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SOME ANATOMICAL STUDIES ON THE QUADRATO-MANDIBULAR ARTICULATION OF OSTRICH (*STRUTHIO CAMELUS*) AND FLAMINGO (*PHOENICOPTERUS RUBER*)

(With 14 Figures)

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بعض الدراسات التشريحية على المفصل المربعى الفكي السفلي في النعام والفلامنجو (البشروش)

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تم أجراء تلك الدراسة على عشرة رؤوس لطيور النعام البالغة والتي تم الحصول عليها من الشركة المصرية السعودية للنعام في محافظة الاسماعيلية وكذلك عشرة رؤوس لطيور الفلامنجو (البشروش) البالغة تم الحصول عليها من صائدي الطيور المهاجرة في محافظة شمال سيناء. تم في هذا البحث إجراء دراسة عيانية للحافظة المفصلية والأربطة المتصلة بالمفصل المربعى الفكي السفلي بالإضافة إلى وصف الأسطح المفصلية المكونة له. وقد تبين من تلك الدراسة الاختلاف الواضح بين شكل أسطح التمفصل وكذا الحافظة المفصلية والاربطة الخا صة بالمفصل في كل من النعام والبشروش والتي يمكن أن تكون نتيجة تباين أسلوب وطريقة تناول الطعام والشراب في هذين الطائرين. هذا وقد تم تحديد أنسب مكان لحقن العقاقير الطبية داخل تجويف المفصل في حالات إصابات هذا المفصل. وقد نوقشت نتائج الدراسة مع مثيلاتها في الطيور الأخرى.

SUMMARY

This study was performed on the quadratomandibular joint of ten heads of both ostrich (as a flightless bird) and flamingo (as a flying migratory bird). The gross morphological features of the articular surfaces and capsule associated with the joint in both species of birds were thoroughly investigated.The study revealed that the quadratomandibular joint was formed between the quadrate bone of the skull and the articular bone of the mandible without intervening inter-articular disc. It was observed that, there was a great difference between the form of the articular surfaces of these bones in either ostrich or flamingo as well as in the capsular construction and the anatomical arrangement of the ligaments of the joint which might be correlated with the different patterns of feeding

behaviour. The present work suggested the suitable site for the intra-articular injection of this joint in both ostrich and flamingo, which might be significant in treatment of affections of face joints. The obtained results were discussed with those of other birds.

Key words: *Quadrato-mandibular articulation, Ostrich, Flamingo*

INTRODUCTION

Interest in avian structures and function has grown with the increasing importance of birds as food producers, models in biological research and pets (McLelland, 1990). Ostrich (*Struthio camelus*) as a member of Struthionidae (flightless ratites) is not only the largest living bird but can survive successfully in some of the most open arid regions of Africa, usually in bands of 10-50 individuals (Walters, 1980; Young, 1981 and Louw and Seely, 1984).

Ostriches are fast-running birds (King and McLelland, 1984). They feed on small plant material as well as grains (Bout and Zweers, 2001). They tend to be of increasing veterinary significance and are domesticated for meat and eggs and also bred for their valuable tail feathers (Louw and Seely, 1984).

Flamingoes as a member of Phoenicopteridae are large birds having long legs, long bills and with pink feathers. Unlike ostriches, they are strong flyers and feed on shrimps, crustaceans, small molluscs and other small invertebrates. They inhabit eastern Africa, south Europe, south Asia and India, living mostly in marshes and are often very numerous on the sea-shore (Young, 1981; Mackworth-Praed and Grant, 1981 and Martin, 1987).

Some studies have been made on the morphology of the quadrato-mandibular joint in different species of birds (Fujioka, 1963; King, 1975; Nickel, Schummer and Seiferle, 1977; King and McLelland, 1984; Selianski, 1986; McLelland, 1990 and Dyce, Sack and Wensing, 2002), yet the available informations concerning the anatomical details of components of such joint are insufficient particularly in ostrich and flamingo which live in different ecological conditions. Moreover, affections of face joints such as Mycoplasmosis, Infectious coryza and Staph. aureus infections are problems frequently encountered in birds especially in pheasants which could be treated with good results by an intra-articular injection of medicinal drugs (Joine and More, 2003).

Therefore, the present study was performed in an attempt to obtain some informations on the morphological features of the quadrato-mandibular joint in ostrich as a model of walking bird of high economic value and in flamingo as a flying bird. Such basic informations are necessary for understanding the different mechanisms of feeding and drinking patterns. Furthermore, the study suggested the optimum site for injection in such joint of both birds in order to provide basic data for the clinicians.

