Comparison of the Mid-shaft Bone Geometry Between Fractured and Non-fractured Femora in Newborn Calves

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ABSTRACT

Background: Femoral fractures are one of the most common fractures in newborn calves. Other than trauma, some factors may play a role in femoral fractures in newborn calves. The evaluation of the mid-femoral bone geometry in calves may provide valuable information to the veterinary orthopaedists due to the relationship between the success of the orthopaedic surgery. The purpose of the study was to determine the mid-femoral bone geometry in newborn calves, even if there was difference between fractured and non-fractured femur radiographs.

Materials, Methods & Results: Fractured femora in 20 newborn calves were enrolled to study, and 40 femora from 20 age and sex-matched calves without any obvious orthopedic diseases were included. All calves (n: 40) were Holstein, at the age of 1-10 days, weighing 20-45 kg. Mediolateral femur radiographs were taken and measurements of the periosteal (Wp) and endosteal widths (We), as well as cranial (Tcr) and caudal (Tca) cortical thicknesses were performed directly with digital caliper from the mid-shaft of the femora, where the minimum outside diameter and thickest cortex were present. Craniocaudal radiographs were not evaluated due to the abnormal projections. Three consecutive measurements were obtained at once a week interval. A paired t-test and Wilcoxon test was used to determine the differences between the same measurements of the right and left sides of non-fractured femora in normally and not normally distributed variables, respectively. The repeated-ANOVA was used to compare to the three consecutive measurements. The femoral cortical index (FCI) was calculated, using the formula: (periosteal width - endosteal width) / periosteal width. Additionally, the volume per area (VPA) was calculated, assuming the cylindrical shape of the femoral mid-shaft, by formula: \[ \pi \times (\text{periosteal width} - \text{endosteal width}) \times (1 - \frac{\text{periosteal width}}{\text{endosteal width}}) \]. Two-way analysis of variance (ANOVA) was conducted to assess the effects of bone status (fractured or non-fractured) and gender on variables consisting of the age, body weight (BW), periosteal (Wp) and endosteal widths (We), cranial (Tcr) and caudal (Tca) cortical thicknesses, femoral cortical index (FCI), and volume per area (VPA). Post hoc multiple comparisons were performed using Tukey test. No significant differences were found in all measurements regarding to gender and bone status-by-gender interactions between the fractured and non-fractured groups. However, fractured group presented thinner Tcr \((P = .001)\), lower femoral cortical index-FCI \((P = .006)\) and higher We \((P = .041)\) than non-fractured group. No significance was found for Wp \((P = .623)\), Tca \((P = .301)\) and VPA \((P = .158)\) between fractured and non-fractured groups.

Discussion: Cortical thickness and periosteal width at the fractured site may cause technical problems for obtaining accurate measurements. Because of the mid-shaft of the bones was not affected, mediolateral femur radiographs were used in this study. The periosteal width was reported in literature that, on the midshaft femur of calves as 25.4 ± 2.1 mm on left and 25.5 ± 2.1 mm on right. In this study, the periosteal widths of the midshaft femur were measured as 23.8 ± 4.05 mm and 24.4 ± 2.92 mm, in fractured and non-fractured groups, respectively. Even though there were differences between studies, the periosteal widths were found similar to each other. Cortical index is useful variable for evaluating periosteal and endosteal width of the bones. In this study, fractured group had higher endosteal width and lower cranial cortical thickness and femoral index than controls. These findings may indicate abnormal modeling of the femur, especially on the endosteal expansion in the fractured group. To understanding for medullar expansion and lower cortical thickness of the femur during prenatal period, further studies may be warranted in newborn calves.

Keywords: calf, femur, bone geometry.
INTRODUCTION

Calves are exposed to various infectious and non-infectious diseases during neonatal period [23,27], and trauma is one of the most important non-infectious etiological factor that playing an important role in bone fractures. Kicking by other animals, sliding down, transportation, traffic accidents, pressing on extremity by mother, dystocia or wrong manipulations during dystocia have been encountered as the traumatic causes of these fractures in calves [2,16-18,32]. Apart from trauma, some other factors that can be determined by morphometric techniques may also play a role in fracture aetiology. For instance, the material properties and the geometry of a bone are mainly related to the bone strength [1,5,21,25]. Recent studies have shown that the bone geometry is more important than the bone material properties in the assessment of bone strength, and this method has possessed an increasing interest among anthropologists and orthopedists in human medicine [1,9,11,14,15,19-21,25,29,30,33]. Femoral fracture is one of the most common fractures following the metacarpal fractures in newborn calves [2,6,7,13,18]. Some factors other than trauma may play a role in femoral fractures in newborn calves. Therefore, the evaluation of the mid-femoral bone geometry in calves may provide valuable information to the veterinary orthopedists due to the relationship between the success of the orthopedic surgery and understanding of a bone with all aspects [16,32]. The purpose of the present study was to determine the mid-femoral bone geometry in newborn calves, even if there was difference between fractured and non-fractured femur radiographs for its prognostic usability in newborn calves.

