Osteological investigations of the incidence of cranial alterations in domestic ducks (Anas platyrhynchos f. dom.) with feather crests

T. Bartels¹, J. Brinkmeier², S. Portmann³, M.-E. Krautwald-Junghanns⁴, N. Kummerfeld², and A. Boos⁵

¹Institut für Tierzucht der Universität Bern, Bremgartenstraße 109 a, CH-3012 Bern, Schweiz; ²Klinik für Geflügel der Tierärztlichen Hochschule Hannover, Braunschweiger Platz 15, D-30173 Hannover; ³Institut für Tierzucht und Haustiergenetik der Justus-Liebig-Universität Gießen, Oberer Hardthof 18, D-35398 Gießen; ⁴Professur für Vogelkrankheiten der Klinik für Kleintiere der Universität Leipzig, An den Tierkliniken 17, D-04103 Leipzig; ⁵Anatomisches Institut der Tierärztlichen Hochschule Hannover, Bischofsholer Damm 15, D-30173 Hannover, Deutschland

Summary. The feather crest of the domestic duck (Anas platyrhynchos f. dom.) represents a peculiar mutation of the integument of the head, which has been known since the 17th century. In literature this is described as a variety with malformations in skull and brain anatomy in which various central nervous deficiencies in affected birds are possible. Our examinations demonstrated several conspicuous anatomical alterations in the skulls of domestic ducks with feather crests. Osteophytes of different size in the hypodermis of the crest integument were found as well as cranial perforations located in the parieto-occipital region. In morphometric studies, a significant increase in the capacity of the cranium was found in Crested ducks compared to other examined breeds (Abacot Ranger, German Pekin ducks). This increase in cranial capacity in Crested ducks results from the occurrence and enlargement of a tentorial fatty depot during craniogenesis. The formation and enlargement of the fat body can influence cranium growth as long as the cranial bones are not entirely fused. Thus, in comparison to other phenotypically similar domesticated birds like the crested chicken, the expression of feather crests in domestic ducks demonstrates symptomatologic differences. In conclusion, our examinations demonstrate that the skulls of Crested ducks show various peculiar morphological alterations whose genesis is up to now not known with satisfactory accuracy. Further investigations are continuing to ascertain whether there are linkages between cranial alterations (malformations of the calvaria, osteophytes, increased capacity of the cranium) and the extremely high prenatal and postnatal mortalities and numerous abnormalities described in crested breeds of the domestic duck.

Key words: Domestic duck – Feather crest – Exhibition poultry fancy – Cranial malformations – Persistent fontanels – Osteophytes

Introduction

The feather crest of the domestic duck (Anas platyrhynchos f. dom.) represents a peculiar mutation of the integument of the head which has been known since the 17th century (Praetorius 1678; Chapman et al. 1996). The feathers of the crest of the domestic duck insert into a thickened patch of the skin on the rear of the head, the so-called "crest cushion". With large crests, the crest cushion can develop into an extensive hump consisting of adipose and connective tissues (Requate 1959; Bartels et al. 2000).

In addition, Crested ducks show several remarkable anatomical modifications. Fatty tissue deposits in the Tentorium cerebelli partially result in considerable alterations of the brain morphology. Radiographic examinations have demonstrated that these intracranial fatty depots sometimes contain ossified structures of unknown origin (Bartels et al. 2000).

Furthermore, the head skeleton of domestic ducks with

Correspondence to: T. Bartels

© Urban & Fischer Verlag
http://www.urbanfischer.de/journals/annanat

0940-9602/01/183/1-73 $15.00/0
feather crests exhibits several anatomical alterations. Current radiographic examinations demonstrate osteophytes in the hypodermis of the feather crest integument as well as persistent fontanels in numerous Crested ducks, which explain the presence of encephaloceles seen in some specimens (Bartels et al. 1998, 2000; Brinkmeier 1999).

In comparison with the mammalian skull, the examination of the skull structures of birds presents difficulties, due to the specific anatomy of the head skeleton, in particular, the intense aeration of numerous cranial bones (Kostka et al. 1989). Diagnosing of perforations of the calvaria is frequently not possible with satisfactory accuracy due to perspective distortions and superposition of projection planes (Brinkmeier 1999). This is also applicable to the exact localization of osteophytes and malformations of the neurocranium which can be identified only in macerated skulls.

The aims of this study are:
- to examine the skulls of Crested ducks relating to the incidence of cranial alterations in this fancy breed and
- by doing so, to compare morphological and morphometrical results obtained from these birds to those obtained from other breeds of ducks and to other phenotypically similar domesticated birds described in literature.

