Effects of aluminum hinged shoes on the structure of contracted feet in Thoroughbred yearlings

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We applied aluminum hinged shoes (AHSs) to the club foot-associated contracted feet of 11 Thoroughbred yearlings to examine the effects of the shoes on the shape of the hoof and third phalanx (P III). After 3 months of AHS use, the size of the affected hooves increased significantly, reaching the approximate size of the healthy contralateral hooves with respect to the maximum lateral width of the foot, the mean ratio of the bearing border width to the coronary band width, and the mean ratio of the solar surface width to the articular surface width. These results suggest that the AHSs corrected the contracted feet in these yearling horses.

Key words: club foot, contracted foot, foal, hinged shoe

Contracted foot is a farriery term describing the condition in which the inner and outer buttresses of the foot become closer together than normal, with potential atrophy of the frog [1, 3, 8]. This condition can occur in horses of all ages. Possible causal factors include genetics, shrinkage due to moisture deficiency in the hoof wall, low heel growth accompanied by poor blood circulation due to insufficient exercise and disproportionate load balance on the frog and heel due to abnormal limb/foot conformation [2–4, 11]. In young foals, contracted foot can be congenital or acquired. Conditions requiring long-term rest because of navicular syndrome, untreated long-toe/low-heel conformation, or progressive club foot are often associated with acquired contracted foot [2, 3]. We have observed foals that developed this abnormality. In our experience, the irregular shape of the affected foot tends to persist, inducing narrowing of the posterior (i.e., palmar) end of the third phalanx (P III), when this abnormality is not treated with special farriery. In addition, if only one foot is contracted, the resulting uneven feet can shorten a horse’s racing career [7]. The principles of shoeing dictate that the right and left feet should be corrected, if possible, to appear as mirror images [9]. Consequently, a contracted foot can negatively impact the commercial value of a young horse, even if the horse’s conformation or gait is unaffected [6]. Thus, appropriate adjustment of foot shape is very important for foals.

A 2009 survey of equine club foot in Japan revealed a large number of cases of club foot and subsequent contracted foot in foals kept in the Hidaka area of Hokkaido [12]. Suitable devices for the treatment of this condition are still being developed. Earlier methods involved shoeing using a hoof spring combined with an expanding shoe [3]. Attachment of these expanding shoes requires nailing. Expansion and concentration of mechanical stress at the nail points of the hoof can easily corrupt the relatively softer hoof wall of a foal. Thus, this technique has not been widely accepted by Japanese farriers. Aluminum hinged shoes (AHSs) have been recently introduced; designed and developed in the U.S.A., these devices are attached using adhesive resin but no nails. Because these shoes are glued to the entire bearing border of the hoof that contacts the ground, the expansion
force disperses across the entire hoof wall, making them safer and more practical for use in young foals. However, there is no quantitative data indicating the efficacy of AHSs in correcting irregular hooves and P III shapes. Here we used this special shoe in a group of Thoroughbred yearlings and measured changes in the shape of the hoof and phalanx, allowing us to evaluate the efficacy of the AHS in treating contracted foot.

Eleven Thoroughbred yearlings (weight, 330–408 kg; median weight, 351 kg; age, 364–438 days; median age, 403 days) born at three ranches in the Hidaka area of Hokkaido were selected for this study (Table 1). Each foal was affected with “club foot” in one front foot and consequently developed contracted foot in the affected limb. To correct their club feet, all foals were constrained to a pasture and treated, treated with NSAIDs and a muscle relaxant, and an acrylic resin toe extension was applied to the hoof according to the method described by Curtis [5]. However, their conditions did not improve. The coronary band bulging in the toe, concaved dorsal hoof wall, P III rotation, and contracted heels gradually progressed. We waited until spring to apply the AHSs to avoid the risk of slipping or falling on slick ground. From late April to May, when the snow on roads had melted, we applied the AHSs to their contracted heels. After AHS application, all affected horses were free to move in their paddocks during the day and were kept in a barn at night.

