Long Bone Fractures in Impala (Aepyceros melampus): A Classification System and Review of 55 Cases

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Funding: This project was funded by the Department of Companion Animal Clinical Studies, Faculty of Veterinary Science, University of Pretoria, South Africa.

Abstract

Objective: The purpose of this study was to introduce a modified-Unger fracture classification in impala and report the findings of 58 long bone fractures classified according to this system.

Methods: This was a retrospective radiographical study evaluating 122 radiographs of 58 long bone fractures in 55 impala. The Unger fracture classification was modified and fracture illustrations for the metacarpal and metatarsal bones added. Each fracture was classified and assigned a four symbol α-numeric code using our classification. The patient signalment, skeletal maturity, fracture-associated soft tissue changes, presence of fissure lines, periosteal reaction and cause of the fracture were recorded.

Results: The overall fracture distribution based on location, found tibial (n = 17) fractures to be the most common fractured long bone. When combined, the majority of fractures involved the metacarpal and metatarsal bones (n = 23). Forty five of 58 fractures occurred in the diaphyseal bone segment. In all long bones, the distribution based on complexity was simple (n = 27), wedge (n = 16) and multi-fragmentary (n = 15) fractures. Thirty one of 58 fractures were open and fissure lines were detected in 20 of 58 fractures.

Clinical Significance: Our modified-Unger fracture classification was applicable in classifying 58 impala long bone fractures. This classification should provide the basis for further advances in veterinary and comparative ungulates, and particularly the antelopes, orthopaedics and traumatology.

Keywords:

fracture classification - fracture distribution - long bone fracture - impala - ungulate

Introduction

The importance of antelope for conservation and their value in zoological and private wildlife collections has led to an increase in the need for sophisticated veterinary care.[1] The diagnosis and treatment of long bone fractures have consequently become more common in valuable antelope species, more specifically certain colour variations in impala (Aepyceros melampus). The foundation of any investigation into fracture management of a species is the development of a fracture classification that guides treatment, prognosis, comparative and retrospective studies. Ideally this classification should be simple, precise, repeatable and applicable to the species in question.[2] Classifications developed for long bone fractures in humans[3] and dogs and cats[2] meet this demand and still form the basis of the fracture classifications used by Arbeitsgemeinschaft für Osteosynthesefragen today. In these classifications, fractures are assigned an alphanumerical code based on the fracture location and morphology. The Unger classification has been extensively utilized in dogs and cats, and was historically found easy to apply and useful in processing and quick retrieval of data.[4] [5] [6] For dogs and cats, additional detailed fracture classifications exist for the central tarsal bone, accessory carpal bone, long bones, open fractures, sacrum, scapula and recently the pelvis.[7] [8] [9] [10] [11] [12] [13] In addition, growth plate fractures in dogs, cats and equines are classified based on the Salter and Harris classification developed for humans.[14] [15] [16]

Despite attempts to document fracture types in horses, no detailed fracture classification for long bones in this species has been published; however, a fracture classification of the third carpal bone, the olecranon and the distal phalanx is available.[17] [18] [19] [20] Furthermore, dog and cat fracture classifications were found to be inapplicable to long bone fractures in horses.[21] The purpose of this study was to develop a fracture classification system with a glossary of terms to define classification criteria and illustrations of fracture symbols. The findings of the 58 long bone fractures in impala classified with this system are subsequently reported.

Materials and Methods

Modified Unger Classification

Due to the lack of a fracture classification system available for ungulates, the Unger fracture classification was modified to apply to long bone fractures in impala. The fracture illustrations were drawn from an impala skeleton, depicting the species-specific skeletal anatomical details. Besides the incorporated unique anatomy of the impala, the most notable change to the Unger classification was the addition of a fracture illustration for the metacarpal and metatarsal bones. The same long bone fracture methodology was applied to this fracture illustration as for other long bone fractures. The anatomical similarity of the impala metacarpus and metatarsus allowed for one illustration to incorporate both long bones. To facilitate comparative studies, wherever possible the Unger classification was retained, while incorporating some changes and additions based on the most recent fracture and dislocation compendium.[22]

Fracture Location

The first symbol of the α-numeric code represented the fractured bone involved, followed by the segment of bone over which the fracture was centered.[2] The proximal and distal segments were demarcated by using the Heim square rule, by drawing a numerical square over the epiphysis on a craniocaudal radiographic projection ([Fig. 1]).[23] The only exception was for the proximal radius and ulna, where a rectangle incorporated the olecranon. Where fractures crossed the demarcated borders, the location was determined based on the segment possessing the larger portion of the fracture element.[9]

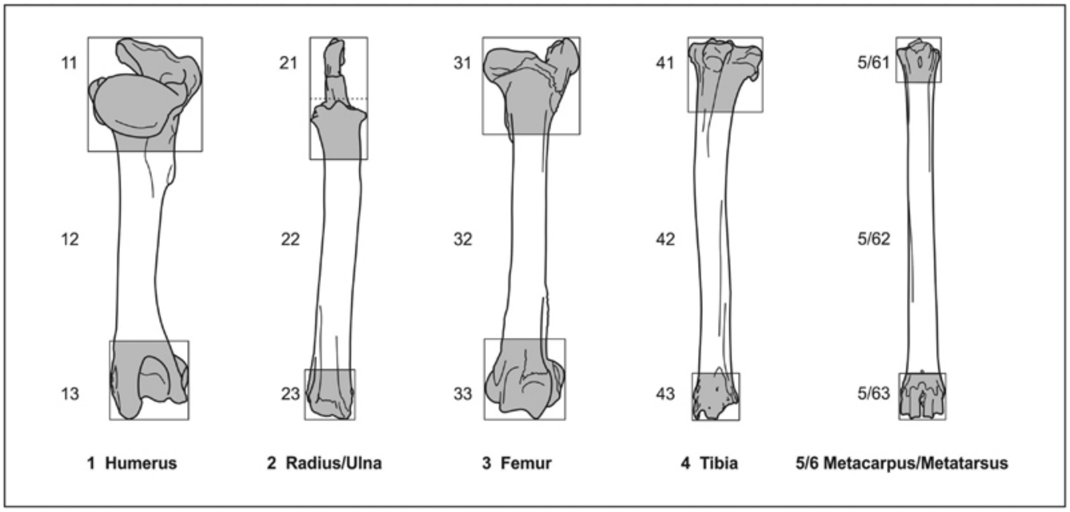

Fig. 1 A schematic illustration of numerical fracture location. First digit refers to the affected bone, second digit to the affected bone segment.