MATERIAL and METHODS

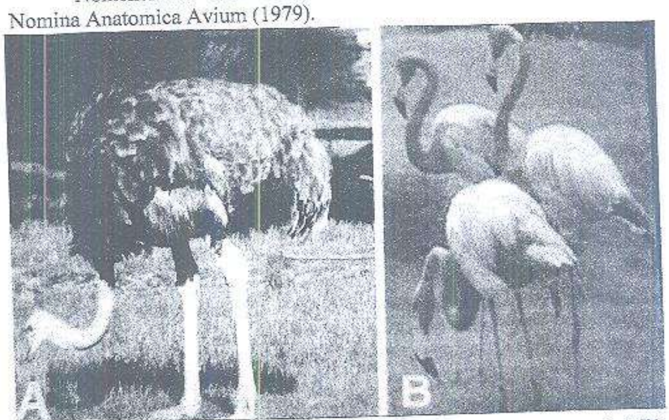
The present work was conducted on ten heads from freshly slaughtered healthy adult ostriches obtained from the slaughter house of the Egyptian Saudi Ostrich Co. at Ismailia Governorate, Egypt.

A similar number of heads were separated from healthy adult flamingoes gathered from migratory bird's hunters at North Sinai Governorate, Egypt.

Species identification and age determination were adopted according to Klos and Lang (1982) in ostriches and Mackworth-Praed and Grant (1981) in flamingoes.

Seven heads of each species were thoroughly dissected freshly to describe the gross morphological features of the joint under research regarding the articular capsule and associated ligaments. The articular surfaces entering in the formation of the joint were also described on the bones left after dissection. In addition, some gross measurements were recorded using Vernier's caliber. The exact site for the intra- articular injection in ostrich and flamingo was also determined in the remainder three specimens.

Nomenclature used in the text was adopted according to the Nomina Anatomica Avium (1979).



Photographs of ostrich (*Struthio camelus*) (A) and flamingo (*Phoenicopterus ruber*) (B).

RESULTS

Thorough gross dissection revealed that the quadrato-mandibular articulation in ostrich and flamingo was located nearly at the same level of the upper border of the mandibular ramus. The osseous elements involved in this joint were the quadrate bone of the skull and the articular bone of the mandible. The joint included the area of the attachment of the articular bone (Fossa articularis quadratica) with the mandibular process of the quadratum (Figs.1&5).

I. Articular surfaces:-

It was observed that the articular surfaces of the bony elements entering in the formation of the quadrato-mandibular joint in both ostrich and flamingo were congruent and articulated with each other only by their articular cartilages without an intervening inter-articular disc.

A. In ostrich

The quadrate bone (Os quadratum) of ostrich appeared irregular quadrangular in form (Figs.1&2). It formed the link between the mandible and the cranium. The quadratum had three processes, namely otic, orbital and mandibular. The otic process (Processus oticus quadrati) articulated with the Facies articularis quadratica of the Os temporale rostral to the external acoustic meatus. The orbital process (Processus orbitalis quardrati) appeared broad and short and pointed towards the orbit for muscular attachment .The third strongest process was the mandibular process (Processus mandibularis quadrati) that articulated with the mandible (Figs.1&2).

The mandibular process of the quadratum carried ventrally two distinct articular condyles (medial and lateral). The lateral condyle beared a cotyla on its superficial surface for articulation with the caudomedial surface of the rod –like Os quadrato-jugale. The deep surface of that condyle appeared as an elongated convex articular area about 0.8-1.0 cm long and 0.3-0.4 cm wide.

The medial condyle was larger than the lateral one, strongly convex and oval in shape (about 1-1.2 cm long and 0.6-0.8 cm wide). This condyle had attached medially with the processus quadraticus of the pterygoid bone. In addition, these two condyles of the mandibular process were attached ventrally with the cotylae of the articular bone of the mandible in the articulatio quadrato mandibularis. It was seen that both condyles were separated rostrally from each other by a small transversely rectangular synovial fossa and caudally by a small intercondylar tubercle (Figs.3A&4A). The latter tubercle was fitted into a small facet located just caudal to the lateral cotyla of the mandible.

By means of its Fossa articularis quadratica, the articular bone of the mandible joined the quadrate bone. This fossa presented two cotylae (medial and lateral) which represented the receiving articular sockets for the condyles of the quadratum (Figs.3B&4B). These cotylae of the articular bone appeared strongly interlocked with the opposed surfaces of the quadrate bone.

The smaller lateral cotyla appeared slightly concave and received the corresponding articular area of the lateral condyle of the quadratum. Just caudal to the lateral cotyla there was a small smooth facet that became in a complete contact with the synovial fossa and the articular tubercle of the mandibular process of the quadrate bone when the jaws are closed.

The medial cotyla was larger and deeper, received the medial condyle of the quadratum. It was bounded medially by the medial mandibular process.

Between the two cotylae rostrally, there was a small tuberculum intercotylare (Figs.3B&4B) that lodged into a small depression present on the rostral surface of the medial condyle of the quadratum when the jaws are closed.

