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Research Article

Bone pathologies in a modern collection of guanaco (*Lama guanicoe*): Contributions to the interpretation of bone lesions in archeological contexts

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ABSTRACT

Research on animal paleopathology has significantly grown in the field of zooarchaeology during the last years. Usually bone lesions have been associated to specific activities carried out by animals. However, the etiology and prevalence of many bone abnormalities are still uncertain due to the scarcity of studies in modern reference collections. The aim of this study is to determine the postcranial skeletal lesions that characterize a population of wild camelids and to differentiate bone lesions related to human management of camelids. For this purpose, we analyze the health status of a modern collection of guanaco by recording a series of indicators and its manifestation in different anatomical units. The osteological sample comprises 54 guanacos from Cinco Chañares, San Antonio department, Rio Negro province, Argentina. The frequency of lesions by anatomical unit, sex, and age were studied in order to generate parameters for comparison with other samples of contemporary camelids and with zooarchaeological record. The analyzed sample is characterized by infectious, traumatic, degenerative and congenital abnormalities in low prevalence. The most common pathologies were degenerative origin. These were significantly more frequent among senile adults, and were differentiated of the ones registered among domestic camelids.

1. Introduction

In recent years, publications on animal paleopathology have significantly grown in number. This discipline encompasses a wide variety of topics, such as the presence of pathology on sites (Miklíková, 2008; Vann, 2008), regional scales of analysis (Bartosiewicz, 2008; Murphy, 2005; Shaffer and Baker, 1997), the description of case studies (Bendrey, 2007), and the development of methodologies for lesion quantification and differential diagnosis (Baker, 1978; Bartosiewicz, 2007; Bartosiewicz et al., 1997; de Cupere et al., 2000; Johannsen, 2005; O'Connor and O'Connor, 2005; Thomas and Grimm, 2011; Thomas and Johannsen, 2011; Von Hunnis, 2009).

However, the etiology and prevalence of many bone anomalies are still uncertain due to the scarcity of modern collections as well as clinical case studies. As exceptions, Bartosiewicz et al. (1997), de Cupere et al. (2000), and Thomas and Grimm (2011), systematically analyze bone pathologies on modern collections from animals with known functional activities or lifestyle.

With respect to paleopathological studies in South American camelids, there is growing interest in exploring bone indicators (e.g., osteoarthritis, bone exostosis) to evaluate the management and domestication of animals by human groups, through the study of osteoarticular lesions (e.g., deFrance, 2010; Izeta and Cortés, 2006; Moore, 2008). Other osteological bioindicators (e.g., infection, trauma) have received much less attention. In order to systematically generate new information about the health status of camelids and broaden the discussion regarding the anthropogenic manipulation of animals, the present study was conducted. The main objective of this work is to analyze the health status of a modern collection of guanaco (*Lama guanicoe*, Müller, 1776) in order to apply a paleopathological perspective on postcranial skeletal lesions that characterize a wild camelid population. The osteological sample comprises 54 guanacos from Cinco Chañares, district of San Antonio, Río Negro province, Argentina (Fig. 1). The guanaco, as well as the vicuña (*Vicugna vicugna*, Molina, 1782), represent the wild South American camelid population, while the llama (*Lama glama*, Linnaeus, 1758), and the alpaca (*Lama pacos*, Linneaus, 1758) correspond to domestic forms of camelid. Through the creation of a database of modern bone pathologies in wild camelids, this work intends to give new insights into regarding the nature, frequency, and significance of bone pathology within archeological collections. Paleopathological studies of animals which are processed and consumed by humans can provide information about the health status of those animals that were selected for hunting, identify bones with lesions caused by hunters' weapons, and recognize pathologies that developed due to animal management by humans (Baker and Brothwell, 1980; Noe-Nygaard, 1974).

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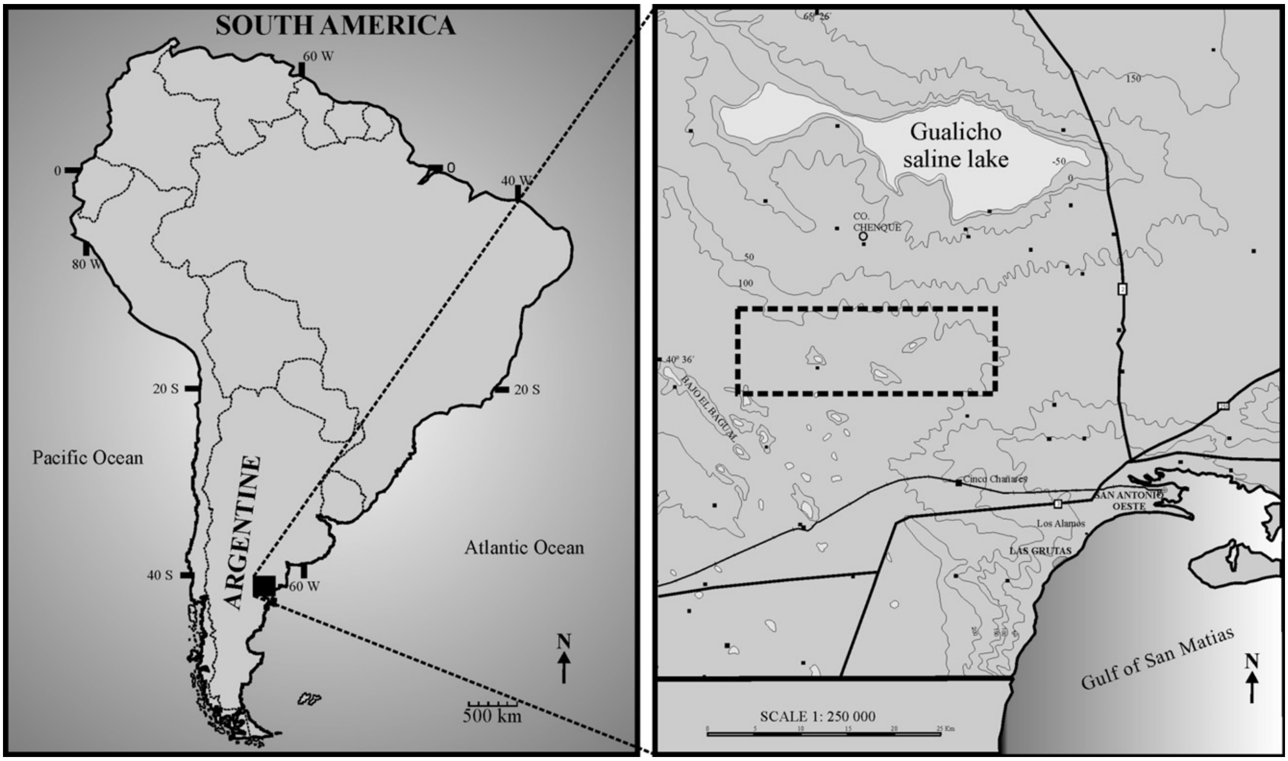

