FRACTURE CHARACTERIZATION VIA COMPUTED TOMOGRAPHY IN THOROUGHBRED RACEHORSES

Megan Posukonis, Dr. Jodie Daglish, DVM, Dr. Christopher Kawcak, DVM, PhD, DACVS, DACVSMR

Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO, 80523

Introduction

- Fracture of the distal limb remains associated with high morbidity and mortality in the Thoroughbred racehorse
- The primary mechanism of proposed fracture formation begins with localized sclerosis initiating the formation of microcrack arrays resulting in a visible fracture line if loading and time progress[1]
- Fracture mechanics equations dictate that fracture line propagation varies directly with fracture toughness (i.e., bone mineral density)
- The geometric patterning of bone mineral density could dictate fracture line propagation, resultant configuration (i.e., spiral, complete, incomplete, or unicortical) and therefore associated prognosis
- Currently no previous work has attempted to compare the geometry of increased bone mineral density (sclerosis) over the entire joint surface relating to fracture line configuration
- Computed tomography is a useful and clinically accessible tool for qualitative and quantitative assessment of bone sclerosis [2]
- This study examines a novel and robust clinical population (Table 1) of fractures of the third metacarpal or metatarsal bone (MC3 or MT3) affecting medial or lateral condyles to retrospectively identify possible predictors of fracture configuration

We hypothesize that mapping the fracture line and associated sclerosis patterns will have a positive association with fracture configuration, and could therefore be explored as a clinically relevant diagnostic screening tool.

Materials and Methods

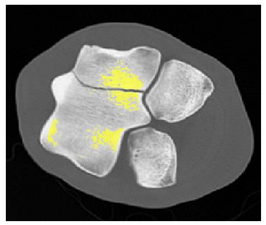

Figure 1: Isolation of sclerotic region by image segmentation. Image threshold for segmentation determined by cortical bone pixel values. Cortical bone was manually removed from resultant segmentation.

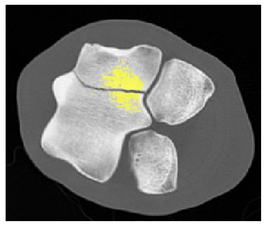

Figure 2: Sclerotic region (yellow) of fractured condyle. Process repeated for unaffected condyle (not shown). Transverse slices were selected at specific location on MC3/MT3 for consistency, determined by shape of condyles.

Sclerotic area comprising the convex hull = sclerotic area (mm²)/ convex hull area (mm²)

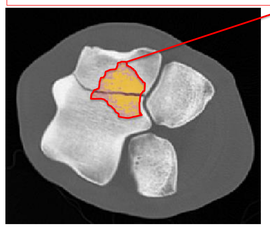

Figure 3: Convex hull of sclerotic region of fractured condyle (red). Process repeated for unaffected condyle (not shown). Convex Hull represents the smallest convex area that contains every pixel of interest (yellow).

CLASSIFICATION	LAT	MED	TOTAL
Incomplete	22	5	27
Complete	19	1	20
Spiral	7	14	21
Unicortical	24	10	34
Control	23		23

Table 1: Breakdown of experimental population by fracture classification and condyle location. *N* = 127 condyles, of which 85 condyles had a visible fracture line in the selected CT slice in the transverse plane. Fracture population obtained with permission from Newmarket Equine Hospital. Control population obtained with permission from Royal Liverpool University Hospital.

The following parameters were evaluated in each transverse CT slice:

- Fracture Location in Cortex
  - Axial, Median, or Abaxial
- Total Sclerotic Area
- Sclerotic Area of Fractured Condyle
- Sclerotic Area of Opposite Condyle
- Entropy of Fracture Condyle Sclerosis
- Entropy of Opposite Condyle Sclerosis
- Convex Hull of Fractured Condyle Sclerosis
- Convex Hull of Opposite Condyle Sclerosis

Discussion

- This study's methodology of dividing the condyle into affected (fractured) and unaffected (opposite) halves may explain the lack of significant difference observed in the CH analysis of the unaffected condyle as a relatively discrete sclerotic region from the fractured condyle was frequently divided and therefore biasing the geometry of the unaffected condyle toward a more diffuse distribution by CH analysis.
- Pairwise comparison indicates significant difference in CH analysis of the fractured condyle originates from spiral vs. unicortical fracture types. One possible hypothesis is that progression from unicortical to bicortical fracture is mitigated by a sclerotic barrier, while spiral fracture types have no associated stiffening to prevent progression throughout the bone (Figures 6-9).
- While the experimental population examined here (Table 1) is robust by the standards of current literature, the parameters examined here displayed enough variability amongst individuals to warrant exploration of a significantly larger sample size. It is difficult to estimate at this time whether the significance of sclerosis geometry examined via convex hull would be exaggerated or diminished given a greater number of experimental cases.
- As fractures are naturally 3-dimensional constructs, this study was limited in that only a single slice was examined for each case in order to examine the entire population on the required timeline. This study posits the utility of 3-dimensional geometry of sclerotic patterns based on 2-dimensional patterns.
- Protocols used to assess the sclerotic area to CH area ratio are minimally invasive, cost effective, and require little additional time beyond the current diagnostic paradigm. If further exploration of this parameter proves specific in predication of fracture configuration, we have developed a clinically relevant and accessible diagnostic tool for that parameter.

