed and opening muscles.

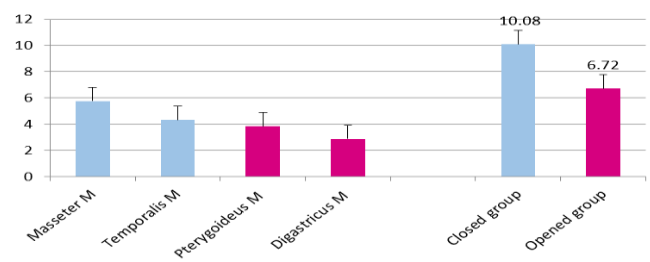

Figure 9: Diagram illustrating the average force of MMs and a comparison between the closed and opened muscles group.

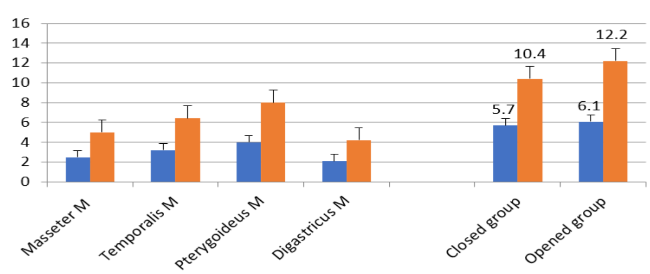

Figure 10: Diagram illustrating the average of PSCA and maximum isometric force and a comparison between the closed and opened group muscles.

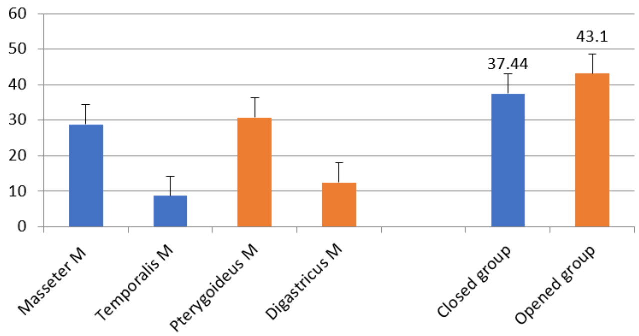

Figure 11: Diagram illustrating the average torque of the chowing muscles and a comparison between closed and opened muscle groups.

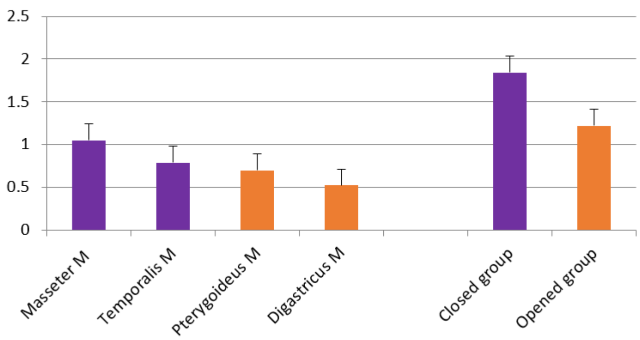

Figure 12: Diagram illustrating the average of KE and comparison between the closed and opened group muscles.

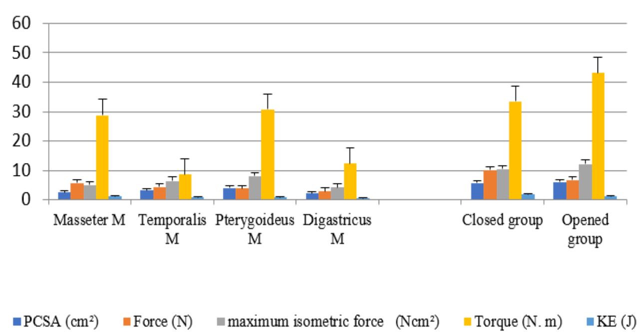

Figure 13: Diagram illustrating the average of the measuring results of the physical functional characteristics of each muscle and the closed and opened masticatory groups.

