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Research Article

Functional Anatomy of the Masticatory Mechanism: A Comparative Study of Physical Characteristics of Jaw- Unilateral Muscles in Sheep

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ABSTRACT

The study of the functional anatomy of the unilateral masticatory muscles represented the adaptation of these muscles to achieve the rotation function. This study very important for understanding the mastication mechanism during eating. Fifteen heads of sheep (Mean ± SD age: 18 ± 4 month) and of both sexes were included in this study. In the study, the mass, sizes, orientation of action fibers, (Pcsa), force and torque led to patterns of jaw movement. Specially rotation pattern for moving the jaw laterally or medially. A comparative gross anatomical study and linear measurements of the unilateral movement type 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 study showed that the sheep jaw-unilateral muscles were the lateral and medial pterygoid muscles. The physiological cross- sectional area (PCSA) was 2 and 2cm² for the lateral and medial pterygoid muscle, respectively. The maximal isometric force for those muscles was 4,4 cm², respectively. The force of those muscles was 0.098, 0.098 N, respectively. The torque of each muscle was 2,96 Nm, respectively. While the kinetic energy of the jaw-unilateral group was 20 Joule. The values of the PCSA, force, maximum isometric force, torque and kinetic energy of the unilateral muscles were equal to both muscles. We find these muscles have the equal activity capacities that the muscle moves from one side to other and then returns to the reset status. This study will enable us to know the mechanic movement of rotation unilateral masticatory in sheep.

Key words: Functional, Anatomy, Masticatory muscles, Sheep

INTRODUCTION

The functional anatomy study of the mastication muscles in sheep is very important to understand the mastication operation during eating, an important for their health and breeding success.

There were very a few literatures about the physical properties of the mastication muscles for explanation masticatory operation in sheep. The masticatory muscles were previously studied and describe clearly in domestic animals ruminants anatomically by Getty (1976) and Dyce *et al*. (2010). Therefore, no detailed description is available of masseter mechanics in sheep. Moreover; the function of the masticatory muscles correlates with similarity generally skull shape and food natural of the deer reported (Janis, 1990). However, no detailed description of masticatory mechanics is available in sheep. The oro-facial system (including stomatognathic system, maxilla-mandibular apparatus and masticatory system) is a functional unit composed (Patial and Bindra, 2012). The actions of masticatory muscles differ of a variety of mammals in which feeding behavior and the configuration of the masticatory apparatus (Gorniak, 1985 and Gans, 1978). On the other hand, Geerling (2009) mentioned that the muscles match the altered functional demand by hypertrophy of fibers and changes in the fibers composition type. 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 (1991), 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 cross-sectional areas of the medial pterygoid muscles in subjects wearing overdentures supported by a small number of teeth (Newton *et al*., 2004). On the other hand, (Widmer *et al*., 2002) recorded that there were biomechanical forces generate during

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mastication, such as joint torques The present work which aimed to investigate the functional anatomy of the different masticatory muscles in the sheep could be considered as supporting The present study was aimed to present the research concerning the comparison of the masticatory functional biomechanics of the closing and opening movements of the masticatory muscles in sheep in addition to understand the dynamics of masticatory muscles of adult's sheep.

MATERIALS AND METHODS

Head of fifteen slaughtered adult sheep of both sexes and different ages (18 ± 4 month) were used for this study. They were obtained from Buraidah slaughtered Qassim Region Saudi Arabia Kingdom. Ten heads were dissected using standard instruments to investigate the anatomical features including weight and measurements of masticatory muscles. In addition, five heads of alive sheep were used for taking the time expended by the jaw opening and jaw closing muscle during mastication mechanism.

