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A Comparative Study of the Physical Characteristics of the Masticatory Muscles in Sheep

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Abstract

The aim of this study is to know the normal movement of the masticatory muscle in sheep. Through estimated values of the physical characteristics of the masticatory muscles. Fifteen heads of sheep (Mean ± SD age: 18 ± 4 month) of both sexes were comprised in this work. Linear measurements of the three types of masticatory muscles were conducted on slaughtered sheep heads. The Physiological Cross- Sectional Area (PCSA), maximal isometric force, torque and kinetic energy were calculated. The Physiological Cross- Sectional Area (PCSA) was 5.08, 3.1 and 6 cm^2 for the closed, opening and unilateral groups respectively. The maximal isometric force for those muscles was 10.2, 6.2 and 12 cm^2, respectively. The force of those groups was 5.8, 1.96 and 1.96 N, respectively. The torque of those muscles was 0,588, 0.196 and 5.92 Nm, respectively. While the kinetic energy of the jaw-closed group was 90 Joule, that of the jaw-opening group was 30 Joule while the kinetic energy of the jaw-unilateral group was 40 Joule. This study was done via comparison of the physical characterizes values such as PCSA, force, maximum isometric force, torque and kinetic energy between three different groups of the closed ,opening and unilateral groups. This is suggested to be due to the increased activity of the jaw-masticatory muscles.

Introduction

Study movement of the masticatory muscles in sheep is very important to understand the mastication mechanism during eating. Little information about the physical properties of the masticatory muscles was avoided that explain masticatory mechanism in sheep.

The anatomy of the masticatory muscles was formerly studied in domestic animals in details. Moreover the function of the masticatory muscles correlates with resemblance generally skull shape and food natural indeers [1]. However, no detailed description was available about comparative physical characteristics of the closed, opening and unilateral movement of the masticatory muscles in sheep.

The oro-facial system including stomatognathic system, maxilla-mandibular apparatus and masticatory system was a functional unit. Weijs et al., [2] the masticatory system was completed by including a jaw opener digastric muscle using the origin and insertion sites. The involvement actions of masticatory muscles in a variety of mammals in which feeding behavior and the configuration of the masticatory apparatus were different reported by Gans [3]. The mechanism of jaw opening and closed is complex [4,5]. The mechanical advantage of the superficial layer of the masseter muscle was promoted by elevation of the jaw joint and expansion of the mandibular angle [6].The cross-sectional areas of the medial pterygoid muscles in subjects wearing over dentures supported by a small number of teeth.

On the other hand, Widmer recorded that there were biomechanical forces generate during mastication, such as joint torques. The rotation process is enlarged and the site of origin of the masseter at least, often extends far out onto the face. Because the masseter attaches to one side of the lower jaw and the pterygoid to the other Greaves, the author added large rotation processes in ungulates imply pterygoid muscles, they are rotate directed and thus produce force for all the jaw muscles taken together. The present work aimed to investigate the function anatomy of the different masticatory muscles in sheep. In comparative manner could be considered as supporting.

Materials and Methods

Materials

Fifteen heads of sheep of both sexes and different ages (12-24 months) collected from Buraidah slaughter house, Qassim Region, KSA were used in this study. Ten heads were dissected using standard instruments to investigate the anatomical features including weight and measurements of masticatory muscles. In addition, five heads of a live sheep were used for taking the time expended by the jaw opening and jaw closed muscle during mastication mechanism.

Table 1: The mass of an individual muscle is compared as a proportion of the total masticatory muscles mass and volume. The ratio of groups muscles functionally of the total masticatory muscles mass.

	Muscle	Weight/g	Ratio Wight	Volume		weight	Volume
1-	Masseter muscle	50	83%	31%	Closed	60%	43%
2-	Temporal muscle	10	17%	12%			
3-	Digastric muscle	20	100%	31%	Opening	20%	31%
4-	Lateral Pterygoid muscle	10	50%	12%	unilateral	20%	24%
5-	Medial Pterygoid. Muscle	10	50%	12%			
	Total	100%		100%			

Table 2: The measurement of the physical characterizes of the masticatory muscle.