Discussion

The main and accessory muscles used for chewing operate together in a synchronized manner to create movement of the mandible. The primary muscles in chewing are the masseter, temporalis, pterygoideus, and digastricus muscles, while muscles involved in the chewing process are the buccinator, mylohyoid, geniohyoid, sternohyoid, sternothyroid, thyrohyoid and omohyoid muscle. This study showed that the camel possesses an integrated and masticatory system composed of a group of muscles. This was obvious through studying and comparing the physical characteristics of MMs, which agrees with records in ruminants that have a more prominent mastication apparatus, and added MMs of ruminant species with higher grass intake are comparatively larger than others (40). The large MasM was enclosed by a dense and concentrated tendinous apone urosis. It is bigger than TM. However, the camel has a sizable temporalis muscle. The present findings were similar to those of Parker (41). However, a recent study showed that MasM is composed of three layers: superficial, middle, and deep. The current results concur with those in camel (42), cattle (43), sheep (44,45), horses (46), and carnivores (16,47); this is an adaptation for better control of the jaw joint and a decrease in forces at the mandibular joint. However, a recent study showed that MasM is composed of three layers: superficial, middle, and deep. In contrast, it consists of two laminae, superficial and deep, in cattle (43) and camels (42).

Digastricus muscle is made up of two muscle bellies connected by a small intermediate tendon; this finding agrees with Kim *et al.* (24) and Kim *et al.* (25), Getty (13) in domestic animals, in camel (42), in cattle (43), in sheep (44-45), and in horses (46). On the other hand, the digastricus muscle exhibits considerable anatomic variation (48-50). The dorsal belly of the digastricus muscle is the only one with fibers oriented horizontally (51). On the other hand, the muscle can move mediolaterally and superior forlornly (52). It found the variations of digastricus muscle in a variety of types, including bilaterally or unilaterally multiple-headed bundles (53,54).

According to the current study, the superficial fibers of MasM were directed dorsocaudally, whereas the intermediate and deep laminae of the masseter were oriented vertically as ventrodorsal. Rostro-caudally fiber direction of the temporal muscle, caudorostrally of digastricus muscle, and ventrodorsally of pterygoideus muscles. These findings were consistent with those of Gorniak (19), who observed that muscles with fibers oriented markedly in anteroposterior directions produce horizontal motions, while muscles with fibers distributed more or less vertically produce vertical motions. The current results were similar in cattle, where the muscle fibers in a cow have two different orientations: a superficial layer with nearly parallel muscle fibers and a deep layer with caudo-ventral fiber orientation (43), as well as horses (46). The presence of different directions of muscle fibers in the different MMs means that the direction of the fibers is responsible for the movement of the muscle, whether it is horizontal, vertical, or inclined to perform a rotational movement. The present study showed that the orientation of the fibers of the temporal muscle is mostly horizontal in camels; the results are similar in llamas, which resemble herbivores like equids. The masseter superficial and pterygoideus have acquired a mostly horizontal orientation. Pterygoideus muscles consist of multiple bundles, and their size is moderate (55). Functional consistency was seen in the relative mass of closed and opened muscle groups. The current work found the total mass of MasM 588g amounts to almost a third of the values for MMs 1120g.

The mass and volume of the muscles responsible for the closing process were greater compared to 1028g to the muscles responsible for the opening process 686g. They were similar to mammals (17,47). Also, current results exhibited disagreement in the camel to white-tailed deer (masseter 57% in camel while 46.1% in deer, temporalis was 42% in camel and 29.3% in deer). This is consistent with Janis (17), who found that the role of the MMs relates to resemblances between the outline of the skull and the natural diet. Axmacher and Hofmann (56) in ruminants recorded that masseter weight is significantly associated with body weight regardless of body size and feeding type. The Pterygoideus muscle acts as the only muscle of mastication that enables the mandible to open. It also helps with the lateral movement of the lower jaw (57,58). While the role of the cranial and intermediate fibers of the temporal muscle closed the mandible. The posterior fibers of the TM serve opened the lower jaw (26).

