Applied Biological Research 24(1): 70-75; (2022)
DOI: 10.5958/0974-4517.2022.00014.3

COMPARATIVE GROSS ANATOMICAL STUDIES ON THE FREE CAUDAL VERTEBRAE AND PYGOSTYLE OF KITE, CROW AND PIGEON USING DERMESTID BEETLE TECHNIQUE

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(Received 26 December, 2021; accepted 13 February, 2022)

ABSTRACT

The present study was aimed to study the gross anatomy of free caudal vertebrae and pygostyle of kite, pigeon and crow and compare individual vertebrae within and between the species. Twelve dead adult birds from each specie were used. The collected bones were prepared for study as per Dermestid Beetle Decomposition technique. The number of free caudal vertebrae in kite, pigeon and crow were 7, 6 and 6, respectively. The presence of bifid dorsal & ventral spine, and a distinct cranial articular process in initial segments was characteristic in kite. In pigeon, ventral spine was absent in 1st three caudal vertebrae while 6th caudal vertebra was mostly fused with pygostyle. In crow, ventral spine was absent in 1st two caudal vertebrae while in rest vertebrae it was tuberous. The length of transverse process in all the species was initially less, increased in middle region and reduced towards end. The last free caudal vertebra in pigeon lacked transverse process. The pygostyle was trapezoid in kite, triangular in crow and roughly quadrilateral in pigeon. The study revealed significant differences in caudal vertebrae within and between the species. The presence of cranaial articular processes and tuberculous structures suggested that free caudal vertebrae in kite were well-developed for strong catch hold to the skeletal muscles for better hunting. The pygostyle and free caudal vertebrae were more closely related in kite and crow than in pigeon.

Keywords: Caudal vertebrae, crow, kite, pigeon, pygostyle

INTRODUCTION

The skeletal system forms one of the important components in the body of animals, including birds. It forms a pivot, through the formation of joints, around which the muscles perform their action. In birds, the importance of skeletal system is further annunciated by its active role in flight, a feature distinct to the avian class. The system, besides being a preferred source of study, additionally plays a role in predicting the structure and average size within the population (Laydyguin, 2000). Caudal vertebrae, a skeletal component, comprise the posterior most region of the vertebral column in animals. The vertebrae nearly show all the features of the typical vertebra. The number of these vertebrae in birds varies from 10 to 15, depending upon the species. The initial segments are fused as a part of synsacrum, which is followed by free caudal vertebrae (5 to 9). The terminal portion of caudal skeleton is known as 'Pygostyle', a structure formed by the fusion of 3 to 7 rudiments (Baumel and Witmer, 1993). The fusion of these bones to form a more streamlined and fortified skeleton, with a reduced tail, is thought to improve flight dynamics and stability (Heers and Dial, 2012). A positive correlation exists between the length of tail and fusion of the last caudal vertebrae (Rashid *et al*., 2018). A reduced tail is considered beneficial for flight as evidenced by other flying vertebrates, like bats, as well as from the analysis on short tails (Clark and Dudley, 2009). An appreciable work has been done on different skeletal components like, rib cage of kite and crow (John *et al.*, 2015), shoulder girdle of pigeon hawk and kite (John *et al*., 2017), skull of owl (Choudhary *et al.*, 2020) and sternum of Asian Koel (Sathyamoorthy *et al*., 2021). Most of the research related to the caudal vertebrae of birds has been focused on domestic fowl (Konig *et al*., 2016; Low *et al*., 2016). Perusal of literature reveals that the primary anatomic data related to the caudal skeleton in most flight birds is either unavailable or not recorded in detail. The present study was, therefore, designed to gain an insight into the gross anatomy of free caudal vertebrae in kite, pigeon and crow; compare the individual vertebrae within and between the species, and to compare the anatomy of pygostyle among the three species.

MATERIALS AND METHODS

A total of 12 dead adult birds, of either sex, from three different orders *viz*., Columbiformes, Passeriformes and Accipitriformes were used in the present study. The birds *viz.,* pigeon (*Columba livia*), crow (*Corvus brachyrhynchos*) and kite (*Milvus migrans*) were divided into three groups of four birds each. The dead birds were collected in coordination with the Centre for Mountain Wild Life, Faculty of Forestry, Benihamma, Jammu & Kashmir. The bones were collected by using the process of Dermestid Beetle Decomposition (Hefti *et al.,* 1980). The caudal vertebrae were disjointed from the synsacrum and the immediate vertebra post-synsacrum was named as the 1st free caudal vertebrae. The succeeding vertebrae were numbered as per their order, with the vertebra immediately before pygostyle as the last free caudal vertebrae. The bones were finally cleaned in boiling water and dried under sunlight for 1 week. In present study the anatomical features discussed were dorsal spine, ventral spine, transverse process, cranial articular process and neural canal. The photographs were taken using I Phone 6 plus camera.

