Morphological characteristics of subchondral bone cysts in medial femoral condyles of adult horses as determined by computed tomography

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OBJECTIVE
To determine morphological characteristics of subchondral bone cysts (SBCs) in medial femoral condyles (MFCs) of adult horses with orthopedic disease.

SAMPLE
CT scans of 7 MFCs with SBCs from 6 adult horses.

PROCEDURES
CT was used to determine the volume, surface area, and centers of the articular cyst opening and SBC in each MFC. Cysts were ordered from smallest to largest on the basis of volume. Osseous pathological characteristics of the MFC were assessed in the frontal plane. Three-dimensional distance of displacement between the center of the articular cyst opening and center of the cyst was determined for each SBC. Cyst surface area-to-volume ratio was evaluated and compared with that of a true sphere.

RESULTS
All SBCs had a defect in the subchondral bone plate at the cranial 15% to 20% of the MFC. Cyst center was located in a caudal, proximal, and abaxial direction with respect to the center of the articular cyst opening for each horse. Small- and intermediate-volume SBCs were irregular and multilobulated, whereas large-volume SBCs were smooth and discrete with a surface area-to-volume ratio approaching that of a sphere.

CONCLUSIONS AND CLINICAL RELEVANCE
Consistency in morphological characteristics suggested a common etiopathogenesis for SBCs in MFCs of adult horses. Cyst enlargement may have been attributable to a biomechanical predisposition to decrease the surface area-to-volume ratio, resulting in a spherical cyst. (Am J Vet Res 2016;77:265–274)

Subchondral bone cysts are commonly associated with osteoarthrosis in adult horses and humans. Approximately 50% of humans with osteoarthrosis of the knee joint have SBCs, as diagnosed via MRI. The etiopathogenesis of SBCs has historically been believed to be a breaching of the subchondral bone plate by synovial fluid. This belief is supported by the existence of a communication through the subchondral bone plate between the cyst and articular surface, also known as a cloaca. Primary bone contusion has also been suggested as an initiating cause of SBCs. Studies involving the femotibial joint in humans have revealed a correlation between cartilage loss and SBCs. Furthermore, results of finite element analysis of the human hip joint suggest that cartilage thinning and erosions result in increases in focal stress throughout the underlying subchondral bone, theoretically supporting the role of a primary cartilage defect in the etiopathogenesis of SBCs.

Osteochondrosis is believed to be the primary cause of SBC development in MFCs of juvenile horses because of the young age at onset and high incidence of bilateral lesions. In MFCs of adult horses, trauma and osteoarthrosis are hypothesized causes of SBC formation. Regardless of the initiating cause, SBCs are dynamic in nature and their morphological characteristics change with time. These features have been demonstrated in longitudinal studies in rodents and humans, computational and finite element analysis models, and in MFCs of horses. Lesion identification is typically delayed until after osteoarthrosis has developed, resulting in poor outcomes. A better understanding of the morphological characteristics of SBCs would potentially lead to earlier diagnosis, more effective treatments, and improved clinical outcomes.

Correlations between the presence of SBCs and abnormal clinical and imaging findings have been reported, but little is known about the initiation and subsequent progression of the lesions. Morphological similarities between horses and humans

ABBREVIATIONS
HU  Hounsfield unit
MFC  Medial femoral condyle
ROI  Region of Interest
SBC  Subchondral bone cyst
in cartilage and subchondral bone plates have resulted in conduction of numerous experiments involving horses for the translational study of osteoarthritis and cartilage repair. The MFC is the most common site of SBCs in horses and represents the most common clinical condition in horses evaluated at referral hospitals for femorotibial joint lameness. Unlike humans, who develop lesions at multiple loci on a given articular surface, SBCs in horses develop in a predictable location on the MFC and therefore have been used for understanding the development of and evaluating treatments for SBCs. In horses, experimental induction of SBCs in MFCs has been achieved through creation of a primary cartilage defect or penetration through the subchondral bone plate with subsequently induced repetitive trauma.

Development of therapeutic interventions designed to minimize expansion of SBCs requires understanding the morphological characteristics of SBCs in horses. MFCs can be used for this purpose because of the high incidence of SBCs therein. In addition, therapeutic interventions can be evaluated in horses with experimentally induced SBCs. The purpose of the observational study reported here was to use quantitative, qualitative, and mathematical models and CT to comprehensively determine the morphological characteristics of SBCs in MFCs of adult horses with naturally acquired orthopedic disease.