The buccal cutting in the middle, then the mandible was separated from both side at the level of the Para condylar process, and the second was cut behind the mental foramen by saw to show the lateral and medial pterygoid muscles on the medial surface of the mandible. 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:

$$Density = D = \frac{Mass}{Volume}$$

$$Physiological\ cross - sectional\ area = PCSA = (\frac{Mass}{density}) \ / \ fiber\ length$$

$$Maximum\ isometric\ force\ generation\ capacity = 2 \times PCSA$$

$$Force\ (F) = Mass\ \times Gravity$$

$$Torque\ (T) = F.d = F.r.\sin\theta$$

$$Kinetic\ energy\ (K.E) = \frac{1}{2}\ .m.v^2$$

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 (cm^3), density (g/cm^3), force (N), PCSA(cm^3), the torque (Nm), the kinetic energy (Joule)

RESULTS

The masticatory system in the sheep is a complete functional system including three groups: the closing, the opening and the unilateral (medially and laterally).

In the present study we focus on the anatomical, physiological and physical characteristics of masticatory muscles unilateral muscles was performed. They were presented as follow as the lateral and medial pterygoid muscles. These muscles have different orientation fibers and are like of physiological cross section area, Force, torque and kinetic energy.

The lateral pterygoid muscle (Fig. 1, 2, 3, 4, 5) occupies most of the medial surface of the vertical ramus of the lower jaw externally and *has* round shape nearly. It has the same weight of the medial pterygoid muscle its about 10 g. The lateral pterygoid muscle weight is about 8-12 g (10g). It is representing about 50% of weight of unilateral muscle mass and represents 4 cm² volume of the muscle, about 50% of the volume of these muscles. The average length of this muscle is about 4 cm cranio-caudally, 5 cm upper- lower, about 0.2 cm lateromedially.

Length of muscle fibers are about 4cm (6±2) cm which are oriented caudoventrally according to the horizontal line. Because of the muscle fibers orientated caudoventrally rotating the lower jaw laterally according to the midline of the mouth.

The physical characteristics of the lateral pterygoid indicate the volume is 4 cm³. Density of the muscle is 0.83 g/cm³. Moreover, the physiological cross-sectional area (PCSA) is the area of the cross section of a muscle perpendicular to its fibers. It is typically used to describe the contraction properties of pennate muscles PCSA = 10/0.83)/4 = 3 cm². Maximum isometric muscle force= physiological cross- sectional area x 2 = 6 Ncm².

According to the estimated force of the lateral pterygoid muscle, it is about 0,098 N due to the fibers orientation and arrangement had a role on a muscle's ability to produce movement and to generate force. While the torque is the force applied to the distance between the center of the axis of the force and the axis of rotation. It is constant during muscle rotation. It is a measure of turning force on muscle. The estimated torque is about 2,96 Nm. The big value of the torque of the lateral pterygoid muscle causes the rotation of the lower jaw externally or away of the median plane (Fig. 6).

The kinetic energy of the lateral pterygoid muscle was estimated by 5 Joule which causes rotation movement of the lower jaw. It depends on the move speed of the muscle, it represents the work needed to move a 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 state of rest. The main function of the lateral pterygoid muscle is to stabilize and rotating the temporo-mandibular joint externally. Also, it responsible about lower jaw abduction unilateral laterally.

The medial pterygoid muscle (Fig. 1, 2,3, 4, 5) lies most of the medial surface of the vertical ramus of the lower jaw internally. It occupies along the lateral pterygoid muscle. It has round shape nearly. It is an equal to the lateral pterygoid muscle in mass about 8-12 g. It represents about 50% of weight of unilateral muscle mass and represents 4 cm² volume of the muscle, and it is 50% of the volume of these muscles. The average length of this muscle is about 4 cm cranio-caudally, 5 cm upper- lower, about 0.2 cm lateromedially. The length of muscle fibers is about 4cm (6±2) cm which are oriented cranioventrally and in some parts laterally according to the horizontal line. Due to the muscle, fibers orientated cranioventrally rotating the lower jaw medially according to the midline of the mouth.