Muscles	Fiber Length cm	Mass g	Volume cm²	Density cm³	
Masseter muscle	10	50	10	1.61	2.44
Temporal muscle	6	10	4	0.83	
Digastric muscle	20	20	10	0.64	0.64
Lateral Pterygoid muscle	4	10	4	0.83	1.66
Medial Pterygoid muscle	4	10	4	0.83	

Methods

An incision was made in the masticatory muscles along its length bell to reveal the muscle fibers. Linear measurements (cm) concerning the muscles longitudinal axis were taken. The muscle volume was determined using water displacement technique.

Notes:

Density = D = Mass/Volume

Physiological cross-sectional area = PCSA = (Mass/density) / fiber length

Maximum isometric force generation capacity = 2×PCSA

Force (F) = Mass ×Gravity

Torque (T) = F.d = F.r.sin θ

Kinetic energy (K.E) = 1/2 .m.v²

Where: (M) mass of muscle, (V) volume of muscle, (F) Force, (G) Gravity=(g×9.8), (T) Torque, (r) the vertical distance of the center of force for the axis of rotation, (Sin θ) a numerical value for the rotation angle of each masticatory muscle, (v) speed of muscle.

The muscle weight was estimated (g), volume (cm³), density (g/cm³), force (N), PCSA (cm³), the torque (Nm), the kinetic energy (Joule).

Results

The masticatory system in the sheep is including three groups: the closed, the opening and the unilateral. They move the mandible is upward, downward and laterally. In this study, we focus on the comparative of the physical characteristics of mastication muscles as groups in sheep. These groups have different volume, fibers direction, physiological cross section area, force, torque and kinetic energy. The masticatory muscles were divided into three groups: the closed, the opening, and the unilateral (medially and laterally) (Tables 1-3).

The closed group

It forms the biggest group, it occupies most of the lateral surface of the cheeks and the dorso-caudal surface of the skull, it includes two muscles which are masseter and temporal. The closed group representing about 60% of weight of masticatory muscle mass, and presents about 43% of the total volume of masticatory muscles in sheep. The closed muscles mass weight is about 60 g. The average length of the closed muscles mass is 12±2, 6±10 cm cranio-caudally. Length of closed muscle fiber is about 8±2, 6±4 cm of both muscles

Table 3: The calculation of the physical characterizes of the masticatory muscle. PCSA, force, Maximum force, torque and kinetic energy.

Muscles	PCSA cm²		Force N		Maximum isometric force cm²		Torque Nm		kinetic energy	
	*	**	*	**	*	**	*	**	*	**
Masseter muscle	3.08	5.08	4.9	5.8	6.16	10.16	0,49	0.588	75	90
Temporal muscle	2		0.98		4		0,098		15	
	*	***	*	***	*	***	*	***	*	***
Digastric muscle	1.5	1.5	1.96	1.96	3	3	0,196	0,196	30	30
	*	****	*	****	*	****	*	****	*	****
Lateral Pterygoid muscle	3	6	0.98	1.96	6	12	2,96	5.92	20	40
Medial Pterygoid muscle	3		0.98		6		2,96		20	

*: individually, **: Closed group, ***: Opening group, ****: Unilateral group.

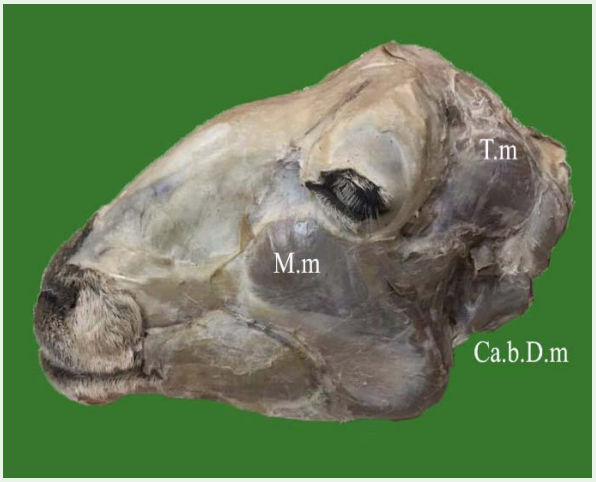

Figure 1: A photograph showing the masticatory muscles. Opening and closed muscles group. Masseter m (M.m),Temporal m (T.m) and caudal belly of digastric muscle (Ca.b.D.m).