Materials and Methods

Horses

Computed tomographic scans of 7 femorotibial joints from 6 adult horses (3 sexually intact females and 3 castrated males) with an SBC in the MFC for which no surgical intervention had been received were included in the study. Median age was 6 years (range, 3 to 7 years). Distal portions of both femurs (containing cysts 1 and 5) from 1 horse cadaver were severed at the distal diaphysis and disarticulated from the femorotibial joint. Those specimens were initially frozen and then thawed for 24 hours prior to CT scanning within a saline water bath. The CT scans for the other 5 horses were performed on live horses. The study protocol was approved by the Animal Care and Use Committee of Colorado State University, and owner consent was obtained prior to imaging of horses for study purposes.

CT protocol

Computed tomography was performed with a commercially available CT scanner. Scans of the femorotibial joints of the 5 live horses were acquired with horses positioned in lateral recumbency, with the affected side down and the affected hind limb fully extended. Scans of the 2 cadaveric stifle joints were acquired in an orientation mimicking right lateral recumbency. A range of image acquisition settings was used for optimal clinical image quality. Scans were performed and reconstructed at a slice thickness of 0.8 mm and slice increment of 0.8 mm with a bone filter.

After image acquisition, unprocessed CT data were imported into a custom-written software program allowing for specimen alignment, quantitative morphological analysis, and 3-D mapping. Alignment was achieved in 3 planes with a validated technique. Briefly, frontal and sagittal alignment was achieved cranially at the transition of the MFC and medial trochlear ridge of the femur and caudally at the most proximal aspect of the caudal portion of the MFC in perpendicular and parallel orientation, respectively. Transverse alignment was established parallel to the most distal points of the medial and lateral femoral condyles.

Quantitative measurements of SBC morphology

Length, height, and width of MFCs were determined similarly to methods used in a previous study. Cyst volume was determined with a custom-made segmentation operation that created an ROI between −1,000 and 500 HUs (Figure 1). Each scan slice was evaluated in the frontal plane through the entire length of the condyle, and all pixels within the ROI, but not within the cyst, were manually removed so only the cyst proper remained. A 3-D reconstruction was generated for each cyst ROI. Volume and surface area were recorded. Subchondral bone cysts were then ordered from smallest (cyst 1) to largest (cyst 7) volume for the remainder of data analysis.

Morphological characteristics were quantified with the surface area-to-volume ratio of each SBC plotted as a function of cyst size. These measured ratios were compared with the corresponding ratio of surface area ($4\pi X$ radius$^2$) to volume ($4/3\pi X$ radius$^3$) of a perfect sphere. In this comparison, the sphere radius was determined by measuring the SBC volume and deriving from that volume the corresponding radius. A sphere is characterized by a single radius in 3 planes, resulting in an oversimplified depiction of overall cyst geometry. Therefore, the SBC surface area-to-volume ratio was also compared with that of an ellipse, whereby the measurement of 3 separate radii in 3 planes allowed a more accurate assessment of biological variability and true SBC shape. In this situation, evaluation of a generalized 3-D cyst shape was performed by assessing the 3-D cyst radii as half of the maximal cyst length, width, and height in sagittal, transverse, and frontal planes, respectively. The 3-plane measurements of cyst radii were used to calculate the surface area-to-volume ratio for the fitted ellipse by use of the following equations:

\[
\text{Surface area} = 4\pi(a^2b^2 + a^2c^2 + b^2c^2)^{1/3}
\]
\[
\text{Volume} = 4/3\pi abc
\]

in which $a$ represents the greatest SBC radius in the sagittal plane, $b$ represents the greatest SBC radius in the frontal plane, and $c$ represents the greatest SBC radius in the transverse plane, and $p$ is $1.6075$. 

\[\text{Materials and Methods}\]
\[\text{Horses}\]
\[\text{CT protocol}\]
\[\text{Quantitative measurements of SBC morphology}\]
Qualitative measurement of pathological characteristics

The MFC length line derived in the sagittal plane was evenly divided into 10 frontal sections at the cranial 50% of the MFC, resulting in 5% intervals of the MFC length line (Figure 1). All 10 frontal slices were examined for each MFC with standard grayscale CT images and a customized color scale. Each slice was evaluated for the presence of a concavity in the otherwise convex curvature of the MFC, a cloaca extending from the articular surface through the subchondral bone plate, an SBC within the subchondral trabecular bone, and regions in which the subchondral bone plate was intact beneath the cyst within the subchondral trabecular bone. Data points in each frontal slice were summed to determine the most common region of pathological characteristics in the MFC and their position relative to the SBC.

