Macro and Micro Architecture of the Wing in Three Different Avian Habitats

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ABSTRACT

Key words: wing, avian, macro and micro architecture

The present study was performed on forty adult species of chickens (galliformis), ducks (Anseriformes) and pigeons (columbiformis), with different of both sexes, apparently healthy for description. The present study was undertaken to compare the gross features of the bones of pectoral limb of the examined birds to correlate their morphological peculiarities with its possible function. In this study, chickens, ducks and, pigeon, were investigated as three different habitant groups walking, flying and swimming respectively. All the bones were comparatively stronger in ducks and pigeon that could be an adaptation towards the functions necessary to perform the flight stroke. The wing skeleton was formed by the humerus, a thick radius paired with a thinner curved ulna, ulnar and radial carpals, carpometacarpal, and three digits. Pieces of the bones and muscles were processed for histological examination. Pectoral muscle fragments were collected carefully in 10 % formalin for histology examination, and the wings were cleaned to study the bones and muscles. The arterial blood supply of the wing in domestic chickens was studied to investigate the course and distribution of the subclavian artery. The birds were slaughtered and the subclavian artery of five chickens was cannulated and flushed with warm normal saline (0.9%), then injected with red gum milk latex. The specimens were subjected to fine dissection to demonstrate the origin, course, relations and distribution of the subclavian artery. The other three chickens injected with Urografin for x-ray purposes. The arterial supply of the thoracic limb of the fowl was formed mainly by the pectoral trunk and axillary artery. The obtained results were photographed, described. The arterial supply of the thoracic limb of the fowl was formed mainly by the pectoral trunk and axillary artery.

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1. INTRODUCTION

The anatomy and histology of the wing of chicken, duck and pigeon were carefully ascertained by gross anatomical observation and microscopic examination. The results confirmed that the wing skeleton and there were many studies on the wing of the birds. Among contemporary workers in avian osteology, the wing skeleton was studied by several authors (Bellairs and Jenkin, 1960; Feduccia, 1975) in chicken and (Woolfenden, 1961) in water fowl) which formed by the humerus, a thick ulna paired with a thinner radius, ulnar and radial carpals, carpometacarpal, and three digits.

The breast muscles that move the wing are mainly vascularized by the pectoral trunk, which is the strongest branch of the subclavian artery and divides into the cranial, middle and the caudal pectoral arteries. Studies concerning the vasculature of the wing in birds indicate that the main blood supply was derived from the subclavian artery (Nickel et al. 1977). Two brachiocephalic trunks arise fundamentally from the arch of the aorta and give rise to the common carotid and subclavian arteries in birds. However, the branching of the brachiocephalic trunk shows differences among the avian species (Nickel et al. 1977; King and McLelland 1984).

In addition, the sternoclavicular artery is giving strong rami to the supracoracoid muscle by the lateral border of the coracoid. The subcutaneous thoracoabdominal vessels that supply the brood patches are branches of
the pectoral trunk too, recommended by the (Baumel et al., 1993).

Microarchitecture of avian bones indicated that, they have the same basic composition as those of mammal. As some bones are either solid, contain blood vessels and others are pneumatized. This low bone density allows flight and water buoyancy. The air passages extend from the air sacs of the respiratory tract into the shafts and central portions of the pneumatized bones studied by (Peter Sakas, 2002).

The pectoral muscles constitute the largest and most energy-consuming organ of flying birds (Butler,1991). An ability to adjust pectoral muscle mass to the required power output would yield important energy savings. For example, adaptive decreases in the size of the pectoral muscles during long flights, tracking body mass changes, would allow birds to extend their flight range considerably. Moreover, pectoral muscle thickness changed rapidly and consistently in parallel with body mass changes caused by flight, fasting and fuelling (Lindström et al., 2000).

The purpose of this work is to provide a deeper insight into anatomy of the wing. Although the appendicular skeletons have been studied in a few birds by various investigators, no one has made a concerted attempt to work out in detail the similarities and differences between the various genera and species. Moreover, the present study was carried out to clarify the structural features of the wing among birds that show difference in its ability to fly.