B. In flamingo

The articular surfaces of the bony elements of the joint in flamingo were quite different from those of ostrich. The quadrate bone was cup-shaped (Figs.5&6) and much smaller than that of ostrich. Its mandibular process articulated ventrally with the Os articulare of the mandible by means of three articular condyles. The medial condyle was the largest and attached with the pterygoid bone. The lateral condyle was smaller and carried on its superficial surface the quadrato-jugal bone, which overlapped the upper part of the lateral surface of the pars caudalis of the mandibular ramus (Figs.5, 7A&8A) which might strengthen the joint. The third condyle was the smallest and caudally located.

The medial, lateral and caudal condyles of the quadratum were received into three small facets (medial, lateral and caudal, respectively) that present in the Fossa articularis quadratica of the Os articulare of the mandible (Figs.7B&8B). The medial facet was the largest; the lateral was much smaller while the caudal one was the smallest.

Likewise ostrich, the condyles of the quadratum and their receiving articular facets of the Os articulare were firmly interlocked without an interposing articular disc.

II. Articular capsule:-

A. In ostrich

The outer fibrous capsule was tight on the side aspect of the joint (Fig.9). It extended dorsally to be attached to the postorbital process of the temporal bone. This fibrous sheet-like extension of the capsule from the quadratojugal bone to the postorbital process of the temporal bone was much thicker (Fig.9) than the rest of the capsule which might assist in supporting both the quadratojugo-quadrate and quadrato-mandibular articulations.

The capsule also extended rostrally to cover the lateral aspect of the rod-like quadratojugal bone, continuing with its periosteum, and extended caudally to the zygomatic process of the temporal bone, while ventrally the attachment was about 0.5 cm from the articular margin of the Os articulare of the mandible. The capsule was reinforced on its lateral aspect by a condensation of some fibers, which might be regarded as the Lig. jugo-mandibulare (Lig. quadratojugo-mandibulare) (Fig.10). The ligament was attached to the lateral surface of the lateral condyle of the quadratum and the caudolateral end of the quadratojugal bone and extended obliquely rostroventrally to the upper part of the lateral aspect of the pars caudalis of the mandible about 2 cm. rostral to the quadratomandibular joint. Such ligament was about 3-4 cm. long and 0.3-0.4 cm. wide and not distinctly separable from the capsule. During opening of the jaws, the quadratojugo-mandibular ligament became stretched.

It was observed that another short thick fibrous band extended from the mandibular process of the quadratum between its two condyles to the mandible just caudal to the intercotylar tubercle and near the base of the medial mandibular process. This band might be regarded as the Lig. quadrato-mandibulare (Fig.10) that also became stretched during opening of the jaws.

Caudal to the quadratomandibular joint, there was a wide ligamentous sheet connecting the upper jaw with the lower one. This ligament was named according to the basis of its bony attachment as the Lig. occipito-mandibulare (Fig.10). It consisted of two parts. The strongest medial part was attached along the caudal border of the medial mandibular process and some of its fibers ended in the Fossa caudalis, the concavity that present on the caudal surface of this process. The lateral part of the ligament was attached to the ala tympanica and processus paroticus of the Os. exoccipitale. Such ligament was observed to complete the caudoventral wall of the external acoustic meatus (Fig.10) and it stretched during closure of the jaws.

It must be noted that the inner synovial stratum of the articular capsule was much thinner and limited only to cover the articular margins of the joint.

B. In flamingo

The joint capsule in flamingo (Fig.11) was much thinner than that in ostrich. It was consisted of slender short fibers extending between the articulating bones and attached around the margins of the articular surfaces. It was so difficult on gross dissection to distinguish between the fibrous and synovial layers of the capsule.

The capsule was reinforced on its lateral aspect by a condensation of some fibers, which might be regarded as the Lig. jugo-mandibulare (Lig. quadratojugo-mandibulare) (Fig.12). It was the only ligament present in the quadratomandibular joint in flamingo and was not distinctly separable from the capsule. The ligament appeared as a slender fibrous band (about 1.0-1.4 cm. long) and stretched during opening of the jaws. It extended from a small depression caudal to the caudal facet of the Os articulare of the mandible. It curved laterad and rostrad passing on the caudal and lateral condyles of the mandibular process of the quadrate bone to end in the lower border of the quadratojugal bone about 0.3 cm rostral to the quadratojugo-quadrate articulation.

Sites of intra-articular injection:

The suitable site suggested for injection into the cavity of the quadratomandibular joint in ostrich was determined by introducing the needle obliquely dorsocaudally lateral to the ramus of the mandible in the distance between the upper border of its caudal part and the caudal part of the jugal arch (quadratojugal bone) which could be palpated externally and about 0.5- 1 cm. rostoral to the quadratojugo-quadrate articulation (Fig.13/A).