Fig. 1. Geographical provenance of the guanaco (*Lama guanicoe*) osteological sample.

2. Materials and methods

The individuals analyzed here were selected from a modern reference collection of 158 guanacos, which were collected during actualistic research by one of the authors (C.K.) in the district of San Antonio (Río Negro province, Argentina) between 2000 and 2006 (Kaufmann, 2009). The area of collection covers ca. 40,000 ha and is subdivided in six lots by 1.20 m tall fences, and unpaved public and private roads. The guanaco populations have shared the pasture and watering areas with cattle, sheep, and horses for at least six decades. The collection comprises guanaco carcasses deriving from the same biological population, whose causes of death includes poaching (41%), unknown causes (35%), entanglement in fences (18%), and puma predation (6%) (Kaufmann, 2009). This sample is currently being stored in the INCUAPA Research Centre (Universidad Nacional del Centro de la Provincia de Buenos Aires).

The region is characterized by a semi-desert, arid climate, and a landscape dominated by shrub vegetation typical of the Monte phytogeographical province (Cabrera and Willink, 1980). In this region, the landscape is made up of plateaus and plains forming a gently rolling relief, interrupted by depressions of varying depths (Guarido and Mazzitelli, 2003).

The sample consists of 54 guanacos (3515 postcranial skeletal elements) of different sex and age (Table 1). The individuals chosen for this analysis correspond to those with a greater skeletal completeness. With regards to the representation of different anatomical units, the standardized frequencies of skeletal parts (MAU%) reveals that the axial skeleton and pelvis and scapular girdle are very well represented (100–66%), with the exception of the sternebrae that have a very low frequency (33–1%), and the caudal vertebrae which are absent. The appendicular skeleton in general is well represented, although with low frequencies of patellae, metacarpals and phalanges (66–33%).

Osteopathological analysis was performed macroscopically and skeletal abnormalities were described according to their appearance, morphology, location, and involvement of the bone. Bone lesions were grouped according to possible etiology as traumatic, congenital, degenerative, and infectious/inflammation. Degenerative joint disease was identified based on the presence of porosity, the formation of new bone around the margins of the joint, and eburnation or a combination of two of these characteristics. The stage scoring system developed by Bartosiewicz et al. (1997) for recording deformations of the lower limb bones of domestic cattle was used in this sample to standardize criteria for describing and permitting comparison with other studies. In the present work, wide nosological classifications are used, and probable causes are discussed as hypotheses.

The prevalence of each nosological group was calculated considering, on the one hand, all the bones studied, and on the other, the number of individuals. Based on the behavioral activity of the guanaco during their regular lifespan (Franklin, 1982; Larrieu et al., 1982; Merino and Cajal, 1993; Ortega and Franklin, 1995;

Table 1
Number of analyzed individuals by age and sex.

Age category	Age (years)	Male	Indet.	Female	Total
Juvenile	0–1	–	11	–	11
	1–2	1	7	1	9
Prime	2–3	1	4	1	6
	3–4	–	–	3	3
	4–5	1	1	1	3
	5–6	2	–	2	4
	6–7	–	–	2	2
Senile	7–8	–	–	1	1
	8–9	–	2	1	3
	9–10	–	–	4	4
	10–11	2	–	3	5
	11–12	–	–	3	3
Total	–	7	25	22	54

Raedeke, 1979) the prevalence of lesions were estimated by one year age classes and three main age categories (juvenile: 0–2 years; prime: 2–7 years; and senile: 7–12 years). The observed differences between the frequencies of lesions by age and sex categories were tested through Chi-square statistical tests (differences at or below $p = 0.05$ are considered significant).