Fracture Morphology

Fracture complexity represented the third symbol, which in the diaphyseal bone segment, was based on the amount of cortical contact between the two main fracture fragments after envisaged reduction. Complete cortical contact in simple fractures was classified as (A), partial cortical contact in wedge fractures as (B) and no cortical contact in multi-fragmentary fractures as (C) (including segmental fractures). Fracture complexity in the proximal and distal bone segments was based on the amount of articular involvement: extra-articular (A) involved the metaphysis only, partial articular (B) involved either the lateral or medial aspect of a joint surface and complete articular (C) involved the metaphysis and the joint surface.

The fourth symbol represented the fracture severity ranging from 1 to 3, with 3 being the most severe. This was based on the morphological complexity, difficulty of treatment and prognosis of the fracture.[2] For simple fractures in the diaphyseal bone segment, the following definitions for fracture severity, as described by Unger, were used.[2]

- Incomplete: A fracture line with only partial cortical disruption (mono-cortical or 'greenstick' fracture).
- Oblique: A fracture line with circumferential cortical disruption. The fracture line is more than 30° to the transverse plane of the bone.
- Transverse: A fracture line with circumferential cortical disruption. The fracture line is less than 30° to the transverse plane of the bone.

For wedge and multi-fragmentary fractures in the diaphyseal bone segment, the following definitions for fracture severity are given below.[2]

Reducible wedge: An intermediate fragment (separated from the two main fracture fragments), with a length and width greater than one-third of the mid-diaphyseal bone diameter.

Non-reducible wedge: An intermediate fragment, with a length and width less than one-third of the mid-diaphyseal bone diameter. Fracture severity in the proximal and distal bone segments was based on the anatomy of the bone segments (e.g. lateral condyle, basicervical, medial malleolar), as well as some previously defined terms (including incomplete, simple, multi-fragmentary).[2]

[Figures 2] [3] [4] [5] to [6] illustrate typical individual impala long bones with the different locations, morphologies and severities of fracture classifications. The anatomical similarity between the metacarpus and metatarsus allowed for one illustration to incorporate both bones.

Our modified-Unger classification was applied to 58 long bone fractures in 55 impala. Three patients had two long bone fractures. Radiographic images of long bone fractures obtained from four private clinics (Pierre van Ryneveld, Kimberley, Medivet, Zodiac) and our academic hospital (Onderstepoort) were examined retrospectively. Only digital radiographic images of diagnostic quality, which allowed thorough assessment of the fractures, were examined. One-hundred and twenty-two radiographic images of long bone fractures were evaluated in digital imaging and communication in medicine format on a medical-grade, black-and-white two-megapixel monitor. Brightness, contrast and magnification were adjusted as needed to optimize the identification of lesions. Each fracture was classified and assigned a four symbol α-numeric code using the modified-Unger classification. The first two symbols represented the fracture location and the last two symbols the fracture morphology. The overall fracture distribution based on location and fracture morphology was determined using the α-numeric code assigned to each fracture. The patient signalment, skeletal maturity, fracture-associated soft tissue changes, presence of fissure lines, periosteal reaction, fracture displacement and cause of the fracture were recorded.

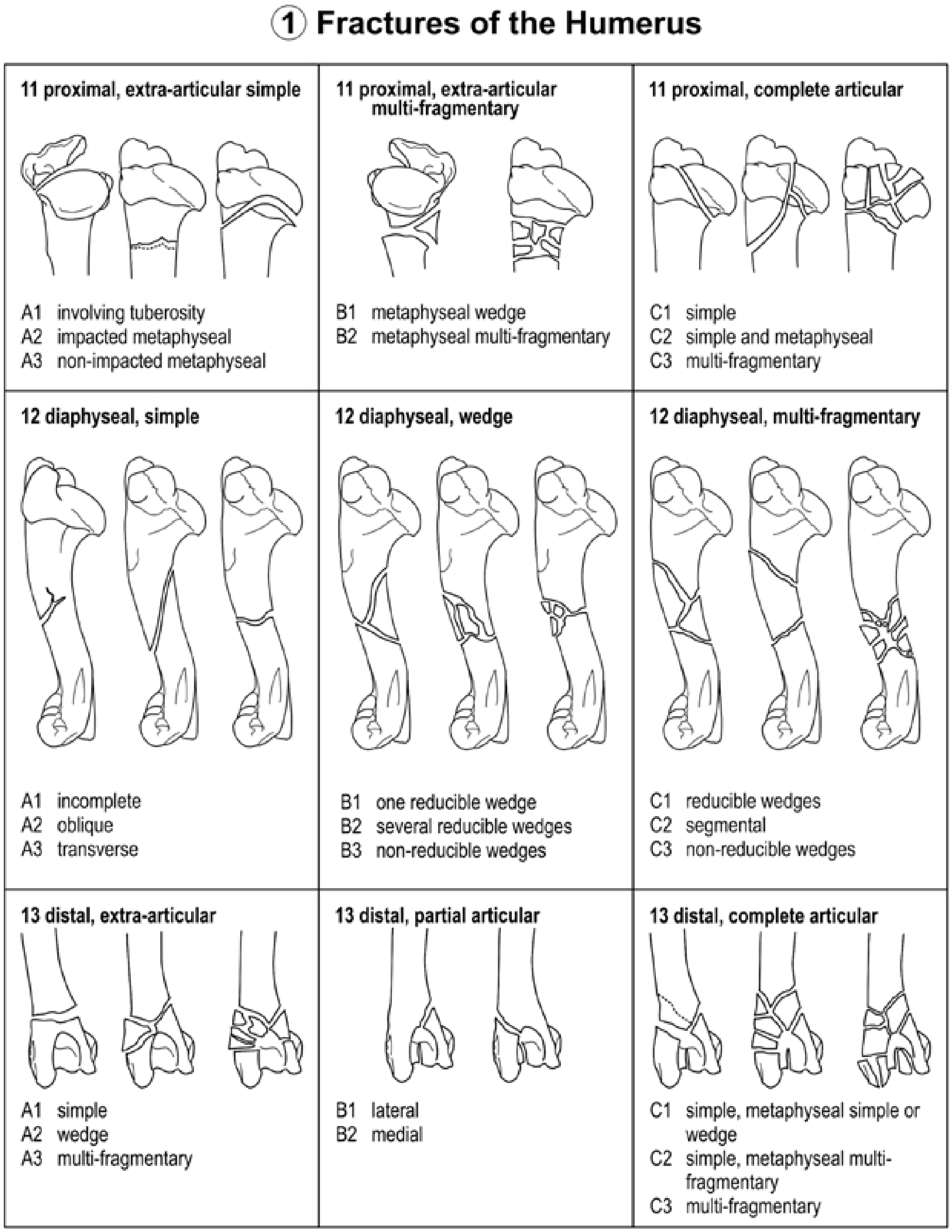

Fig. 2 Classification of the different groups of humerus fractures in impala.