2. MATERIAL AND METHODS

The present study was conducted on forty adult, apparently healthy birds from (pigeons, ducks and chickens) from both sexes. The obtained results were photographed using Sony® digital camera 12.1 mp, 4x. The before mentioned materials was treated by several procedures, according to the scope under investigation, as follow:

I- Gross morphological study of the wing:
A- Bones: the morphological features of the bones and muscles of wing in the examined species were studied on five specimens. The birds were euthanized, and then eviscerated, skinned and muscles were removed from the skeleton. The specimen was soaked in cold water with 0.03% ammonia solution for 24 h to remove blood and making the bones white (Tahon et al., 2013). Further studies were performed on the most of the bones left after dissection. Additionally radiographical work was also conducted on the wing of four specimens, in order to determine the normal angle as well as the range of motion at each Joint. Wing of each species was processed for X-ray for studying their morphology. This was conducted at the surgery department, faculty of veterinary medicine, Sadat City University. X-ray images were processed with the parameters: 53 kV and at 5 mAs. The Anatomical nomenclature is based largely on the (Nomina Anatomica Avium, 1993).

B- The musculature of wing: in order to elucidate the different muscle act on the wing, two of each species muscles were formalized and other two were used in fresh state. Individually, muscles were dissected and their attachment is noted.

II- Angeological study:

Macroscopic course and pattern of distribution of arterial blood supply of the wings were studied. This study was conducted on six specimens. A- The arteries were injected via subclavian arteries with 60% gum milk latex colored red with Rotring® ink. (Tompsett and Wakelly, 1965). They were left in a mixture of 10% formalin, 2% phenol and 1% glycerin for only two days before the routine dissection to keep the flexibility of the wing. B- Other birds were injected with urograffin® for x-ray purposes. Injection was carried via sub clavian arteries. These radiographs were an attempt to obtain a true picture of the topographic relations of the arteries, with bony skeletons. The exposure factors were 100cm. FFD, with 15 mAs and 55.

III- Histological examinations:
A- Pectoral muscles sample
Small pieces from pectoral muscles of birds were taken from (breast muscles) the samples were immediately fixed in 10% buffered neutral formalin solution for 24-48 hours, dehydrated and embedded in paraffin blocks. Tissue sections (5 μm) were processed with the routine histological methods; stained with hematoxylin-eosin (H&E) stain for routine histological studies and two special stains (PAS and Alcian blue for detection of neutral and acidic mucopolysaccharide granules).

B- Humerus samples
Humerus cut with the microtome into sections 5 μm thick after softening by using formic acid10% in order to decalkify and softening. Then were stained with
H&E stains, for histological study, samples were taken from shaft and both extremities.

3. RESULTS

A - The skeleton of the wings:

Despite the great diversity in birds and their wings, they still have common overall bones, which can be seen in the examined birds.

The bones are relatively long, and the wings taper to a point allowing high flight speed with low drag, and low energy consumption during flight. The skeleton of the birds have a unique conformation that accommodates its ability to flight. It consists of the humerus, the ulna and the radius, the wrist or carpus, the carpometacarpus and the digits (Fig. 1). Wing of the chicken has short, dark and very fragile bones, which easily fractured. In case of ducks; the bones are relatively long, and the wings taper to a point. While in the pigeon `wing it is free movable up and down as humerus freely attached to the girdle.

In the chicken, the humerus is short, dark in color and thick at its extremities. It carries large and convex head with two tuberosities; dorsal which higher than ventral. The Pneumatic fossa which is large and flattened in fowl and contain small pneumatic foramen. (Fig. 1).

On the other hand, ducks has long, thick humerus with very large convex head, which fused with the tubercle. The two tuberosities dorsal and ventral are present with very large pneumatic fossa. In pigeon, the humerus is short, pneumatic and Cleary white long bone, carrying a very long, blunt head higher than tubercle on proximal extremity, the pneumatic fossa is large, round carry numerous pneumatic fossa.

Radius and ulna constitute the bones of the forearm where, the ulna is larger and the radius is slightly thinner than it is. Moreover, ulna forms the support for the mid-wing. The cylindrical shaft of ulna is slightly curved proximally leaving a wide interosseus space between it and the radius. The shaft present small raised projections indicate the origin of the secondary follicles of the wing feathers. The proximal end of ulna carries the olecranon and two concave articular surfaces for the condyles of the humerus as well as a radial articular facet. The distal end of the ulna is trochlear in shape it consists of a small cranial condyle that articulates with the ulnar carpal bone and relatively large caudal condyle that articulates with both ulnar carpal and radial carpal bones. On the distal end of the ulna, there is a small radial sulcus, sulcus radialis to form the distal radio ulnar joint.

On manipulation of the fresh specimen of the outer surface of ulna in pigeon, it is notice that there is small bony projection, which represents the point of attachment for the secondary feathers of the wing, while in chicken they are reduced. The radius is a small, rod-like bone; its proximal extremity represents the head of the bone, caput radii that articulates with the humerus, as well as the ulna. The shaft of the radius is slightly curved.

