Equine Veterinary Education

EQUINE VETERINARY EDUCATION
Equine vet. Educ. (2017) •• (••) ••-••
doi: 10.1111/eve.12742

Original Article

Single transphyseal screws for the correction of moderate to severe angular limb deformities in 28 Thoroughbred foals

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Keywords: horse; valgus; varus; surgery

Summary

This study reports on the effective use of a single transphyseal screw for the treatment of moderate to severe angular limb deformities (ALDs) of the fetlocks and carpi of 28 young Thoroughbred foals. The objective was to evaluate the surgical management of foals with moderate to severe ALDs treated with single transphyseal screws. Evaluation of medical records of 28 Thoroughbred foals treated with single transphyseal screws placed across the distal radial, metacarpal and metatarsal physes was undertaken. The angle of joint deviation was measured prior to implantation and at removal of the implants, and the degree of improvement was calculated. A total of 39 screws were placed: 24 in the distal metacarpus or metatarsus and 15 in the distal radial physis. Varus or valgus deformities in the fetlock improved by 4–5° over a period of 15–30 days. Varus or valgus deformities in the carpi improved by 8–11° in 11–56 days. One case failed to improve adequately due to implant infection. Single transphyseal screws were effective in treating moderate to severe varus and valgus ALD of the fetlocks and carpi in young Thoroughbred foals. Further investigation into their use in the distal radius in young foals is needed. While single transphyseal screws are almost exclusively used by some clinics in the distal metatarsal and metacarpal physes, many clinicians do not use them in the distal radial physis of young foals due to fear of over-correction, physitis and metaphyseal collapse. This was not observed in any of our cases.

Introduction

Congenital angular limb deformity (ALD) observed as an axial deviation in a frontal plane is relatively common in foals and strategies for management thereof, including surgical techniques, are well established (Auer 2012). Foals with ALD can present with either a varus deformity (medial deviation distal to the affected joint/physis) or a valgus (lateral deviation). These deviations are often associated with axial rotation of the distal limb and are mainly observed in the fetlocks, tarsal or carpal regions (Auer 2012).

Diagnosis is mainly based on inspection, manipulation and radiography. To ensure optimal outcomes, early recognition and monitoring are important. The need for early diagnosis is essential, especially if incomplete ossification is suspected, and the clinician always needs to evaluate the entire limb during weight bearing and locomotion. Radiography is used as a complementary examination to allow exact determination of the location and degree of the deformity and is essential for assessment of cuboidal bone ossification (Bramlage and Embertson 1990).

Angular limb deformity conditions require corrective management and one needs to decide on the most appropriate treatment. Most ALDs are self-correcting and only require conservative management, including restricted exercise, splints, corrective hoof trimming and, in some cases, shoeing with extensions placed on the medial or lateral aspect (Ruggles and McIlwraith 2008).

In cases of severe deformities (>10° valgus or 3° varus of the carpus, >3° valgus or varus of the fetlock) (Munroe and Weese 2011) or those that fail to respond adequately to conservative approaches, other treatments focused on growth acceleration or retardation of the bones involved in the ALD, need to be considered. These techniques depend on the growth potential at the physis of the developing foal. Growth acceleration is performed on the concave aspect of the limb and growth retardation on the convex aspect. Periosteal transection and elevation is the original method (Auer and Martens 1982) of growth acceleration but modifications of the technique to minimise the surgical approach have been described, such as hemicircumferential periosteal transection through a stab incision (Auer 2012) and physeal stimulation (Colles 2008). There is currently a debate about the efficacy of these growth accelerating techniques: a recent study by Baker *et al.* (2015) indicated that periosteal elevation has no effect on carpal angulation. Conversely, work on lambs has shown that periosteal transection and elevation have a direct effect on parthyroid hormone and related peptide, all of which are involved in bone growth (Von Rechenberg *et al.* 2010).