MATERIALS AND METHODS

A total of 35 calves with fractured femur were presented to Department of Surgery of the Veterinary Faculty at Adnan Menderes University in Aydin (TR) between January 2002 and January 2012. In fractured group; 20 newborn calves with fractured femora were enrolled (51.4%). The selective criteria were that of the mid-shaft of the femur not affected. Classifications of the fractures were not available (data not shown). However, according to the aim of the study, all fractures seen in distally were considered. In non-fractured group; 40 femora from 20 age and sex-matched calves without any obvious orthopedic diseases were included. All calves (n: 40) were Holstein, at the age of 1-10 days, weighing 20-45 kg (Table 1).

Mediolateral femur radiographs (High Frequency Inverter Radiography X-ray System) were taken and measurements of the periosteal (Wp) and endosteal widths (We), as well as cranial (Tcr) and caudal (Tca) cortical thicknesses (Figure 1) were performed directly with digital caliper from the mid-shaft of the femora, where the minimum outside diameter and thickest cortex were present [16,28]. Three consecutive measurements were obtained at ones a week interval by the same investigator in order to eliminate any possibility of intra-observer variability. Cranio-caudal radiographs were not evaluated due to the abnormal projections of the femur arising from muscle contraction on radiographs.

Considering relatively limited numbers of the sample, all data were checked for the normal distribution with Shapiro-Wilk test. First of all, a paired t-test and Wilcoxon test were used to determine the differences between the same measurements of the right and left sides of non-fractured femora in normally and not normally distributed variables, respectively. If there was no significance between the two sides and among the triple measurements, the arithmetic means of these values was used for further statistical evaluations. The repeated-ANOVA was used to compare to the three consecutive measurements of each variable. The femoral cortical index (FCI) was calculated, using the formula: (periosteal width – endosteal width) / periosteal width. Additionally, the volume per area (VPA) was calculated, assuming the cylindrical shape of the femoral mid-shaft, by formula: \( \pi \times (\text{periosteal width} - \text{endosteal width}) \times (1-\text{femoral cortical index}) \). Two-way analysis of variance (ANOVA) was conducted to assess the effects of bone status (fractured or non-fractured) and gender on variables consisting of the age, body weight (BW), periosteal (Wp) and endosteal widths (We), cranial (Tcr) and caudal (Tca) cortical thicknesses, femoral cortical index (FCI), and volume per area (VPA). Post hoc multiple comparisons were performed using Tukey test. \( P \) values <0.05 were considered to be significant. The results were presented as the means ± standard deviations (SD). Statistical analysis was performed using the SPSS statistical package program (SPSS for Windows®, version 19.0, California, USA).
Table 1. The comparisons of the variables between the fractured and nonfractured groups.

<table>
<thead>
<tr>
<th>n</th>
<th>Gender</th>
<th>Age (days)</th>
<th>BW (kg)</th>
<th>Wp (mm)</th>
<th>We (mm)</th>
<th>Tcr (mm)</th>
<th>Tca (mm)</th>
<th>FCI</th>
<th>VPA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fractured</td>
<td>12</td>
<td>♂</td>
<td>3.92±2.91</td>
<td>32.5±8.77</td>
<td>24.1±4.05</td>
<td>15.4±2.47</td>
<td>3.99±1.04</td>
<td>4.78±1.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>♂</td>
<td>3.75±1.98</td>
<td>31.9±6.88</td>
<td>23.5±4.30</td>
<td>14.2±4.00</td>
<td>4.22±1.08</td>
<td>4.80±1.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>Total</td>
<td>3.85±2.52</td>
<td>32.3±7.88</td>
<td>23.8±4.05</td>
<td>14.9±3.12</td>
<td>4.08±1.03</td>
<td>4.79±1.36</td>
</tr>
<tr>
<td></td>
<td>Non fractured</td>
<td>11</td>
<td>♂</td>
<td>3.00±1.00</td>
<td>30.0±4.88</td>
<td>24.2±3.05</td>
<td>13.4±1.37</td>
<td>5.34±1.19</td>
<td>5.03±1.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>♀</td>
<td>5.56±2.07</td>
<td>36.8±5.19</td>
<td>24.6±2.92</td>
<td>12.7±2.17</td>
<td>5.78±1.69</td>
<td>5.54±1.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>Total</td>
<td>4.15±2.01</td>
<td>33.1±5.99</td>
<td>24.4±2.92</td>
<td>13.1±1.77</td>
<td>5.54±1.41</td>
<td>5.26±1.49</td>
</tr>
</tbody>
</table>

Bone status | NS | NS | NS | NS | NS | NS | NS | NS | NS
Gender | NS | NS | NS | NS | NS | NS | NS | NS | NS
Bone status-by-Gender Interaction | NS | NS | NS | NS | NS | NS | NS | NS | NS

*P < 0.05. **P < 0.01. NS: Not significant.

