Subchondral Bone Density Patterns and Morphometrics in the Distal Femur of the Horse

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ABSTRACT

Joint disease is a major cause of lameness and retirement in horses. One region of great concern in western performance horses is the femorotibial joints which undergo tremendous torsional forces. A recent study determined that 44.5 % of western performance horses had radiographic evidence of stifle lesions[1], however, the pathogenesis of many of these lesions remains unknown. Computed tomography has proven to be an effective way of determining subchondral bone density, which is thought to be an effective indicator of joint impact. Recent work looking at the fetlock joint of the horse demonstrated that abnormal joint geometry and subchondral bone density patterns predisposed racehorses to condylar fractures[2]. The purpose of this study is to determine an effective way of analyzing the subchondral bone density patterns and morphometrics of the distal femur of the horse. This method will then be used on the distal femurs of multiple Thoroughbreds and Quarter Horses without joint disease as well as a collection of pathologic stifle joints in an effort to determine if subchondral bone density patterns and condyle shape are involved in the pathogenesis of joint disease in the distal femur of the horse.

PURPOSE and HYPOTHESES

Purpose: Develop a method to evaluate subchondral bone density patterns and morphometrics in the distal femur of the horse. This model will be used to compare bone density patterns and morphometrics between breeds and between healthy and diseased stifle joints.

Hypothesis:

1. The medial femoral condyle will have a greater mean subchondral bone density than the lateral.
2. The distribution of load between corresponding sections of the medial and lateral femoral condyles will be inversly related.
3. The morphometrics of the femoral condyles can be consistently determined.

METHODS and MATERIALS

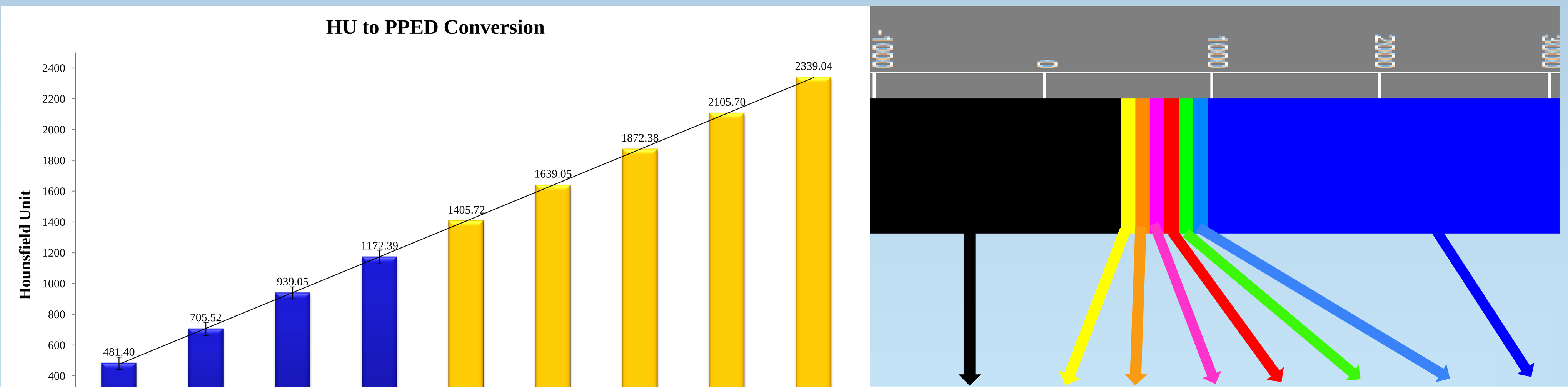
- Stifles from a ten year Quarter Horse gelding were collected and dissected for CT scanning.
- Using a dipotassium phosphate phantom, a regression equation was developed to determine equivalent bone densities (Figure 1).
- 2 methods of bone density distribution were analyzed at 1, 4, and 7mm from the distal surface of the medial and lateral femoral condyles. Analysis was performed with the CT software program Osteoapp, and the image software program ImageJ. The two methods were compared to each other for efficacy (Figure 2).
- Also using Osteoapp, the length, width, and height of the medial femoral condyle were measured in frontal and sagittal sections. These measurements were made 3 times to determine the coefficient of variation (Figure 3).

REFERENCES

1.) Contino EK. Master's Thesis: The prevalence of radiographic changes in yearling and 2-year-old Quarter Horses intended for cutting. 2009.

2.)Kawcak CE, Zimmerman CZ, Easton KL, McIlwraith CW, Parkin TD. The effects of third metacarpal geometry on the incidence of condylar fractures in Thoroughbred racehorses. Am Assoc Equine Pract. 2009 (Accepted).