Another site for reaching the articular cavity in ostrich could be also detected by introducing the needle just rostral to the external acoustic meatus between the caudal border of the zygomatic process of temporal bone which could be palpated externally and the otic process of the quadrate bone. The needle introduced in an oblique rostro-ventral direction about 1 cm. above the quadratojugo-quadrate articulation, which also could be clearly palpated from outside (Fig.13/B).

In flamingo, the articular cavity of the quadratomandibular joint could be reached by introducing a small needle in a ventral direction just rostral to the external acoustic meatus and about 1 cm. above the point of attachment of the quadratojugal bone with the quadratum (Fig.14).

DISCUSSION

The joint studied in the present work was named by the bones or parts of bones that are united at the joint. The osseous elements involved in the formation of that joint in the present work were similar to those given in other domestic birds by King (1975); Vanden Berge (1975); Nickel *et al.*, (1977); Selianski (1986); McLelland (1990); Kent and Carr (2001) and Dyce *et al.*, (2002) who stated that the avian quadratomandibular joint was formed between the quadrate bone of the skull and the articular bone of the mandible. On the other hand, Hofer (1945) and Zweers (1974) discovered a distinct wedge-shaped Meniscus articularis in the caudal part of the quadratomandibular joint in Anas, Anser and Cairina.

As described by Zusi (1967), the avian articulatio quadratomandibularis as a consequence of its formation between the quadrate bone of skull and the articular bone of the mandible was also named the articulatio quadrato-articularis.

Such joint in respect to its existence between the upper and lower jaws corresponds to the temporo- mandiblular joint of mammals. However, the congruence seen between the articular surfaces of the joint in ostrich and flamingo as well as in other birds and the consequent absence of an intervening interarticular disc were in contrary to that reported in domestic mammals where an interarticular disc was found to produce congruence in the articular surfaces of the temporo- mandiblular joint of equines and carnivores (Sisson, 1975), ruminants (Erasha, Ragab and Ahmed, 1992) and camel (Erasha, 2000).

In addition, the articular and quadrate bones in mammals have been withdrawn from the articulation of the jaw and converted into the auditory ossicles (malleus and incus, respectively) as reported by King and McLelland (1975, 1984).

Moreover, the tip of the zygomatic process of the temporal bone was fused with that of the postorbital process in fowl (Nickel *et al.*, 1977); whereas in the present work, they were completely separate.

The ossa quadrata are so-called because of their shape (Nickel *et al.*, 1977). This was in an agreement to a large extent to that reported in ostrich in the current work where the quadrate bone was irregular quadrangular in form. However, the quadrate bone of flamingo was cup-shaped rather than quadrilateral in outline.

Moreover, the three processes of the quadrate bone, namely otic, orbital (pterygoid) and mandibular processes given in the current study were also reported in fowl, ducks, geese and pigeons (Feduccia, 1975; Chiasson, 1984; King and McLelland, 1984 and Selianski, 1986 and Shively, 1987). In this respect, the orbital process of the quadratum in ostrich was short and broad, whereas, in pigeon it was elongated (Chiasson, 1984). This might explain the extreme large orbit in ostrich rather than any other bird. Moreover, this short and broad orbital process in ostrich might give origin to a longer muscle which causes a higher mobility of the quadrate bone and in turn reflected on the movement of the quadrato- mandibular joint.

The present work revealed that the mandibular process of the quadrate bone in ostrich present only two articular condyles (medial and lateral) for articulation with the cotylae of the mandible. Meanwhile, in flamingo the mandibular process of the quadratum had three articular condyles (medial, lateral and caudal), the result which was in an agreement with Bock (1960), who stated that the quadrate bone of birds articulates mostly with the Os articulare of the mandible usually by means of three articular condyles.

The observed results declared that the quadrate bone in ostrich and flamingo formed the primary link between the lower jaw and the skull, this was in parallel with that given by Feduccia (1975), King and McLelland (1975, 1984) and Selianski (1986) in other domestic birds, who also added that the quadrate bone is highly mobile and it is the basis of the mechanism of cranial kinesis. Furthermore, the articulation between the quadrate mandibular process with the caudal part of the jugal arch (quadratojugal bone) seen in ostrich and flamingo was also observed in domestic birds by Nickel *et al.* (1977); Baumel (1979) and King and McLelland (1984). This jugal arch is the homologue of the mammalian zygomatic arch (Dyce *et al.*, 2002).

Concerning the articular fossa of the mandible, it consisted of two cotylae in ostrich forming the receiving sockets for the condyles of the quadratum, whereas in flamingo it consisted of three small facets rather than cotylae. However, Baumel (1979) described three cotylae that present in the fossa articularis quadratica of the mandible in birds.

In this respect, the condyles of the quadrate bone and the receiving surfaces of the mandible were tightly interlocked in ostrich and flamingo, while in other birds (e.g. *Rynchops nigra* and *Pygoscelis* *adeliae*) which having weak interlocking between the quadrate bone and mandible, the medial process of the mandible articulates with either the medial or lateral basiparasphenoid (basitemporal) processes in order to support the mandible and to prevent its caudal disarticulation (Bock, 1960). However, Zusi (1967) disagreed with the latter viewpoint.