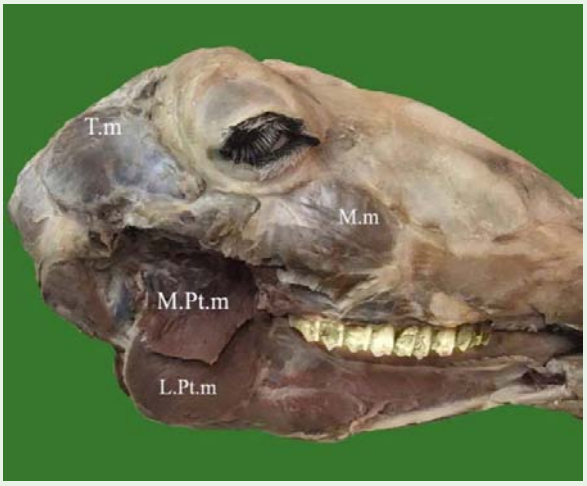

Figure 3: A photograph showing the masticatory muscles, unilateral group position on the head without mandible of Medial Pterygoid muscle (M.Pt.m), Medial Pterygoid muscle (M.Pt.m), Masseter m (M.m), Temporal m (T.m).

which are oriented in different direction either cranioventrally or horizontally to the horizontal line according to the muscle or layer of the masseter muscle. Because of this cranioventral or ventral orientation, it contributes to elevate the mandible and retracts the mandible posteriorly (Figures 1-4).

The physical characteristics of the closed muscle indicate the volume of the closed muscles group was 14 cm^3, density of these group is 2.45 g/ cm^3. Moreover, the Physiological Cross-Sectional Area (PCSA) is the area of the cross section of the closed group perpendicular to its fibers. It is typically used to describe the contraction properties of pennate muscles: (PCSA) = (mass/density)/ fiber length. PCSA [{(50/1.61) /10 = 3.1}, {(10/0.83)/ 6= 2.08)}]=5cm^2. Furthermore, the maximum isometric force generation capacity of muscle is representing PCSA. 5 x 2= 10 Ncm^2.

Regarding the estimated force that of the closed muscles group, it is 5.8 N. The torque is the measurement of the turning force on muscle. The torque is estimated about 0.588Nm due to the fibers direction which increases the torque of the movement by closing the lower jaw. The kinetic energy move the closed muscles group of the mouth either it is vertically or horizontally, is about 90 Joule. It depends on the movement speed of the muscle. It represents the work needed to moves muscle mass from rest state to limited distance to the new position.

The same used kinetic energy of work is done by the muscle to return from its new position to a rest state. The closed movements confirmed are produced by action of the masseter and temporal muscles. The main function of the closed muscles group is to stabilize the tempo-mandibular joint elevating the mandible and aides in the simple rotating movement.

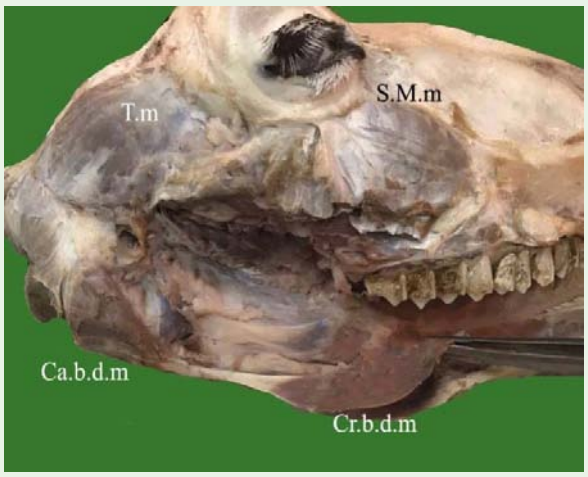

Figure 2: A photograph showing bellies od digastric muscle. cranial belly of digastric muscle (Cr.b.d.m), caudal belly of digastric muscle (Ca.b.d.m). Superficial masseter layer (S.m.m),Temporal m (T.m).