Growth retardation is achieved by means of a temporary transphyseal bridge that acts to retard growth on the convex aspect of the limb. The original transphyseal stapling methods (Heinze 1963) are used less frequently for routine bridging except in very young foals, age <3 weeks, and have mostly been replaced by screws and cerclage wire (Fretz and Donecker 1983), the latter material sometimes replaced by a small bone plate (Auer 2012). A nonsurgical approach to local growth retardation has also been described, using radial shockwave therapy (Bussy *et al.* 2013).

More recently, implantation of a single transphyseal screw has been described as an effective method for retarding growth of distal metacarpal and metatarsal bones in young horses with mild to moderate ALDs (Kay *et al.* 2005; Roberts *et al.* 2009). In this case series we report the results of foals with moderate to severe ALDs in the fetlock or the carpi, treated with only a single transphyseal screw.

Materials and methods

Animals and study design

All animals that underwent evaluation/surgery for ALD between August 2010 and April 2015 were identified. Each foal underwent a preoperative examination which consisted of clinical and dynamic locomotor examination as well as radiographic examination. Thoroughbred foals that showed deviations of 4° or greater at the fetlocks or carpal valgus of 10° or greater or varus of 2° or greater were selected for inclusion in this study. Single transphyseal screws were placed in most foals after more conservative approaches failed to correct the deviation adequately. Medical records were reviewed for age in days at time of screw placement and removal, the joint affected and direction of deviation, the number of screws placed and degree of angulation of the deviation before placement and after removal of screws. Cosmetic blemishes and post-operative complications were also noted. Dorsopalmar and dorsoplantar radiographs taken prior to screw placement and at or after time of removal were evaluated for each case.

Prior to surgical intervention, all foals were examined standing and walking in a straight line on a firm surface to and from the examiner. Limbs were evaluated perpendicular to the frontal plane of the outward-rotated limb (Auer 2012). The affected limbs were subsequently radiographed using digital radiograph equipment with dorsoplantar and dorsopalmar views taken with the x-ray beam at a right angle to the frontal plane of the limb with a minimum of 10 cm of the long bones above and below the affected joint included in the projection. Shape and degree of ossification of the cuboidal bones was noted. For the carpus, angle of deviation was calculated after drawing two lines, one through the middle of the distal radius and one through the middle of the McIII/MtIII diaphysis. For deviations of the fetlocks, lines through McIII/MtIII and P1 were drawn. The angle of deviation was calculated where these lines intersected. Radiographs were all evaluated by two authors and the degree of angulation measured independently.

A standard premedication and anaesthetic protocol was used for surgery.

Surgery

Single transphyseal screws were placed under general anaesthetic using the same technique as described by Kay and Hunt (2009). Hooves were balanced, and extensions placed as necessary.

Post-operative follow-up

A standard controlled exercise regime was followed post-operatively.

Foals were re-evaluated every week to assess limb angle and decide on time of screw removal. Once the limb appeared clinically straight, radiographs were taken to assess bone alignment, to ascertain whether correction of the angular deviation was complete. Some screws were removed while a 1–2° deviation remained as there is some further correction of the deformity after implant removal. Radiographs of the affected limb were evaluated either at the time of screw removal or later, and angles of deviation measured as described above. Screws were then removed, either under standing sedation with local anaesthesia or under a short general anaesthetic.

Results

There were 157 foals with ALD of the fetlocks or carpus region that were operated on over a 4-year period, from August 2010 to April 2015 at the first author's clinic. Of these, 28 foals with placement of 39 cortex screws met the inclusion criteria. These are detailed in **Table 1**. All individuals were assessed clinically before and after surgery by the same clinician.

Sixteen screws were placed into 10 foals for front fetlock varus. All screws were removed when a radiographic angle of 0–2° varus was achieved and the clinician was satisfied upon subjective clinical evaluation. One foal had an unrelated lameness of the left forelimb and one foal had a large wound on the operated leg due to a bandage rub, leading to white hairs and a cosmetic blemish.

Six foals received screws in the hind fetlock for unilateral varus. All screws were removed when the radiographic degree of angulation was 0–1°. One foal had a persistent periosteal reaction at the site of screw placement, which was later surgically removed prior to yearling sales.