The Lig. jugo-mandibulare seen in ostrich and flamingo regarding its attachment was corresponding to the Lig. jugo-mandibulare laterale in Ardea cinerea reported by Bas (1955). It was worthy to suggest that the presence of only the Lig. jugo-mandibulare in flamingo might give a great freedom of protraction and retraction of the lower jaw in such bird.

The Lig. quadrato-mandibulare described in the current study only in the ostrich, was recorded in most passerines, extending from the petrygoid process of the quadratum to the base of the mandibular medial process (Bock and Morony, 1972).

The obtained results concerning the Lig. occipito-mandibulare in ostrich, were similar to those observed in corvus (Bock, 1964). Such ligament was not found in flamingo.

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LEGENDS OF FIGURES

Figs. 1 and 2: A photograph and an illustrative diagram of the quadrato-mandibular joint of an adult ostrich (left aspect) showing:

1-Corpus quadrati. 2-Processus oticus quadrati.
3-Processus orbitalis quadrati. 4-Processus mandibularis quadrati.
5-Os quadratojugale. 6-Os jugale.
7-Processus zygomaticus of Os squamosum (temporale).
8-Processus postorbitalis of Os squamosum (temporale).

9-Crista temporalis of Os squamosum (temporale).
10-Fossa temporalis of Os squamosum (temporale).
11-Os articulare of the mandible. 12- Meatus acousticus externus.

Figs. 3 and 4: A photograph and an illustrative diagram of the articular surfaces of the quadrato-mandibular joint of an adult ostrich showing:

(A) Articular surface of the Processus mandibularis quadrati, having:
1-Condylus medialis.
2-Condylus lateralis.
3-Tuberculum intercondylare.
Note: Os quadratojugale (4) & Os pterygoideum (5).

(B) Articular surface of the Os articulare of the mandible (Fossa articularis quadratica) having:
1-Cotyla medialis. 2-Cotyla lateralis.
3-Tuberculum intercotylare.
Note: Processus mandibulae medialis (4).

Figs. 5 and 6: A photograph and an illustrative diagram of the left quadrato-mandibular joint of an adult flamingo, showing:
1- Quadratum. 2- Processus mandibularis qudrati.
3-Os mandibulae. 4- Processus retroarticularis of the mandible.
5-Processus zygomaticus of Os squamosum .
6- Processus postorbitalis of Os squamosum.
7- Meatus acousticus externus. 8- Os quadratojugale.
9-Fossa temporalis

Figs. 7 and 8: A photograph and an illustrative diagram of the quadrato-mandibular joint of an adult flamingo, showing:

(A) Articular surface of the Processus mandibularis quadrati, having:
1- Condylus medialis. 2- Condylus lateralis.
3- Condylus caudalis.
Note: Os quadratojugale(4) & Articulatio quadratojugo-quadrate (5).

(B) Articular surface of the Os articulare of the mandible (Fossa articularis quadratica) having:
1- Facet medialis. 2- Facet lateralis.
3- Facet caudalis.
Note: Processus retro-articularis mandibulae(4).

Fig. 9: A photograph of the right quadrato-mandibular joint of an adult ostrich, showing the Capsula fibrosa (1) and its sheet-like extension (2).
Note: Processus postorbitalis of Os squamosum (3).

Fig. 10: A photograph of the left quadrato-mandibular joint of an adult ostrich, showing:

1- Lig. quadratojugo-mandibulare. 2- Lig. quadrato-mandibulare.
3- Lig. occipito-mandibulare.
4- M. adductor mandibulae externus & its tendon .
5- Os jugale. 6- Quadratum.
7- Processus orbitalis quadrati. 8- Os mandibulae.
9- Processus zygomaticus. 10- Processus postorbitalis.

The arrow indicates the Meatus acousticus externus.

Fig. 11: A photograph of the right quadrato-mandibular joint of an adult flamingo, showing:

1- Capsula fibrosa of the joint. 2- Processus postorbitalis.

The arrow indicates the Meatus acousticus externus.

Fig. 12: A photograph of the right quadrato-mandibular joint of an adult flamingo, showing:

1- Lig. quadratojugo-mandibulare. 2- M. adductor mandibulae externus.
3- M. depressor mandibulae.
4- Processus retro-articularis mandibulae.
5- Processus postorbitalis 6- Os quadrato jugale.
7- Quadratum.

Fig. 13: A photograph of the head of an adult ostrich, showing two predilection sites (A: first site & B: second site) for intra-articular injection of the quadrato-mandibular joint. Note the Meatus acousticus externus (M).