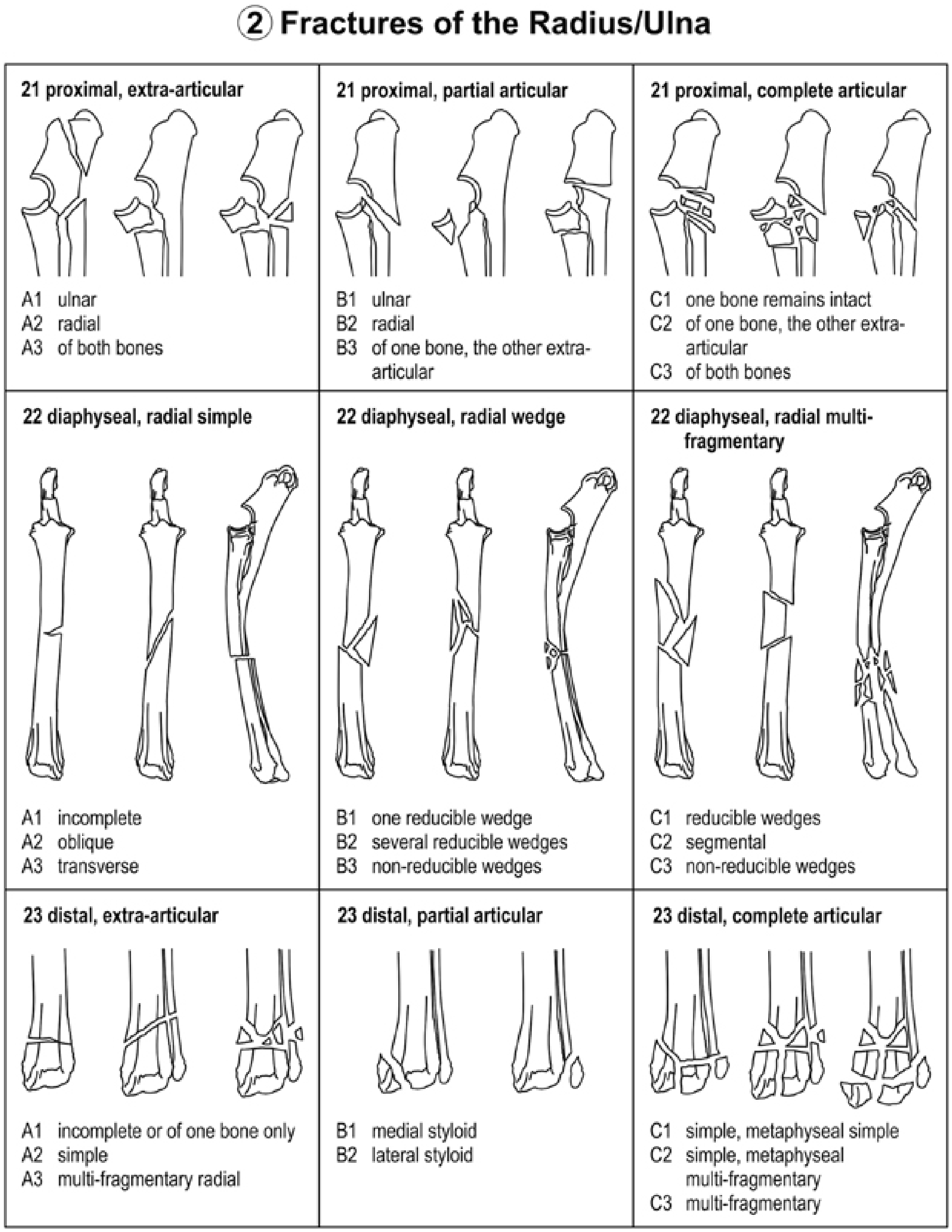

Fig. 3 Classification of the different groups of radius and ulna fractures in impala.

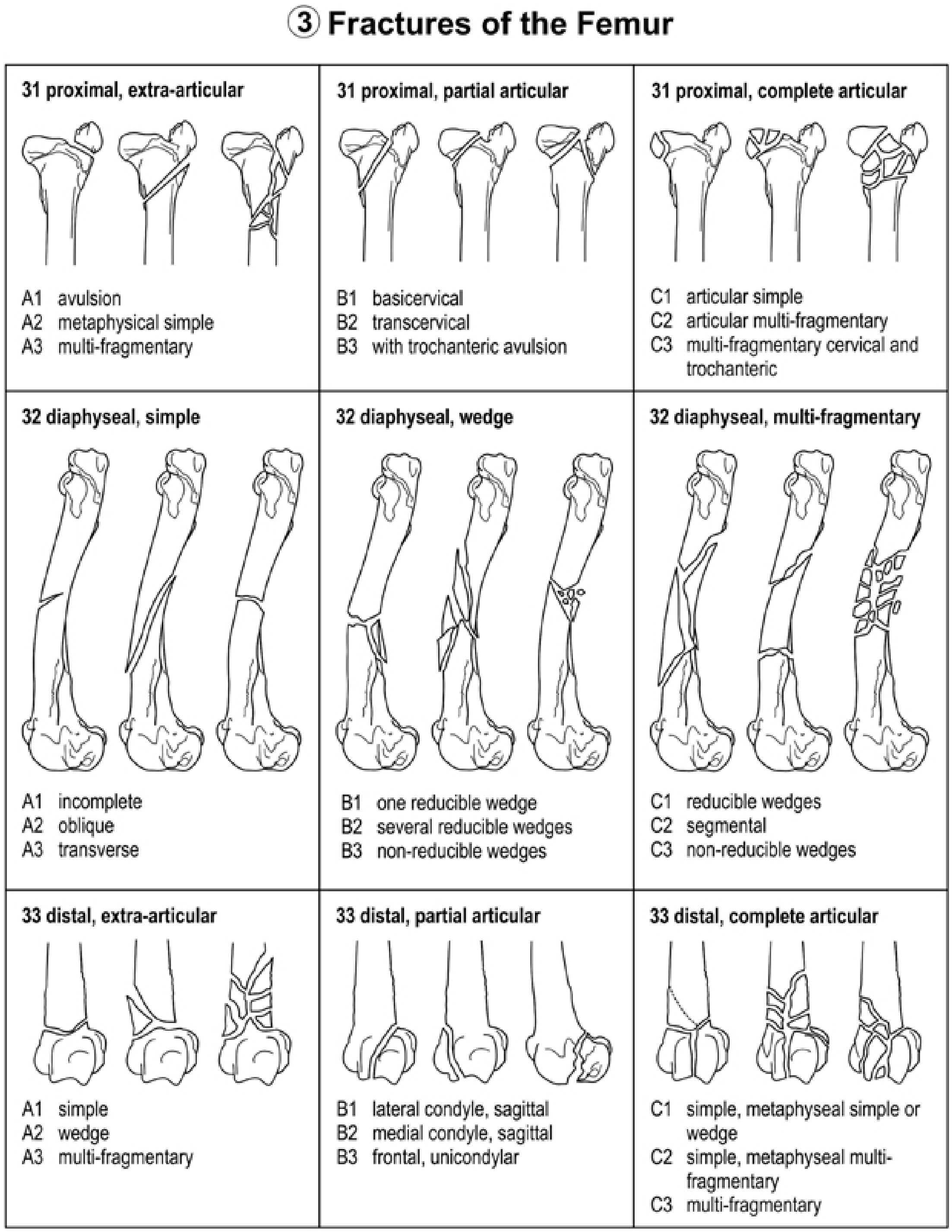

Fig. 4 Classification of the different groups of femur fractures in impala.