The distal end of the radius bears the radio carpal articular surface for articulation with radial carpal bone. The distal ends of the radius and ulna are separated by the radio ulnar interosseous ligament. In
chicken, the straight radius articulate with thick curved ulna between two bones there is large, oval interosseous space (Fig.3). However, both bones in ducks were long, thick, dark and straight, so the interosseus space becomes large, wide and elliptical. In pigeon, straight radius articulate with much curved ulna, a wide, oval interosseous space.

Regarding the constituents of the bony architecture of the wrist, it includes each of the following bones, carpal, carpometacarpal and digits. Ossa carpi consists of two carpal bones; the ulnar and radial carpal bones. The U-shaped ulnar carpal bone (Os carpi ulnare) is situated in the caudal aspect of the wrist region, and it articulates proximally with ulna while distally with the carpometacarpal bone. The radial carpal bone (Os carpi radiale) is rectangular in shape, situated on the cranial aspect of the wrist. It articulates proximally with the distal end of the radius and the ulna and distally with the carpometacarpus.

Concerning the proximal end of the compound carpometacarpal bones, it bears the cranial and the caudal carpal fossae, the carpal trochlea as well as a strong pisiform process (proc pisiformis) which projected from the palmar surface of the proximal end of the carpometacarpus. From the compound carpometacarpus, the, three carpometacarpal bones extend distally. The third carpometacarpal bone (major carpometacarpus) is the largest and strongest of them, from its proximal radial end projects, a small projection represents the second carpometacarpal bone, (alular carpo metacarpus) that carries the extensor process on its proximal end. The fourth carpometacarpus, this is a thin arched bone, fuses proximally and distally with the third carpometacarpus leaving a large interosseous space. It was identified that the wrist is fused with the hand to form a single unit, Ossa digitorum manus.

There are three digits in the wing articulating proximally with the corresponding carpometacarpal bones. The second digit is also called thumb or pollex consists of one long proximal phalanx. It articulates proximally with the second carpmetacarpus, the third digit is the longest and strongest digit; it articulates with the distal end of the third carpmetacarpus and consists of two phalanges. The first phalanx is the larger and has thick cranial border and a sharp curved edge. The distal phalanx is in the form of a pointed cone. The fourth digit, the minor digit has only one phalanx that articulates with the distal end of the fourth carpmetacarpus. In chicken, the intermetacarpal process a small triangular shaped process projecting from the third carpometacarpal bone, which is directed caudally and overlapping part of the fourth carpometacarpus.

The scope of the present topic pays more attention and gives separate photographic consideration, so we prefer to regard, comparative approach as an attitude that should pervade all photographs of all regions of the wing in the examined birds than one constituting independent repetitive study. The portions of the wing structure in examined birds that are easily accessible to x-ray include the bony architecture. Other areas are too thick for even the most penetrating X-ray beam. The X-ray photographs of the different bones constitute the wing in birds under investigation were demonstrated in (Fig. 2).

Fig. 2. Radiograph showing bony structure of the wing in A- chicken, B- Duck, C- Pigeon. A: 1-Humerus, 2-Ulna, 3-RADIUS 4-Alula ,5-Carpometacarpus, 6- phalanges Ulna. B: 1-carpometacarpus, 2- feathers, 3- digit. C: 1-Humerus,2-Ulna, 3- Feather, 4-Digits, 5-Carpometacarpus, 6-RADIUS, 7,Patagial tendon

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B-Musculature of the wing:
The two primary flight muscles are the pectoralis major (largest muscle in the birds body) and the supracoracoidus. The pectoral musculature is represented by both superficial pectoral muscles and deep pectoral muscles these muscles are involved in the wing movement of all poultry species and, having different histological and physiological features. The supracoracoidus is the primary elevator of the wing in the upstroke and is most important for take-off. The supracoracoidus lies internal to the pectoralis major. It also originates on the carina of the sternum, the furcula and sternal ribs. Its insertion on the proximal dorsal surface of the humerus is byway of a tendon that travels through the triceps seal canal and acts as a pulley to lift the wing. Propatagium of the wing is the triangular fold of the skin from leading edge of the wing between the shoulder and carpal joint (Fig.3).

C-The arterial blood supply of the thoracic limb:
Blood supply of the thoracic limb of domestic fowl was taken as a model for other domestic birds and mainly achieved by two branches from the subclavian artery; the pectoral trunk and the axillary artery (Fig.3,4&5). The latter considered the continuation of the Subclavian artery in the thoracic limb.

