Scapular Glenoid Observations of Six *Canis lupus dingo*

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Abstract

Scapular skeletal remains of six 20th century dingoes (*Canis lupus dingo*) were examined. One had been an elderly zoo resident, and five were taken in the wild. The zoo specimen and one wild-caught specimen each revealed an unusual bilateral ossified feature of the scapular glenoid fossa. The roughly triangular feature is visually similar to the appearance of a SLAP tear (glenoid superior labral tear, anterior-posterior) in humans. However, the SLAP tear injury is not compatible with current understanding of biceps tendon attachment on the domestic dog scapula. Additionally, the pattern of lateral peri-articular rimming in these six specimens suggests possible incipient pathological change. We discuss the differential diagnoses for these observations.

Keywords: *Canis lupus dingo*, dingo, glenoid fossa, ossification, scapula, shoulder

Introduction

Genomic studies suggest that the dog (*Canis lupus familiaris*) developed across multiple lines of Eurasian grey wolves (*Canis lupus lupus*), over considerable geographic range (Vila et al. 1997; Savolainen et al. 2002; Pang et al. 2009). The wolf - dog divergence appears to have originated around 100,000 years ago, with continued genetic exchange since that time (Vila et al. 1997; Hindrikson et al. 2012).

The development of the dingo (*Ca-*

nis lupus dingo), possibly from a small group of already-domesticated dogs (Oskarsson et al. 2012), and the pathways of its dissemination, are recognized regionally but not resolved temporally. Archaeological evidence supports Australian introduction of the dingo about 3,500 years ago, by migrating human groups. However, some genetic studies suggest possible Australian introduction ranging from 4,600 to as much as 18,300 years ago (Savolainen et al. 2004). With respect to cultural influences, whether the dingo's Australian introduction was associated with pre-Neolithic or Neolithic humans also remains unresolved (Milham and Thompson 1976; Gollan 1984; Newsome and Corbett 1985; Corbett 1995; Wilton et al. 1999; Pang et al. 2009; Ding et al. 2012; Oskarsson et al. 2012; Sacks et al. 2013).

We report our evaluation of scapular skeletal remains of 6 modern dingoes, describing unusual glenoid articular surface features in 2 individuals. We also examine articular margin and periarticular changes as possible incipient pathologies. Our purposes are to describe these features, discuss differential diagnoses, and suggest their possible significance.

Materials and Methods

Skeletal remains of one dingo (catalog ISM 688121) described in this report are curated at the Illinois State Museum Research and Collections Center in Springfield, Illinois (USA), where they are part of the Mammalogy collection. This specimen is an elderly adult with history of maintenance in a zoological park (Lowry Zoo Park, Tampa FL, USA), but with no other information available. Five additional skeletal remains of wild-caught dingoes are curated at the Field Museum of Natural History, Chicago, Illinois (USA).

All 6 individuals are 20th century adults. All skeletons had been disarticulated as a part of the clearing process. For this report, observations of 9 available scapular articulations and periarticular structures were described and photographed. Only scapulae are included in this report to allow focus on the glenoid morphological features, within a larger in-progress work.

Results

The right scapular articular surface of an immature *Canis lupus familiaris* provided a reference for gross morphology of the developing glenoid fossa (Fig 1). We evaluated glenoid fossa and articular margin morphology of 9 adult *Canis lupus*

dingo scapulae (5 right, 4 left) from 6 individuals (Table 1).

Articular bone surface

Normal glenoid articular bone surface was noted on 2 scapulae (different individuals). Rough glenoid articular bone surface was noted on 2 scapulae (same individual); one of the latter also revealed a medial-to-lateral 2-mm depression in the area of the small centrolateral ossification focus (Table 1). A 5th specimen was not cleared well enough to evaluate the articular surface thoroughly.

Four glenoid fossae, right and left from two individuals, revealed a slightly raised, rough-surfaced, approximately triangular feature extending from the mid-lateral notch area onto the articular surface (Figs 2, 3; Table 1). One dingo displaying this feature is the Illinois State Museum specimen (ISM 688121) (Fig 2), which also revealed a medial-to-lateral 2-mm linear depression near the periphery of the triangular feature on the left glenoid fossa (Table 1). Wild-caught dingo FMNH 54203, Chicago Field Museum, revealed the bilateral triangular feature at the same focus as did the Illinois Museum specimen (Fig 3; Table 1).