Vector morphology mapping of cysts

The 3-D quantitative topographic relationship between each cloaca and corresponding SBC was evaluated by determining the relative position of the center of the articular cyst opening and center of the cyst for each MFC. The center of the articular cyst opening and center point of the cyst were individually determined with a circle area measuring tool to determine a single approximate center locus in each of the 3 planes (Figure 2). Because MFC dimensions can vary with typical differences in body size, the percentage of individual 3-D displacement distance in each plane (sagittal, frontal, and transverse) over specimen dimensions (length, height, and width) for each MFC was applied to the mean length, height, and width of all MFCs rounded to the nearest 5 mm. This action normalized all distances and angles of displacement so that comparisons could be made among MFCs. To determine the principle direction of cloaca-to-cyst displacement, 3-D vectors were projected in sagittal, frontal, and transverse planes. These data were analyzed to extract the mean angle of displacement from the center of the articular cyst opening to the center of the cyst. The absolute amount of displacement from center of the articular cyst opening to the center of the cyst was determined for each SBC. A linear regression model (with 95% confidence bounds) of the relationship between distance of displacement and size of cyst, with the y-intercept forced at 0, was used to determine the variability in displacement distance that could be attributed to the size of the SBC.

Results

The 7 MFCs from 6 adult horses had a mean length of 70 mm, mean height of 30 mm, and mean width of 45 mm when rounded to the nearest 5 mm. Characteristics of each SBC were summarized (Table 1).

Qualitative assessment of frontal, sagittal, and 3-D reconstructions of SBCs revealed that small and intermediate-sized cysts were highly irregular while larger...
cysts became smooth and spherical in shape (Figure 3). The smallest SBC consisted of a subchondral bone plate defect with limited extension into the subchondral trabecular bone, whereas the majority of cyst volume in the larger SBCs was within the subchondral trabecular bone. All SBCs had an articular surface opening at the cranial 15% to 20% of the MFC in the sagittal plane. The articular surface opening extended caudally as SBCs increased in size (Figure 4). Most MFCs had a subtle concavity in the otherwise convex articular surface cranial to the cloaca, and that concavity tapered back to the typical convex shape as analysis of the MFC moved caudally. The majority of cyst volume was located caudal to the location of the articular communication. A concave but intact subchondral bone plate was present at the caudal aspect of the 3 largest SBCs between the articular surface and the cyst.

All articular surface openings were located at a similar point on the MFC and passed along a similar trajectory, approximately perpendicular to the articular surface. Centers of the articular surface openings were located at the cranial 15% to 20% of the MFC length line in the sagittal plane, distal 32% to 52% of the MFC height line in the frontal plane, and axial 37% to 47% of the MFC width line in the transverse plane for all SBCs. In sagittal, transverse, and frontal planes, all SBCs were located caudal, abaxial, and proximal to the correspond-

Table 1—Horse characteristics and corresponding CT measurements for 7 SBCs in the MFC, ordered from smallest to largest on the basis of cyst volume.

<table>
<thead>
<tr>
<th>SBC</th>
<th>Age (y)</th>
<th>Sex</th>
<th>Breed</th>
<th>Affected hind limb</th>
<th>Volume (mm³)</th>
<th>Surface area (mm²)</th>
<th>Volume (mm³)</th>
<th>Surface area (mm²)</th>
<th>Length (mm)</th>
<th>Height (mm)</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>Sexually intact female</td>
<td>Thoroughbred</td>
<td>Right</td>
<td>6.50</td>
<td>16.70</td>
<td>4.84</td>
<td>13.98</td>
<td>68.24</td>
<td>27.54</td>
<td>42.84</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>Sexually intact female</td>
<td>Quarter Horse</td>
<td>Right</td>
<td>98.46</td>
<td>111.21</td>
<td>104.77</td>
<td>110.09</td>
<td>64.82</td>
<td>28.89</td>
<td>44.04</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>Castrated male</td>
<td>Arabian</td>
<td>Left</td>
<td>880.66</td>
<td>928.64</td>
<td>1,304.31</td>
<td>595.33</td>
<td>62.83</td>
<td>28.7</td>
<td>39.59</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>Castrated male</td>
<td>Quarter Horse</td>
<td>Left</td>
<td>1,757.99</td>
<td>1,209.64</td>
<td>2,708.59</td>
<td>942.68</td>
<td>72.55</td>
<td>29.49</td>
<td>44.27</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Sexually intact female</td>
<td>Thoroughbred</td>
<td>Left</td>
<td>1,901.19</td>
<td>1,497.00</td>
<td>2,152.06</td>
<td>816.77</td>
<td>68.79</td>
<td>29.99</td>
<td>44.83</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>Sexually intact female</td>
<td>Quarter Horse</td>
<td>Right</td>
<td>3,303.69</td>
<td>1,255.65</td>
<td>3,361.81</td>
<td>1,145.35</td>
<td>62.53</td>
<td>28.35</td>
<td>40.63</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>Castrated male</td>
<td>Quarter Horse</td>
<td>Right</td>
<td>5,035.31</td>
<td>1,827.79</td>
<td>5,570.63</td>
<td>1,529.28</td>
<td>69.52</td>
<td>30.59</td>
<td>46.78</td>
</tr>
</tbody>
</table>