Materials and methods

Skull specimen. In the present study, 159 skulls of adult domestic ducks (Anas platyrhynchos f. dom.) from both sexes were available. Research was done on skull specimens from 122 Crested ducks. Ninety-six ducks showed feather crests of varying size whereas 26 ducks showed no phenotypically recognizable crests. Skulls of ten Abacot Ranger and 27 German Pekin (duck breeds without hereditary feather crests) as well as skull specimen of five Mallards (the ancestor of the domestic duck) were compared.

Before defleshing the skulls, latero-lateral and dorso-ventral radiographs were made for determining the occurrence and position of osteophytes in the crest cushion. Several Crested ducks demonstrate intracranial fat bodies (Krautwald 1910; Requate 1959) which affect cranial development (Bartels et al. 2000). Because it is impossible to determine these structures by using conventional radiography, magnetic resonance images of each duck were made for determining the occurrence and position of cranial alterations in this fancy breed. Several Crested ducks demonstrated additional perforations in the caudolateral region of the Ossa parietalia whereas three further specimens showed alterations exclusively. Regardless of size and localization, the lamina externa of the parieto-occipital region was straight-edged in the area of the cranial defects. No signs of desmal osteogenesis such as spongy bone tissue could be noticed with the naked eye. In some degree the fringes of the cranial defects were vaulted. Five specimen (5.2%) demonstrated reductions in size of the Fonticuli occipitales. One skull showed a unilateral, another a bilateral occlusion of these cranial orifices.

Maceration. Defleshing the heads of the slaughtered ducks was performed by disjointing and then macerating them for 48–72 h at 65 °C in a 10% aqueous solution of enzymatic additives for detergents (Biozym SE, Fa. Spinnrad) (Bartels and Meyer 1991). This approved method is known for providing excellent results because the bone tissue is not affected by the maceration solution, and a significant influence on the calcium content of the bones of birds cannot be noticed (Rabeil 1995). After discharging in a 5% aqueous solution of hydrogen peroxide and drying the skull specimens were mounted with commercial glue (Ponal express, Fa. Henkel) with the help of the present radiographs.

Measurement of capacity of the cranium and determination of a skull index. For determining the capacity of the cranium, skull specimens of 55 Crested ducks (20 ducks of the phenotypically plain-headed variety, 15 ducks with feather crests of different size and 20 ducks with feather crests and intracranial fat bodies), ten German Pekin ducks, ten Abacot Rangers and five Mallards were examined. Cranial capacity was measured volumetrically by filling the cranial cavity with shot grain (diameter 2 mm). The basilar length of the skull (= maximal distance between the rostral part of the Os premaxillare and the Condylus occipitalis) was measured by using a sliding caliper (accuracy of measurement 0.05 mm). The skull index was derived mathematically as a proportion of basilar length of the skull and \( \frac{1}{3} \) cranial capacity (Röhrs and Ehinger 1978; Schauze Grotthoff 1984).

Statistical evaluation of data. Data of basilar length, cranial capacity, and skull index were analyzed using one way analysis of variance (ANOVA), last square means procedure, Pearsons correlation coefficient and regression analysis employing SAS® software (SAS Inst., 1988) and a personal computer.

Results

Crested ducks with feather crests. Eighty specimens (83.3%) out of 96 skulls of Crested ducks with feather crest showed morphological alterations of various degree. Seventy-eight skulls (81.3%) exhibited abnormal perforations of the calvaria of different number (1 to 5) and size (3.2 to 275.4 mm²) (Figs. 1–4). Forty-five specimens (46.9%), 24 specimens (25.0%), and eight skulls (8.3%) showed one, two and three cranial perforations respectively, at the occiput. In one duck, the neurocranium was perforated in the parieto-occipital region by a series of three extensive fissures and two smaller perforations in the calvaria separated only by narrow bony bars (Fig. 4). In 75 skulls (78.1%), the cranial defects were located in the intersections of the Sut. supraoccipitoparietalis, Sut. interparietalis and Sut. frontoparietalis. Four skulls demonstrated additional perforations in the caudolateral region of the Ossa parietalia whereas three further specimens showed alterations exclusively. Regardless of size and localization, the lamina externa of the parieto-occipital region was straight-edged in the area of the cranial defects. No signs of desmal osteogenesis such as spongy bone tissue could be noticed with the naked eye. In some degree the fringes of the cranial defects were vaulted. Five specimen (5.2%) demonstrated reductions in size of the Fonticuli occipitales. One skull showed a unilateral, another a bilateral occlusion of these cranial orifices. In eight skulls (8.3%), unilateral malformations of the caudal parts of the Ossa parietalia were observed. The Crista unchialis transversa of the latter skulls was also displaced ventrally. Unilateral anomalies of the Os paraspino- dale, that lead to malformations of the Cavum tympani and the Meatus acusticus externus, were found in four specimens. The Ala tympanica was absent and therefore, the ventral border of the external auditory canal was not developed. Distensions of the neurocranium in the area...
of the Ossa frontalia, Ossa parietalia and Ossa squamosa, as well as a remarkable transparency of the calvaria, was determined in eleven specimens (11.5%).