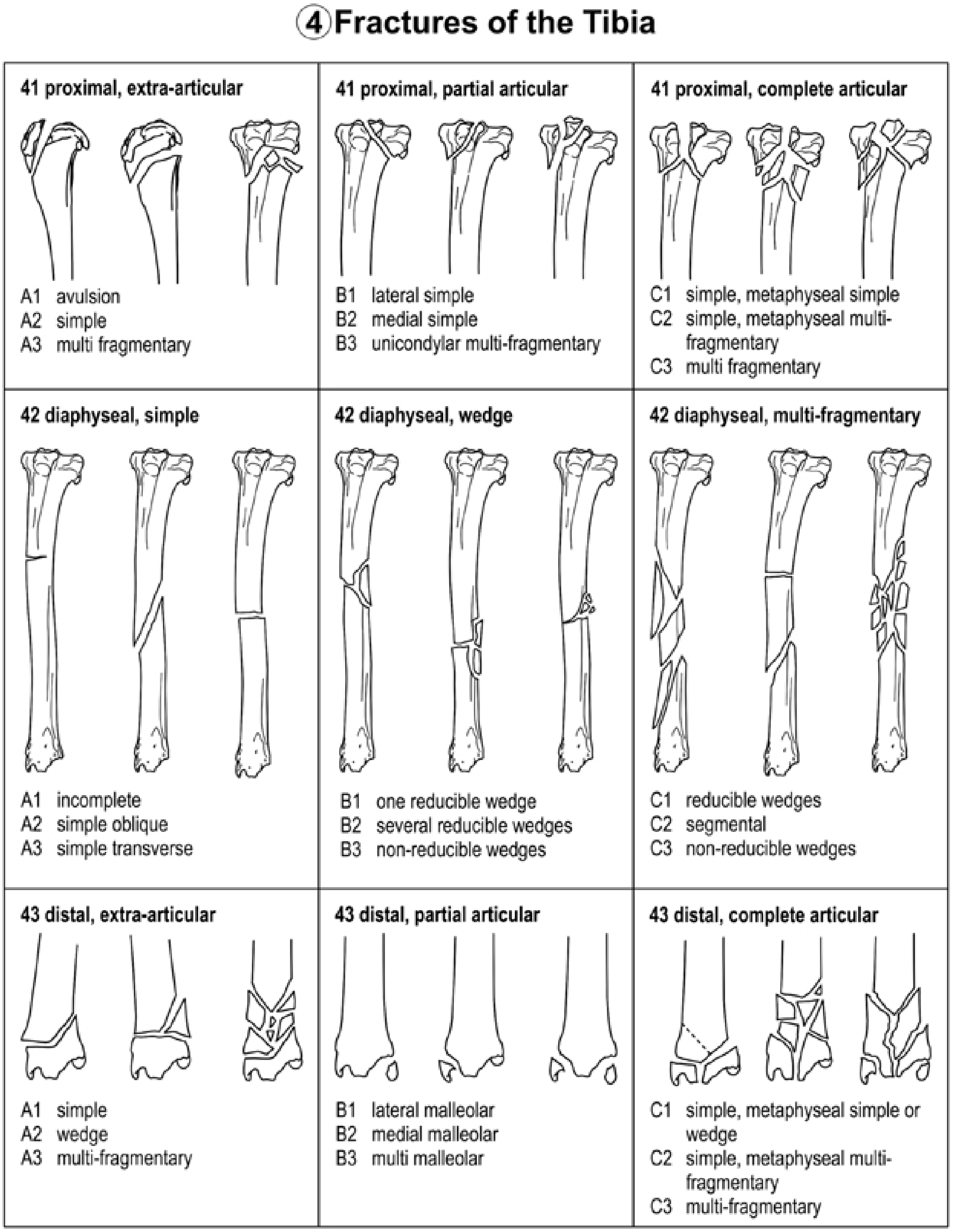

Fig. 5 Classification of the different groups of tibia fractures in impala.

