Beak Deformities: Form, Function and Treatment Methods

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Abstract: This master class reviews key aspects of the skeletal anatomy of the beak, proper anatomic terminology of those structures, the muscles that move the jaws, their associated innervation, and the macro and micro integumentary anatomy of the beak. From this foundational understanding, specific medical and surgical approaches to a variety of these deformities are then explored, focusing on the prokinetic anatomy of the taxonomic order Psitaciformes.

Introduction: Clinical problems with the beak are common, and can be complex to address in many situations. Abnormal delivery of force vectors across the multiple joints of cranial kinesis and coupled kinesis can result in abnormal keratin wear, leading to progressive augmentation of malocclusion and beak deformities. Corrective beak trimming procedures, focusing on a balanced approach to altering force vectors can result in a return of normal function or reduced frequency maintenance procedural schedule for many birds. Surgical procedures of the head and beak are explored, including repair of palatine luxations and trans-sinus pin with tension band application for scissors beak deformities.

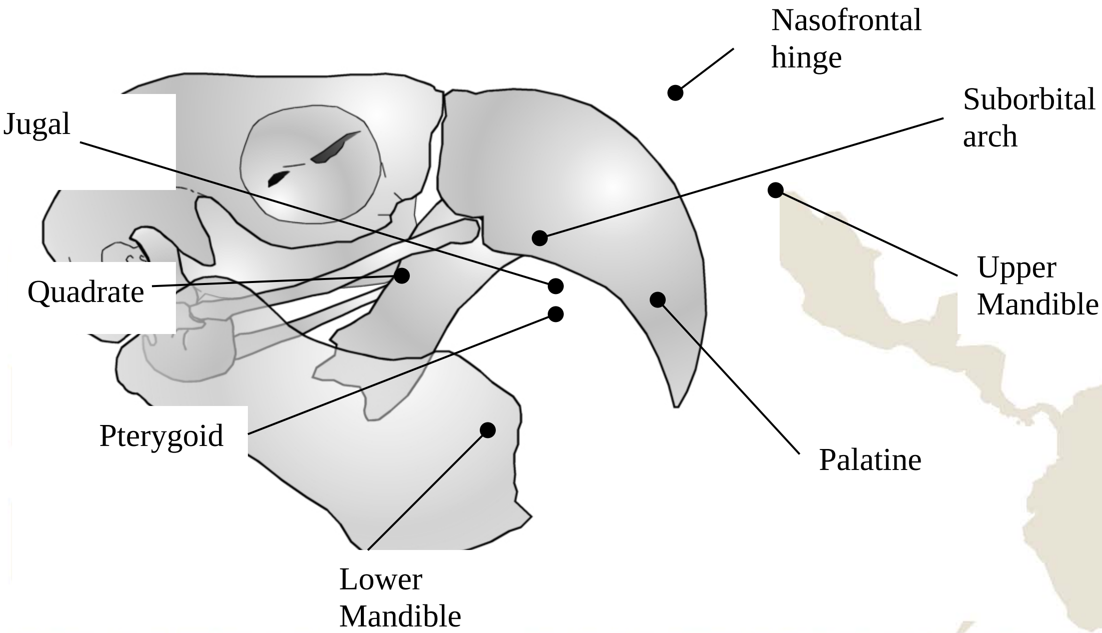
ANATOMY OF THE HEAD AND BEAK

Most of the unique skull morphology of parrots seems to be a product of the increased kinesis of their skulls.[1] There remains, understandably, confusion regarding their anatomic terminology. The bill or beak of birds is known anatomically as the rostrum.[2] It includes the bones of the upper and lower jaws and their horny sheaths. The upper component of the bill is known as the maxillary rostrum (rostrum maxillare) and the lower component as the mandibular rostrum (rostrum mandibulare).[1,2] The upper and lower beak of birds is covered by a hard epidermal structure, keratin, which covers the rostral parts of the upper and lower jaws. Synonyms for this keratin covering are the horny bill, or rhampotheca.[2] Synonyms for the upper and lower horny sheaths are the maxillary rhampotheca or rhinotheca, and the mandibular rhampotheca or gnathotheca.[2]