Twenty-nine skulls (30.2%) were marked by osteophytes of variable size and shape (Figs. 3–5). In 14 specimens these structures were attached to the parieto-supraoccipital region of the cranium and arched into the crest cushion, while in 15 cases, isolated osseous structures without any contact to the cranial skeleton were located in the hypodermis of the crest integument. Most of the osteophytes had the shape of small pins with a length of 7 mm to 33 mm and a diameter of 1 mm to 3 mm. Furthermore, in some cases, roundish exostoses as well as uncinated or flattened bones of an irregular form were found (Fig. 5). All osteophytes demonstrated a smooth surface.

In four specimens torsions of the skull were observed. In three cases, the whole skull was affected by a rostro-caudal twist, while in one specimen, only the maxilla was concerned. Additionally, three skulls showed an asymmetric course of the longitudinal axis of the cranium (Fig. 6).

Plain-headed Crested ducks. Two out of 26 skulls of phenotypically plain-headed offspring reared by pure-breeding Crested ducks, showed narrowings of the Fonticuli occipitales. Another specimen showed a flexion of the longitudinal axis of the viscerocranium.

German Pekin ducks. All skulls of the German Pekin ducks demonstrated Fonticuli occipitales which narrowed to small clefts (Fig. 7). Further morphological alterations could not be noticed.

Abacot Ranger and Mallards. The skull specimen of the Abacot Ranger (Fig. 8) and the Mallards showed no morphological conspicuousness. The Fonticuli occipitales were species specifically developed.

Basilar length, cranial capacity, and skull index. Basilar length differs significantly with breed (see Table 1, F value 13.41, p < 0.001). All types of domesticated ducks exhibit significantly higher basilar lengths than the ancestor, i.e., the mallards (p < 0.001, 105.4 ± 5.0 vs. 120.9 ± 3.4 to 127.4 ± 6.1 mm). German Pekin ducks and Abacot Rangers also exhibit significantly smaller basilar lengths than some varieties of Crested ducks (p < 0.05 and 0.01).

The cranial capacities of the examined duck breeds and varieties differ significantly (Table 1, F value 28.25, p < 0.001). Crested ducks with intracranial adipose tissue accumulations show a significantly higher (p < 0.001) cranial capacity (9445 ± 1668 mm³) in comparison to all other examined ducks (means ranging between 6140 ± 542 mm³ and 6685 ± 511 mm³). With maximum va-
Fig. 5. Lateral aspect of the skull of a Crested duck (Bird No. 334) with a large osteophyte of an irregular form attached to the occiput, x 0.7.

Fig. 6. Dorsal view on the skulls of two Crested ducks. In contrast to the upper specimen (Bird No. 10), the skull below (Bird No. 110) shows an asymmetric course of the longitudinal axis of the cranium, x 0.7.

Fig. 7. Caudal aspect of the skull of a German Pekin duck (Bird No. 603). The Fonticuli occipitales are narrowed to small clefts, x 1.4.

Fig. 8. Caudal aspect of the skull of a Mallard (Bird No. 78). The Fonticuli occipitales are developed species specifically, x 1.4.

Values up to 13,000 mm$^3$ compared to 7000 mm$^3$ in the other groups, the cranial capacity of Crested ducks with intracranial fat bodies can considerably exceed the cranial capacity of Crested ducks without intracranial fat bodies and non-crested birds (Fig. 9).

These differences are also evident by comparing the skull indices of the examined ducks (Table 1, F value 22.46, p < 0.001). With the exception of Crested ducks (16.84 ± 1.25) with intracranial fat bodies, all breeds or rather varieties of the examined domestic ducks showed a significant (p < 0.001) decrease in the skull index (mean skull indices 14.81 to 15.48) being compared to Mallards (17.37 ± 0.37). Crested ducks with intracranial fat bodies demonstrated a wide range of the respective data ranging from 14.31 to 19.27. This reflects a tendency to a disproportionate increase in the cranial capacity in numerous specimens of this morphological variety of the crested breed of the domestic duck (Figs. 10 and 11).