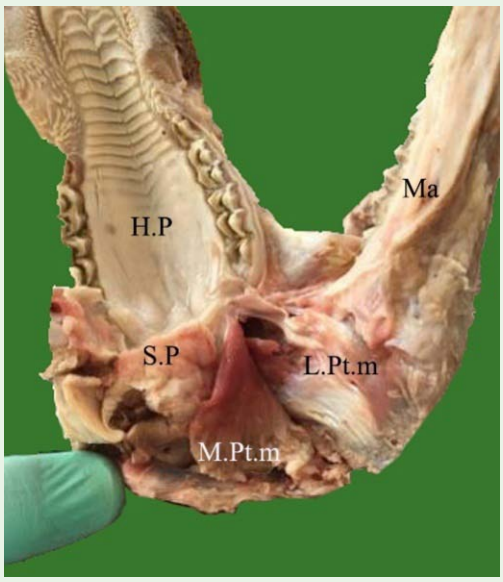

Figure 4: A photograph showing the medial Pterygoid muscle (M.Pt.m), Medial, Lateral Pterygoid muscle (L.Pt.m), Mandible (Ma), Hard Palate (H.P) and Soft Palate (S.P).

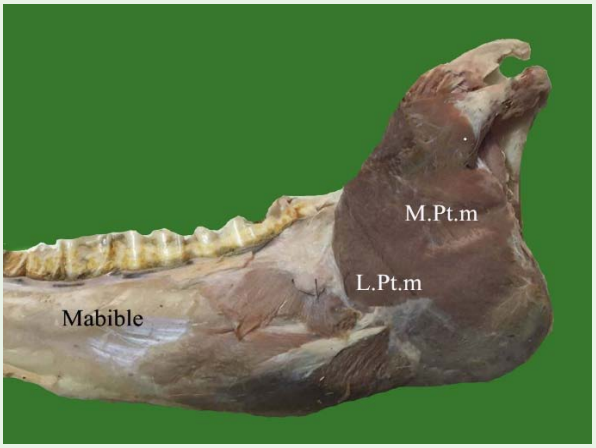

Figure 5: A photograph showing the position of the masticatory muscles, unilateral group on the mandible before its remove. Medial Pterygoid muscle (M.Pt.m), lateral Pterygoid muscle (M.Pt.m).

The opening group

It forms the smallest groups, includes one muscle which is digastric muscle (Figure 5), it occupies the internal surface of the cheeks, near the muscles of the tongue. The opening group representing about 20% of weight of masticatory muscle mass and presents about 31% the total volume of masticatory muscles in sheep. The opening muscles mass weight is about 20 (15-25) g. The average length of the opening muscle is 20 cm and oriented crainoventrally and ventrally. The length of opening muscle fiber is about 10±2 cm of each belly of the muscle which is oriented in cranioventrally and ventrally to the horizontal line. Because of this cranioventral or cranially orientation, it contributes to open the lower jaw.

The indication of the physical characteristics of the digastric muscle was the volume of the opening group muscle was 10 cm^3, density of this group 0.64 g / cm^3. Moreover, the Physiological Cross-Sectional Area (PCSA) is the area of the cross section of the opening group perpendicular to its fibers. It is typically used to describe the contraction properties of pennate muscles (PCSA) = (mass/density)/ fiber length. = (20/0.64) / 20=1.5cm^2. Furthermore, the maximum isometric force generation capacity of muscle is representing PCSA. 1.5x 2= 3 Ncm^2.

