Histological Comparison of Long-Bone Cortex between 11-Year-Old Giant Cow with Dermal Dysplasia and the Child Cow Aged 8.5 Years

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ABSTRACT. Young calves are known to be formed with laminar bone in long-bone cortex during growing periods and the osteon formation begins later. Previously, we reported that an 11-year-old giant Holstein cow with dermal dysplasia showed a delayed osteon formation. An 8.5-year-old cow, born from the giant Holstein cow, also showed some dermal dysplasia and the outer-half layer of the child almost retained laminar bone similar to that of the mother, although the body weight was approximately normal. The mother had formed the inner circumferential lamella and the child was going to form the inner circumferential lamella, but their outer circumferential lamellas were not formed yet in both of them, when compared with a 12-years-old cow as a control of the mother. Therefore, we suggest on long-bone formation pattern that the child resembled the mother rather than the control, and that the child had more or less succeeded to the mother genes of delayed osteon formation as well as dermal dysplasia which seemed to be genetic collagen disorder, although there were mild gene appearances.

KEY WORDS: giant cow and the child, laminar bone cortex, osteon formation.


Table 1. Profiles of Holstein cows used in this radius-bone histological study

<table>
<thead>
<tr>
<th>Connection</th>
<th>Sex</th>
<th>Age</th>
<th>Body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child 1</td>
<td>♀</td>
<td>8.5 years</td>
<td>650–700 kg</td>
</tr>
<tr>
<td>Cow 1</td>
<td>♀</td>
<td>11 years</td>
<td>1,000 kg</td>
</tr>
<tr>
<td>Cow 2</td>
<td>♀</td>
<td>12 years</td>
<td>700 kg</td>
</tr>
</tbody>
</table>

The laminar bone has been reported to form long-bone cortex in young calf, pig, sheep, and other young large animals [2, 3, 5, 8–12, 15] including some larger dinosaurs [4, 6]. One laminar bone unit consists of a hypercalcified primearl line in the center, woven bone on both sides of the line, and lamellar bone with laminated appositional lines [2–6, 9–12]. Such a laminar bone as calf bone-cortex is gradually replaced by Haversian bone with osteons during their growth periods [2, 10, 11, 15]. Previously [9], we reported that an 11-year-old giant Holstein cow with dermal dysplasia (Cow 1) [7, 14] showed a delayed osteon formation in a larger number of the remaining laminar bone volume compared with a 12-year-old Holstein normal cow (Cow 2). In additions, the outer circumferential lamella formation, meaning the stop of bone growth in thickness [1, 6, 16], was not formed yet. That is, the giant cow bones were suggested to be growing yet at the 11-year-old stage of about 1,000 kg by body weight.

In this short bone-histological report, we compared the radius of Cow 1 with that of the 8.5-year-old Holstein cow (Child 1) born from Cow 1 by backcrossing. Table 1 is the profiles of three Holstein cows used in this study. Such a Child 1 also possessed more or less dermal dysplasia as well as Cow 1, although the body weight was an approximately normal weight from 650 up to 700 kg [13]. In this study, we aimed to investigate the bone histology whether Child 1 possessed the delayed formation osteon shown in Cow 1 or did not. The transverse polished surfaces at 4 directions including mesio-distal and cranial-caudal regions were measured by quantitative analysis of backscattered electron (BSE) images in a scanning electron microscope (S-2500CX, Hitachi, Tokyo, Japan). This was performed on a Windows computer using the public domain Scion image program (developed at the U. S. National Institute of Health and available from the Internet by anonymous FTP from zippy.nimh.gov.), followed by our previous study [11]. In each cow, the total bone volume including laminar bone and Haversian bone (osteons and interstitial lamellas), and the osteon number per a unit (mm²) were shown as mean values (n=4 in 4 directions including the exterior, interior, anterior, and posterior sides). The osteon number was counted with Haversian canal.

Figure 1 shows the BSE image of the transverse polished surface from the inner to the outer circumferential periphery in the cranial-side long-bone cortex of Child 1. Osteons showing various calcifications by bone-remodeling and interstitial lamellas without Haversian canals were visible in the inner-half layer, whereas laminar bone was clearly retained in the outer-half layer. In additions, the interstitial lamellas dotted among the osteons. The inner circumferential lamella was initially formed only in the exterior side, but...
the outer circumferential lamella was not formed yet.

Figure 2 shows the BSE images of the outer (upper side) and the inner circumferential lamella (lower side) in Child 1 (left side), Cow 1 (center) who was the mother of Child 1, and Cow 2 as the control of Cow 1 (right side). In Child 1, the inner circumferential lamella was observed in the inner peripheral layer except, but the outer circumferential lamella was not found in the outer periphery at all. Cow 1 formed the inner circumferential lamella, but the outer circumferential lamella was not found at all. Cow 2 formed the inner and outer circumferential lamellas in all around the peripheral layers.