Two foals had valgus deviations of the fetlocks. One foal with a hindlimb valgus of the fetlock had a concurrent valgus deformation of MtIII, which was addressed with growth acceleration along the lateral aspect of the bone.

Ten foals were treated with 12 screws for carpal valgus deformities. Two foals had bilateral carpal valgus (**Figs 1 and 2**),

TABLE 1: Details of the 28 Thoroughbred foals with severe angular limb deformities treated with the transphyseal screw technique

	Number of screws placed	Mean age at screw placement (days)	Mean duration of implant (days)	Mean angle of deviation at insertion (degree)	Mean angle of deviation at removal (degree)	Mean degree of improvement	Complications
Front fetlock varus	RF 8, LF 8	85.5	32	5.3	0.93	4.4	1 bandage rub with resultant skin defect, 1 poor response
Hind fetlock varus	RH 2, LH 4	68	27	4.8	0.3	4.5	1 persistent periosteal reaction
Front fetlock valgus	LF 1	105	24	4	2	2	
hind fetlock valgus	LH 1	14	27	7	2	5	
Carpal varus	RF 1, LF 2	35	30	5	3	8	
Carpal valgus	RF 8, LF 4	47	35	15	4	11	1 implant infection

LF, left frontlimb; LH, left hindlimb; RF, right frontlimb; RH, right hindlimb.

six foals had valgus of the right carpus, two foals had valgus of the left carpus, one foal that had a right carpal valgus had a contralateral left carpal varus. All screws were removed when the carpus reached an angle of between 1° and 5°. There was one case of implant failure due to implant infection with *Staphylococcus aureus*. This particular foal had poor patient compliance with bandaging. There was one complication during surgery when a drill bit tip broke within the radius of the foal; the tip was left in place and did not affect the foal. The broken drill bit may have affected the sales value of the horse; however, this particular horse was not destined for sales so no attempt at retrieval was made.