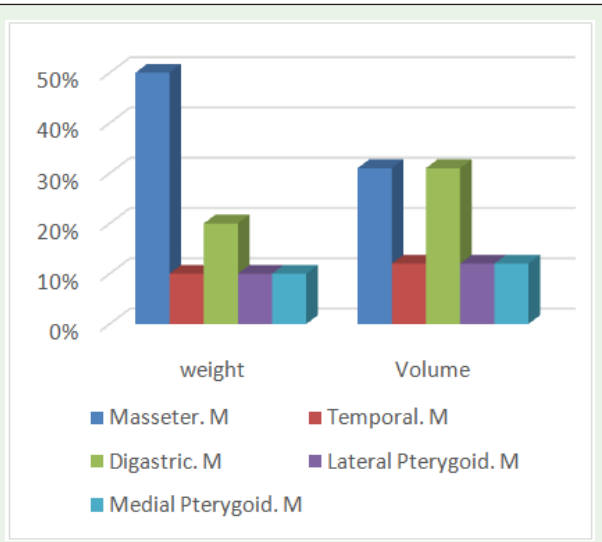

Figure 6: A diagram showing the relationship between the weight and volume of the muscles of the masticatory muscle.

According the estimated force that of the opening muscles group, it is 1.96 N. The torque is the measurement of the turning force on muscle. The torque is estimated about 0.196 Nm due to the fibers direction which increases the torque of the movement by opening the lower jaw. The kinetic energy moves the opening muscles group of the mouth is horizontally, is about 30 Joule. It depends on the movement speed of the muscle. It represents the work needed to moves muscle mass from rest state to limited distance to the new position.

The same used kinetic energy of work is done by the muscle to return from its new position to a rest state. The opening movements confirmed are produced by action of the digastricus muscle. The main function of the opening muscles group is to stabilize the tempro-mandibular joint opening the mandible and aides in the simple rotating movement.

The unilateral group

It occupies the medial surface of the mandible, it includes two muscles which are lateral and medial pterygoid that are responsible for medialand lateral movement. The unilateral muscles group representing about 20% of weight of masticatory muscle mass and present about 24% of the total volume of masticatory muscle in sheep.

The unilateral muscles mass weight is about 20 g. The average length of the unilateral muscles mass is 4 cm cranio-caudally. The length of unilateral muscle fiber is about 4 (6±2) cm of both muscles which are oriented in different direction either ventrally in the lateral pterygoid muscle or caudo-ventrally in the medial pterygoid muscle to the horizontal line. Because of this cranioventral or ventral orientation, contributes to rotate the lower jaw laterally and medially (Figures 6 and 7).

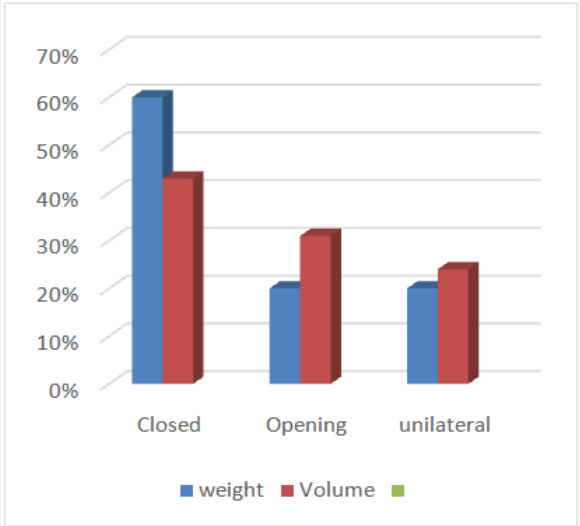

Figure 7: A diagram showing the relationship between the weight and volume of the three groups of the masticatory muscle (closed, opening and unilateral).