The latter aspect, i.e., the disproportionately greater cranial capacity in crested ducks with intracranial fat bodies, is corroborated best by the low Pearson’s correlation coefficient between basilar length and cranial capacity ($r = 0.076$, $p > 0.05$) as well as by the completely different respective regression equation ($y = -23x + 12356$). In all other breeds and varieties of the domesticated ducks included in the present study, correlation coefficients are significantly ($p < 0.05$) positive and range between $r = 0.65$ and $r = 0.81$, the highest value occurred in the wild duck, the Mallard ($r = 0.88$, $p < 0.05$). Correspondent regression equations are presented in Table 1.
Table 1. Basilar lengths, cranial capacities, skull indices, correlation coefficients and regression equations of the examined skulls of domestic ducks and Mallards

<table>
<thead>
<tr>
<th>Breed or variety</th>
<th>n</th>
<th>Basilar length [mm] mean ± sd</th>
<th>Cranial capacity [mm³] mean ± sd</th>
<th>Skull index¹ mean ± sd</th>
<th>correlation between basilar length and cranial capacity</th>
<th>regression equation between basilar length and cranial capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crested ducks with feather crest and intracranial fat body</td>
<td>20</td>
<td>125.3 ± 5.6abc</td>
<td>9,445 ± 1,668d</td>
<td>16.84 ± 1.25j</td>
<td>-0.076</td>
<td>&gt; 0.05</td>
</tr>
<tr>
<td>Crested ducks with feather crest</td>
<td>15</td>
<td>124.9 ± 7.2a</td>
<td>6,386 ± 4,888k</td>
<td>14.88 ± 0.59m</td>
<td>0.764</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Plain-headed Crested ducks</td>
<td>20</td>
<td>127.4 ± 6.1abcdef</td>
<td>6,695 ± 511k</td>
<td>14.81 ± 0.52mn</td>
<td>0.695</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Abacot Ranger</td>
<td>10</td>
<td>120.9 ± 3.4abcdef</td>
<td>6,560 ± 276k</td>
<td>15.48 ± 0.26mno</td>
<td>0.819</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>German Pekin ducks</td>
<td>10</td>
<td>121.7 ± 3.7ah</td>
<td>6,530 ± 363k</td>
<td>15.36 ± 0.34mn</td>
<td>0.657</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Mallards</td>
<td>5</td>
<td>105.4 ± 5.0b</td>
<td>6,140 ± 542k</td>
<td>17.37 ± 0.37lj</td>
<td>0.882</td>
<td>&lt; 0.05</td>
</tr>
</tbody>
</table>

Basilar length data differ significantly: a > b, p < 0.001; c > d, p < 0.05; e > f, p < 0.01; g > h, p < 0.05
Cranial capacity data differ significantly: i > k, p < 0.001
Skull index data differ significantly: l > m, p < 0.001; n < o, p < 0.05

¹Skull index = ( cranium-capacity / basilar length ) × 100

Fig. 9. Capacity of the cranium-basilar length-relationship of the examined ducks.

Fig. 10. Skull indices on the examined ducks (mean values and extreme values).
Discussion

This study demonstrates that Crested ducks exhibit several changes in skull morphology in comparison to non-crested breeds of the domestic duck. The development of the anatomical alterations has not yet been satisfyingly cleared. Phenotypically similar breeds of the domestic chicken (*Gallus gallus* f. dom.) with feather crests form a crest on the anatomical basis of a bubble-shaped distension of the skull (Requate 1959; Frahm and Rehkämper 1998). In contrast, the head skeleton of Crested ducks is not primarily involved in the development of a feather crest. In domestic ducks, the crest feathers are inserted into the crest cushion, a hypodermal thickening of the skin on the rear of the head. In former publications the genesis of the feather crests and associated alterations in domestic ducks had already been discussed. Krautwald (1910) and Rüst (1932) supposed that the development of a feather crest had been caused by an inhibition of the growth of several cranial bones, especially the *Os parietalia* and the *Os supraoccipitale*. As a result of an incomplete fusion of the calvaria, the protruding brain stimulates the hypodermis to thicken; thereby, the growth of a hypodermal crest cushion is induced as a cover for the calvaria defect and the underlying brain, as Krautwald (1910) and Rüst (1932) supposed. Requate (1959), however, assumed the primary alteration to be a thickening of the integument of the head and an increased formation of hypodermal adipose tissue. As a result, the proliferated tissue provokes an increased tissue pressure on the fontanel. This effects a fusion of the periosteum of the calvaria with the meninges and evokes persistent perforations of the skull typical for Crested ducks.