3. Results

Forty-seven bone lesions were registered in the 3515 anatomical units analyzed (1.33%). From this sample, 33.33% of the individuals showed some kind of bone abnormality (18/54), and affecting both sex with similar frequencies ($\chi^2 = 0.56$; $p = 0.45$). Likewise, significant statistical differences were not identified among the frequencies of lesions by affected elements in both sexes ($\chi^2 = 0.03$; $p = 0.84$). In the following paragraphs, bone lesions registered in the osteological sample are presented, according to their possible nosological group.

3.1. Degenerative conditions

A total of 29 osteoarticular abnormalities were identified, which could be classified as degenerative (0.82%; Table 2). They affected 11 individuals (20.37%), mostly of more than 7 years of age. There were a slight prevalence of females (1.25%) over males (0.46%), but this is not statistically significant ($\chi^2 = 2$; $p = 0.15$) (Tables 2 and 3). Lesions were registered in different bone types, with different frequencies, and they show similar characteristics and degrees in the articulations (lower limb bones with grade 2 of Bartosiewicz et al., 1997), such as porosity in articular borders, and marginal osteophytosis. A brief description of osteopathological cases is given here.

The axial skeleton presented two types of bone alterations. Two individuals showed misalignment of spinous processes of thoracic vertebrae, following different directions. In individual #150 (Table 3, Fig. 2A), scoliosis was observed in vertebrae. The vertebral lesion is related to a congenital abnormality of the sacrum (vide infra; Table 3). Furthermore, marginal osteophytosis and porosity were observed in the articular borders, in the cervical vertebrae facets, in the lumbar vertebrae superior facets, and both surfaces of vertebral bodies (Fig. 2B).

In the appendicular skeleton, lesions were similar in all bone items. In long bones of the anterior extremities, marginal lipping was registered in the proximal epiphyses of both humeri from individual #15 (Fig. 3A). Similar lesions were detected in the radius-ulna of another two individuals (#3 and #72; Table 3). In the case of the posterior extremities, a greater variability of articular lesions was registered. In femora, there were marginal osteophytes in the medial aspect of both femoral condyles (Fig. 3B). Articular osteochondrosis in the center of a medial condyle was recorded also. Only one tibia showed alterations in the proximal articular surface (Table 3). Marginal lipping was registered in short bones, in some cases associated with enthesial alterations in proximal phalanges (Fig. 3C). An isolated case of marginal lipping was also registered in the proximal end of a rib. Comparison of the skeletal distribution of lesions revealed that axial bones were more frequently affected (1.36%; 13/952) than appendicular elements (0.62%; 16/2563). This difference is statistically significant ($\chi^2 = 4.66$; $p = 0.03$).

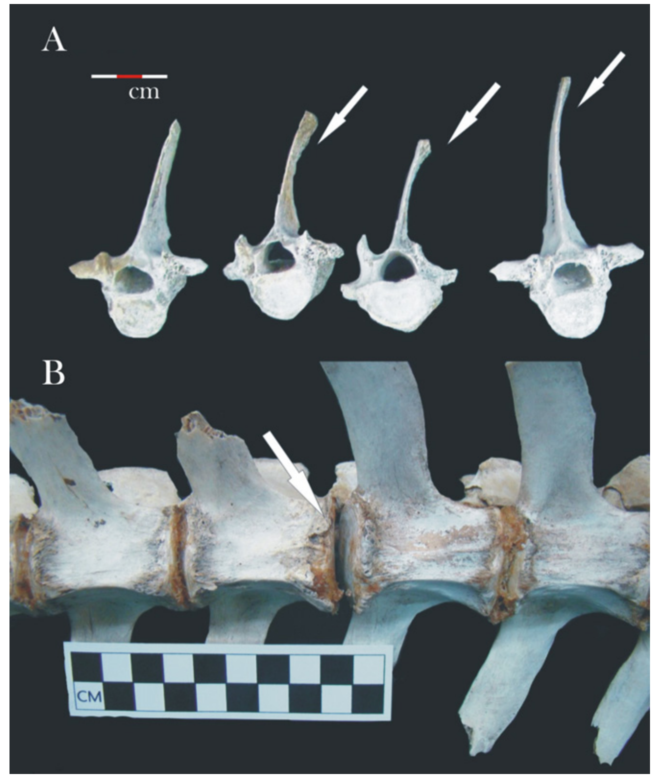

Fig. 2. Degenerative lesions: (A) misalignment of spinous processes in thoracic vertebrae (individual #150). (B) Marginal osteophytosis in lumbar vertebral bodies (individual #111).

Frequency of lesions by age categories shows that senile adult individuals (7–12 years) were more affected (2.22%; 20/900) than reproductive adults (2–7 years) (0.84%; 9/1062). This difference is statistically significant ($\chi^2 = 6.32$; $p = 0.01$). When considering the prevalence of lesions over the total number of affected individuals, a similar trend was observed, since 50% (8/16) of senile adults were affected compared with 16.7% (3/18) of reproductive adults; this difference is statistically significant ($\chi^2 = 4.30$; $p = 0.03$) (Table 4).

3.2. Traumatic conditions

Thirteen bone lesions with a probable traumatic origin were detected (0.36%; Table 2), affecting nine individuals (16.6%) of both sexes and different ages, with a slight prevalence among adults older than 4 years (Tables 3 and 4). Diverse types of fracture were registered, especially in ribs ($n = 6$) and, to a lesser degree, in coxae ($n = 2$), sternebrae ($n = 2$), tibia ($n = 1$) and vertebrae ($n = 2$). In the following paragraphs, the most conspicuous cases are presented.