Fig. 14: A photograph of the head of an adult flamingo, showing the suitable site (S) for intra-articular injection of the quadrato-mandibular joint. Note the Meatus acousticus externus (M).

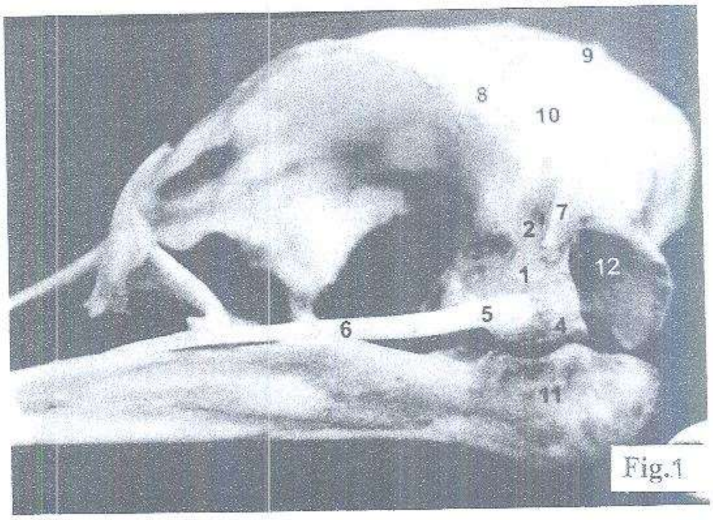

Fig.1

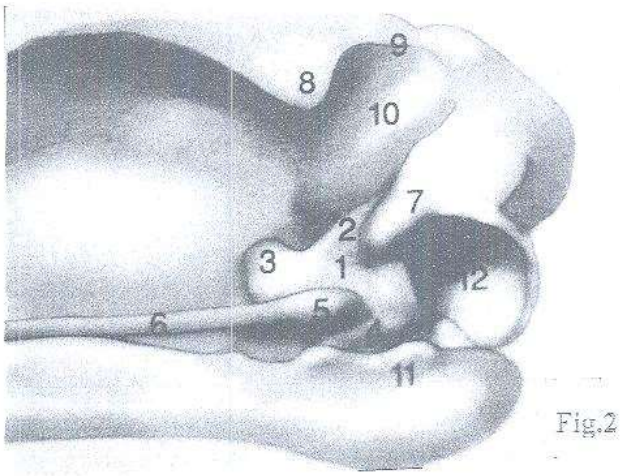