As further alterations of Crested ducks Krautwald (1910) described osteophytes of wheat grain size inserting at the skull. These exostoses were situated in bundles of connective tissue which passed through the perforation of the calvaria into the crest cushion. Krautwald (1910) supposed that they would functionally replace the absent parts of the calvaria. In the present examination in particular, slender-built bony pins were found which either stood perpendicular to the calvaria or were located in the crest cushion as isolated structures without direct contacts to the head skeleton. Furthermore, in many cases, the lumina of the cranial perforations were more extensive than the diameter of the osteophytes and therefore unsuitable for protecting the brain below the cranial perforations. Requate (1959) assumed that these bony structures might act as support for the crest cushion. Additionally, this function cannot be performed by bones lying isolated in the hypodermal adipose tissue; therefore, the osteophytes appear to be of no functional relevance to the affected ducks. It is still unknown as to what extent the osteophytes are related to additional rudimentary legs found inserting on the heads of some fetuses of Crested ducks (Bartels et al. 1998).

A similar phenotype to the crest development in domestic ducks seems to be verified in crested breeds of the domestic goose (*Anser anser* f. dom). The crested domestic goose not only develops a feather crest, but also shows perforations of the cranial roof (Lühmann 1949; Bartels et al. unpublished data). It is still unknown if and to what extent intracranial adipose tissue deposits which can influence cranium growth, occur in crested geese, as well as the heredity and gene expression of the feather crest of this species.

In numerous skull specimens of two breeds (Crested ducks and German Pekin ducks), reductions of various degrees of the lumen of the Fonticuli occipitales attract attention. Normally, these large paired openings dorso-lateral to the Foramen magnum permit the Sinus occipitalis to join with the Vena occipitalis dorsomediana (Baumel 1979; Vollmerhaus 1992). The question as to what extent the blood flow from the brain and the cranial cavity is hampered by narrowing or occlusion of the Fonticuli occipitales has not yet been answered.
In contrast to their wild ancestors, most domestic animals demonstrate distinct decreases in brain weight. Several cerebral regions are affected to different extents (Herre and Röhrs 1990). These reductions in brain weights, characteristic for the process of domestication, are also documented in domestic ducks (Ebinger 1995). It could be observed that the total brain weight of female domestic ducks had been reduced by 17.1% whereas the total brain weight of male domestic ducks had been reduced by 20.4%. In contrast to their wild ancestors, domestic ducks showed no sex related differences in brain size. Thus, domestic drakes have encountered a higher reduction of brain weight during the process of domestication than female ones (Ebinger and Löhmer 1985).

When compared to Mallards, the capacity of the cranial of domestic ducks shows a mean decrease of 8.1% (Schulze Grotthoff 1984). Certainly these results are unassignable to Crested ducks. In contrast to Abacot Ranger (6 000 to 7 000 mm³) and German Pekin ducks (5 600 to 6 800 mm³), the cranial capacity of the examined Crested ducks demonstrate a wide range of measured values (5 300 to 13 000 mm³). These results coincide dimensionally with cranial capacities of these duck breeds as revealed by using computer-assisted tomography (Bartels et al. 2000). The increased capacity of the cranium of Crested ducks develops as a consequence of partially voluminous fat deposits in the Tentorium cerebelli which were found in this duck breed with a high incidence (Brinkmeier 1999; Bartels et al. 2000). This increase can influence the growth of the skull, as long as the cranial bones are not yet fused. After conclusion of the neurocranial growth, a further increase of the intracranial fat body is viewed as the cause of sensory disorders frequently seen in Crested ducks (Krautwald 1910; Requate 1959).

In conclusion, our examinations demonstrate, that the skulls of Crested ducks show a number of peculiar morphological alterations the genesis of which is not known with satisfactory accuracy up to now. Further investigations are ongoing to demonstrate possible linkages between cranial alterations (malformations of the calvaria, osteophytes, increased capacity of the cranium), with the high prenatal and postnatal mortalities and numerous abnormalities described in crested breeds of the domestic duck (Krautwald 1910; Requate 1959; Bartels et al. 1998, 1999, 2000).

Acknowledgements. The skillful help of Mr. S. König (Institut für Tieranatomie der Universität Bern) is gratefully acknowledged. This study was supported by the Federal Ministry of Food, Agriculture and Forestry of Germany.

References


Krautwald F (1910) Die Haube der Hühner und Enten. Thesis (Diss vet med), Bern


79

Accepted July 17, 2000

80