Skeletal anatomy

In most birds, the upper jaw functions as a rigid triangular block which may be elevated or depressed.[1,3] The upper jaw hinges at the flexible junction of the upper jaw with the braincase at the craniofacial hinge in parrots, which is a synovial joint.[1,] This form of cranial kinesis is prokinesis, where the movement of the jaw occurs at the junction of the jaw and the braincase.[1,3] Prokinetic movement of the upper beak requires the movement of four pairs of bones: the jugal arch, the pterygoid, palatine and quadrate bones.[1,3] (Figure 1)Movement of the upper jaw is also made possible by the presence of flexible elastic zones in the facial bones.[1] The two rami of the avian mandible are fused in the rostral midline at the symphysis.[1] The quadrate bone forms the primary link between the lower jaw and the cranium.[1,3] The pterygoid articulates rostrally with the rostral portion of the palatine bone and caudally with the quadrate bone in a synovial hinge joint.[1,3] The jugal arch articulates rostrally with the maxilla and caudally, it forms a ball and socket joint with the quadrate bone.[1,3] The quadrates are immensely mobile and function as the key elements in most of the movement of the upper and lower mandibles: articulating with the lower jaw (mandible), the braincase, the jugal arch and the pterygoid bone.[3] The joint formed between the quadrate and the braincase is a double articulation.[4] All of these bony elements are coupled mechanically; hence force applied at any point in the system either internally by muscle contraction or via external factors will be transmitted throughout the system and cause deflection of the system in one or the other direction.[1,3] The convention is to consider the quadrate as the starting point and to describe all movements as initiated from it.[1]

Figure 1: Skull anatomy of the Scarlet macaw (*Ara macao*)[3]



The muscles of the jaws

In most birds, 7 pairs of muscles act on the upper and lower jaws.[1] Parrots have 2 unique pairs of muscles and lack 1 of this original 7 pair, the pseudotemporalis profundus.[1] The 2 unique pairs of muscles that are present in parrots are Ethmomandibularis and Pseudomasseter.[1] The Ethmomandibularis closes and protracts the lower jaw, and the Pseudomasseter raises the lower mandible.[1] By seeking to capitalize on adjusting force vector delivery to the keratin contact surfaces of the upper and lower bills, the more balanced use of these muscles can result in more uniform keratin growth and wear in many deformities of the beak

Integumentary anatomy of the beak

The mid-dorsal profile of the maxillary rhampotheca is the culmen.[5] The maxillary rhampotheca has a cutting edge or tomium, on the left and right side (the maxillary tomia), which matches the opposing mandibular tomium, on the left and right side.[5] The midventral profile of the whole length of the mandibular rhamphtoeca is termed the gonys.[5] The gonys is formed entirely by horny tissue, and does not include the soft tissues of the lower mandible. The interramal region, or interramal space, is the zone of soft tissue which begins at the caudal end of the gonys and extends caudally between the mandibular rami as far as the end of the mandible.[5]The caudal portion of the interramal space is the gular region, which forms the floor of the caudal part of the oropharynx.[5] The entire opening of the mouth is called the oral opening or gape.[5] The rictus is the caudal part of the oral opening, beginning at the caudal end of the tomia and ending caudally at the angle of the mouth.[5]

Keratin is produced by the underlying dermis of the beak with varying contributions from the cere.[5] Both keratin surfaces are made up of a covering type (very thin) and a pressure bearing type (very thick) of keratin. Covering type keratin is located on the outer and lateral surfaces of the upper and lower beak. Pressure bearing type keratin is located on the undersurface of the upper mandible, the piercing/shearing point of the upper mandible and at the shearing edges of the upper and lower mandibles (tomia). Keratin normally migrates rostrally along the surface of the beak and laterally from its vascular bed.[5] The base of the culmen in some species is enlarged to form ornamental escrescences, some of which are molted after completion of breeding season.[5]

The horny bill of resembles skin, consisting of epidermis, dermis and bone. Dermis is closely attached to the periosteum. The epidermis is modified in two ways: The stratum corneum is very thick, and the cells of the stratum corneum contain free calcium phosphate and orientated crystals of hydroxyapatite.[5] These modifications, combined, provide the horny bill with its typical hardness.[5] Keratin arises from the malpighian cells of the bird's epidermis, growing from plates at the base of each bill.[5]

In waterfowl, the bill is hard only at the tip of both the upper and lower bill. These specific adaptations form the maxillary and mandibular nails respectively.[5] The nail and its associated dermis form a complex sensory organ. The whole complex is known as the bill tip organ and plays an important role in the sensory discrimination between food and other particles. The horn of the nail is perforated by canals which open through minute pores on the occlusal surface of the nail. Each of these canals is filled by a dermal core, corresponding to a highly specialized dermal papilla containing a profuse array of mechanoreceptor nerve endings. These dermal papillae project slightly through the pores on the occlusal surface of the nail, their projecting tips being capped by a thin covering of keratinized epithelium. Since the tips of the dermal papillae reach the occlusal surface of the nail, they are directly accessible to tactile stimuli during feeding. A bill tip organ has been described in the Senegal parrot, and likely exists in a large number of other parrot species.[6] In the Senegal parrot, seven pairs of pits within the rhamphotheca can be seen along the tomial edges of the rhinotheca, with a single pit at the bill tip. These pits, as described in waterfowl, probably contain clusters of mechanoreceptors. Irregular grooves are present in the maxilla or mandibular bone of the Senegal parrot, leading down towards the bill tip, suggesting the course of the blood vessels or nerve fibers supplying mechanoreceptors embedded in the keratin sheath. Many parrots also have grooves in the hard keratin (occlusal ledge) of the oral aspect of the upper mandible, which likely aids in grip of food items.[6-8] A similar arrangement of tactile pits in the maxilla is found in the mandible of the Senegal parrot, but in smaller numbers.[6]