Table 2
Frequency of lesions by sex and nosological groups. MNE, minimal number element.

Sex	*N*	MNE	Degenerative	Traumatic	Infection/inflammation	Congenital	Total lesions	%	% lesions/individual
Indeterminate	26	1727	10	0	0	0	10	0.57	7.69
Male	7	436	2	5	1	0	9	2.06	42.85
Female	22	1352	17	8	3	1	30	2.21	59.09
Total	54	3515	29	13	4	1	47	1.33	33.33
%/total lesions	–	–	59.18	24.07	8.16	2.04	–	–	–
%/total bones	–	–	0.82	0.36	0.11	0.02	–	–	–

Table 3
Lesions registered in each individual.

Specimen no.	Sex	Age	Bone	Side	Bone sector	Lesion
158	Female	19–24 months	Tibia	Right	Shaft	Osteomyelitis
			Tibia	Left	Shaft	Osteitis
148	Indet.	24–30 months	Cervical vertebra	–	Body	Osteophytosis
			Cervical vertebra	–	Body	Osteophytosis
			Cervical vertebra	–	Body	Osteophytosis
			Cervical vertebra	–	Body	Osteophytosis
132	Female	24–30 months	Coxae	Left	Ilium	Fracture
			Rib	Left	Body	Fracture
31	Male	5–6 years	12th thoracic-1st lumbar	–	Neural arch	Ankylosis
152	Female	5–6 years	Calcaneus	Right	Body	Periostitis
			Rib	Right	Body	Fracture
			Rib	Right	Body	Fracture
4	Female	5–6 years	First forelimb phalanx	–	Distal	Osteoarthritis
150	Female	6–7 years	Sacrum	–	Body	Sacralization
			Thoracic vertebra	–	Spine	Scoliosis
			Thoracic vertebra	–	Spine	Scoliosis
			Thoracic vertebra	–	Spine	Scoliosis
			Thoracic vertebra	–	Spine	Scoliosis
15	Female	7–8 years	First hindlimb phalanx	–	Proximal	Osteoarthritis
			Humerus	Right	Proximal	Osteoarthritis
			Humerus	Left	Proximal	Osteoarthritis
151	Female	8–9 years	Thoracic vertebrae	–	Spine	Scoliosis
			Thoracic vertebrae	–	Spine	Scoliosis
3	Indet.	8–9 years	Femur	Left	Distal	Osteoarthritis
			Radius-ulna	Left	Distal	Osteoarthritis
			Metatarsal	Right	Distal	Osteoarthritis
			Metatarsal	Left	Distal	Osteoarthritis
			First forelimb phalanx	–	Proximal	Osteoarthritis
			Carpus = scaphoid	Left	Articular surface	Osteoarthritis
72	Female	9–10 years	Femur	Left	Distal	Osteoarthritis
			Radius-ulna	Right	Distal	Osteophytosis
111	Female	9–10 years	Lumbar vertebra	–	Body	Osteoarthritis
			Lumbar vertebra	–	Body	Osteoarthritis
			Lumbar vertebra	–	Body	Osteoarthritis
			Rib	Left	Neck	Fracture
			1st and 2nd forelimb phalanx	–	Distal – proximal	Osteoarthritis
30	Female	10–11 years	Tibia	Right	Shaft	Fracture
24	Male	10–11 years	Tibia	Right	Proximal	Osteophytosis
			Scapula	Right	Spine	Enthesial alterations
			First hindlimb phalanx	–	Proximal	Osteoarthritis
			Rib and sternebrae	–	Sternal end	Ankylosis and infection
92	Female	10–11 years	Rib	Right	Vertebral end	Osteophytosis
			Rib	Right	Body	Fracture
5	Female	11–12 years	Second forelimb phalanx	–	Proximal	Enthesial alterations
50	Female	11–12 years	Coxae	Left	Ilium	Fracture

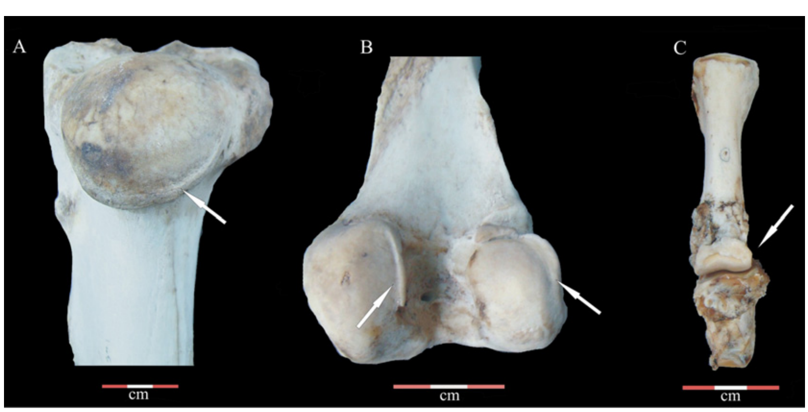

Fig. 3. Degenerative lesions: (A) marginal lipping and articular contour deformation in the proximal epiphysis of left humerus (individual #15). (B) Marginal lipping and slight articular osteochondrosis in the distal epiphysis of the left femur (individual #72). (C) Osteoarthritis in the distal epiphysis of a first forelimb phalanx, associated with eburnation in the superior portion, and exostoses in the distal. The second phalanx presents similar characteristics in its proximal articulation (individual #111).

Table 4
Frequency of bone pathology estimated by years.