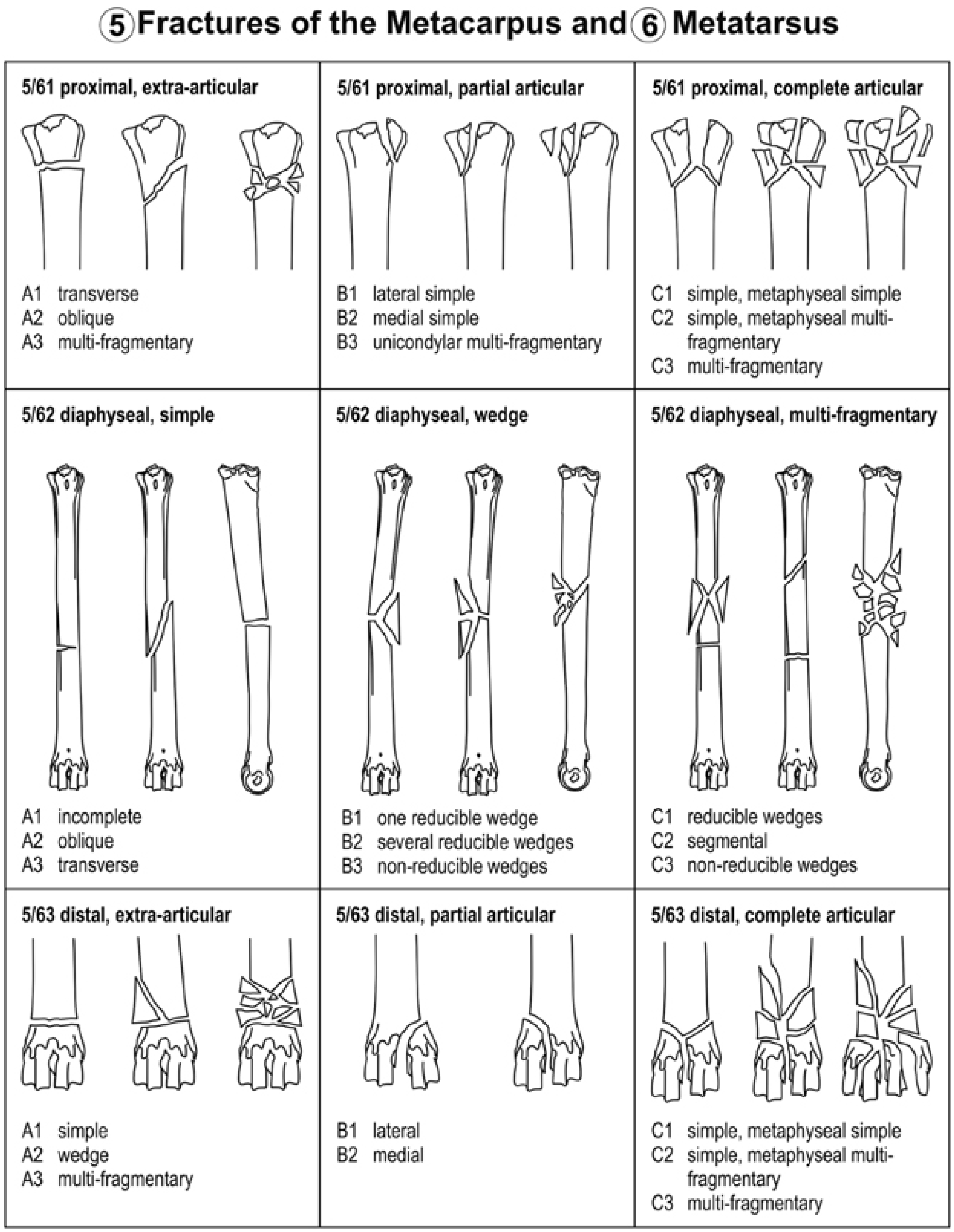

Fig. 6 Classification of the different groups of metacarpal and metatarsal fractures in impala.

Results

One hundred and twenty-two radiographs of 58 long bone fractures in 55 impala were studied. The sex of 35 cases were recorded of which 20 were rams and 15 ewes. Based on growth plate closure and apophyseal fusion, 40 of 58 fractures occurred in skeletally immature and 18 in mature patients. Most patients (52 impala) had isolated fractures involving a single bone, while three patients had multiple fractures, one patient had bilateral humerus fractures, one patient had a metacarpal and a metatarsal fracture and one patient had a radius/ulna fracture and a metatarsal fracture. The fracture distribution based on location found that tibial (n = 17), metacarpal (n = 13) and metatarsal (n = 11) fractures were most common. The anatomically similar metacarpal and metatarsal fractures combined, made up 24 of 58 fractures. Forty five of 58 fractures occurred in the diaphyseal bone segment. The overall fracture distribution based on location is shown in [Fig. 7]. The fracture distribution based on complexity was simple (n = 17) ([Fig. 8]), wedge (n = 16) ([Fig. 9]) and multi-fragmentary (n = 16) ([Fig. 10]). Ten out of the 11 metatarsal fractures were simple type fractures, with the rest of the individual long bones, including the metacarpus, having a near equal distribution of simple, wedge and multi-fragmentary fractures. Fracture distribution based on severity was severity 1 (n = 21), severity 2 (n = 21) and severity 3 (n = 16). The seven most common fracture configurations based on the determined α-numeric codes were 52C1, 62A2, 42C1, 42B2, 42A2, 62A3 and 63A3 ([Fig. 11]).

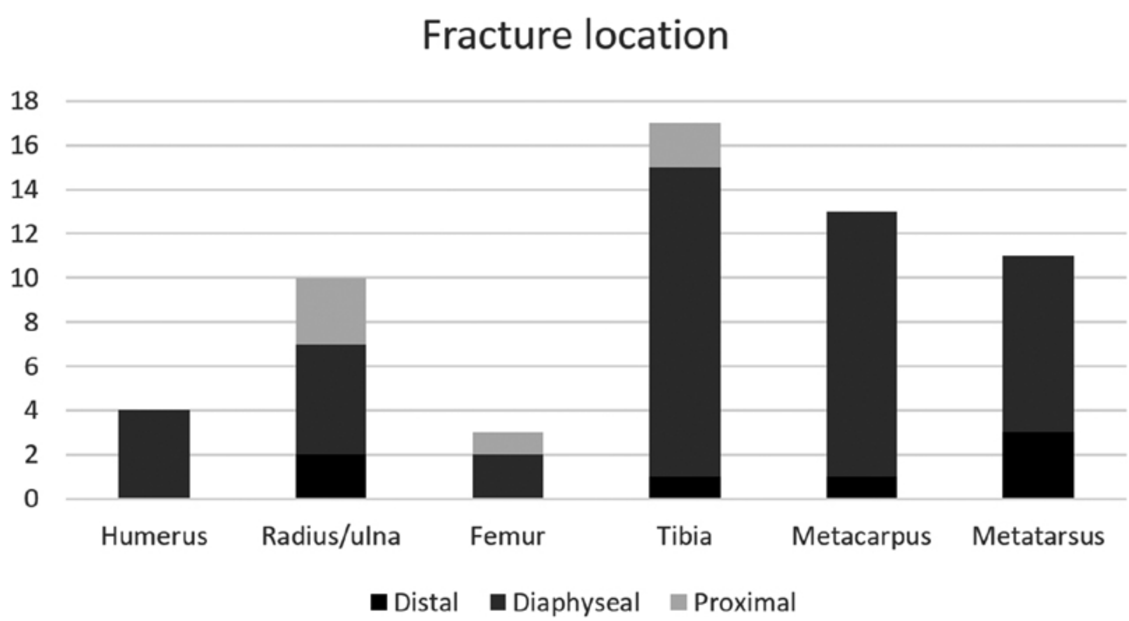

Fig. 7 Overall fracture distribution in impala based on location.