Results

Of these parameters, all showed a significant (*p<0.01, n = 127)* difference between the control group and fracture groups, indicating that occurrence of a fracture is related to the presence of an alteration in bone stiffness, as described by relative sclerosis of the bone. All parameters were therefore explored to identify possible predictors of a specific fracture configuration occurring.

Only convex hull (CH) analysis of the fractured condyle sclerotic area showed a significant difference *(p<0.048, n = 85)* between fracture configurations (Figure 4). Post hoc examination reveals only a significant *(p<0.02)* difference between unicortical and spiral fracture types (Figures 6-9). A convex hull analysis of the opposite condyle however, yielded no statistical significance between fracture configurations *(p = 0.40, n = 85)* (Figure 5). The convex hull analysis relates the sclerotic area of the condyle to its associated convex hull, as described below. Higher sclerotic area to CH area ratio indicates a more focal sclerosis distribution, while a lower ratio indicates a more diffuse distribution.

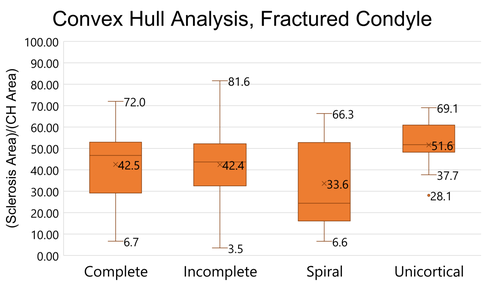

Figure 4: Convex Hull Analysis, Fractured Condyle (n=85)

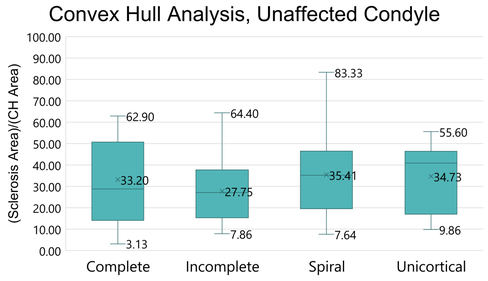

Figure 5: Convex Hull Analysis, Unaffected Condyle (n=85)

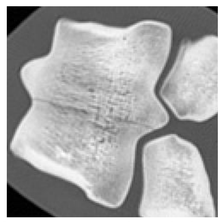

Figure 6: Example, spiral fracture. Unsegmented CT transverse slice.

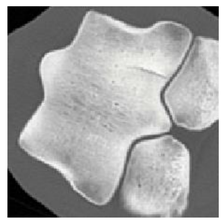

Figure 8: Example, unicortical fracture. Unsegmented CT transverse slice.

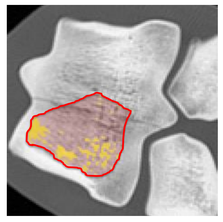

Figure 7: Example, Convex hull (red) of spiral fracture sclerosis (yellow) in fractured condyle. 16% of convex hull area is sclerotic, describing diffuse distribution of sclerosis.

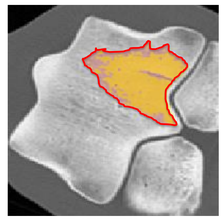

Figure 9: Example, Convex hull (red) of unicortical fracture sclerosis (yellow) in fractured condyle. 66% of convex hull area is sclerotic, describing focal distribution of sclerosis.

Conclusions

- Patterns of sclerosis can be used to determine a fractured versus non-fractured condyle.
- Specific geometry of the sclerotic area can distinguish spiral fractures from unicortical fractures but not bicortical incomplete or complete fracture types.
- Emerging trend of significance of the sclerotic area : CH area ratio suggests that geometry of the sclerotic area may be of significant importance to the diagnostic and prognostic picture of thoroughbred racehorses.

References

1. Kawcak CE, Trotter GW, Powers BE, et al: Comparison of bone healing by demineralized bone matrix and autogenous cancellous bone in horses. Vet Surg 2000; 29: 218–226
2. Morgan JQ, Santschi EM, Zekas LZ, Scollay-Ward MC, Markel MD, Radtke CL, Sample SJ, Keuler NS, Muir P. Comparison of radiography and computed tomography to evaluate metacarpo/metatarsophalangeal joint pathology of paired limbs of Thoroughbred racehorses with severe condylar fracture. Vet Surg 2006; 35: 611-617.

Acknowledgments

This project was funded by the Colorado Racing Commission. The auth wish to acknowledge the contributions of Newmarket Equine Hospital.