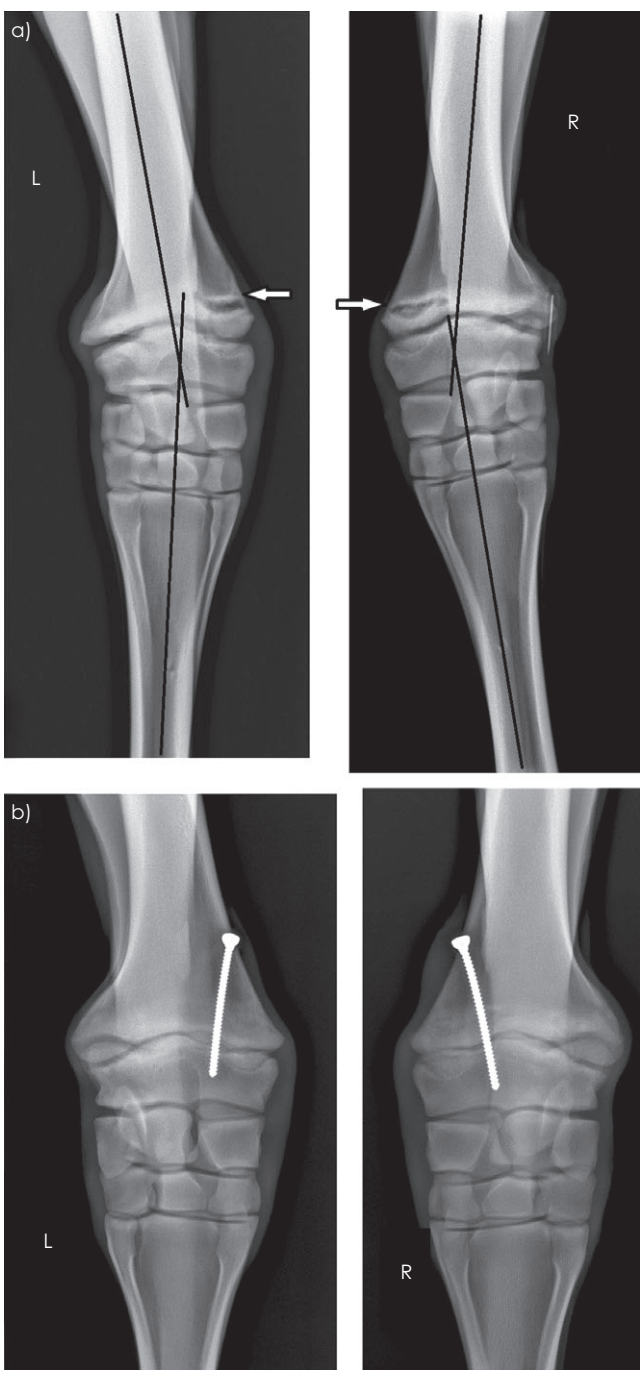

Fig 1: a) Dorsopalmar radiographs of the carpi of a 31-day-old colt with bilateral carpal valgus (left carpus 17°, right carpus 14°) and physeal dysplasia (arrow) prior to surgery. b) Dorsopalmar radiographs of the carpi of the same colt prior to removal of the right screw 35 days later,

Two foals were treated for carpal varus deformities. One had bilateral carpal varus (2° on the left and 3° on the right). This foal also had concurrent fetlock varus deformities.

Long-term follow-up was achieved through personal owner or farm manager communication. Except for one foal with white hairs, and one with a persistent periosteal reaction, all cases were reported to have excellent cosmetic outcomes.

Discussion

Most ALDs in foals are self-limiting or self-correcting, or responsive to conservative approaches and management changes. Some researchers are of the opinion that all angular deformities will correct with conservative management alone (Read *et al.* 2002); however, one study evaluating a large number of horses through the first year of life showed that up to 14% of carpal valgus deformities did not self-correct to what was considered a desirable conformation (Santschi *et al.* 2006).

It is imperative to recognise severe deformities or those that are not improving, or are deteriorating, in order for timeous surgical intervention. Early surgical intervention at the level of the distal metacarpus and metatarsus is essential, as rapid growth reduces at approximately 10 weeks of age (Auer 2012), and failure to utilise this window of growth potential leads to poor response to treatment. Intervention at the distal radius and distal tibia is possible up to the age of 15 months (Auer 2012); however, valgus deviation in the carpi at an angle of >10° may potentially lead to lateral physeal collapse and should be approached more aggressively (Ruggles and McIlwraith 2008). Fetlock varus or toe-in conformation is a highly undesirable trait leading to severe penalty at time of sales as well as potential degenerative changes in the fetlock joint during athletic career (Marks 2000; Ross 2003).

There have been large retrospective studies on the effectiveness of a single transphyseal screw for correction of both forelimb and hindlimb fetlock varus (Kay *et al.* 2005; Roberts *et al.* 2009). Some authors exclusively use single transphyseal screws in the fetlock region, even in animals younger than 4 weeks (Roberts *et al.* 2009). The majority of cases in these large studies had mild to moderate varus deformities (<4°), whereas our inclusion criteria selected for those foals with more severe deviations (≥4°). The mean age at time of implant placement and duration of time the implants remained in place in this case series was comparable to other reported studies. There are also reports that single transphyseal screws are not effective in younger foals, due to poor holding potential of the soft epiphyseal bone (Auer 2011; Russell 2013). Transphyseal screws were placed in the distal metatarsal physes of two foals younger than 14 days (one hind fetlock varus, 6°, one hind fetlock valgus, 7°); in both cases, holding potential of the epiphysis was sufficient and no over-correction occurred with the use of 4.5 mm standard cortex screws. In both of these cases, great care was taken to remove the implants prior to complete correction of the deviation due to the potential for further correction after removal of the implants. Neither foal developed excessive callus reaction. Two foals were treated