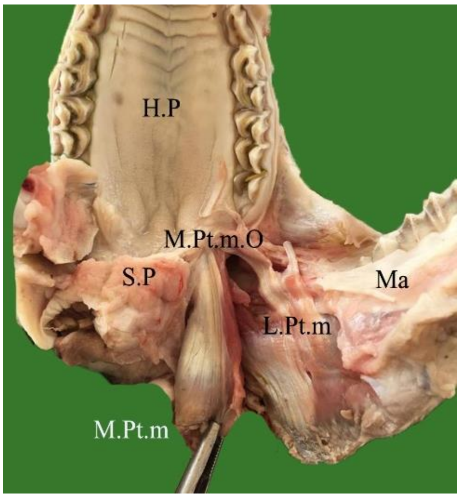

Fig. 1: A photograph shows the masticatory unilateral muscles group. Medial Pterygoid muscle origin (M.Pt.m.o), Medial Pterygoid muscle (M.Pt.m), Lateral Pterygoid muscle (L.Pt.m), Mandible (Ma), Hard Palate (H.P) and Soft Palate (S.P).

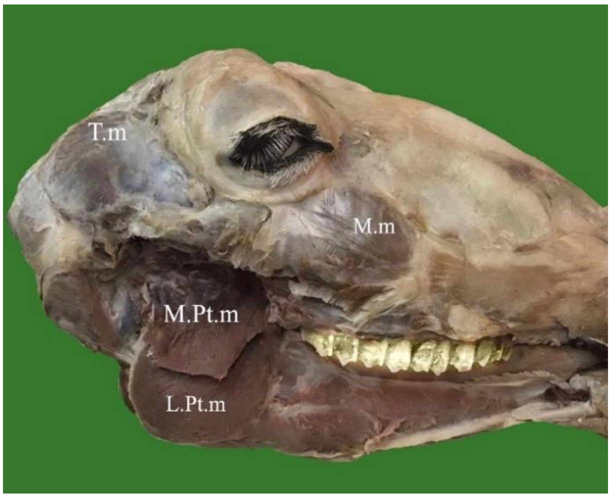

Fig. 2: A photograph shows the masticatory unilateral group position on the head without mandible of Medial Pterygoid muscle (M.Pt.m), lateral Pterygoid muscle (L.Pt.m), Masseter m (M.m),Temporal m (T.m) .

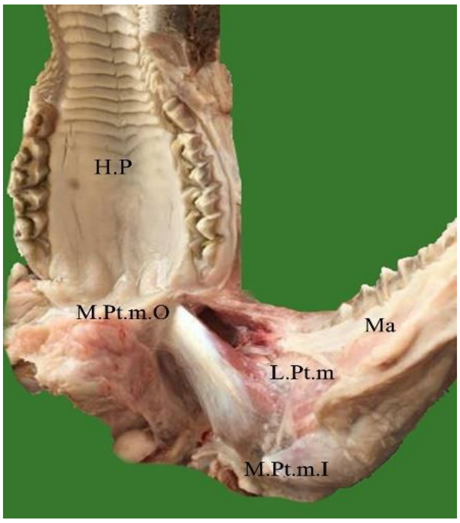

Fig. 3: A photograph shows the medial Pterygoid muscle origin (M.Pt.m.o), lateral Pterygoid muscle (L.Pt.m), Mandible (Ma),, Hard Palate (H.P).

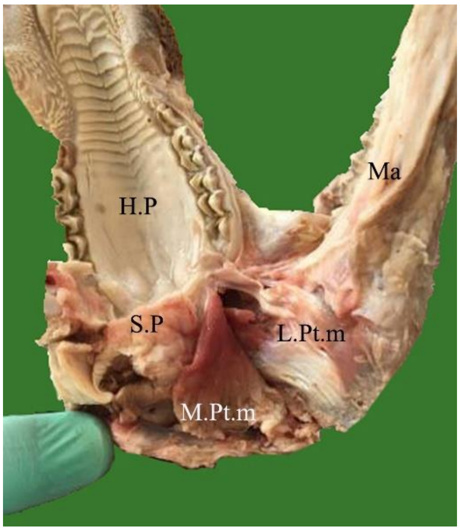

Fig. 4: A photograph shows the medial Pterygoid muscle (M.Pt.m), Lateral Pterygoid muscle (L.Pt.m), Mandible (Ma), Hard Palate (H.P) and Soft Palate (S.P).