Cysts 1 and 5 were identified on different MFCs in the same horse. The approximate fitted ellipsoid measurements of cyst volume and surface area were derived from the largest diameter in sagittal, frontal, and transverse planes to create a more accurate depiction of the biological cyst morphology rather than representation as a true sphere. Medial femoral condyle measurements were averaged and rounded to the nearest 5 mm to provide a normalized value for vectored displacement measurements.
Mean vector angle of displacement for all SBCs was 52°, 24°, and 71° to the x-axis in sagittal, transverse, and frontal planes, respectively (Figure 5). As cyst size increased, distance of displacement between the articular surface opening and the cyst also increased for each MFC (Figure 6). Linear regression revealed that approximately two-thirds of variability in the amount of articular surface opening-to-cyst displacement could be attributed to the ultimate size of the defect ($R^2 = 0.68$), whereas the remaining variability was likely from uncontrolled biological and experimental factors. Actual measurements of the SBC surface area-to-volume ratio agreed favorably with the surface area-to-volume ratio of a sphere with an equivalent cyst volume as well as with the fitted ellipsoidal surface area-to-volume ratio that approximated the overall cyst shape. When the percentage difference between the actual surface area-to-volume ratio and that of a sphere was calculated, intermediate-sized cysts had the largest deviations.

**Discussion**

Although the morphological characteristics of SBCs reportedly change with time, no reports exist of the use of qualitative and quantitative methods to evaluate such characteristics. The present study involving SBCs in MFCs of adult horses revealed a consistent site of articular communication and a 3-D vectored angle of displacement from the articular surface opening to the SBC center for each MFC. All MFCs examined had an intact subchondral bone plate (SCBP) distal to the SBC. All MFCs had a cloaca at the cranial 15% to 20% of the MFC length line.
The qualitative results of the study reported here suggested that SBCs in MFCs of adult horses could have a common etiopathogenesis. Identification of an articular surface opening with limited subchondral trabecular bone lysis for 1 cyst (cyst 1) and detection of a cloaca at the cranial 15% to 20% of the MFC for all cysts suggested that SBCs first developed at the cranial aspect of the MFC with a breach in the subchondral bone plate. This breach could have been a result of subchondral bone plate collapse secondary to microscopic damage in the subchondral trabecular bone or a primary disruption in the subchondral bone plate. The displacement and qualitative morphological data suggested that cyst expansion occurred primarily in a caudal direction within the subchondral trabecular bone, leaving an intact subchondral bone plate (Figure 4). Large SBCs had an intact but concave subchondral bone plate caudally, suggesting

![Figure 5](image-url)

**Figure 5**—Three-dimensional plot of the vectored displacement from the articular surface opening center to the SBC center with an overlay CT 3-D reconstruction of an orthopedically normal MFC (A) and plots of articular surface opening-to-cyst displacement in sagittal (B), frontal (C), and transverse (D) planes. The black line in panel A represents the mean 3-D vectored displacement in each plane for all 7 SBCs represented in Figure 4. All articular openings were at the cranial 15% to 20% of the MFC. In panels B through D, angle of displacement was calculated with the point of the articular surface opening center normalized for all cysts. Mean angle of displacement from the articular surface opening center to the cyst center was identified at a 52° angle from craniodistal to caudoproximal in the sagittal plane, at a 71° angle from axiodistal to abaxioproximal in the frontal plane, and at a 24° angle from cranioaxial to caudoabaxial in the transverse plane.
that cloaca expansion was caused by collapse of the subchondral bone plate after progression of the cyst within the subchondral trabecular bone. However, this possible explanation for SBC cyst initiation and expansion in MFCs of adult horses is based on 1-time measurement of a small number of specimens and therefore needs to be validated by a longitudinal study in which the morphological progression of SBCs is monitored over time.