The lateral and medial pterygoidmuscles indicate the physical characteristics of the volume of the unilateral muscles group was 8 cm^3, density of these group is 1.66 (0.83+0.83) g/ cm^3. Further, the physiological cross-sectional area of each muscle was (PCSA) = 10/0.83)/4 = 3 cm^2. Also, the maximum isometric force generation capacity of muscle is representing PCSA. 3 x 2= 6 Ncm^2.

Concerning the estimated force that of the unilateral muscles group, it is 1.96 N. The torque is estimated about 5.92 Nm due to the fibers direction which increases the torque of the movement by rotation movement of the lower jaw. The kinetic energy moves the unilateral muscles group of the mouth either it is laterally or medially, is about 40 Joule. It depends on the movement speed of the muscle. It represents the work needed to move muscle mass from rest state to limited distance to the new position. The same used kinetic energy of work is done by the muscle to return from its new position to the rest state. The unilateral movements confirmed are produced by action of the lateral and medial pterygoid muscles. The significant function of these muscles group is to contribute to unilateral abduction lateral of the mandible of approval muscle and help to settle the temporo mandibular joint.

Discussion

The masticatory muscles of sheep were different from carnivores functionally in methods of food mastication especially in the rotation movements. In this study, it had been investigated the functional anatomy of the masticatory muscles through comparative physical characteristics (Orientation fibers, Pcsa, force, maximum force, torque and kinetic energy in sheep).

The relative mass of the closed and opening muscles group was functionally consistent, we find the closed group was 60%, they were nearly similar to white-tailed deer which were 75.4% among the mammals investigated by Turnbull [7] while the relative mass of the opening group was 20%. The relative mass of the unilateral muscles group was 20% represented by lateral and medial pterygoid muscles. This was similar to white-tailed deer; muscle proportions, pterygoids 24.6% among the mammals investigated by Turnbull [7] and that is agree with Janis [1], who recorded that the function of the masticatory muscles correlates with similarities generally skull shape and food nature of the deer.

The present study showed the function of muscles related to the length and the orientation of muscle fiber. Our finding agree with who mentioned that the horizontal movements were produced by muscles having fibers arranged in marked anteroposterior direction, whereas vertical movements are generated by muscles having more or less vertically arranged fibers. In ruminants Suzuki [8] recorded that the masticatory fibers of the ruminant differed from those of the other species in histochemical properties. Draset and Habel mentioned that a superficial layer with almost horizontal muscle fibers, and a deep layer with caudoventral fiber direction of masseter muscle in bovine and added the digastric muscle the two parts have different fiber directions. While in horse recorded that the superficial layer fibers run obliquely and caudoventrally, but the deeper ones run nearly vertically.

The results showed that the Physiological Cross-Sectional Area (PCSA) of the closed masticatory group in sheep was 5.1 cm^2. While PCSA of the opening masticatory group was 3.1 cm^2. On the other hand, the PCSA of the unilateral group in sheep was 6 cm^2. According to Watson et al., [9] in the rabbits the PCSA was 5.3 cm^2 of the closed group. He didn't mention PCSA of digastric muscle and added the author the PCSA was 2.9 cm^2 of the both pterygoid muscles. This results explain the PCSA of the closed muscles group larger and nearly double than the PCSA of the opening group, this is due to mass, density, length of fiber of the muscle and function of the muscle. These results agree with Watson et al., [9] as value of PCSA to closed and opening mastication group. The difference in PCSA measurements can be attributed to variations in the muscle mass and the type of the comparative studied animals (Figure 8).

Also in the present study, we find that strong chewing was the maximum force within 10.16 of the closed muscles group and 3 of within opening muscle group while it was12 of the unilateral muscles group. A maximum force within the unilateral group had maximal effect its due to large size of these muscles and its extension on the distance in rums of the mandible (Figure 9). While the maximum