Mechanoreceptors of the beak

The principal type of mechanoreceptor in the bill tip organ is the Herbst corpuscle.[6] These corpuscles have an

onion-like structure with a central axonal ending surrounded by numerous slender concentric cellular lamellae. These corpuscles are highly sensitive to vibration, and are capable of following very fast frequencies up to 1000Hz. The number and location of Herbst corpuscles that are present in the bill is related to the way the bill is used as a tactile exploratory organ during feeding.[6-8] In grain-eating birds, including many parrot species which cut or crack open seeds, the tip and lateral ridges of the bill are well supplied with Herbst corpuscles. These corpuscles are the most widely distributed mechanoreceptors in the avian body, occurring wherever there is mechanical disturbance that may require tactile detection. These can be found at the base of feather follicles, along the bones of the wing and pelvic limb, in muscles, tendons and joint capsules, near large blood vessels, and even in association with the alimentary canal and especially the cloaca.
Grandry corpuscles are distributed in the dermis of the bill that is associated with the soft horn in waterfowl, particularly near the sides and tip.[10] These corpuscles consist of one or two granular cells associated with numerous axonal endings, and closely resemble mammalian Merkel cells. These are rapidly adapting, velocity-sensitive mechanoreceptors. Grandry corpuscles are present in the dermis of the bill of grain-eating passerine species. In birds generally the nerve endings of the upper bill are innervated by the maxillary and ophthalmic divisions of the trigeminal nerve and those of the lower bill by the mandibular division.[9] The ophthalmic nerve supplies the palate, the edge of the upper beak and the bill tip organ.[9] The maxillary nerve is purely afferent and supplies receptor endings in the lateral tomia of the upper bill. The mandibular nerve is both somatic afferent and efferent, and passes the length of the mandibular canal, and provides branches to the skin associated with the lower beak, including the mandibular bill tip organ.[9]
Merkel cell receptors share similarity with the intraepidermal Merkel cell receptors of mammals, however, these are located in the dermis of birds.[10] Merkel cells have been found predominantly in the beak and tongue of various nonaquatic birds. It is speculated that Merkel cells function as secondary sensory cells like hair cells in the inner ear. Merkel cells may occur as single cells as well as in groups and may even be organized as corpuscles with stacked arrangement similar to Grandry corpuscles of aquatic birds.

Normal and abnormal keratin wear

Despite its hardness, the horny tissue of the bill is normally lost by wear and is continuously being replaced.[4] In birds that are maintained in companion or captive settings, the bill is sometimes not subjected to its' biologically intended use and resulting wear. This may be the result of the consumption of different food items, a lack of the normal enrichments that would provide such wear, or other factors. A frequent consequence of the lack of normal wear is the perceived or potential need for trimming of these beaks.
Beak trimming (amputation of the distal aspect of the upper bill) has been used in the poultry industry to provide a mechanical prevention of feather-pecking and cannibalism, and this practice continues in many countries today. The practice of beak trimming in poultry is typically done very early in life. When carried out correctly, the upper beak is trimmed / amputated not more than one third of the distance from the tip to the entrance to the nostrils Coping the beak in this manner results in altered prehension between the upper and lower bills, which mechanically prohibits these undesired behaviors. Normal food prehension, feather care and

normal occlusion and keratin wear are also altered. Feeding efficiency (number of pecks per gram of pellets ingested) is also reduced by beak trimming.[4] In adult poultry, this type of beak trimming has been observed to result in a temporary fall in the intake of food and a reduction in body weight that lasts at least six weeks.[4] These effects are seen to be greater if half of the beak is removed rather than one-third. Humanely and ethically, the profuse sensory innervation of the beak and the loss of capability of normal behaviors to be performed should be taken into account before advocating this procedure.[4]

Abnormal keratin buildup is frequently removed from captive parrots and the procedure(s) are often also referred to as beak trim procedures; although they do not imply the removal of bone as occurs in poultry. Beak trimming is often performed on parrots by veterinarians in private practice for cosmetic purposes and/or to remove excessive keratin that could lead to abnormal force vector delivery. Prokinetic muscle tension, form and function can become altered, as can the shape of the bones of the upper and lower mandibles itself. The joints and linkage ligaments of the prokinetic mechanisms of these birds can become secondarily strained or altered as a result. These deviations in force vector delivery in turn lead to continued development of malocclusion, and continued abnormal keratin growth as a result. As keratin grows abnormally, force vector delivery of the bills becomes progressively altered, leading to augmented malocclusion.