Our findings indicated that the camels closed and opened MM group had a PCSA. Represented the closed group by 5.7cm² included 43.85% MasM, and 56.15% cm² of the temporal muscle, whereas; represented by 6.1 of the opened group included 34.43% digastricus and 65.57% of the pterygoideus muscles. Measuring the PCSA of muscles is essential for estimating bite forces. PCSA usually correlates with and governs the highest force-producing capability. The present findings agree with those of Santana *et al.* (38), Van Eijden *et al.* (57), and Watson *et al.* (59), who found a proportionality between muscle force and physiological cross-sectional area differences in muscle mass and the types of animals compared in the study can be the type to explain the discrepancies in PCSA measurements (60).

The present work found that the muscles that had relatively short fascicles had high PCSA values, while the muscles that had relatively long fascicles had low PCSA values. The fascicle length of the temporal muscle was comparatively longer at 14 cm. leading to their diminished PCSA ratio of 3.2 cm². On the contrary, the pterygoideus muscle had a shorter fascicle length, measuring 10 cm. leading to an increased PCSA ratio (4cm²). These long fibers express relatively lengthy fascicles and are made for force mastication. This indicates that chewing power is affected by the existence of lengthy fiber bundles and low PCSA value. They were shown to have short fascicle lengths and relatively high PCSA values, allowing them to produce significant forces. The reasons are that, firstly, the angle changes over time while the jaw moves, meaning a stationary muscle may not accurately represent the actual angle. Secondly, the removed muscles no longer retained their place, which limits the accuracy of the estimation of the 3D writing angle; these results agree with those of Furuuchi *et al.* (32). Till now, only ungulates have had their MM PCSA reported (31).

PCSAs of MasM were noted to be 26.6 cm^2 for a female wild boar. Herring (31) maintained that the masseter and temporal muscles, along with the zygomatic-mandibular muscle) constituted 40 percent and 43 percent of the overall MM mass, respectively. The muscle mass in giraffes was comparable to that of pigs. Instead, giraffes exhibit a greater PCSA ratio of 42.09 to 48.19 percent for MasM in contrast to pigs, which have a reported ratio of 29-37% (31).

In contrast, giraffes and pigs exhibit greater PCSA ratios of PM than all additional stated creatures, considering that PM is crucial for generating the lateral aspect of mandible movement in ungulates (61). PM in the giraffe indicates that the lateral vector section is predominant throughout its mandible movements. The rabbits, being very herbivorous animals, exhibit a PCSA ratio of PM similar to that of pigs and giraffes; nevertheless, they are unique in having a high MasM PSCA ratio as well. MasM is recognized for being significantly activated during incisor biting (62). Our study found that the force of MasM (5.76 N) was stronger than the temporalis muscle 4.3N based on all the indicators we received from the anatomical characteristics and physical characteristics. The force of the pterygoideus muscle 4N was an important characteristic of the camel masticatory apparatus. The findings in this research agree with the earlier study on napes and carnivores referenced by Dvorak (63).

This force was required to close and open the mouth caused by MasM's large mass. This force was generated by the mass; the muscle's extension facilitates the mandible's medial and vertical movement. This clarifies why gravity requires more force to cause a close where the force of the closure was three times that of the opening, and the force of the opening was one-third of the force of the closure; this is in line with Watson *et al.* (59).

The current research revealed that the maximum isometric force was 5 Ncm² of the masseter, 6.4 Ncm² of the temporal, 4.2 Ncm² of the digastricus, and 8 Ncm² of the pterygoideus muscles. Because of the muscle mass, it had the greatest impact on the closed force and the highest force within MasM. Watson *et al.* (59) stated that rabbits exhibit the greatest extreme force among all MMs, 60.9 N, and the muscles show considerable variation in their direction because of their pennate construction.