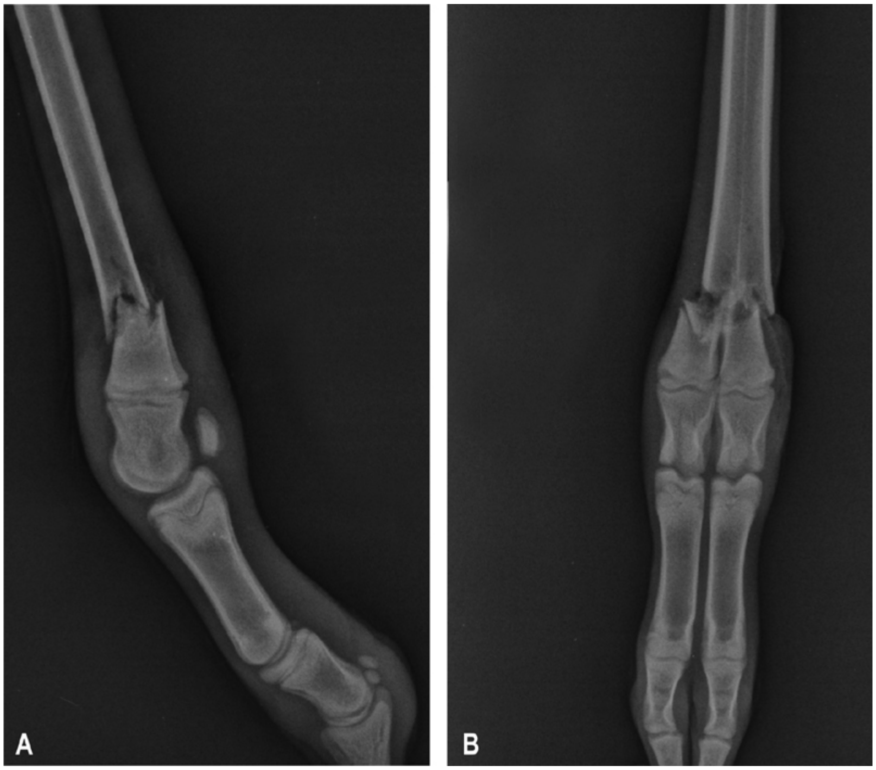

Fig. 8 Medio-lateral (A) and cranio-caudal (B) radiographical views of a skeletally immature, impala ewe with a 63A2 fracture, cause unknown.

Fig. 9 Medio-lateral (A) and cranio-caudal (B) radiographical views of a skeletally immature, impala ewe with a 32B2 fracture, caused by an immobilization dart. Note the metallic dart needle in A and dart gas tract in B (arrow).

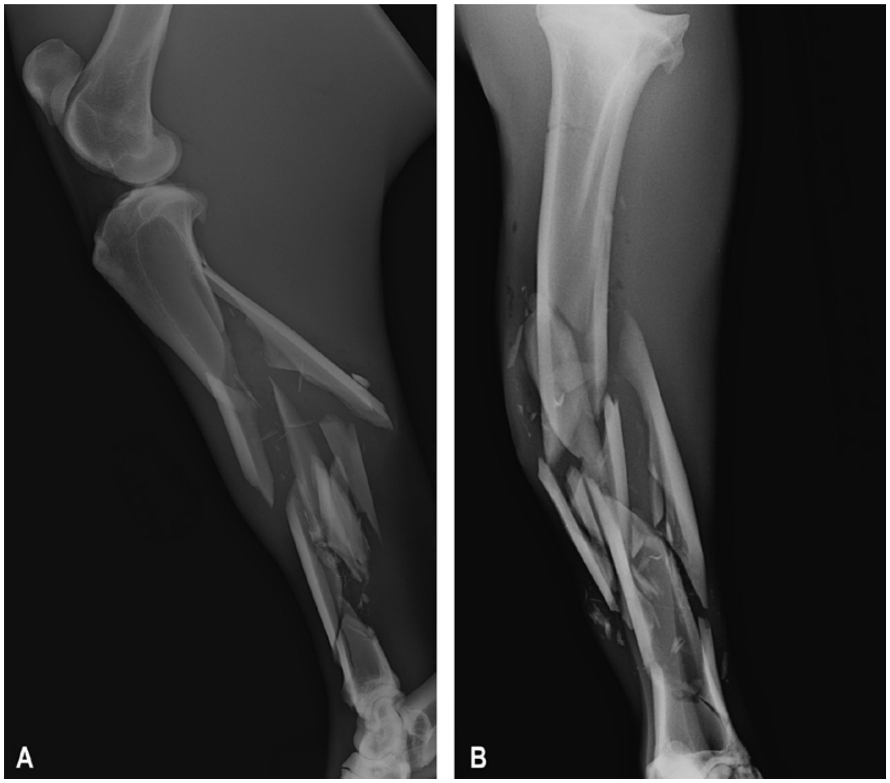

Fig. 10 Medio-lateral (A) and cranio-caudal (B) radiographical views of a skeletally mature, impala ram with a 42C3 open fracture, caused by an immobilization dart.

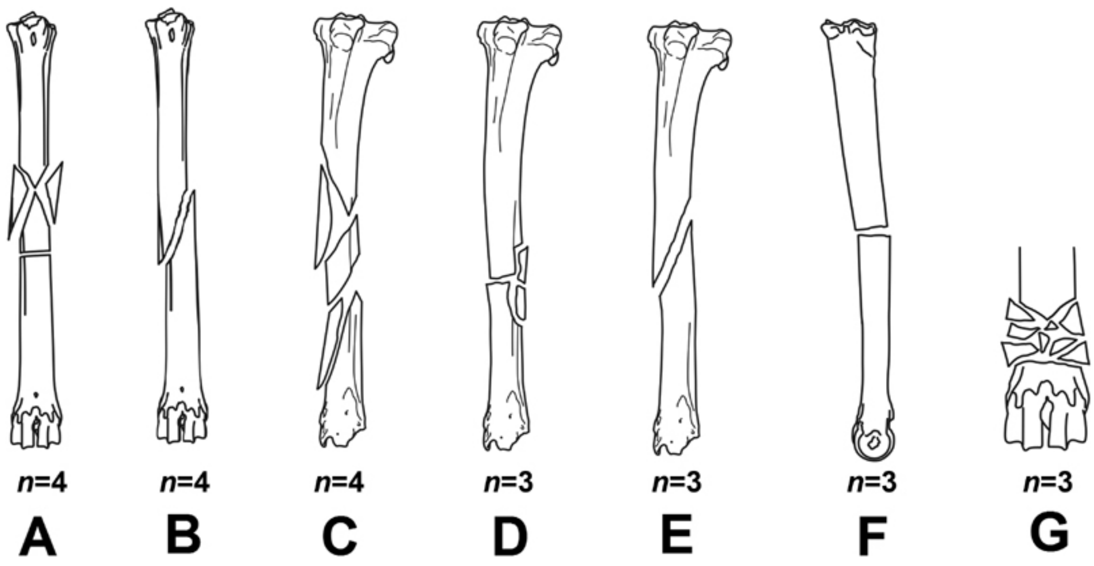

Fig. 11 A schematic illustration of the seven most common fracture configurations in impala; 52C1 (A), 62A2 (B), 42C1 (C), 42B2 (D), 42A2 (E), 62A3 (F) and 63A3 (G).

Twenty of the 40 fractures in immature patients were simple type fractures, compared with eight of 18 fractures in mature patients. Two Salter–Harris type 1 fractures were recorded, one distal metatarsal and one femur head fracture. Four intra-articular fractures were recorded which affected the proximal radius/ulna (n = 3) and proximal tibia (n = 1).