A subtle concavity was recognized cranial or adjacent to cloaca formation in all MFCs in the present study (Figure 4). Such a concavity has been recognized in horses with and without SBCs that undergo intensive exercise. The articular irregularity is believed to represent a normal morphological characteristic of the MFC, to be a result of osteochondrosis, or to be due to bone remodeling caused by repetitive trauma. Although the clinical importance of the identified articular irregularity is unclear, finite element analysis of the human hip joint has revealed that even partial thinning of cartilage results in peak stress within the subchondral bone plate and trabecular bone. The identified articular irregularity could result in disparate joint loading, potentially leading to maladaptive bone remodeling and formation of a subchondral bone plate, microfracture. Repetitively induced trauma at the site of microfracture could permit the breach of synovial fluid through the subchondral bone plate, leading to cloaca formation and progression of SBCs.

Subchondral bone cysts of the MFC in horses develop in a predictable location, suggesting a common etiopathogenesis. Computed tomographic imaging in the present study revealed a consistent locus of articular surface opening for all SBCs, particularly in the sagittal plane (Figure 5). The small disparities in articular surface opening center loci were likely attributable to expansion of the articular surface opening as the cysts enlarged rather than to a different site of initiation. Results of histologic studies involving SBCs of the MFC indicate that mechanical trauma at the point of load bearing likely results in microfractures, leading to osseous resorptive activity and cyst formation. The SBC articular surface opening for each MFC in the present study was located at the same ROI that would be loaded had the femoro-tibial joint been maximally extended. Focal increases in femorotibial pressures occur when the joint is maximally extended in orthopedically normal horses and in the presence of pathological change, suggesting that repetitive trauma to the cranial aspect of the MFC as the limb strikes the ground in maximal extension is an initiating cause of SBCs in adult horses.

The amount of articular surface opening-to-cyst displacement generally increased in the present study as cyst size increased, suggesting that expansion of SBCs was dynamic and did not occur around a single fixed epicenter (Figure 6). Angle of displacement from the center of the articular surface opening to the cyst center was measured in each plane, and displacement occurred in a cranial to caudal, distal to proximal, and slightly axial to abaxial direction for all SCBs evaluated. Displacement in the sagittal plane was most profound.
from a cranial to caudal direction. Vectored displacement findings were consistent within all SBCs and likely represented the direction and amplitude of the articular forces that existed when the limb struck the ground in extension. These results can contribute to the development of a finite element analysis model to elucidate the hinge and rotational elements of the medial aspect of the femorotibial joint in horses.

Morphological characteristics changed dramatically as cyst volume enlarged in the present study. Smaller and intermediate-sized SBCs were highly irregular and multilobulated (Figure 3), whereas larger cysts were more spherical and had a sclerotic rim. Similar clinical morphological descriptions of SBCs have been published for horses, although no correlation with disease severity has been established. By integrating biophysical principles with the observed morphological patterns, a mathematical and morphological correlation can be made. In particular, the finding that SBCs became more spherical as they increased in size suggested that 2 competing mechanisms were involved: one that acted to minimize the surface area of the defect and another that maximized its volume. Investigations of the properties of fluids, membranes, and other plastically deforming objects have revealed that the competition of these forces drives objects to become spherical. In these examples, surface tension forces typically serve as a mediator, and thus, we argue by analogy that the morphological evolution of SBCs may be driven by an effective surface tension that arises from the interplay among mechanical loading, forces at the fluid-bone interface within the joint, and bone remodeling. Findings of the study reported here indicated that effective surface tension may be related to bone remodeling and a mechanical impetus for osteoclastic activation to create more spherical SBCs.

In the present study, intermediate-sized cysts had extensive intraskeletal trabecular struts that disappeared as the cysts became larger, smooth, and spherical. The presence of intraskeletal trabecular struts within intermediate-sized cysts resulted in a honeycomb appearance with small ellipsoid cavities coalescing at multiple points similar to a cluster of grapes (Figure 3). In a finite element analysis of surface tension within a fluid pressurized bone cyst, an increase in fluid pressure resulted in stress shielding and decrease in strain energy to the surrounding trabecular bone. The outcome was net bone resorption and enlargement of morphologically irregular cysts. Further modeling that incorporated bone adaptation in response to cell death resulted in a large spheroid cyst with a sclerotic rim. Although the exact method of cyst volume expansion is poorly understood, findings of the present study suggested a predilection for decreasing the surface area-to-volume ratio, leading to a spherical shape as cyst size increased. Those findings indicated that SBCs in MFCs of adult horses were potentially initiated with an articular surface opening, developed an irregular multilobulated shape, and finally became a large spherical cyst with sclerotic margins. The newly proposed effective surface tension hypothesis for cyst progression is based on the interplay of mechanical loading, fluid-solid forces within the joint, and bone remodeling. This hypothesis is in its infancy and thus deserves much scrutiny. A combination of longitudinal observational and experimental studies would help to elucidate the details of SBC progression.