Articular Margin & Periarticular Structure

The ISM 688121 (Fig 4) and FMNH 54203 specimens both revealed prominent lateral periarticular rim formation that was lipped in a dorsal direction at mid-lateral. A lateral scapular radiograph (Fig 5) of specimen ISM 688121 revealed the periarticular rim structure as near-normal to mildly increased radiographic density, while the triangular articular surface feature was not visible. Similar articular margin rim or focused margin features also were noted on the other 5 scapulae (Table 1), varying in visual prominence.

Discussion

Articular Bone Surface

Differential Diagnosis: The primary differential diagnosis of the triangular feature observed on four glenoid fossae includes SLAP-type tear (human terminology: glenoid superior labral tear, anterior-posterior) (Andrews et al. 1985; Burkhart et al. 1998; Maurer et al. 2003-04; Snyder et al. 1990), osteochondrosis (OC) (Olsson 1982), acute or chronic trauma, non-OC developmental articular cartilage disruption (biochemical or nutritional lesion), or ossification center variant/abnor-mality.

Slap Tear: SLAP tear occurs in humans, associated principally with overhand movements such as throwing (Andrews et al. 1985). In humans, the tendon of the long

head of the biceps muscle arises 50% from the supraglenoid tubercle and 50% from the superior glenoid labrum. The latter is a fibrocartilagenous meniscus-like structure lying between the articular cartilage and the joint capsule; it is subject to tearing-type trauma (Maur-er et al. 2003-04; Vangsness et al. 1994).

Two arguments against SLAP tear in our specimens are that descriptions of the tendon of the long head of the domestic dog biceps indicate origination only from bone, on the tuber scapulae (Evans and Christensen 2003), and quadrupeds do not make the overhand provoking motions for SLAP tear. However, an evolutionary argument also should be considered. It has been suggested that the dingo may have developed from a small group of domestic dogs (Oskarsson et al. 2012), raising the possibility of a variant biceps tendon attachment among the originating domestic dog group, with subsequent perpetuation in a dingo cohort.

Osteochondrosis: A second diagnostic differential, osteochondrosis (OC), is a localized disruption of endochondral ossification leading to thickened articular cartilage. Separation of bone and articular cartilage may occur; this is termed osteochondritis dissecans. Usually, OC results from repetitive insult that creates focal loss of vascular supply to growing cartilage in a younger individual (Probst and Johnston1993; Ytrehus et al, 2007). An OC lesion can heal spontaneously or dislodge to leave a crater that heals by fibrocartilage deposition (Olsson, 1982; Yoshida et al, 1998). Since bone changes underlying the articular cartilage are not well explored post-OC in the domestic dog, and since clinical OC presentations vary by joint and species, OC cannot be ruled in or out with certainty.

Trauma: Post-acute trauma is a diagnostic possibility that also cannot be dismissed entirely. A sudden powerful force vector, applied from a distal direction, is a plausible explanation. However, three contrary arguments include (a) minimal existing additional pathology of the scapular glenoid, even during advanced life (specimen ISM 688121); (b) no obvious explanation for highly similar bilateral lesions in the second individual (FMNH 54203), and (c) the centrolateral portion of the scapular glenoid articular surface is partly shielded by the overlying scapular acromion (Evans and Christensen 1979), which was normal in both of these specimens.

Chronic low-grade movement-related trauma, secondary to nearly any other potential cause, conceivably could disrupt the centrolateral

glenoid fossa surface and margin, either during development or post-maturity. Periarticular rim formation is further suggestion of this diagnostic possibility.

Ossification Variant: The comparative view of the premature glenoid fossa of a domestic dog puppy suggests that the dingo feature could reflect an ossification plate variant or error, because of the positional alignment of the former and the observed triangular features. The short linear left glenoid fossa depression in specimens ISM 688121 and FMNH 57807 suggests possible incomplete ossification in the same area. While ISM 688121 demonstrated the glenoid articular surface triangular feature, FMNH 57807 revealed a laterally-oriented rough bone surface. The relationships among these features may or may not reflect interdependence, and require further research.

Possible Additional Factors: Additional potentially contributory factors such as biochemical and nutritional lesions are difficult to explain on the basis of current knowledge, and likely are not strong differential diagnostic possibilities. Likewise, lifestyle factors related to zoo confinement seem less likely when specimen sources are considered. However, a presently-unexplained disruption of calcification of the layer of articular cartilage immediately overlying the bony articular surface could not yet be dismissed.

Articular Margin and Periarticular Structure

Bony Rim Formations: Since the periarticular rim feature was noted on all 9 specimens, it could represent either an independent process or a multi-causal change. An additional factor requiring further research is whether the periarticular rim feature is a normal or near-normal aspect of aging, or whether incipient pathology is represented.