Thirty one of 58 fractures were open based on the assessment of fracture-associated soft tissues. Fourteen of 17 tibial fractures were open ([Fig. 10]). Thirteen of 31 open fractures were simple type fractures. Fissure lines were detected in 20 of 58 fractures. Nine of the 20 fractures with fissure lines were simple fractures. Forty eight of 58 fractures had no periosteal reaction associated with the fracture.

The cause of the fractures varied from iatrogenic fracture due to an immobilization dart (n = 6), fighting (n = 1) and stuck in fence (n = 1) with the cause in the majority of fractures unknown (n = 50). Fractures caused by an immobilization dart could be identified, based on the presence of a metallic opacity (dart needle) or a dart gas tract, associated with the fracture ([Fig. 9]). Of the six fractures caused by an immobilization dart, five affected the hind limb. Of these fractures four were wedge and two multi-fragmentary. Four of the six patients were skeletally immature. Three ewes and two rams were recorded, with the sex of one patient not available.

Apart from the 58 long bone fractures, an additional four fractures, one multi-fragmentary calcaneus fracture (caused by an immobilization dart), three phalangeal fractures; simple (n = 1), wedge (n = 1) and multi-fragmentary (n = 1), and one fetlock joint luxation were recorded.

Discussion

Fracture classification systems are aimed at improvement in clinical record keeping.[17] Long-term benefits accrue when the clinician wishes to obtain complete and statistically relevant data for publication,[17] which could serve as foundation for further anatomical, biomechanical and clinical studies based on specific fracture locations or morphologies. To enable wider participation, it is necessary to use a common language when studying fractures.[17] In this study, an existing fracture classification was modified to ensure that standardized terminology was used when classifying fractures based on location and morphology. In our study, the first modification was removal of the hyphen in the fracture code which facilitated data entry and reduce error rate.[22]

For fracture location, the Heim square rule was applied to the unique skeletal anatomy of the impala.[23] In our study, the demarcation of zones for the radius and femur were simplified, removing the special demarcation based on the radial tuberosity or the minor trochanter as described by Unger.[2] In impala, the radius and ulna are fused and the fibula is vestigial. The radius and tibia were consequently classified as individual weight bearing bones.

In fracture morphology descriptions, the term complex or comminuted is confusing and was replaced with multi-fragmentary which is more suited for fractures with no cortical contact after envisaged reduction.[22] In our study, the classification of intermediate fragments was based on their size and possible incorporation in surgical reduction, resulting in the classification of either reducible or non-reducible wedges. Current principles on fixation of multi-fragmentary fractures, however, have evolved toward bridging fixation and secondary bone healing, which focuses on decreasing the inter-fragmentary strain by not anatomically reducing the wedges.[24] Consequently, in human fracture classifications, intermediate fragments are classified as either intact (single) or fragmentary (multiple) wedges, which are more aligned with current treatment principles.[22] [24]

Fracture severity is based on its inferred relationship between difficulty of repair and worsening prognosis.[17] Because of the effect that fissure lines and open fractures have on repair and prognosis,[10] a recommendation can be made to include open or closed status and presence of fissure lines as additional criteria under fracture severity for future studies.

As with antelopes in South Africa, the increasing popularity of camelids in North America leads to camelid fractures becoming part of the normal caseload.[25] The relatively high commercial value of llamas and alpacas also encourages clients to pursue treatment.[25] Due to anatomical similarities, the classification developed in this study can potentially be applied to long bone fractures in other ungulate species, including camelids. Similar to our findings, the tibia is the single most commonly fractured long bone in llamas, alpacas and camels.[26] [27] [28] However, in a study in goats the metacarpus was reported the most commonly fractured long bone.[29] The femur was found to be the most commonly fractured long bone in goats in another study.[30] When the anatomically similar metacarpus and metacarpus were combined, they were the most commonly fractured long bones in goats, cattle, llamas and alpacas, as well as in our impala.[26] [29] [31] The diaphysis was reported to be the most commonly affected bone segment in llamas, alpacas and camels as in our study.[26] [27] [28]

The fracture morphology reported for llamas and alpacas was mostly comminuted fractures, which differs from our results where only 16 of 58 fractures were multi-fragmentary.[26] Similar to impala, the most common fracture morphology in camels were simple fractures.[27] [28] These two camel studies included fractures of the head, neck and mandible, which could have biased the results.[27] [28] A higher proportion of fractures affected rams, probably because they are more frequently involved with territorial fighting, which might increase the risk of trauma. Our study recorded more ewes affected by immobilization darts, possibly due to reduced muscle mass as compared with rams. A higher incidence of fractures in goats under 6 months of age has been reported.[29] In another study, they found 53% of long bone fractures in llamas and alpacas affected skeletally immature patients.[26] One study done on young camels found more fractures in camels under 6 months of age, whereas another study found only 28% of fractures occurred in camels under 1 year of age.[27] [28] Our study reported 40 of 58 long bone fractures occurred in skeletally immature patients; however, the low number of Salter–Harris type fractures recorded was unexpected. Our study reported 31 of 58 fractures were open compared with 32% open fractures in llamas and alpacas, and 66 to 45% compound fractures in camels.[26] [27] [28] Despite the high number of open fractures recorded, the majority of the fractures had no periosteal reaction associated with the fracture, which could be due to the acute nature of the fracture or minimal contamination of the fracture fragments. As in our study, primary causes of fractures in alpacas and llamas are thought to be traumatic, though the exact cause is not reported and mostly unknown by the owners.[25]

The mechanical behaviour of bone is dependent on the type and density of bone, the rate and direction of the applied load and the age and health status of the patient.[32] Because of the viscoelastic properties of bone, the more rapidly a bone is loaded, the stiffer it becomes and the more energy it stores. Once rapidly loaded bone reaches the failure point, more multi-fragmentary fractures and greater soft tissue compromise occurs.[33] Interestingly, our study found a relatively high proportion of open fractures were associated with simple type fractures. In these cases, the limited soft tissue envelope of the long bones in impala might have rendered simple fractures open.

The retrospective nature of this study precluded the use of standardized radiographic positioning and exposure settings. However, the quality of the majority of the radiographs was rated good to excellent by the authors. This is due to the digital radiography systems used by the participating veterinarians. The low number of cases included in this study is inherent to the fact that impala are not domesticated.

No fracture classification system for long bone fractures in ungulate species has been published. According to the authors, this is the first fracture classification system, for long bone fractures in ungulate species or domesticated large animals, containing the metacarpus and metatarsus. The results of this study will form the foundation for further anatomical, biomechanical and clinical studies of the more common fractures by our study group, to ultimately develop an ideal fracture treatment methodology for impala and other small antelope.