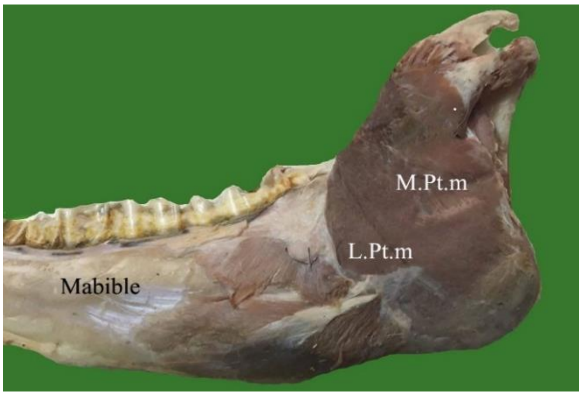

Fig. 5: A photograph shows the Position of the masticatory muscles, unilateral group on the mandible before its remove. Medial Pterygoid muscle (M.Pt.m), lateral Pterygoid muscle (M.Pt.m).

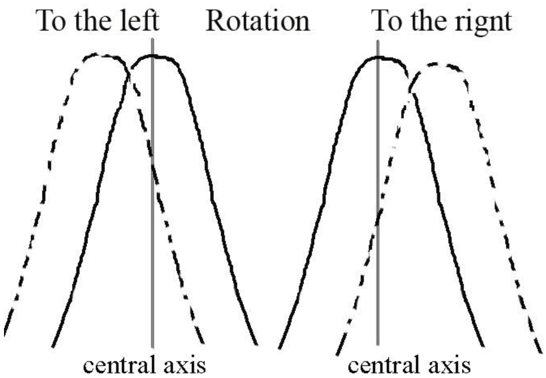

Fig. 6**:** A Diagram shows the rotation way of the lower jaw through of the unilateral masticatory muscles.

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	Volume	Force		weight	Volume	Force
4-	Lateral Pterygoid. M	10	50%	0,098	unilateral	20%	24%	20%
5-	Medial Pterygoid. M	10	50%	0,098				
	Total	100%	100%	100%				

Table 2: presents the calculation of the individual muscle physical characterizes of masticatory muscle and PCSA , force, Maximum force, torque and kinetic energy.

Muscles	Fiber Length cm	Mass/g	Volume cm²	Density cm³	PCSA cm²	Force N	maximum isometric force Ncm²	Torque N.m	KE J
Lateral Pterygoid. M	4	10	4	0.83	3	0.098	6	2,96	20
Medial Pterygoid. M	4	10	4	0.83	3	0.098	6	2,96	20

The physical characteristics of the lateral pterygoid indicates the volume is 4 cm³. density of the muscle is 0.83 g/cm³. Moreover, the physiological cross-sectional area (PCSA) is the area of the cross section of a muscle perpendicular to its fibers. It is typically used to describe the contraction properties of pennate muscles PCSA = 10/0.83)/4 = 3 cm². Maximum isometric muscle force= physiological cross- sectional area x 2 = 6 Ncm².

According the estimated force of the medial pterygoid muscle it is about 0,098 N due to the fibers orientation and arrangement had a role on a muscle's ability to produce movement and to generate force. While the torque is the force applied to the distance between the center of the axis of the force and the axis of rotation. It is constant during muscle rotation.

It is a measure of turning force on muscle. The estimated torque is about 2,96 Nm. The big value of the torque of the medial pterygoid muscle causes the rotation of the lower jaw internally or away of the median plane.

The kinetic energy of the medial pterygoid muscle was estimated by 5 Joule which causes rotation movement of the lower jaw. It depends on the move speed of the muscle, it represents the work needed to move a muscle 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 state of rest. The main function of the medial pterygoid muscle is to stabilize and rotating the temporo-mandibular joint internally. Also, it contributes to adduction unilateral medially of the lower jaw of approval muscle.