Radiography: A brief additional comment about the prominent rim-like articular margin-periarticular features is appropriate. The radiographic appearance (specimen ISM 688121) suggests only slightly increased density at the involved sites. Again, the question is raised: Are these features normal morphological variants, early pathological changes, or reactive structures that lead to later osteoarthritis only under given circumstances? Only further study can resolve this question.

Genetic Aspects of Further Research

Further genomic exploration of potential familial influence on the expression of the observed features on the glenoid fossa and articular margin-periarticular structure would

be a complex task, based on present knowledge. A large number of phenotyped individuals (minimum about 300) would be required, along with having DNA from each individual. Obtaining DNA of the necessary quality from museum specimens is a second challenge.

Study of living subjects would require pilot evaluations of imaging methods, along with resolving issues of specimen availability. If any modern domestic dog breeds are affected similarly, comparing dingo genome sequences to those of specified dog breeds could provide further, but indirect, evidence for a genetic effect. Given a captive study population with known pedigree, it would be possible to calculate heritability if a sufficient number of individuals were phenotyped (e.g. 50) and the phenotype was segregating in that population.

Conclusion

Differential diagnostic alternatives are presented for unusual features of the scapular glenoid articular bone surface, and for prominent articular articular margin-periarticular features. The diagnostic differentials likely could be resolved further for both observation sets, but examining large numbers of dingoes, and probably adding additional comparisons to domestic dogs, would be required.

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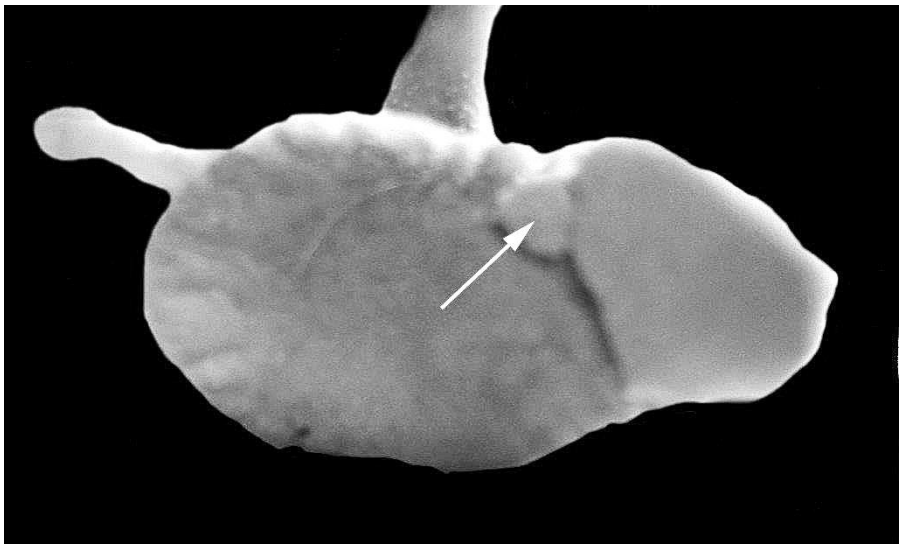

Fig (1): Right scapular glenoid fossa, juvenile domestic dog, showing immature ossification center (white arrow) in the location of the triangular feature observed bilaterally on two dingo specimens; Illinois State Museum Collection