Fig.2

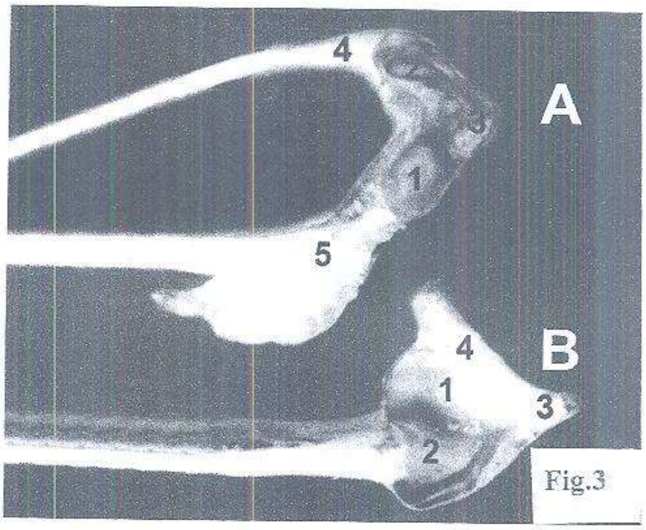

Fig.3

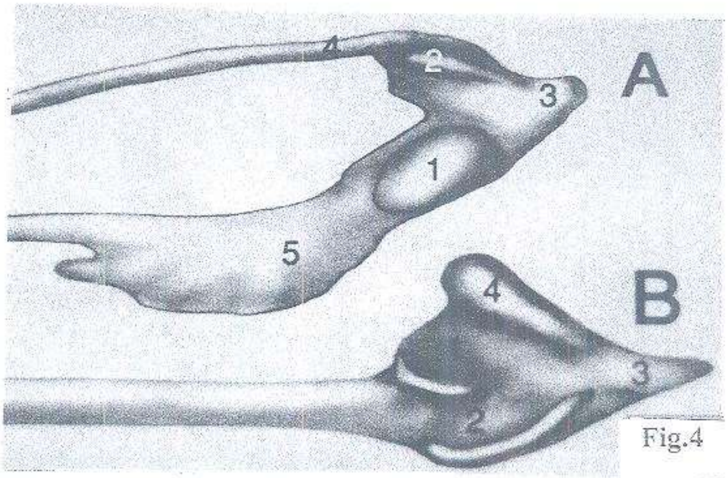

Fig.4

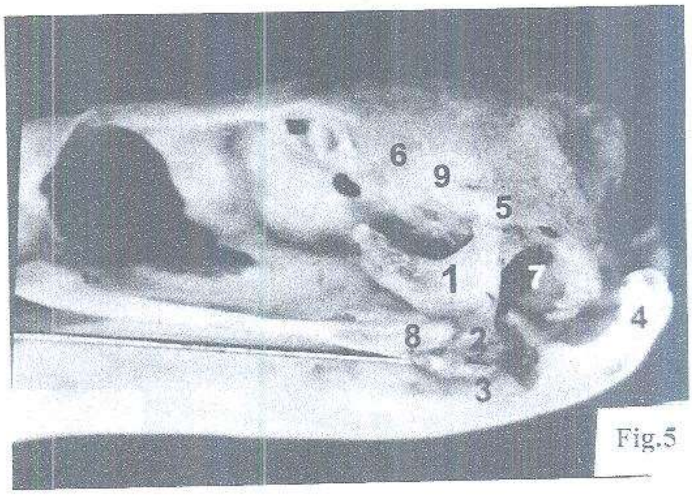

Fig.5

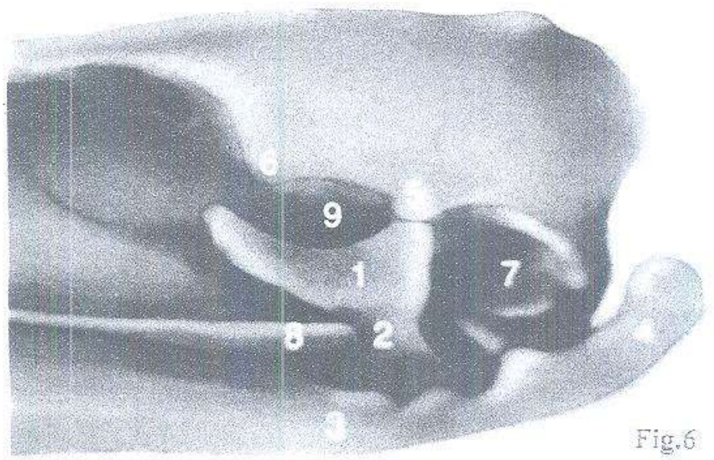

Fig.6

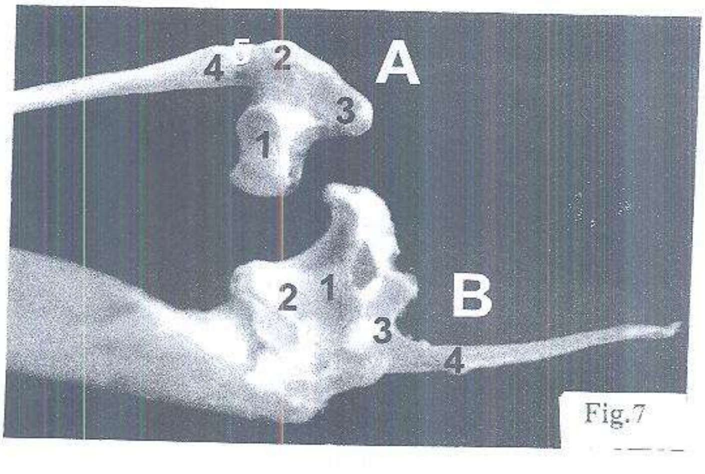

Fig.7

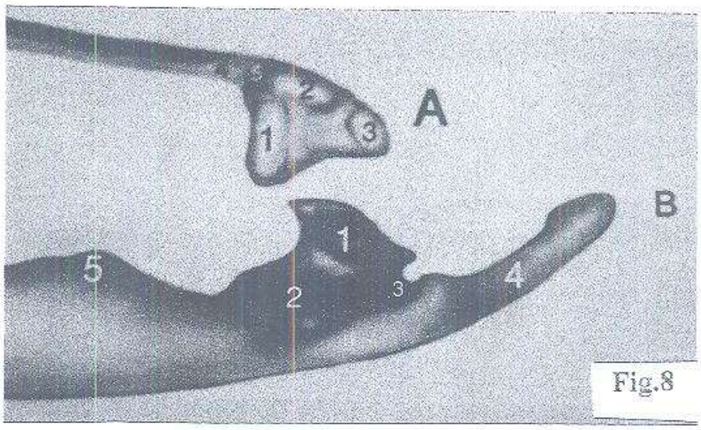