RESULTS



	Black	Yellow	Orange	Pink	Red	Green	Light Blue	Blue
HU	<471	471-556	557-641	641-727	728-813	814-897	898-985	>985
PPED	<551	551-650	651-750	751-850	851-950	951-1050	1051-1150	>1150

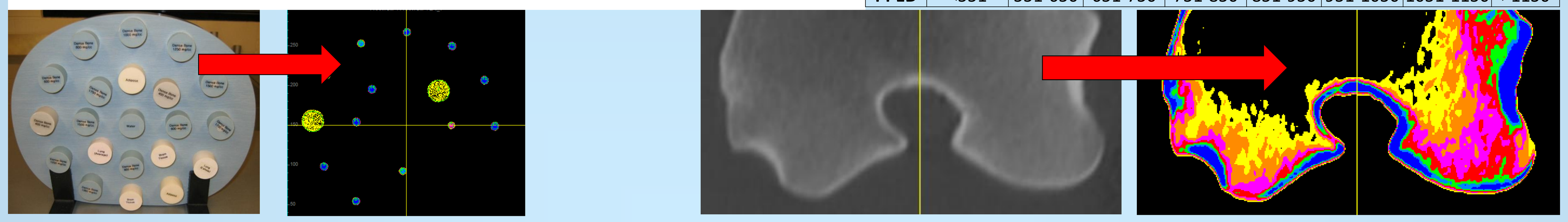


Figure 1: Conversion of Hounsfield Units to PPED's using the regression equation PPED=1.1667(HU) + 1.005

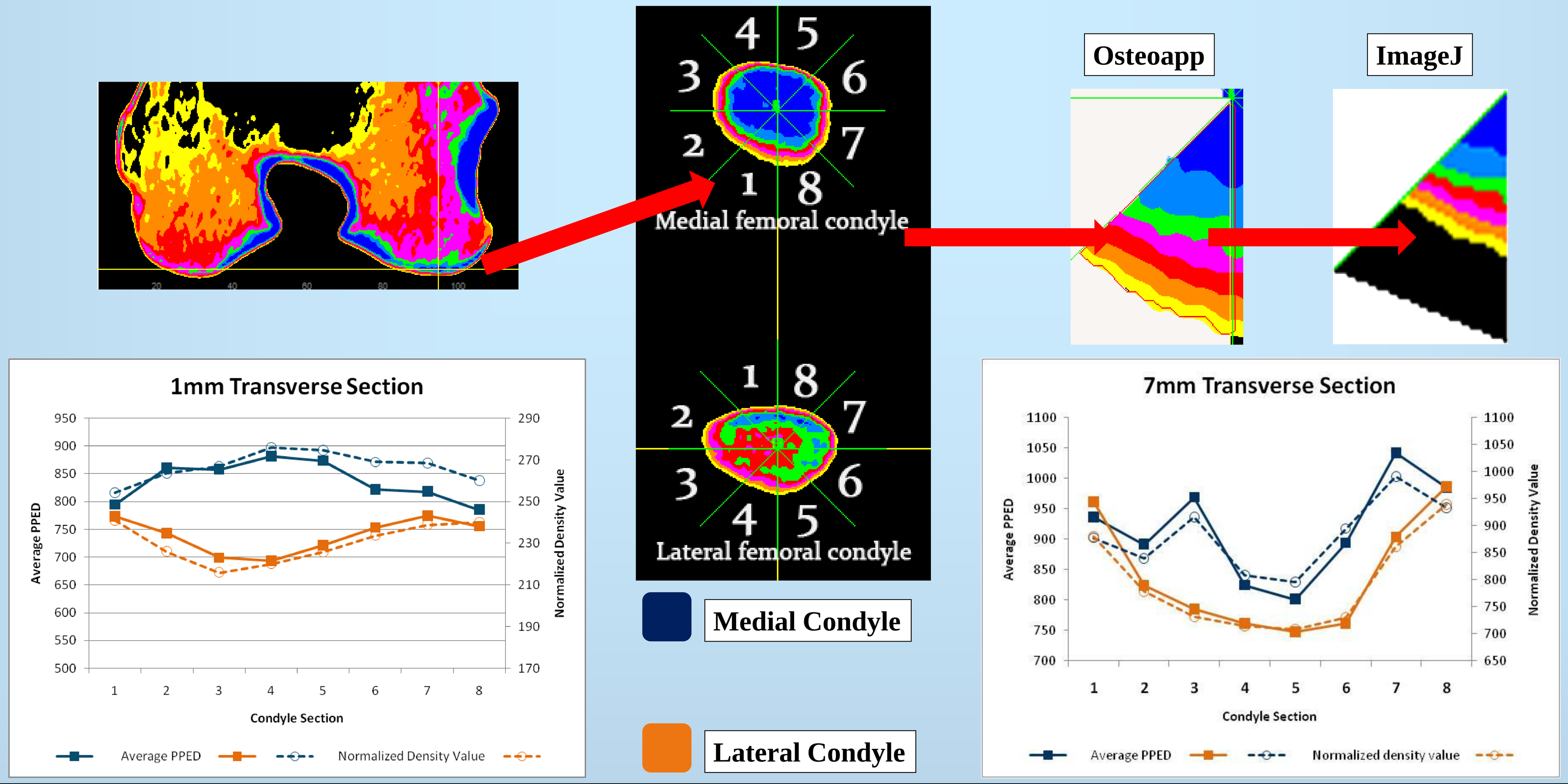
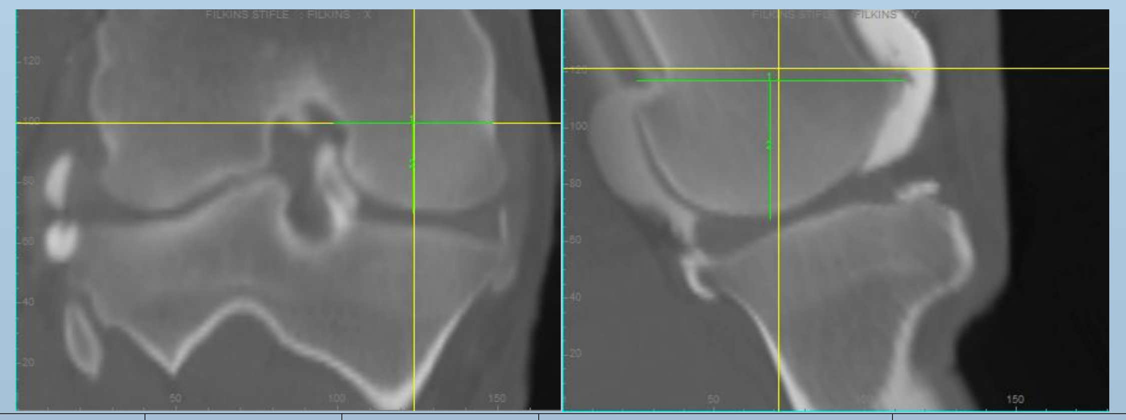