Fig. 3. Photograph showing the propatagia of chicken wing. 1-Propatagia

Fig. 4. Photograph showing the origin and branching of the subclavian artery. 1-pectoral trunk, 2-internal thoracic,3-caudal pectoral, 4-cutaneus branch, 5-cranial pectoral 6-axillary, 7-subscapularis, 8-supra coracoids, 9-subclavian, 10-brachiocephalic, 11-trachea.

Fig. 5. Photograph showing the axillary artery branches. 1-deep brachial, 2-collateral ulna, 3-collateral radial, 4-humeral circumflex, 5-bicepetal,6-brachial, 7-superficial radial, 8-biceps brachii, 9-axillary a., 10-ulnar, 11- ulnar, 12-radial, 13-recurent ulnar, 14- elbow, 15- pronatoralis superfascial 16- flexor carpi ulnaris.
III – Histological structure of wing of birds:

In terms of histological variation, we found that mid shaft sections, proximal and distally located sections show differences of bone tissue of humerus compact bone tissue was detected in the shaft of bones. In chicken characterized by, the bone lamellae that organized to form Haversian lamellae (osteons), interstitial lamellae and outer and inner circumferential lamellae. It is long, cylindrical with bifurcate cylinder parallel to the long axis of diaphysis. On the other hand cancellous bone tends to be composed of parallel bone lamellae forming branching and anastomosing trabeculae between it there is wide spaces filled with bone marrow. It is found in epiphysis of long bone of chicken and ducks but in the epiphysis and diaphysis of pigeons (Fig. 6, 7 & 8).

Fig. 5. Radiograph showing the branching of the axillary a. by using x-ray. 1-axillary a, 2-brachial, 3-deep brachial, 4-humers, 5-elbow joint, 6-recurent ulnar, 7-ulnar a, 8- radial a, 9-ulna, 10-radius, 11-radial carpal, 12-ulnar carpal, 13-alula metacarpal, 14-alula digit, 15-major metacarpal, 16-minor metacarpal, 17-digit, 18-manus.

Fig. 6 photomicrograph showing the histological difference of the proximal extremities of humerus of A: chicken, B: duck and C: pigeon.

Fig. 7 photomicrograph showing the histological difference of the mid shaft of humerus of A: chicken, B: duck and C: pigeon.

Fig. 8 photomicrograph showing the histological difference of the of the distal extremities of humerus A: chicken, B: duck and C: pigeon.
The musculature architecture appears to be composed of cells that form muscle fibers. In flying birds as pigeon, pectoral muscles of red fibers were predominant but in chicken’s predominance of white fibers, in duck contain both (white and red muscles fibers). The skeletal muscle fibers are long, cylindrical in shape and usually not branched their cytoplasm appears acidophilic, and contain myofibrils. This arranged longitudinally showing cross striation. The cytoplasm may contain glycogen and occasionally fat droplet. The fibers are multinucleated reach to several hundreds. The nuclei are elongated in (duck and pigeon) or oval in case of chicken in shape peripherally located under sarcolemma (Fig. 9).

![Histological difference of pectoral muscles fibers stained with H&E, PAS and Alcian blue.](image)

**Fig 9.** Photomicrograph showing the histological difference of pectoral muscles fibers stained with H&E, PAS and Alcian blue.

4. DISCUSSION

All birds are adapted to their habitats; in the air, on land and on or around water. Some able to fly (flight birds)-swimming or (duck) –terrestrial or flightless. Such differences and similarities may serve as a basis for a study of functional morphology, an understanding of avian anatomy is essential for avian practitioners. The anatomy and structures of wing of birds had been described and depicted in various degree of detail by several authors and textbooks (Brown, 1963; Rayner, 1985; Dial et al., 1987; Norberg, 1990; Rossier et al., 1994; Askew et al. 2001; Tobalske et al., 2003; Bishop, 2005).

In agreement with Sissons and Grosmann, (1975), the skeletons of birds need to be lightweight to minimize the metabolic cost of flight, and at the same time strong enough to withstand the forces encountered during flight. Therefore, the skeleton is lighted by extensions of extensive air sac systems into many bones. The air sacs extension system replaces bone marrow in many of limb bones. Pneumaticity of the avian postcranial skeleton results from invasion of bone by extensions from the lung and air sac system, a trait unique to birds among living amniotes (Duncker, 1989). Further, it has been observed that the extent, or degree, of Pneumaticity varies greatly between different groups of birds (King, 1956; McLelland, 1990). Two main topics of discussion surrounding post cranial Pneumaticity. Relate to the influence of body size and diving on the relative degree of Pneumaticity between species. First, it is commonly stated that larger bodied birds are relatively more pneumatic than smaller-bodied ones (McLelland, 1990). Additionally, many authors note a reduction or absence of Pneumaticity in diving forms (e.g., penguins, loons, diving ducks (King, 1956; Bellairs and Jenkin, 1960; Jones and Furilla, 1987), this is supported by the present work. (Muller and Alberc, 1990) also emphasized that although the size and shape of pneumatic foramina vary from taxon to taxon, the locations of foramina remain relatively constant. (Witmer, 1990) pointed out that not all pneumatic bones actually have pneumatic foramina on their surfaces. Pneumatic diverticula adjacent to bone may partially invade the bone.