Fig.8

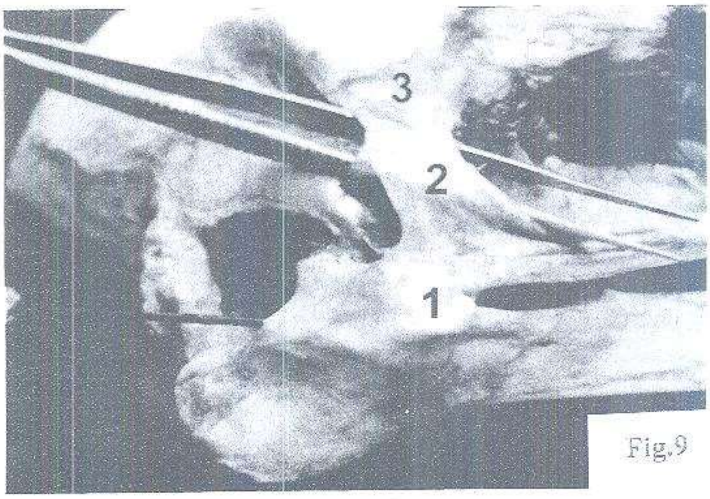

Fig.9

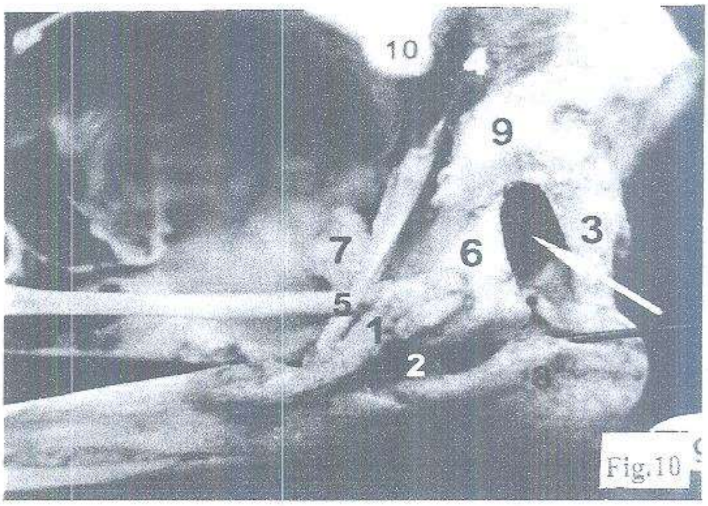

Fig.10

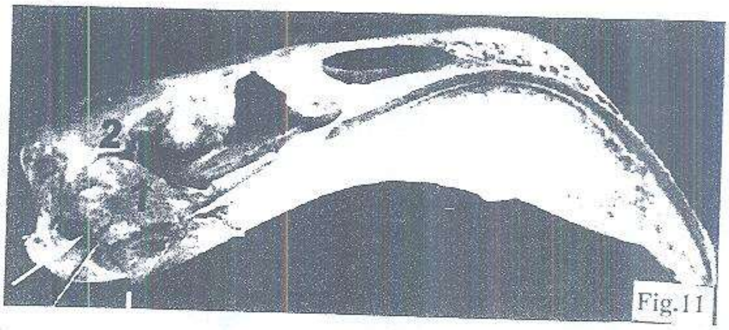

Fig.11

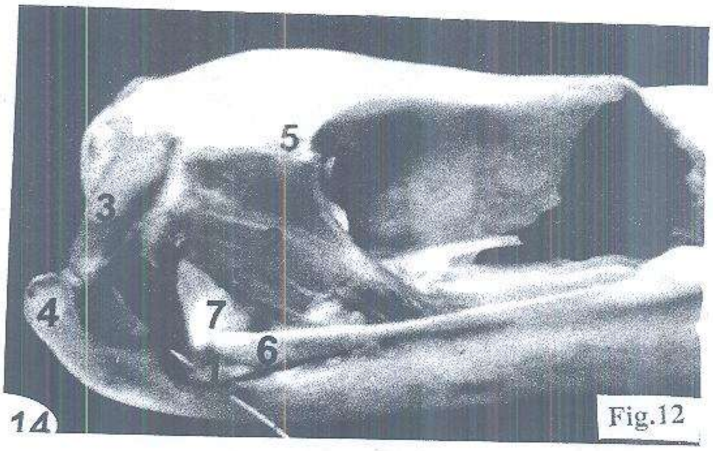

Fig.12

Fig. 13

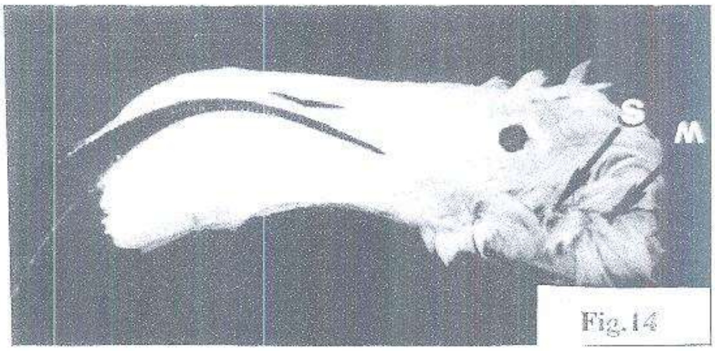

Fig. 14