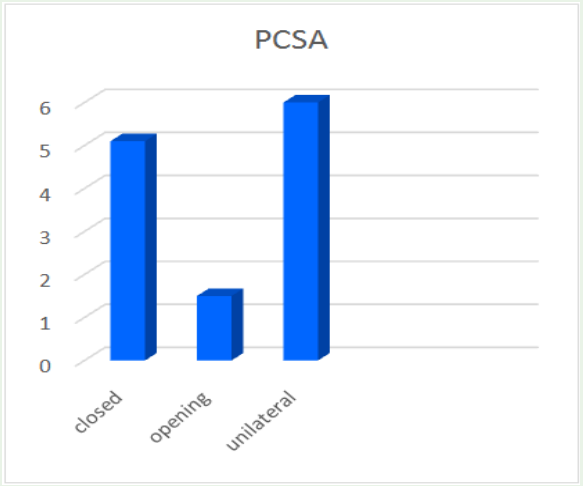

Figure 8: A diagram showing PCSA of the three groups of the masticatory muscle closed, opening and unilateral).

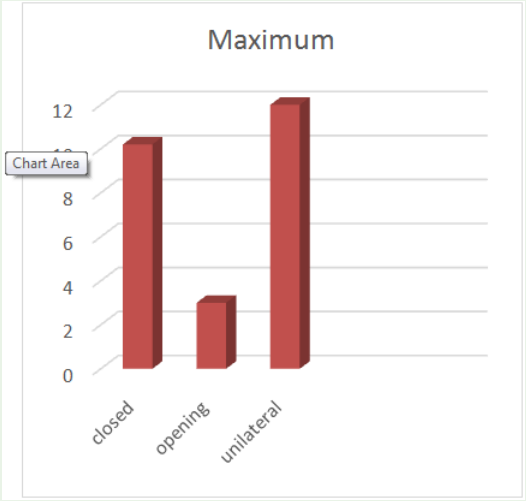

Figure 9: A diagram showing Maximum force of the masticatory opening, closed and unilateral group.

force within closed group had larger than the maximal affect on the opening group about 70% its due to large size of these muscles and its extension on the distance in the cheek and skull. This result agrees with Watson et al., [9] who recorded that the highest maximum force of all the masticatory muscles due to its pennate structure and their orientation.

The present study revealed the force of the muscles was 5.8, 1.96,1,96 N of the closed, opening, unilateral group respectively. This force necessary for closed, opening and unilateral movement of the mouth. Our findings the force of the closed muscles group was higher than about threefold of the opening or unilateral muscles group this is due to muscles mass, work nature of the muscles to move the mandible vertically or horizontally. On the other hand, the force was necessary for opening the mouth by digastricus muscle which serves to move the mandible vertically and to provide the opening force. This is explaining who the force of the opening was 1/3 of the closed force it's due to the gravity which need to the less force to closed. This agrees with Watson et al., [9] mentioned that the closed force was almost completely attributed to a vertical component (97.4% of resultant), with only minor contributions from the anterior and medial components (20.6% and 9.8% of resultant, respectively (Figure 10).

Also the force of the unilateral group has the equal value of the opening group. This force was necessary for bring the mouth external or return to rest model, this force serves both moving the mandible horizontally and providing the movement force for one side externally or internally or to the median plane. Our results support Herring [4] recorded that the most common contraction pattern for moving the mandible laterally involves a force couple of lateral and medial pterygoid muscles on one side on the other. Greaves revealed that the unilateral muscle forces in the mammals with asymmetrical muscle forces are expected to have heavier loading on the balancing side.

The current study revealed that the torque was 0.588 Nm of the closed muscles group, 0.196 Nm of the opening group and 5.92 of the unilateral muscles group. The torque value of the closed muscles group was higher than the opening group about threefolddue to area increased attached the muscles on the bone and activity of the closed muscle in compares with the activity of the opening muscle. On the other hand; the torque of the unilateral group was much higher compares with the closed and opening group. The torque value were big of the unilateral muscle group because of the area of muscular attachment to the bones was large. These results agree with Serway and Jewett [10] revealed that the torque is rotational force as a linear force is a push or a pull and it is a measure of the turning force on muscle. Herring [4] recorded that the torques asymmetrical muscle usage sets up torques on the skull. On the other hand; our results was harmonized with that mentioned that the torques such as other biomechanical forces originated during mastication (Figure 11).