Age	IN	BN	BP	D	T	I	C	IP	D	T	I	C
0–0.9	11	905	0.00	0.00	0.00	0.00	0.00	00.00	0.00	0.00	0.00	0.00
1–1.9	9	648	0.30	0.00	0.00	0.30	0.00	11.11	0.00	0.00	11.11	0.00
2–2.9	6	428	1.40	0.93	0.47	0.00	0.00	33.33	16.66	16.66	0.00	0.00
3–3.9	3	202	0.00	0.00	0.00	0.00	0.00	00.00	0.00	0.00	0.00	0.00
4–4.9	3	114	1.75	0.00	1.75	0.00	0.00	33.33	0.00	33.33	0.00	0.00
5–5.9	4	223	2.24	0.45	1.34	0.45	0.00	75.00	25.00	50.00	25.00	0.00
6–6.9	2	95	5.26	4.21	0.00	0.00	1.05	50.00	50.00	0.00	0.00	50.00
7–7.9	1	44	6.82	6.82	0.00	0.00	0.00	100.00	100.00	0.00	0.00	0.00
8–8.9	3	123	6.50	6.50	0.00	0.00	0.00	66.66	66.66	0.00	0.00	0.00
9–9.9	4	219	3.20	2.74	0.45	0.00	0.00	50.00	50.00	25.00	0.00	0.00
10–10.9	5	306	2.94	1.31	1.63	0.00	0.00	60.00	40.00	60.00	0.00	0.00
11–11.9	3	208	0.96	0.48	0.48	0.00	0.00	66.66	33.33	33.33	0.00	0.00

Note: IN, individual numbers; BN, bone numbers; BP, bone with pathologies; D, degenerative; T, traumatic; I, infection; C, congenital; IP, individual with pathologies.

When considering ribs, a case of a complete fracture in a body was registered (Fig. 4A), with no sign of healing. On the other hand, there were several cases of incomplete fractures. Individual #152 had two ribs with ossified calluses in the neck, with no deviation and well-remodeled callus formation (Fig. 4B), while another individual showed an incomplete fracture in a rib neck, with an ossified callus and a soft and homogeneous surface.

An outstanding pathological case was registered in one rib and several sternebrae (individual #24; Fig. 4C), with bone thickening, and ankylosis of the sternal rib portion and the sternebrae. In the center of the lesion there is a circular abscess, of moderate size (0.13 mm × 0.13 mm), associated with an osteoclastic reaction and an involucrum inside. Taking into account its characteristics, a combination of both traumatic and infectious processes can be suggested (see Section 4).

In os coxae, a case of a complete, remodeled fracture was registered in the antero-superior portion of a left ilium (individual #50). In the center of the lesion, the bone borders are separated, showing that ossification did not develop adequately (Fig. 5A). Another individual (#132) had a complete fracture in the left ilium, with signs of bone remodeling and thickening (Fig. 5B). The superior portion of the lesion showed a flat surface and moderate developed muscular insertions. Despite these abnormalities, no bone alterations were registered in the sacrum or the auricular surfaces of both ilia.

A spiral fracture was observed in a tibia of individual #30 (Table 3), which was well-healed and localized in the center of the diaphysis (Fig. 5C). This remodeling developed with a slight misalignment of the fractured ends, thus not maintaining the bone axis, although secondary complications did not arise.

Finally, a fracture affecting the last thoracic and the first lumbar vertebrae was registered in one individual (#31). It is characterized by a complete remodeling of the lesion, with ankylosis of the neural arches and the spinous processes of both vertebrae (Fig. 5D). The bone tissue regeneration did not produce exostoses or deformity, but it did alter the eleventh thoracic vertebra, ankylosing its inferior articular facets with the superior facets of the twelfth vertebra.

To summarize, traumatic lesions affected the appendicular (0.35%; 9/2563) and axial (0.42%; 4/952) skeletons in similar frequencies, with a non-significant statistical difference ($\chi^2 = 0.08$; $p = 0.76$). The most affected anatomical units were os coxae and sternebrae (Table 5). Trauma did not show a relationship with age, since it was registered in similar frequencies in reproductive adults (0.66%; 7/1062), as well as in senile adults (0.88%; 8/900) (Table 4). This trend is repeated if the total sample is considered, with a similar frequency of reproductive adults (22.22%; 4/18), and senile adults (31.25%; 5/16). No statistically significant differences were identified.

3.3. *Infectious/inflammatory conditions*

Four infectious/inflammatory lesions were non-specific in origin (0.11%; Table 2) and affected three individuals (5.5%) of different ages (Tables 3 and 4). In one individual (#158), a systemic bilateral infection (osteitis and osteomyelitis) was registered in both tibiae. In the right tibia, there was an osteoclastic reaction just along the mid diaphysis, and endosteal new bone formation that resulted in complete occlusion of the medullary cavity (Fig. 6A). There are also sequestrae with involucrum at both ends of the lesion; cloacae were not observed. In the left tibia, periosteal reaction was observed in