Keratin overgrowth can result from primary mechanical injuries to bone, dermis, innervation or the prokinetic musculature itself. Abnormal keratin growth can also result from disease conditions, including but not limited to Knemidocoptic mange, chronic hepatic disease or dysfunction in some species (not all), malnutrition, and infectious disease conditions including but not limited to Psittacine Beak and Feather Disease, neoplastic disease processes, and bacterial or fungal keratitis. As such, when trimming the beaks of these birds, it is logical and prudent to describe the deformities carefully, hypothesize the causality of the deformities with an understanding that the primary cause may be at times elusive, and strategize the most anatomically sound manner in which to trim. In addition, once keratin overgrowth has been shaped more correctly, a targeted enrichment strategy may help to reduce the frequency of necessary trimming procedures if not ultimately eliminate them through a careful restoration of form and function.

Beak Trimming and Shaping Procedural Concepts

Low stress handling and restraint methods are an essential component of these procedures. The potential for escalating escape and avoidance behaviors, learned fear, increased aggression, generalized fear, or even apathy is very real. These undesired consequences can directly adversely affect not only the outcome of the procedure itself, but the longer term health and welfare of the bird, as well as the continued strength of the doctor-client relationship. Where appropriate, skilled handling, strategic shaping of the restraint experience, conscious sedation or even general anesthesia may be indicated. Effectiveness is not merely judged by the accomplishment of the planned task, but it is also judged by the behavior of the bird during future visits and procedures. An escalation of escape and avoidance behaviors, aggression, generalizing fear or even apathy, when noted, should be promptly followed by altered handling and restraint methods.

The use of Dremmel tools is popular and effective for many keratin trimming procedures. These tools offer procedural speed, and access to the multiple keratin surfaces that may require attention. The optimal use of this tool requires the selection of the proper size and shaped bits, manual skills in handling and using the tool, and appreciation of the potential for heat that can be generated with excessive pressure or contact time. Excessive heat can be harmful if not skillfully avoided and mediated. Short bursts of bit-to-keratin contact will help minimize the heat generated, as opposed to continual grinding pressure throughout the procedure. Not all keratin deformities require the use of a Dremmel tool. A variety of other hand held trimming tools can be used, depending on the patient size, behavior, and the specifics and complexity of the deformities being addressed.

Keratin structures that should be evaluated and shaped in concert with each other include the rostral and lateral tomia of the rhinotheca, rostral and lateral tomia of the gnathotheca, the culmen, and the inner occlusal ledge of the rhinotheca. "Routine" beak trims should be questioned in regards to their true need, and a viable goal of reducing the frequency of these procedures or even eliminating their need should be maintained. A simplistic shortening or trimming of one component of the beak, without attention paid to the details of force delivery should be met with a much greater need and frequency of repeat trimming than should be viewed as ideal. Where dermal or boney involvement is planned or is known to have occurred, pain management should be incorporated into the procedural plan. In some select cases, pre-procedural radiography can help delineate the extent of trimming that may be most appropriate, and general anesthesia can be helpful for some more involved beak corrective trimming procedures. Following completion of the procedure, a targeted enrichment strategy to result in the functional increased use of these structures in more normal alignment should be contemplated and incorporated as a part of the whole procedure and its follow up.

Conclusions

Beak trims, although commonly performed and termed as such, are not a routine procedure. The true indications for their need should be critically evaluated, and procedures that are merely done as a part of a grooming protocol should be questioned. Beak trim procedures may not necessarily be appropriate, if the primary goals are cosmetic. Enrichment and behavior-change can help guide more normal beak use and normal wear for many companion parrots, negating the need for some of these keratin grooming procedures. Rather than a procedure that is viewed as merely the trimming of keratin, the immensely and delicate sensory anatomy of these structures should be considered when trimming and shaping keratin deformities of the beak. The biomechanical components of beak form and function and their interactions; keratin, dermis, bone, muscle and nerve anatomy should be considered as a component of what procedures are contemplated and performed. Perhaps more importantly these considerations are keys as a part of the follow up enrichment and functional self-imposed physical therapy for many of these deformities. Correct understanding of the anatomy terminology pertinent to these structures will enable their accurate descriptive use in your medical records, and more a detailed capability of follow up. Improved outcomes and more successful resolution of many, but not all, problem deformities can result. Even with those deformities that cannot be fully corrected, through a more detailed understanding of the biomechanics and anatomy of these structures, the frequency of necessary procedures should be able to be reduced, to the benefit of the birds.

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