Regarding the kinetic energy was 90 Joule of the closed muscles, 30 Joule of the opening muscle group and 40 Joule of the unilateral muscles group. Our findings the kinetic energy value of the closed group was about triple of the opening group. While the kinetic energy value of the unilateral group was 40 joules. The big kinetic energy value of the closed muscles group was a triple value of the opening group due to the size and the muscles act. Because of the gravity that need much kinetic energy to the closed operation comparing with the opening and unilateral groups. This result agrees with who recorded that the kinetic energy has the ability of being stored as an elastic energy in the muscular and tendious tissues then it releases to be a positive movement at the later stage (Figures 12 and 13).

Our findings agree with Parker [11] in sheep described that the internal pterygoid muscle brings the mandible medially. But the fibers of the external pterygoid muscle were oriented so that they produce an anterior pull on the mandible and added in bovine and in horse the unilateral contraction, it move lower jaw laterally, medially especially. On the other hand; our results similar with who mentioned that the horizontal movements were generated by muscles having fibers arranged in anteroposterior orientation, whereas vertical movements were generated by muscles having more or less vertically arranged fibers. The transverse and rotational movements of the lower jaw were restricted in at least laterally well as they were characteristic of grazing [12,13].

Figure 10: A diagram showing the forceof the masticatory opening, closed and unilateral group.

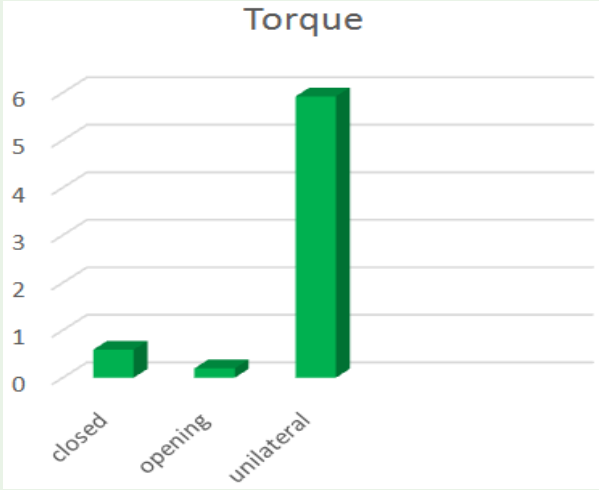

Figure 11: A diagram showing the torque of the masticatory closed, opening and unilateral group.

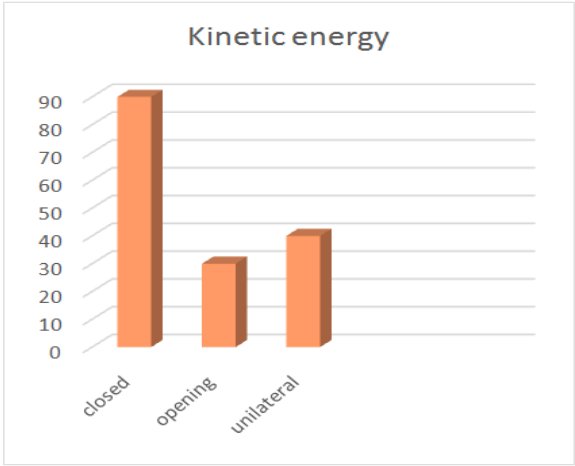

Figure 12: A diagram showing the Kinetic energy of the masticatory opening, closed and unilateral group.

Figure 13: A diagram showing the comparing the physics characteristics of the PCSA, Maximum force, Force and kinetic energy of the closed, opening and unilateral muscles group.

Conclusion

Finally, this study explained a comparative of physical characteristics of closed, opening and unilateral muscles group of the lower jaw to adaptive functional masticatory in sheep by calculated the physical characteristics such as; the PCSA, force, Maximum isometric force, torque and kinetic energy as well as the pattern of lower jaw movements.

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