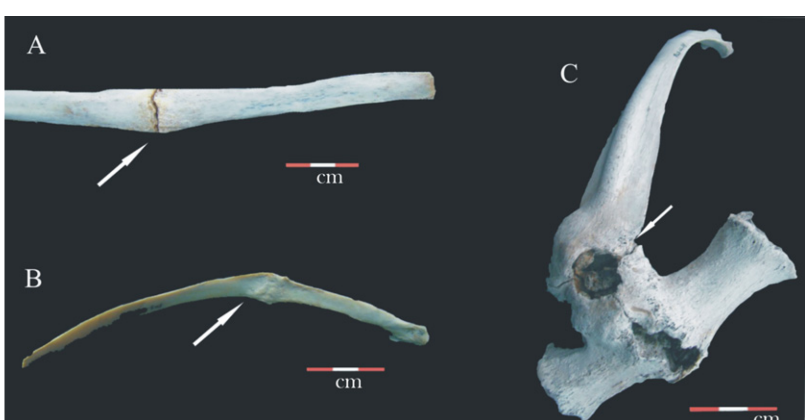

Fig. 4. Traumatic lesions: (A) complete, non-union, non-remodeled fracture in a left rib body (individual #132). (B) Remodeled fracture in a right rib neck. The callus is rough in the lateral surface, with an ossified line that indicates the oblique direction of the fracture (individual #111). (C) Ankylosis of the sternal portion of a right rib and sternebrae. Osteomyelitis in the center of the ossified callus (individual #24).

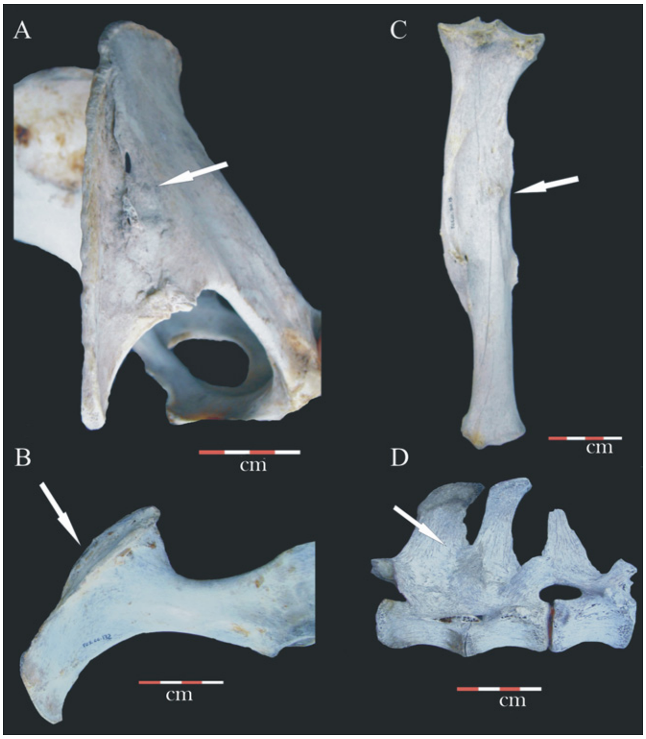

Fig. 5. Traumatic lesions: (A) complete, remodeled fracture in the left ilium (individual #50). (B) Complete fracture in the left ilium. Development of a flat surface and muscular insertions (individual #132). (C) Remodeled spiral fracture, in the center of the diaphysis of a right tibia (individual #30). (D) Ankylosis of thoracic vertebrae (nos. 11 and 12) and first lumbar vertebra (individual #31).

cortical tissue in a moderate surface (43.2 mm × 25.5 mm), at the same location of the previously described lesion. A limited circle localized in the lower third portion of the diaphysis, with an osteoclastic reaction on the cortical surface, was observed (Fig. 6B).

Table 5
Frequency of bone pathology by anatomical unit.

Anatomical unit	Totals	% lesions	% D	% T	% I	% C
Atlas	35	0	0	0	0	0
Axis	35	0	0	0	0	0
Cervical vertebra	163	0.6	0.6	0	0	0
Thoracic vertebra	417	0.7	0.7	0	0	0
Lumbar vertebra	210	0.9	0.9	0	0	0
Sacral vertebra	89	1.2	0	0	0	1.2
Caudal vertebra	14	0	0	0	0	0
Sternebra	108	0.9	0	0.9	0	0
Ribs	664	1.1	0.15	0.8	0.15	0
Scapula	76	1.3	0	1.3	0	0
Humerus	83	2.4	2.4	0	0	0
Radius-ulna	80	2.5	2.5	0	0	0
Metacarpal	35	0	0	0	0	0
Carpal	273	0.4	0.4	0	0	0
Proximal forelimb phalanx	121	2.5	2.5	0	0	0
Middle forelimb phalanx	102	1	1	0	0	0
Distal forelimb phalanx	88	0	0	0	0	0
Coxae	61	6.5	0	6.5	0	0
Femur	50	4	4	0	0	0
Patella	23	0	0	0	0	0
Tibia	74	8.1	1.3	4.1	2.7	0
Metatarsal	64	3.1	2	0	0	0
Talus	59	0	0	0	0	0
Calcaneum	56	1.8	0	0	1.8	0
Tarsal	232	0	0	0	0	0
Proximal hindlimb phalanx	112	1.8	1.8	0	0	0
Middle hindlimb phalanx	101	0	0	0	0	0
Distal hindlimb phalanx	90	0	0	0	0	0