The AHS used in this study comprises an aluminum shoe divided into two sections (the inner and outer branches) (Rood and Riddle Equine Hospital, Lexington, KY, U.S.A.),

Table 1. Studied foals suffering “contracted foot” associated with club foot

| No. | Birth    | Sex  | Weight (kg) | Site of contracted foot | Club foot grade | Age in days at beginning of AHS |
|-----|----------|------|-------------|-------------------------|-----------------|--------------------------------|
| 1   | 10th Feb | male | 348         | LF                      | 3 2             | 418                            |
| 2   | 12th Feb | female | 398        | LF                      | 2 2             | 416                            |
| 3   | 20th Feb | female | 330        | LF                      | 2 1             | 408                            |
| 4   | 25th Feb | male   | 374         | LF                      | 3 2             | 403                            |
| 5   | 11th Mar | male   | 346         | RF                      | 2 1             | 388                            |
| 6   | 18th Mar | female | 348         | RF                      | 1 1             | 398                            |
| 7   | 1st Apr  | female | 408         | RF                      | 2 1             | 423                            |
| 8   | 4th Apr  | female | 358         | RF                      | 2 1             | 364                            |
| 9   | 12th Apr | male   | 380         | LF                      | 3 3             | 397                            |
| 10  | 17th Apr | female | 354         | RF                      | 2 1             | 394                            |
| 11  | 12th May | male   | 390         | RF                      | 1 0             | 438                            |

RF: right forefoot, Pre: before AHS application, LF: left forefoot, Post: three months later the beginning of AHS application.
CONTRIBUTED FOAL FEET WITH HINGED SHOES

A spring (Lazy J Enterprises, Arizona, U.S.A.), and rivets and steel wire (Fig. 1). The assembled shoe was attached to the bearing border of the hoof using an adhesive resin (Equilox, Equilox International Inc., Pine Island, MN, U.S.A.). Once the shoe was attached and fixed to the foot, the tied wire was cut to engage the heel-expanding force of the spring. To keep the spring in place, we filled the ground surface of the sole and frog with urethane packing material (Equi-Pak, Vettec Hoof Care Products Inc., Oxnard, CA, U.S.A.) (Fig. 2). The age of the horses at the time of AHS application was 12–14 months (364–438 days), and the average age was 13 months. The shoes were renewed and replaced approximately every month. Concurrently, the healthy control feet were shod with normal aluminum shoes using nails, which were also renewed and replaced every month.

Each club foot was evaluated before trimming of the foot. Disease progression was classified according to Redden’s grading system [10] (Grade 0 to 3, depending on severity) on the basis of conformational changes in the hoof and degree of flexural digital deformity. Morphological measurement of the foot was performed right after trimming but before shoeing at the first shoe application and again 3 months later. Changes in the conformation of the foot were calculated according to differences in the length of each measured section before and after the AHS trial. We first measured the maximum lateral width of the foot (corresponding to the width of the bearing border on the radiograph) using a caliper (Digimatic Caliper CD-20PSX, Mitutoyo Corporation, Kawasaki, Japan). At the first AHS application, radiographs of the dorsopalmar view of the foot were recorded using a portable X-ray device (Atomscope-20SH, Mikasa Vets Co., Ltd., Tokyo, Japan) and imaged using a computerized imager (Regius model 190, Konica Minolta Inc., Tokyo, Japan). The brightness and contrast were adjusted to sharply define the edges of the hoof in the frontal view. We did not use any contrast agents to sharpen the edges because it was impossible to precisely portray outlines of the randomly curved hoof wall in the dorsopalmar radiograph view. We then measured the breadth of the coronet, the bearing border of the hoof capsule and the width of the articular and solar surfaces of P III (Fig. 3) using a picture archiving and communication system (PACS; Neovista I-PACS EX, Konica Minolta Inc.). The actual length was estimated from the radiograph by scale-to-scale conversions, contrasting the breadth of the bearing border on the radiograph with the maximum lateral width by visual judgment. From the estimated values, the ratio of the bearing border width to the coronary band width (B/C ratio) and the ratio of the solar surface width to the articular surface width of P III (S/A ratio) were calculated. All measurements were made in triplicate, with each of the three sets measured by a different person. When Kendall’s coefficient of concordance showed unanimous agreement with significance ($P<0.05$), averaged data were used in this study. This representative data for the groups were analyzed using the Student’s $t$-test (Microsoft Excel 2003, Microsoft Japan Co., Ltd., Tokyo, Japan), and a $P$-value $<0.05$ was
considered statistically significant.