RESULTS AND DISCUSSION

The total numbers of free caudal vertebrae were 7, 6 and 6 in kite, crow and pigeon, respectively. In all the three bird species, the free caudal vertebrae were followed by a well-developed pygostyle (Fig. 1 and 4). The kite contained maximum number of free caudal vertebrae. Indian eagle owl the number of free caudal vertebrae has been reported to be 7 (Sridevi *et al*., 2020). In other birds the number of free caudal vertebrae are either 5 or 6; for instance, domestic chicken and turkey have 5 free caudal vertebrae (Nickel *et al*., 1977; Baumel *et al*., 1993; Konig *et al*., 2016). The total number of caudal vertebrae in pigeon were 15; of these, 1st five were incorporated with synsacrum, followed by 6 free caudal vertebrae, and the remaining 4 were fused to form pygostyle (Iuliis and Pulera, 2007). From the current study, it may be concluded that domestic birds have less free caudal vertebrae than the birds with strong flying power.

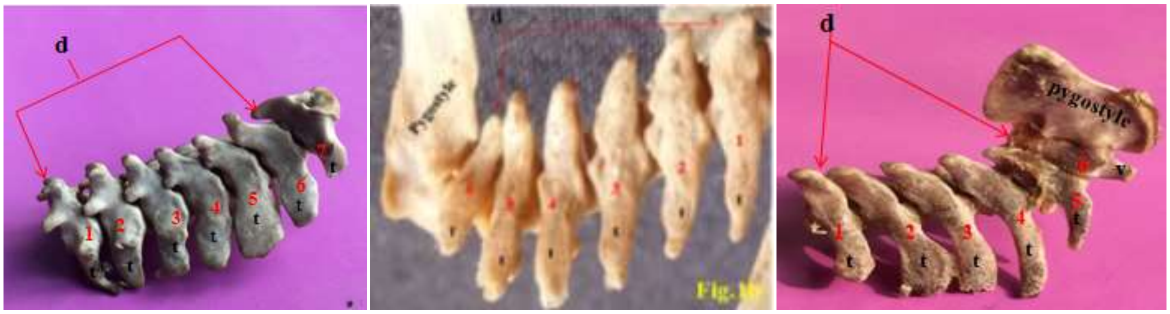

Fig. 1: The dorsal spine (d) and transverse process (t) in kite (left side), crow (middle one) and pigeon (right side)

Dorsal spine

The dorsal spine in the 1st vertebra of kite was bifid, followed by a less distinctly bifid dorsal spine, with a slight cranial tilt, in the 2nd free caudal vertebra. In 3rd and 4th vertebrae the dorsal spine was tuberous and undivided. In the succeeding caudal vertebrae, the dorsal spine appeared to be pointed. The dorsal spine in 7th vertebra was sharply pointed with reduced height and directed caudally (Fig. 1). Unlike kite, the dorsal spine in 1st three caudal vertebrae of crow was undivided and slightly tuberous. The dorsal spine was pointed in the succeeding vertebrae. In 6th free caudal vertebra, it was more cranial and reduced in height significantly. The dorsal spine in all the caudal vertebrae of pigeon was sharply pointed and directed more cranially, with last vertebra being least developed spine. The dorsal spine was bifid in all the 7 free caudal vertebrae of Indian eagle owl (Sridevi *et al*., 2020). Both kite and owl are predator birds. The bifid and tuberous nature of dorsal spine might provide a better support for holding the skeletal muscles to have better hold on the prey animals.

Ventral spine

The ventral spine in the 1st and 2nd free caudal vertebra of kite was in the form of a tubercle, and started to appear bifid in 3rd and the 4th vertebrae. The ventral spine in 5th, 6th and 7th vertebrae was distinctly bifid (Fig. 2). However, the bifid ventral spine of 7th free caudal vertebra fused at its free end to enclose a deep furrow. Irrespective of the nature of ventral tubercle it was always directed cranially. The ventral spines in the last few caudal vertebrae of golden eagle were distinctly bifid, and enclosed a deep furrow in the last caudal vertebra (Rashid *et al*., 2018). The ventral spine was absent in 1st three caudal vertebra of pigeon, well developed and slightly divided in 4th, and distinctly divided, at its tip, in 5th caudal vertebra. The ventral spine of 6th caudal vertebra in pigeon was tuberous at its tip, and was either distinctly separated from pygostyle or in few cases fused with it (Fig. 1). The ventral spine was absent in the 1st and 2nd caudal vertebrae of crow, as reported in Indian eagle owl (Sridevi *et al*., 2020). In 3rd and 4th vertebra, the ventral spine was projected in the form of a pointed process directed cranially. In rest free caudal vertebrae, the ventral spine was tuberous and blunt at free end (Fig. 2).