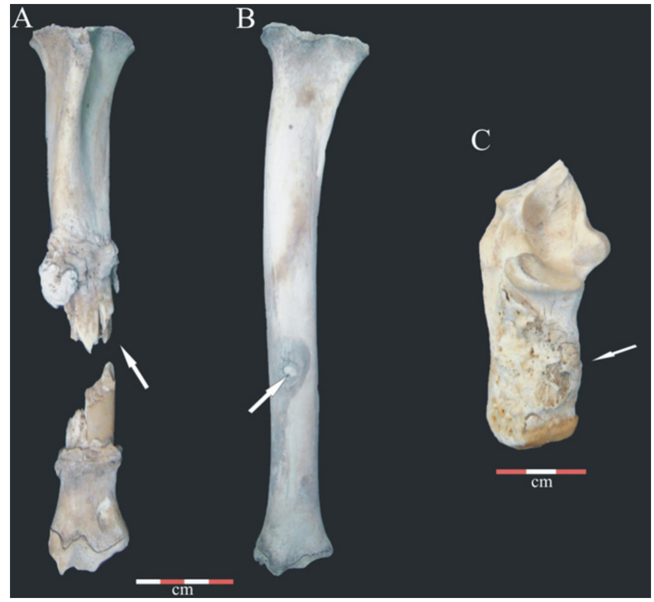

Fig. 6. Infectious/inflammatory lesions of non-specific in origin: (A) osteomyelitis in the right tibia. (B) Periostitis in the left tibia (individual #158). (C) Periostitis in the body of a right calcaneum on the medial and lateral sectors (individual #152).

In another individual (#152) an irregular periosteal reaction was registered in the supero-medial and lateral surfaces of the body of a right calcaneum (Fig. 6C). In a different individual (#24; see Section 3.2) osteomyelitis was recognized based on the presence of sequestra, porous hypervascular periosteal bone, and cloacae (0.15 mm × 0.15 mm) (Fig. 4C).

Few appendicular and axial bone elements were affected. Lesion prevalence by bone elements was similar for reproductive (0.28%; 3/1062) as well as for senile adults (0.11%; 1/900). The same trend was observed between reproductive (11.11%; 2/18) and senile adults (6.25%; 1/16).

3.4. Congenital conditions

Congenital conditions were recorded in only one individual (1.85%; 1/54), corresponding to the sacralization of the fifth lumbar vertebrae (0.02%, Table 2). This was characterized by the partial ankylosis of the inferior surface of the body of the fifth lumbar vertebra with the superior surface of the sacrum, especially on its left side. The non-ankylosed portion is misaligned just posteriorly (Fig. 7). This abnormality triggered degenerative changes in the articular facets and in the alignment of spinous processes of the thoracic vertebrae (Fig. 2A).

4. Discussion

The analysis of a modern osteological collection of wild guanaco showed a low frequency of pathological cases, both within anatomical units and individuals. The distribution of lesions among individuals, their degree of development, and the type of abnormality in each bone element were heterogeneous (Table 3), thus indicating different responses of organisms to stressors during their growth and development.

The most common lesions within the collection were those associated with degenerative processes, for example osteoarthrosis (Baker and Brothwell, 1980; de Cupere et al., 2000). The frequency of lesions registered by anatomical unit and discriminated by age group (Table 5) indicates that degenerative lesions were manifest in higher frequencies in both extremities, especially in the zygopodium and the stylopodium, as well as in the phalanges.

Fig. 7. Sacralization of the last lumbar vertebra (individual #150).

In a lesser frequency, these lesions were registered in the cervical, thoracic and lumbar vertebrae. The results indicate that different bone elements were affected, for both the axial and the appendicular skeleton. The causes of this pathology are not clear. Several deformities in the joints (e.g., acetabular-femoral), and enthesial alterations in posterior extremities (e.g., phalanges) have been associated with animal draught (Armour-Chelou and Clutton-Brock, 1985) and carrying activities (Cartajena et al., 2003, 2007; deFrance, 2010; Izeta and Cortés, 2006; Moore, 2008). However, these authors recognize that other factors, such as secondary response to fractures, normal animal aging, or repeated trauma due to the dwelling alongside abrupt landscapes, can produce this kind of pathology (Baker and Brothwell, 1980; Bartosiewicz et al., 1997; de Cupere et al., 2000; Fabiš, 2004; Thomas, 2008). Our study showed a high correlation between lesion prevalence (by bones as well as by affected individuals) and age, since lesions were more frequent among senile individuals. The frequency of degenerative pathologies rises from 6 years of age, with its highest prevalence at 7–9 years, and with a gradual decrease at the final stage of senility (Table 4 and Fig. 8). As a hypothesis, it is proposed that osteoarthrosic lesions are reactions to the normal aging process of the animal, and, to a lesser extent, affected by traumatic insult.

Within archeological contexts, the main objective of paleopathology has been to understand the impact that human management has on animal health (Thomas and Miklíková, 2008). Research that considers degenerative lesions has been concentrated on modern as well as prehistoric animals from domestic contexts (e.g., cattle, pigs, and sheep; Bartosiewicz et al., 1997; deFrance, 2010; Thomas, 2008; Vann, 2008). When considering camelids, zooarchaeological research has focused on species with evidence of domestication both the central and south Andes (Cartajena et al., 2007; deFrance, 2010; Izeta and Cortés, 2006; Moore, 2008; Park, 2001). The presence of osteoarthritic markers in phalanges and vertebrae has been considered as a possible indicator of carrying and transportation activities. In the present study (wild camelid), the same bone elements were affected, with similar characteristics to those associated with carrying activities (deFrance, 2010). Similar frequencies were also obtained from domesticated camelids in the Formative period (2500–1500 BC) from Chiripa (2.7%; Moore, 2008) and Tiwanaku (1200 BC to 100 AC) (1.6%; Park, 2001), among others contexts from Bolivia. However, the degrees of these lesions that appeared in the analyzed sample were lower (in no case exceeded the grade 2) than those registered in the domestication contexts mentioned above. In this sense, it is necessary to take into account several indicators when making inferences about animal behavior, such as the obtained frequency, the affected anatomical units, age of individuals, degree of bone involvement, and characteristics of lesions.