Finally, the rotation way for moving the lower jaw laterally or medially depends a force both of lateral and medial pterygoid muscles on one side and the other side, generally.

DISCUSSION

The masticatory muscles of the sheep were different from the carnivores in masticatory food methods functionally by the rotation movements specially. In this study, it had been investigated the gross anatomy functional anatomy of the masticatory muscles through studying physical characteristic of mandible muscles (Orientation fibers, Pcsa, force, maximum force, torque and kinetic energy in sheep.

In this study**,** the unilateral muscles group, it moves the jaw-lower laterally or medially by the pterygoid muscles. These muscles pull the jaw-lower medially or laterally and contributed in pulls the mandible upward partially. Our results were similar to what mentioned that by Dyce *et al*., (2010) in domestic animals, Parker (1983) in sheep, Budras and Habel (2009) in bovine, Smiut *et al*., (1980) in camel and Budras *et al*., (2013) in horse.

The relative mass of the unilateral muscles group was consistent functionally. The unilateral muscles group proportions were lateral and medial pterygoids 20%; they were representing by 10% of the lateral or medial pterygoid muscle. The present study was similar to white-tailed deer; muscle proportions, pterygoids about 24.6% among the mammals which were investigated by (urnbull 1970) and that is agree with (Janis, 1990) who recorded that the function of the masticatory muscles correlates with similarities generally skull shape and food natural of the deer.

The current study revealed that the function of muscles was related to the length and the orientation of muscle fibers. The length fibers of the lateral pterygoid muscle were about 4 cm, directed caudo-ventrally according to the horizontal line of the mandible. While fibers bundles of the medial pterygoid muscle are oriented cranio-ventrally and in some parts laterally. The relatively large medial and lateral pterygoids mass may reflect greater transition particularly rotational hemi movements of the mandible. Our finding agrees with (Gorniak,1985) who mentioned that the horizontal movements were produced by muscles having fibers arranged in marked anteroposterior direction.

The results were in accordance with those of Parker (1983) who described that the medial pterygoid muscle brought the mandible upward and medially in sheep. But the fibers of the lateral pterygoid were cranio-ventrally orientation so that they produced an anterior pull on the mandible at the head of the condyle. While they added (Budraset and Habel,2009) in bovine and (Budraset *et al*., 2013) in horse that the medial pterygoid in supported to masseter; in unilateral contraction: moves lower jaw laterally, medially especially.

(Gorniak 1985) mentioned that the horizontal movements were produced by muscles having fibers arranged in marked anteroposterior direction, whereas vertical movement were generated by muscles having vertically arranged fibers.

The transverse and rotational movements of the mandible were restricted in browsing groups by the larger premolar (Sanson, 1980 and 1989; Lentle *et al*., 2003). Furthermore, the molar shearing links that act during transverse movements of the jaw are characteristic of grazing (Sanson,1980 and 1989).

(Suzuki 1977) in ruminants, recorded that the masticatory fibers of the ruminant differed from those of the other species in histochemical properties. While (Budraset and Habel 2009) mentioned that a superficial layer with almost horizontal muscle fibers, and a deep layer with caudoventral fiber direction in bovine and added the digastric muscle the two parts have different fiber directions. This is consistent with the results of our current study. While (Budraset *et al* 2013) in horse recorded that the superficial fibers of the masseter muscle oriented obliquely caudoventrally and the deep ones oriented nearly vertically. These fiber directions were contributed for the lateral and rotational movement.

The present work showed that the physiological cross-sectional area (PCSA) of the unilateral group in sheep was 4 cm² represented by 2 cm² of the lateral or medial pterygoid muscle. While the PCSA was 2.9 cm² of the both pterygoid muscles to (Watson *et al.*, 2017) in the rabbits.