Figure 3 is the histogram of the total bone volume ratio including laminar bone and Haversian bone including osteons with Haversian canals and interstitial lamellas without Haversian canals in Child 1, Cow 1, and Cow 2. They were similar to each other in the total bone volume ratio. The ratio of the Haversian bone volume to the total bone volume was also shown in Fig. 3. This ratio in Cow 2 was tended to be larger than Child 1 and Cow 1. However, the ratio of the Haversian bone volume to the total bone volume in Cow 1 tended to be lower than that in Child 1.

Figure 4 is the histogram of the osteon number per a unit (/mm²) in the entire bone cortex including divided into 5 layers from the inner layer [I] towards the outer layer [V]. On the osteon number per a unit, Child 1 was lowest, and Cow 1 was intermediate between Child 1 and Cow 2 (Fig. 4). However, on the Haversian bone volume ratio including the interstitial lamellas as well as osteons, Child 1 was somewhat larger than Cow 1, i.e., the mother of Child 1 (Fig. 3). These data (Figs. 3 and 4) suggest that the osteon formation and the remodeling followed by the formation of interstitial lamellas in Child 1 at the 8.5-year-old stage had been put into earlier than the Cow 1 at the same stage.

Kawaguchi et al. [7] and Naito et al. [14] reported by biochemistry and microscopically that Cow 1 had the dermal dysplasia of collagen disorder-related skin fragility, probably based on increasing turnover of the dermal collagen fibrils. Previously [9], we indicated in the bone matrix of Cow 1, similar to the dermal collagen formation [7, 14], that a larger amount of newly-formed collagen fibrils, might be calcified during laminar bone formation without bone remodeling [2]; thus, the increasing bone formation was seen in Cow 1 until 11-year-old or so [9]. There was retained as the problem whether such a delayed osteon formation succeeded to the next generation or dose not, as well as the dermal dysplasia based on collagen disorder [7, 14]. However, the descendants were regrettably ceased in Child 1 born from Cow 1.

In Child 1 at 1.5 years after birth, the hairs of the middle-tail region measuring about 15 cm in length were left out following blood running, and external wounds in many parts of the body and wrinkles in the face were clinically recognized, though the dermal dysplasia was less than the mother (Cow 1) [7, 14]. However, there were no abnormalities other than the skin wounds although the violent heavier was shown.
Fig. 2. BSE images of the outer (upper side) and the inner circumferential lamella (lower side) in Child 1 (left side), Cow 1 (center), and Cow 2 (right side). OCL zone: the outer circumferential lamella and ICL zone: the inner circumferential lamella in the interior side. Scale bar: 0.2 mm.

Fig. 3. Histogram of bone volume including laminar bone and Haversian bone (osteons and interstitial lamellas) on the transverse polished surface of radius cortex in Child 1 (left), Cow 1 (center), and Cow 2 (right). Black column: Haversian bone volume. White column: laminar bone volume. Unit: percentage (%).

Fig. 4. Histogram of the density of osteon number to the entire cortex in Child 1 (left), Cow 1* (center), and Cow 2* (right). Examination of the transverse polished surface of radius cortex is equally divided into 5 layers (I to V) from the inner to the outer circumferential periphery. Note: * cited from the reference [9]. Unit: osteon number/mm² × 5 layers.
It has been denoted that Holstein cow was stabilized growth in body weight and height during 5 to 6.5 years after birth in a veterinary dictionary [13]. This note will mean that the laminar bone formation on the thickness-growth of long-bone cortex [2, 6, 9–11] is stopped during 5 to 6.5 year after birth; and then the outer circumferential lamella will be formed already [1, 6, 16] as shown in Cow 2 as the control of Cow 1. Child 1 at the 8.5-year-old stage was 650 to 700 kg by weight. Therefore, Child 1 showed an approximately normal size [13] as compared with Cow 1 at the 11-years-old stage showing a heavier weight of about 1,000 kg [9]. However, in both the Child 1 and Cow 1, their laminar bones containing a smaller number of osteons were retained enough in the outer-third layers and their outer circumferential lamellas were not formed yet. We think that the child cow (Child 1) has more or less inherited the mother (Cow 1) genes of delayed osteon formation as well as dermal dysplasia although their gene appearances were a little. We suggest that the child cow (Child 1) would have become a larger cow in the 11-year-old stage nearly to the mother (Cow 1) [9].

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REFERENCES