Traumatic pathologies were second in order of prevalence after degenerative lesions. The former may correspond to several factors, such as human-generated wounds (e.g., hunting with throwing weapons, fire-arms, and animal management), intergroup conflicts, predator–prey relationship, accidental fallings, articular stress, and bone tissue collapse due to illness (Baker and Brothwell, 1980). Traumatic lesions that were registered among guanacos did not show a relationship with animal age. Several cases of fractures were identified, especially in rib bodies and necks. Most of these lesions were well-healed, thus showing that the guanaco survived the traumatic events. Accidental fallings and hits during their lifetime may possibly be the main factors that influence their development. It is also important to indicate that guanacos are territorial animals, with frequent male fighting. This behavior should be analyzed since it can generate bone lesions such as the ones registered in the sample (e.g., rib fractures); although all rib fractures were recorded in female individuals (see Table 3). Considering the context of the sample, it is also possible to propose that some of the fractures observed are the result of impacts by vehicles traveling on the roads (e.g., fractures of the pelvis).

Most of the trauma produced bone modifications such as changes in muscular insertions (e.g., flexor muscles of the toes in the tibia), callus ossification, cortical tissue thickening, and morphological alteration of anatomical units. However, few lesions generated alterations in the surrounded anatomical units, in other words, they were basically localized.

Fig. 8. Frequency of degenerative pathologies by age.

Infectious processes were registered in low frequencies. The origin of the osteomyelitis and osteitis cases might be related to the presence of bacteria, such as *Staphylococcus aureus*, *Arcanobacterium pyogenes*, *Escherichia coli*, among others (Baker and Brothwell, 1980; Gulbahar and Gurturk, 2002). There are several ways of entering the animal skeleton, for instance an adjacent tissue infection, a compound fracture, or introduction via the blood stream (Baker and Brothwell, 1980). If we take into account the fact that the analyzed sample comes from a landscape dominated by shrub vegetation (Monte phytogeographical province), a potential access to soft and bone tissue is a lesion produced by vegetal thorns. This kind of lesion was observed in high percentages in metapodia and phalanges from the same guanaco reference collection analyzed by Rafuse et al. (2011).

In this sample of wild camelid there were no lesions that could be attributed to infection with bacteria of the genus Mycobacterium. But we do not discard the possibility that this wild species of camelids can carry these bacteria (e.g., *Mycobacterium bovis*) and could suffer from tuberculosis. These infections have been isolated particularly in modern domestic camelids, such as llamas and alpacas, although no record has been found for the guanaco to date (Bastida et al., 2011; Jorge et al., 2008; Ramírez, 1991). We consider it necessary to continue research on these diseases.

An outstanding pathological case was registered in a rib and several sternebrae (individual #24) but its characteristics do not allow the establishment of a specific cause. It is however stated, as a hypothesis, that the lesion resulted from traumatic and infectious conditions. In other words, a traumatic event caused a compound fracture on that bone portion. Bone remodeling generated a callus, whose ossification process ankylosed the sternal portion of the rib and its articulating sternebrae. Then, or simultaneously an unspecific infection (osteomyelitis) occurred. The presence of the cloacae and sequestrum (Fig. 4C), indicate the advanced stage of the infection. The cause of death of this individual could relate to this pathological process.

The present work highlights the low frequency of congenital pathologies, and underlines the absence of cases of polydactyly. This genetic defects seem to be relatively common in domestic camelids due to the high herd consanguinity (Ramírez, 1991), with a prevalence higher than 3.6% (Bani-Ismail et al., 1999; Briones and Valdivia, 1985; Fowler, 1989; Johnson and Gentz, 1990; Moore, 2008; Webster, 1993). Guanaco polydactyly has only been reported for an individual from the province of Tierra del Fuego (Zapata et al., 2008).

5. Conclusions

The analyzed sample of a modern guanaco collection is characterized by infectious, traumatic, degenerative and congenital abnormalities, with a general prevalence of 1.33%. The most common pathologies were those of degenerative and traumatic origin. Degenerative lesions were significantly more frequent among senile adults, and were different to those registered among domestic individuals because of their degree of development, which in any case went over grade 2, as defined by Bartosiewicz et al. (1997) for phalanges and metapodia. Another relevant aspect of this study – to be contrasted with the study of other wild populations – is the low frequency of congenital pathologies, which are related to domestic camelid herds.

The results show that although the analyzed collection comes from a wild population of camelid, they were affected by anthropogenic factors (e.g., roads, fences, cattle, and fire-arms). Such factors likely have impact on animal health and could lead to bone diseases different than those expected in prehistoric contexts. Nevertheless, the results achieved here constitute an important contribution to the knowledge of expected variability in pathological lesions within a wild guanaco population. Furthermore, this case study provides a background for exploring the impact that human societies have had on populations of camelid.

Finally, we consider that the study of samples from different geographical environments will enrich the knowledge of camelid bone pathologies, thus constituting a parameter in order to know types, degrees and frequencies of lesions associated with different cultural practices related to camelid management in the past.

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