RESULTS

All calves examined were the same breed (Holstein). Gender, age and body weights of the groups were presented in Table 1. Classification was not available, indeed fractures were detected on the distal diaphysis of the femurs, and the cause of all fractures was the inappropriate manipulation during assisting calving.

There were no significant differences in all measurements regarding to gender and bone status-by-gender interactions between the fractured and non-fractured groups. However, fractured group had thinner Tcr ($P = .001$), lower FCI ($P = .006$) and higher We ($P = .041$) than non-fractured group (Table 1). No significance was found for Wp ($P = .623$), Tca ($P = .301$) and VPA ($P = .158$) between fractured and non-fractured groups.

DISCUSSION

This study was carried out retrospectively; therefore contralateral femura of the fractured group could not be evaluated. However, calves in non-fractured group were the same breed with similar age, gender and weight distribution with the fractured group (Table 1). Therefore, it was possible to compare the variables between fractured and non-fractured groups.

Femoral fractures are one of the most common fractures detected after the metacarpal fractures in newborn calves. Forced extraction during dystocia is one of the causes of the femoral fractures [2,6,7,13,16-
The causes of all fractures in this study sample were also related to the wrong assisting during calving. It is indicated that measuring cortical thickness and periosteal width at the fractured site may cause technical problems for obtaining accurate measurements [16]. Because of the latter and because of the mid-shaft of the bones was not affected in all cases, mediolateral femur radiographs were used in this study.

The periosteal width was reported on the mid-shaft femur of Fleckviegh calves as 25.4 ± 2.1 mm on left and 25.5 ± 2.1 mm on right [16]. In this study, and the periosteal widths of the midshaft femur were measured as 23.8 ± 4.05 mm and 24.4 ± 2.92 mm, in fractured and non-fractured groups, respectively. Even though there were differences on designing and evaluating of the measurements and the breed of calves between studies, the periosteal widths were found similar to each other.

Geometry and cortical thickness of the bone are thought to be very important parameters in the fracture etiology [1,3,5,12,21]. In addition to a large body of evidence for bone quality, periosteal width and cortical thickness have strong relationship between bone strength and resistance to fracture [3,4]. Evaluating bone morphometry may provide better understanding of the ethiological factors in fracture formation and location. Therefore, several methods are described for assessing bone quality each possessing some advantages and disadvantages [12], and it must be mentioned that, there is no single exact method, which can completely characterize bone quality. Cortical index is one of the noninvasive methods for evaluating bone mass; accordingly, metacarpal cortical index is used for evaluating bone mass and upper limb fractures in children [25]. Measurements used in calculating cortical index are also very useful variables for evaluating periosteal and endosteal width of the bones [28]. Ma and Jones, [25]; indicated that fractured group had a wider endosteal width with same in the periosteal width, resulting in a thinner cortical width and lower metacarpal cortical index than controls. Crabtree et al., [8]; reported that significantly lower local thinning of cortical thickness were found and caused femoral neck fractures in human being. Our findings were in agreement with prementioned studies [8,25] that fractured group had higher endosteal width and lower cranial cortical thickness and femoral index than those of controls. Although it has reported that periosteal width of the long bones predicts up to 55% for bone strength [3], periosteal width was not different between fractured and nonfractured groups in this study. All these data and information described above may indicate abnormal modeling of the femur, especially on the endosteal expansion in the fractured group, and/or may be evaluated as etiologic factors in femoral fractures of newborn calves.

During gestation, formation of the muscles and bones of the fetus could be effected by diseases, nutrients and hormones [10,22,24,31,34,35]. Trabecular bone abnormalities were reported on calf femora while formation of bones in the gestation [26]. Disorders in nutrition, hormonal status and diseases of the dams may be evaluated as possible reasons for abnormal modeling of the bones in newborn calves. However, this study was planned retrospectively; and the calves in the sample were of the same race but not from same origin and environment. Therefore, these effects were missing and could not be used in comparisons. Such investigations in newborn calves may elucidate the factors that contribute to the bone modeling and help to better understand and improve therapy for skeletal pathologies.

CONCLUSION

In conclusion, wider endosteal width and lower cranial cortical thickness associated with lower femoral cortical index may be an additional factor to cause the femoral fractures in newborn calves. Understanding for the provocative factors of medullar expansion and lower cortical thickness during prenatal period, and determining the etiological factors of the femoral fractures further studies may be warranted in newborn calves.

SOURCES AND MANUFACTURERS

1EVA-HF750® COMED, Gwangju, Gyunggi, Korea.
2Mitutoyo 500-707-11®Mitutoyo, Japan.

Ethical approval. This study approved by Institutional Animal Ethics Committee (ADU, 2011/111).

Declaration of interest. The author report no conflicts of interest, and alone is responsible for the content and writing of the paper.
REFERENCES