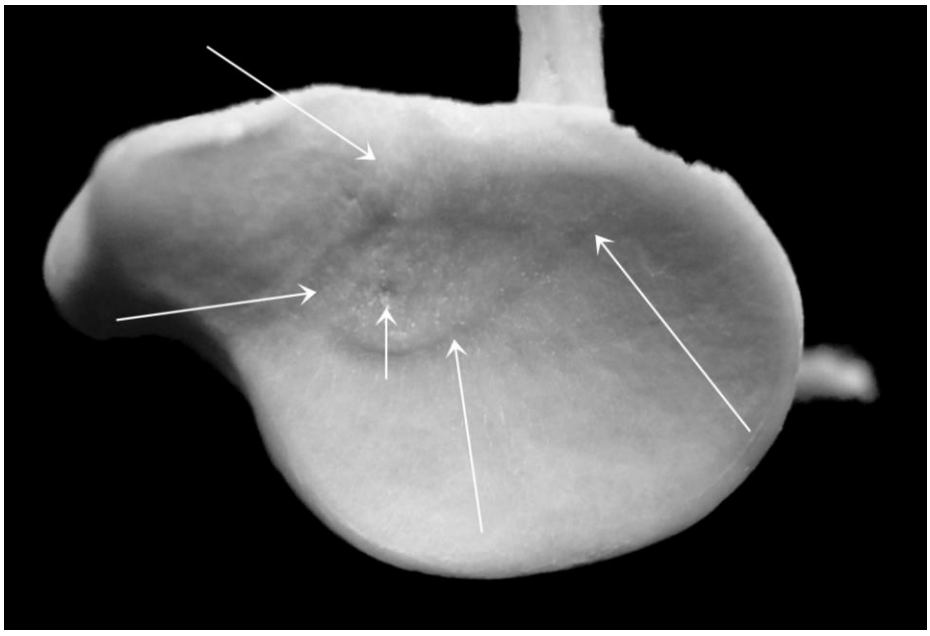

Fig (2): Left scapular glenoid fossa showing triangular feature (white long arrows), and a small hole within the feature that may be a pinpoint ossification center fusion defect (white short arrow); Illinois State Museum Collection (specimen ISM 688121)

Fig (3): Left scapular glenoid fossa showing triangular feature (white arrows); Chicago Field Museum of Natural History (specimen FMNH 54203)

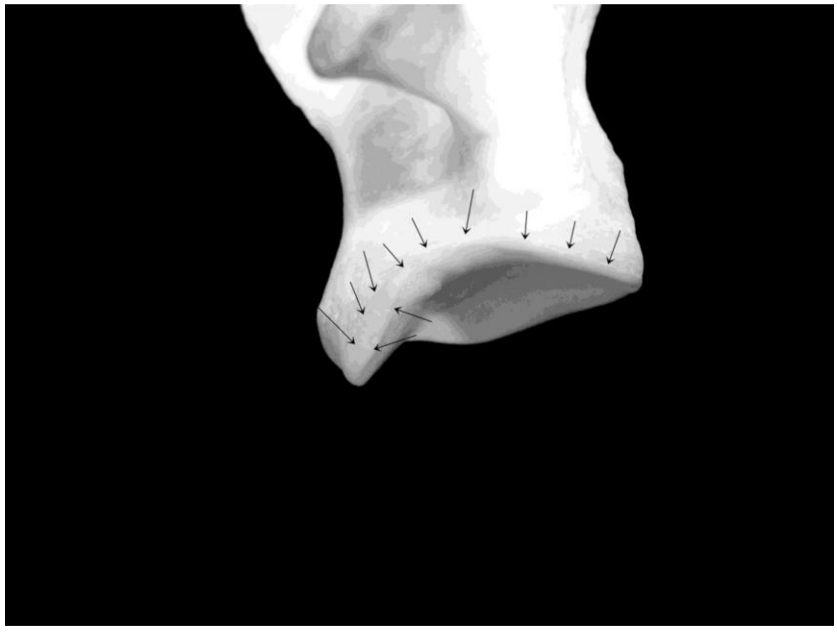

Fig (4): Left lateral scapular periarticular rim formation (black arrows); Illinois State Museum Collection (specimen ISM 688121).

Fig (5): Lateral radiograph of articular-periarticular structure, demonstrating increased density laterally (long arrow) and increased articular margin width with mildly increased density (short arrow); Illinois State Museum Collection (specimen ISM 688121)

Table (1): Scapular Glenoid Features of Six *Canis lupus dingo*

Identification	Structure	Articular Surface	*Articular Margin & Periarticular*
ISM 688121[a] (Zoo-USA)	Scapula (r, l)[c] glenoid	Mid-lateral raised triangular focus	Sharp-edged caudolateral Periarticular rim lateral Mid-lateral rim lipped
	Scapula (l) glenoid	Centrolateral 2-mm unossified focus	
FMNH 119851[b] (W. Australia 1976)	Scapula (l) glenoid	Normal	Craniolateral, -medial margin prominence
FMNH 119852[b] (Queensland 1956)	Scapula (r) glenoid	Obscured	Mild prominence
FMNH 57808[b]	Scapula (r) glenoid	Normal	Mid-medial periartic-ular prominence. Mid-lateral periartic-ular prominence. Mid-lateral rim lipped.
FMNH 57807[b]	Scapula (r) glenoid	Lateral zone of rough bone	Centromedial periar-ticular prominence Caudolateral, -medial margin prominence
	Scapula (l) glenoid	ateral zone of rough bone entrolateral 2-mm unossified focus	Medial periarticular prominence
FMNH 54203[b]	Scapula (r) glenoid	Mid-lateral raised triangular focus (Less prominent than (l) side)	Mid-lateral rim lipped
	Scapula (l) glenoid	Mid-lateral raised triangular focus	Mid-lateral rim lipped

[a] Illinois State Museum Research & Collections Center, Springfield IL USA
[b] Field Museum of Natural History, Chicago IL USA
[c] (r) – right side; (l) – left side