Figure 2: Density trends in the medial and lateral femoral condyles using the normalization and average PPED method for analysis

Frontal Section
Medial femoral condyle height and width.



Sagittal Section
Medial femoral condyle height and length.

Parameter (mm)	Trial 1	Trial 2	Trial 3	Std Dev. Of Mean	Coefficient of Variation
Width	51.150	50.610	49.120	0.496	0.017
Height	29.810	31.630	29.770	0.501	0.029
Length	85.030	84.840	88.090	0.860	0.017
Sag. Height	43.640	44.650	48.810	1.292	0.049

Figure 3: Frontal width and height and sagittal length and height repeated 3 times with a coefficient of variation under 5 %

CONCLUSIONS

Average PPED

Osteoapp Average PPED Analysis;

Pros: The numerical result is the average PPED for its' respective section.

Cons: The software has spatial limitations when creating a ROI, therefore, the ROI boundries do not coinicide perfectly with the boundries of the established section.

Normalized density value

ImageJ Pixel Color Normalization Analysis;

Pros: By performing pixel analysis on ImageJ, every pixel in each section was included in the analysis.

Cons: The normalized number is arbitrary and only useful to demonstrate trends in bone density patterns.
The normalization equation was calculated with only one PPED value representing the entire HU range and therefore did not account for uneven HU distribution within the respective color range, or for very high HUs within the highest HU range (Blue)

- A regression equation of PPED=1.1667(HU) + 1.005 was developed comparing HU and PPED values on a phantom. This equation was used to create a color scale where each color shade represented a PPED range.
- Analyzing transverse sections of the distal condyle at 1, 4, and 7mm sections from the most distal point on the medial and lateral femoral condyles, we were able to quantitatively determine bone density relationships between sections on both condyles.
- The medial femoral condyle has an increased average bone density from its' lateral counterpart and therefore carries more load.
- Average transverse sectional bone densities had oppositely oriented trend lines between condyles at 1mm from the most distal most point of the femur. At 7mm from the distal femur, the average transverse sectional bone densities followed a similar trend between condyles.
- Using Osteoapp software, measurements repeated 3 times of frontal height and width as well as sagittal height and length all had a coefficient of variation under 5%, thus, this system was deemed accurate and repeatable.

FUTURE WORK

- Using the Osteoapp ROI method of sectional density analysis, we will determine if there is a difference in the subchondral bone distribution or morphometrics between breeds.
- We will determine if there is a difference in the subchondral bone distribution and morphometrics between healthy and unhealthy distal femurs.

ACKNOWLEDGMENTS

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