The present work finding in camel, the torque of MMs was 37.44 Nm of closed muscle including 28.8 of the masseter and 8.64 Nm temporal muscles, while it was 43.1Nm of opened represented by 30.72 Nm of pterygoideus and 12.38 Nm of digastricus muscles because of the orientation, which rotates the mandible to increase the torque of the action. This study found that the pterygoid muscle exerted the greatest torque from the opened muscle group, while the temporal muscle exerted the least torque and effort from the closed muscle group. This explains that the muscles in the closed group are more firmly linked to the bone because the masseter and temporal muscles contract more when compared to the pterygoids and digastricus muscles. The torque values of the locked muscles set are lesser than the torque values of the opened muscles set. This study found that torque values decreased along with the region of muscle attachment to the bones. The definition of torque is a dimension of the rotating force on muscle and is a turning force acting as an axial force to push or pull. These findings concur with those of Serway *et al.* (64). Asymmetric muscle usage creates torques on the skull when combined with occlusal stresses. However, other biomechanical forces, like joint torques, are produced during mastication (64-66).

Regarding KE, the closed muscles group had roughly 1.84 Joules. Meanwhile, the KE was 1.22 Joules of pterygoid and gastric muscles. Due to the masseter's increased size and activity in comparison to the temporal muscle, the KE value in the closed muscle group was 1.84 J larger than the opened muscle group 1.22 J. In contrast, the digastricus muscle, which represents the opening muscle group, had the lowest KE of 0.52 Joules of all muscles. Because more KE was required by gravity to complete the closing operation, the KE values of the closed group were approximately double that of the opening group. To change from one condition to another, these muscles require KE. These findings were consistent with the research of Sasaki and Neptune (67), who reported that KE can be conserved as elastic energy in tendinous structures and flexible connective tissue and then released at a later time to perform positive work. The measurement of that part of the lower jaw extending from the jaw joint to the farthest back tooth is notably shorter when the masseter and pterygoid muscles are predominant; this area must be considerably longer when the temporal muscle is substantial (16).

Conclusion

This study discusses the general anatomic features of the mastication muscles and their variation and primary functions. The current study provided the basic anatomic features and physical characteristics of the masticatory muscles that have been comprehensively studied regarding their function and physical characteristics, such as where they are located superficially and deeply. Finally, this study clarified the reason behind the functional variations that govern the mandibular muscles' opening and shutting. The arrangement and direction of the fibers affect a muscle's ability to contract and exert force. It clarified these discrepancies by illustrating the physical traits, including variations in the mandibular movement pattern and PCSA, torque, KE, and maximum isometric force. This study investigated the physical characteristics of closing and opening mouth movements to better understand the functional anatomy of the chewing muscles.

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Conflicts of interest

The authors declare no conflict of interest.

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الخصائص الفيزيائية والتشريحية لعضلات المضغ في الإبل وحيد السنام

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الخلاصة

تهدف الدراسة الحالية إلى فهم ديناميكية عضلات المضغ أثناء حركات الغلق والفتح وتقييم البنية الوظيفية لعضلات المضغ المختلفة في الإبل. تم الحصول على اثني عشر جملًا بالغًا سليمًا من كلا الجنسين وأعمارهم (٢-٣ سنوات) من المسالخ النموذجية في العراق والمملكة العربية السعودية. تم إجراء فحص تشريحي إجمالي مقارن وقياسات خطية لعضلات المضغ على رأس الجمل المذبوح. وشملت هذه العضلات المضغية والصدغية والجناحية والثنائية البطن. تضمنت هذه الدراسة تسجيل قيم طول كل ألياف ووزن العضلة وكتلة العضلات والحجم والكثافة ومساحة المقطع العرضي الفسيولوجي والقوة وأقصى قوة متساوية القياس وعزم الدوران والطاقة الحركية لعضلات المضغ. وفقًا لهذه الدراسة، كانت العضلات المضغية والصدغية تغلق فك الجمل، بينما كانت العضلات الجناحية والثنائية البطن تفتح الفك السفلي. أظهرت هذه الدراسة أن مجموعة العضلات التي تغلق الفك كانت لها قيم مساحة المقطع العرضي الفسيولوجي متساوية القياس، والقوة القصوى وعزم الدوران والطاقة الحركية أعلى من تلك التي تفتح الفك. ويعتقد أن هذا يرجع إلى زيادة نشاط العضلات التي تغلق الفك. أثبتت هذه الدراسة أن كل عضلة لها خصائصها الفيزيائية التي تختلف عن غيرها.