Skeleton of the wings the forelimb composed of three limb bones, the humerus, ulna and radius. The hand, or Manus (carpus, metacarpals, and fingers, which
Ancestrally was composed of five digits, is reduced to three digits (digit II, III and IV or I, II, III) which serve as an anchor for the primaries associated with each wing two group of feathers, one of two groups of feathers responsible for the wing’s airfoil shape. The other set of flight feathers, behind the carpal joint on the ulna, are called the secondaries. The remaining feathers on the wing are known as coverts, of which there are three sets. In chicken, the humerus is short, flat at both ends and its proximal extremity carries dorsal and ventral tubercles. In agreement with the description of (Nickel et al., 1977). The present investigation revealed that, There is too variation in the relative lengths of the humerus, fore arm, and manus. In the divers, as duck the upper section of the arm is the longer than fowl and pigeon .a result which correspond to that in different birds (Rayner,1979; Woolfenden1961).The latter author gave a clear evidence of the vortex theory on animal flight. Similarities and differences among birds, in the contributions of the it humerus, reflect their divergent locomotors and feeding adaptations .The wings of birds are based on elongated forelimb elements, and this is clearly illustrated by their long and relatively heavy humerus. The relative length of wing bones varies much in birds; it is longest in the flying. While in struthious birds, it is the shortest, and in many running birds, the wing is reduced in length.

It is report that, with X-rays examinations the veterinarian can look for signs of trauma, fractures and development bone diseases that impinge on the bones of the wing, or even arthritis and osteomyelitis. Concerning the Pectoralis muscle, it consists of two parts, the thoracic part, arising from the sternum, and an abdominal portion, arising from the pelvis. The largest muscle in a bird is the pars thoracicus m. pectoralis, which acts as the primary down stroke muscle of the wing. The avian pectoralis has been widely studied for its overall role in flight as the depressor (adductor) of the wing (Brown, 1963; Norberg, 1985; Rayner, 1985).

It is relevant to point out that the pectoral muscles are routinely palpated for indication of the general health of birds. They are also used for intramuscular injection when care must be taken not to enter the body cavity , this is supported by the opinion given by (George and Berger,1966), in this respect ,the cranial portion of the muscles should avoided for this purpose, as the larger vessels enter here and if injured, may give rise to total hemorrhage .the latter was in agreement with our work (Bishop,2005) as well as (vanden berger, 1970; King and Maccand,1984 ). Regarding the arterial vasculature of the wing, the present investigation as well as given by (Nickel et al., 1977; Petneházy et al., 2005) agree that source of the blood supply and the distribution of blood vessel to the wing structure was attended via two main trunks namely, pectoral trunk and axillary artery.

Regarding the microscopic examination of bones of examined birds, we found that mid shaft sections, proximal or distally located sections, to detect type of bone tissue compacted coarse or cancellous bone). The histology of bones in a skeleton varies according to the particular bone and its location in the skeleton. The bone wall has a large number of predominantly longitudinally arranged primary osteons, Different types of primary and secondary bone tissues were readily identifiable in the compact of the different bones sectioned. The compact consisted of a mixture of fibro-lamellar bone, parallel-fibred bone, cancellous bone, compacted coarse cancellous bone, and lamellar and/or lamellate bone tissues. Primary osteons were fairly abundant in the bone walls. The bone walls were extremely thin in pigeon than duck and fowl. In the metaphysial regions of the shafts of long bones, there is a predominance of compacted course of bone tissue and usually only a narrow outermost peripheral band of primary bone. In these sections, the medullary cavity often has an extensive development of cancellous bone tissues, while the medullary cavity was packed with compacted coarse cancellous bone in pigeon similar to (Amson et al., 2014).

The present results were the same as reported by (Mobini, 2013; George and berger, 1966) that histological variation in the pectoral muscles of examines birds concerning the nucleus situation where in fowl it has a prephirial situation) but deeply situated in pigeon and duck were in agreement with that given by (George and berger, 1966).

5. REFERENCES