These results explained the PCSA of the lateral pterygoid muscle equal to PCSA of the medial pterygoid muscle due to like the mass, density the muscle and function of the muscle which pulls the mandible laterally then return to its normal position by the medial pterygoid muscle. This result disagrees with (Watson *et al* 2017) mentioned that the PCSA of the medial pterygoid muscle differs from the PCSA of the lateral pterygoid muscle, where the PCSA of the medial pterygoid muscle was 2.5cm² larger than the PCSA of the lateral pterygoid muscle 0.4 cm². The difference in PCSA measurements can be attributed to variations in the muscle mass and the type of the comparative studied animals (Fukunaga *et al.*, 1991). The PCSA of each muscle was calculated via the method described by (Anapol and Barry, 1996).

the cross-sectional areas of the medial pterygoid muscles in subjects wearing overdentures supported by a small number of teeth were comparable with those of subjects with a natural dentition (Newton *et al.*, 2004).

Also, the present study revealed that the force of the unilateral muscle was estimated about 2 N collected by 0.098 from each lateral or medial pterygoid muscle. This force was necessary for bringing the mouth from the external side or return to rest state and move the mandible horizontally This force produced due to mass, location of muscles the study revealed that the move force laterally was equal the amount same the move force internally or the median plane.

The force of mastication is a vertical orientation of the mandible, produced by lateral or medial pterygoid muscle with contribute a little masseter and temporal muscle on the opposite side. Our results support (Herring,2007) who 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 contrary, (Greaves,1978) revealed that the unilateral muscle forces in the mammals are expected to have heavier loading on the balancing side.

In this study, we referred that the maximum isometric force of the muscle was estimated by multiplying muscle PCSA. They were 8 of the unilateral muscles are represented by 4 within lateral pterygoid muscle and 4 within medial pterygoid muscle. A maximum force within lateral pterygoid muscle or medial pterygoid muscle, it had equal effect due to the equal size of the two muscles. (Watson *et al.*, 2017) how recorded that the highest maximum force of all the masticatory muscles (60.9 N) because the unilateral muscles vary significantly in their working mechanism due to the different orientation of the muscles bundles.

Our finding revealed that the torque was big and estimated 5.92 of the unilateral muscles represented by 2.9 of the lateral or medial pterygoid muscle due to the movement of the lower jaw. A torque of the lateral pterygoid muscle had equal value for the medial pterygoid muscle rotation due to the equal size of the two muscles. This result agrees with (Greaves, 1991) who recorded that the symmetrical muscle usage sets up torques on the jaw lower equally. Otherwise, it loads to produce bony deformations. On the other hand; the torque is rotational force as a axial force to push or a pull the muscle and it is a measure of the turning force on muscle reported by Serway and Jewett (2003). Moreover, Herring (2007) explained that the torques asymmetrical muscle usage sets up torques on the skull and combines with occlusal loads to produce bony deformations not only in the tooth-bearing jaw bones.

Regarding to the kinetic energy it was estimated 40 Joule of the unilateral muscles, it was 20 Joule of the lateral or medial pterygoid muscles which causes its horizontal or semi rotation movement. The lateral pterygoid muscle had equal value for of the medial pterygoid muscle due to the equal size and the same of the activity of each muscle. this the kinetic energy needed to move a muscle from rest state to limited distance. The same used kinetic energy of work is done by the muscle to return from its new state to a state of rest. This result agrees with (Sasaki and Neptune, 2006) who recorded that the kinetic energy have the potential to be stored as elastic energy in compliant connective tissue and tendinous structures, and subsequently released to do positive work at a later point.

Conclusion

Finally, the pattern of lower jaw movement rotation for moving the jaw laterally or medially involves a force couple of lateral and medial pterygoid muscles on one side and the other side. This study explained the cause of the functional difference about unilateral muscles of the lower jaw through the comparative physical characteristics such as; the PCSA, force Maximum isometric force, torque and kinetic energy as well as the differences in the pattern of mandible movements.

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Author contributions

GA (Syria) planned and conceived the search. the data. GA (Syri), interpreted the results and designed the figures. Wrote the manuscript. The author read and approved the final manuscript.

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