At the first evaluation of club foot severity, two foals showed grade 1 (G1), six showed G2, and three showed G3. Three months after the initial AHS application, two foals had improved from G3 to G2, five foals had improved from G2 to G1, one foal had improved from G1 to G0, and three foals showed no improvement. In total, eight of 11 foals (72.7%) showed improvement in club foot (Table 1). Kendall’s coefficient of concordance indicated good agreement of the maximum lateral width of the hoof, the bearing border width, the coronary band width, the articular surface width of P III; and the solar surface width between the three observers. Before AHS application, the mean values of the maximum lateral width were 89.06 ± 3.66 mm (± standard deviation; SD) in the contracted feet and 96.01 ± 3.69 mm in the controls, indicating a significant difference. After 3 months, the mean values of the maximum lateral width were 105.39 ± 3.20 mm in the contracted feet and 104.42 ± 4.39 mm in the controls, indicating no significant difference (Fig. 4, top). The mean increases in the maximum lateral widths before and after AHS application were 16.33 ± 1.83 mm in the contracted feet and 8.41 ± 2.16 mm in the controls. The mean B/C ratios were 1.01 ± 0.04 mm in the contracted feet and 1.08 ± 0.04 mm in the controls before AHS application (Fig. 4, middle), indicating that the contracted feet were significantly smaller than the healthy control feet. After 3 months of AHS application, the mean B/C ratios were 1.15 ± 0.04 mm in the contracted feet and 1.15 ± 0.04 mm in the controls, indicating no significant difference. The mean S/A ratios were 1.28 ± 0.05 mm in the contracted feet and 1.36 ± 0.08 mm in the controls before AHS application (Fig. 4, bottom), indicating that the contracted feet were significantly smaller than the healthy control feet and that the P III of contracted feet was significantly smaller than that of the controls. After 3 months of AHS application, the mean S/A ratios were 1.39 ± 0.06 mm in the contracted feet and 1.40 ± 0.07 mm in the controls, indicating no significant difference.

Before AHS application, we observed a significant difference in the maximum lateral width of the hoof between the contracted and control feet. In contrast, 3 months after AHS application, this difference was not significant. In addition, the B/C and S/A ratios of the contracted feet, which were significantly lower than those of the controls before AHS application, showed no significant difference compared with the controls after 3 months. These results suggest that the shape of the contracted foot gradually reached to that of the control foot during AHS application (Fig. 5). The AHS accelerated the growth of the contracted foot (including phalanx development) and normalized the foot conformation. Improvement in the palmar P III conformation could have resulted from expansion of the intrahoof capsular volume. The grade of club foot severity decreased in approximately 70% of the horses after 3 months of AHS use. The mechanism underlying this healing is uncertain. Considering that club foot is directly associated with flexural muscle–tendon contraction but not with the palmar structure of the foot, it is difficult to conclude that the hinged shoe could correct the broken-forward hoof-pastern axis and the higher hoof angle than normal. However, we believe that it is possible that contracted heels can cause some mild pain, and pain can worsen the tendon contracture; therefore resolving the heel contracture may help alleviate a portion of the tendon contracture/club foot syndrome. Furthermore, widening of the buttresses and the heel-bearing border may help to appropriately load the horse’s weight, allowing the heel to contact the ground normally and eventually improving the digital axis. Further research is required to elucidate the mechanism underlying the observed improvement in contracted foot with AHS use. Standard guidelines
CONTRACTED FOAL FEET WITH HINGED SHOES

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for the use of an AHS to treat contracted foot should be developed to achieve the maximum effects.

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