Transverse process of free caudal vertebra

The transverse process of 1st caudal vertebra in kite was stout, with sharp extremities, and curved caudoventrally. The process in 2nd vertebra was somewhat similar but better developed than the 1st one, whereas in case of 3rd vertebra the process was less curved ventrally and had blunt ends. The transverse process of 4th caudal vertebra was wider and longer than 1st three, and that of 5th caudal vertebra was characteristically the widest, largest and straight among all (Fig. 1). These findings are in agreement with the reports of Sridevi *et al*. (2020). In 6th and 7th vertebrae these processes were reduced and least developed. The transverse process in caudal free vertebrae of crow did not present any special features in general, except in 6th vertebra where the process was relatively reduced; the rest vertebrae did not show any significant difference in terms of above features. The dimensions of transvers processes in case of pigeon showed an increasing trend from cranial to caudal aspect, although it was reduced in 5th and practically absent in 6th free caudal vertebra. It can be generalized

Fig. 2: Ventral spines of the kite (left side), crow (middle one) and pigeon (right side). The red circles on 1st & 2nd vertebrae of kite, and 2nd to 6th vertebrae of crow indicate ventral spines which appear tubercle-like. The yellow circle on 5th & 6th vertebrae of kite and 4th & 5th vertebrae of pigeon indicates ventral spine which is bifid in the former and bifid at its tip only in the latter. The blue circle indicates furrow enclosed by fusion of bifid tips in 7th vertebrae of kite.

that while moving from cranial to caudal aspect the length of transverse processes was initially reduced, then increased in middle, and again showed a decrease towards end (Felice and O'Connor, 2014). A distinctive feature of the caudal vertebrae in kite was the presence of a well-developed tubercle at the junction of body and transverse process towards dorsal aspect. The tubercle was well developed in 1st two vertebrae, highly reduced in 3rd but completely absent in 4th and succeeding free caudal vertebrae (Fig. 3). The tubercle was observed in none of the free caudal vertebrae of pigeon and crow. The well-built of transverse process provides strong support to the muscles of lumber and hip region and this is particularly important in predator birds like kite and owl to have better hunting skills. Further evidence to this adaptation is provided by the presence of tuberculous structures on caudal vertebrae of kite, which was absent in pigeon and crow.

Cranial articular process

The cranial articular process was highly developed in 1st two caudal vertebrae, less projected in 3rd and 4th, but rudimentary in 5th caudal vertebrae of kite (Fig. 3). The cranial articular processes were completely absent in the succeeding vertebrae of kite. The cranial articular processes were absent in caudal vertebrae of both pigeon and crow. These processes might act as anchors for the attachment of muscle tendons in raptor birds like kite.

Neural canal

In all the three species the size of neural canal reduced while moving from cranial to caudal aspect of the caudal vertebrae. The size of neural canal was highly reduced in last free caudal vertebra of all the three species.

Fig. 3: Cranial articular process and tubercle-like structure in kite. Yellow circle on 1st to 5th vertebrae show cranial articular process while red circle on 1st and 2nd vertebrae shows tubercle-like structure

Fig. 4: Pygostyles of pigeon (left side), crow (middle one) and kite (right side); Red circle shows a through and through foramen

Fig. 5: Pygostyles in kite (left side), crow (middle) and pigeon (right side). Black circles show the furrow enclosed by the fused ventral spines while red circles show neural canal and 'g' depicts the glenoid cavity-like articular structure

Pygostyle

It was laterally compressed and lacked the transverse process in all the three species. Pygostyle was strongly developed in kite, moderately developed in crow and least developed in pigeon. The shape of pygostyle was trapezoid in kite, triangular in crow and roughly quadrilateral in pigeon (Fig. 4). The pygostyle had a broad base and a caudo-dorsally directed apex. The shape of pygostyle varied from roughly triangular to parallelogram (Konig *et al.*, 2016). The dorsal spine in kite was sharp and strongly curved while it was pointed and blunt in crow and pigeon, respectively. The body was relatively reduced in all the three species of birds and presented a weakly developed neural canal. The size of neural canal was highest in kite, followed by crow and pigeon (Fig. 5). At the junction of body and dorsal spine, a through and through type of foramen was present in the pygostyle of kite (Fig. 4). No such foramen was observed in either crow or pigeon. The cranial articular surface of pygostyle, in all the three species, was highly concave and almost appeared like glenoid cavity, to fit into the highly convex caudal articular surface of the last free caudal vertebra (Fig. 5). Such an anatomical arrangement gives an indication that there should be a very strong joint, as well as have significant mobility between the free caudal vertebrae and pygostyle in flight birds. The ventral spine of pygostyle in kite and crow enclosed a deep furrow (Rashid *et al*., 2018). No such structure was present in the pygostyle of pigeon. The pygostyle in birds formed the terminal skeletal element of vertebral column. The shape of pygostyle in birds is an important predictor of foraging behaviour (Felice and O'Connor, 2014). The pygostyle supports the preen gland and provides attachment to tail feathers (Low *et al*., 2016). Although we did not record the biometry of pygostyle, its size appeared largest in kite and smallest in pigeon. It may be concluded that pigeon have a stronger flying power than crow which, in turn, should be powerful flight bird than kite (Rashid *et al*., 2018). Further, the free caudal vertebrae and pygostyle were more closely related and strongly developed in kite and crow than pigeon. The anatomy of joint between the last caudal vertebra and pygostyle suggest a highly mobile tail in flight birds.

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