Identification of a consistent site of articular communication of SBCs in MFCs and therefore a possible site of initiation could allow additional investigation of subclinical cyst development before SBCs are readily detectable on caudocranial radiographic views. A flexed 20° craniofemoral oblique projection can be used to highlight the cranial 15% to 20% of the MFC where the SBC cloaca is found. In the authors’ hospitals, this projection has been successfully used in the diagnosis of subclinical SBCs in the MFCs of horses that cannot be identified on other projections. Early diagnosis could allow for timely monitoring and rehabilitation before irreversible cyst enlargement and development of advanced degenerative disease ensues. Furthermore, if SBC enlargement is a result of effective surface tension forces at the interface between fluid and bone and an overall predisposition to decrease the surface area-to-volume ratio, then an effort to surgically obliterate any fluid within the cyst cavity may be appropriate. This can be accomplished by packing the surgically debrided cyst with a sealed cancellous bone graft or synthetic bone substitute.

Unlike a sphere, the closed analytic expression for the surface area of an ellipsoid does not exist; however, an empirical approximation of ellipsoid surface area proposed by Knud Thomsen results in a relative error of 1.061%. This approximation has therefore been used extensively in multiple biological studies to investigate the effects of surface area-to-volume ratios of organisms and tumors. Subchondral bone cysts in the present study were believed to have been caused by repetitive trauma to the cranial aspect of the MFC when the affected limb struck the ground in full extension. Subchondral bone cysts in juvenile horses or at other anatomic regions potentially have a different primary etiopathogenesis.

The present study had several limitations. The small number of MFCs used may not have allowed representation of the entire breadth of morphological characteristics of SBCs of the MFC and prevented robust statistical analysis. Acquisition of femorotibial CT scans from live horses is only available at a few institutions because of a limited ability to fit the hind limb of a horse into most standard CT bores. Findings were further constrained by the strict inclusion criteria to exclude SBCs in adult horses that had previously received surgical intervention. Horses > 3 years of age were chosen in an effort to evaluate SBCs that might have developed as a result of repetitive trauma. The age at which each SBC had developed was unknown.
for all horses, and the 2 cysts with the largest volumes were identified in 3-year-old horses. Osteochondrosis could not be ruled out as the primary cause of any SBC, despite inclusion of only adult horses. Disease severity was derived on the basis of SBC volume rather than lameness or degenerative disease within the joint. The presence of SBCs in humans with osteoarthritis is not strongly associated with degree of pain,30 making the correlation between size and disease severity in the present study potentially inappropriate. The study was also observational in design, involving CT scans of 7 MFCs in 6 horses with clinical orthopedic disease. Longitudinal evaluation of horses with experimentally induced or naturally developing SBCs is necessary to identify mechanisms underlying the initiation and progression of SBCs in adult horses.

In the study reported here, an articular communication with the SBC was identified at the cranial aspect of each MFC evaluated. Displacement from the clavicular center to cyst center occurred in a predictable 3-D direction. Distance of that displacement increased as the cyst volume increased, suggesting that the progression of SBCs was dynamic and had not taken place around a single locus. Cyst initiation was believed to have occurred with an articular surface opening and while expansion took place within the subchondral trabecular bone. Secondary collapse of the subchondral bone plate was believed to have resulted in articular surface opening expansion. Small and intermediate-sized SBCs were highly irregular in shape, with a large surface area-to-volume ratio. As volume increased, cysts became more homogenous with smooth spherical boundaries, resulting in a decreased surface area-to-volume ratio. The mechanism of SBC progression in affected horses was not identified; however, findings suggested that a predilection existed to decrease the overall surface area-to-volume ratio similar to that of a sphere. Longitudinal studies are needed to determine the sequence of events leading to SBC formation and expansion in adult horses.

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Footnotes


b. OsteoApp, Orthopaedic Research Center, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, Colo.

c. IDL, version 5.4, Research Systems Inc, Boulder, Colo.

d. MATLAB, Mathworks, Natick, Mass.

References