Conclusion

This modified-Unger fracture classification was found to be applicable in classifying 58 long bone fractures in impala. This classification should provide a foundation for further advances in investigations of fractures in ungulates, particularly antelopes.

Conflict of interest

None declared.

Acknowledgments

The authors would like to thank Ms. Estelle Mayhew of Creative Studios, Onderstepoort, Department of Education Innovation, Faculty of Veterinary Science, for the figures and illustrations.

Author contributions

All authors contributed to conception of study, study design, acquisition of data and data analysis and interpretation. All authors also drafted, revised and approved the submitted manuscript.

References

1 Zeiler GE, Stegmann GF, Fosgate G. , et al. Etorphine-ketamine-medetomidine total intravenous anesthesia in wild impala (Aepyceros melampus) of 120-minute duration. J Zoo Wildl Med 2015; 46 (04) 755-766

2 Unger M, Montavon PM, Heim UFA. Classification of fractures of long bones in the dog and cat: introduction and clinical application. Vet Comp Orthop Traumatol 1990; 3: 41-50

3 Müller ME, Nazarian S, Koch P. The Comprehensive Classification of Fractures of Long Bones. New York: Springer Verlag; 1990: 1-191

4 Miller CW, Sumner-Smith G, Sheridan C, Pennock PW. Using the Unger system to classify 386 long bone fractures in dogs. J Small Anim Pract 1998; 39 (08) 390-393

5 Zaal MD, Hazewinkel HA. Classification of 202 tibial fractures in cats and dogs. Vet Surg 1996; 25: 271-271

6 Meyer-Lindenberg A, Ebel H, Fehr M. Fractures of the distal humerus - experiences with fracture classification according to Unger et al. Eur J Companion Anim Pract 1993; 3: 19-30

7 Dee JF, Dee J, Piermattei DL. Classification, management, and repair of central tarsal fractures in the racing greyhound. J Am Anim Hosp Assoc 1976; 12: 398-405

8 Johnson KA. Accessory carpal bone fractures in the racing greyhound. Classification and pathology. Vet Surg 1987; 16 (01) 60-64

9 Prieur WD, Braden TD, von Rechenberg B. A suggested fracture classification of adult small animal fractures. Vet Comp Orthop Traumatol 1990; 4: 111-116

10 Tillson DM. Open fracture management. Vet Clin North Am Small Anim Pract 1995; 25 (05) 1093-1110

11 Anderson A, Coughlan AR. Sacral fractures in dogs and cats: a classification scheme and review of 51 cases. J Small Anim Pract 1997; 38 (09) 404-409

12 Cook JL, Cook CR, Tomlinson JL. , et al. Scapular fractures in dogs: epidemiology, classification, and concurrent injuries in 105 cases (1988-1994). J Am Anim Hosp Assoc 1997; 33 (06) 528-532

13 Messmer M, Montavon PM. Pelvic fractures in the dog and cat: a classification system and review of 556 cases. Vet Comp Orthop Traumatol 2004; 17: 167-183

14 Berzon JL. The classification and management of epiphyseal plate fractures. J Am Anim Hosp Assoc 1980; 16: 651-658

15 Marretta SM, Schrader SC. Physeal injuries in the dog: a review of 135 cases. J Am Vet Med Assoc 1983; 182 (07) 708-710

16 Embertson RM, Bramlage LR, Gabel AA. Physeal fractures in the horse - I. classification and incidence. Vet Surg 1986; 15: 223-229

17 Fackelman GE, Peutz IP, Norris JC, Auer JA, von Rechenberg B. The development of an equine fracture documentation system. Vet Comp Orthop Traumatol 1993; 6: 47-52

18 Schneider RK, Bramlage LR, Gabel AA, Barone LM, Kantrowitz BM. Incidence, location and classification of 371 third carpal bone fractures in 313 horses. Equine Vet J Suppl 1988; 6 (06) 33-42

19 Denny HR, Barr AR, Waterman A. Surgical treatment of fractures of the olecranon in the horse: a comparative review of 25 cases. Equine Vet J 1987; 19 (04) 319-325

20 Honnas CM, O'Brien TR, Linford LL. Solar margin fractures of the equine distal phalanx. Proceedings American Association of Equine Practitioners 1987; 33: 399-410

21 Struchen C. Use of 3 fracture classification systems for evaluation of fractures of long bones in horses. Schweiz Arch Tierheilkd 1993; 135: 184-185

22 Kellam JF, Meinberg EG, Agel J, Karam MD, Roberts CS. Introduction: fracture and dislocation classification compendium-2018: international comprehensive classification of fractures and dislocations committee. J Orthop Trauma 2018; 32: S1-S10

23 Heim UF. Defining the boundary between diaphysis and metaphysis using quadrant measurement. A contribution to the classification and documentation of fractures of long tubular bones exemplified by the distal tibia [ ]. Unfallchirurg 1987; 90 (06) 274-280

24 Chao P, Lewis DD, Kowaleski MP, Pozzi A. Biomechanical concepts applicable to minimally invasive fracture repair in small animals. Vet Clin North Am Small Anim Pract 2012; 42 (05) 853-872 , v

25 Newman KD, Anderson DE. Fracture management in alpacas and llamas. Vet Clin North Am Food Anim Pract 2009; 25 (02) 507-522

26 Brounts SH, Racette M, Muir P. Comparison of fixation methods for treatment of long bone fractures in llamas and alpacas. Vet Surg 2011; 40 (01) 115-119

27 Mohamed AF. Fractures in single-humped camels: a retrospective study of 220 cases (2008–2009). J King Abdulaziz Univ 2012; 23: 3-17

28 Ahmed AF, Al-Sobayil FA. Fractures in young, single-humped camels (Camelus dromedarius). Turk J Vet Anim Sci 2012; 36: 1-8

29 Dass L, Sahay P, Khan A, Deokioliyr U, Ehsan M. Incidence of fractures in goats in the hilly terrain of Chhotanagpur. Indian Vet J 1985; 62: 766-768

30 Singh AP, Mirakhur KK, Nigam JM. A study on the incidence and anatomical locations of fractures in canine, caprine, bovine, equine and camel. Indian J Vet Surg 1983; 4: 61-66

31 Anderson DE, St Jean G. Management of fractures in field settings. Vet Clin North Am Food Anim Pract 2008; 24 (03) 567-582 , viii

32 Radasch RM. Biomechanics of bone and fractures. Vet Clin North Am Small Anim Pract 1999; 29 (05) 1045-1082 , v–vi

33 Cross AR. Fracture biology and biomechanics. In: Tobias KM, Johnston SA. , edsVeterinary Surgery Small Animal. St. Louis, MO: Elsevier Saunders; 2012: 565-566