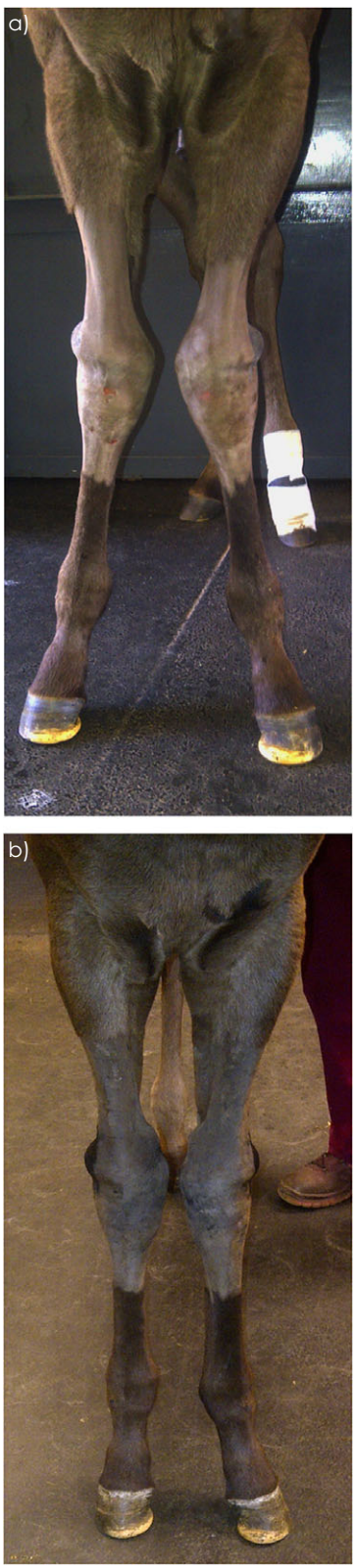

Fig 2: Photographs of colt in Figure 1 at time of screw (a) placement and (b) removal. (Note the periosteal and soft tissue reaction at the site of previous hemicircumferential periosteal transection laterally on both limbs, as well as the medial toe extension. This was done by the referring veterinarian prior to presentation, with minimal response).

for bilateral fetlock varus after 140 days of age and some improvement of the deformity still occurred, with one foal achieving acceptable conformation of 0° from a left forelimb varus of 6° and a right forelimb varus of 4°. The other foal failed to respond adequately on one of the limbs; however, in this particular case, the foal was confined to a stall for the duration of implantation due to a concurrent, unrelated lameness. Interestingly, the load-bearing limb corrected to an acceptable angle (from a 7° varus to 1° varus), while the nonweightbearing limb did not (radiographs shown in **Fig 3**). This is potentially due to a lack of dynamic compressive forces across the physis, which are believed to stimulate physeal growth (Jansson and Ducharme 2005). Many of the foals had a small periosteal reaction at the screw placement site at the time of screw removal; however, in all but one case, this resolved by yearling age. A persistent periosteal reaction remained in one horse and a second surgery to remove the blemish was performed prior to sale at the age of 14 months. A change in technique has been described (Kay and Hunt 2009), which reduces this periosteal reaction.

Case series have been reported on the placement of single transphyseal screws in the distal radius; however, the majority of these focus on correction of carpal varus and offset limbs in older foals and yearling groups (Baker *et al.* 2011; Carlson *et al.* 2012). We report on the use of single transphyseal screws placed in the distal radius of foals younger than 2 months. Most authors do not utilise single transphyseal screws in foals younger than one month and alternatively use screw and wire transphyseal bridging or a transphyseal staple. It was previously believed that a single transphyseal screw may cause over-correction of a deviation due to a 'spot-weld' of the physis and the rapid growth potential in younger foals (Roberts *et al.* 2009). The effect of premature closure of the growth plate of the distal radius in young foals would be catastrophic as the distal radius is responsible for 75% of the longitudinal growth of the distal limb (Fretz *et al.* 1984). In contrast to a transphyseal screw causing a 'spot-weld', Kay *et al.* (2005) report that any transphyseal growth-retarding implant can potentially lead to over-correction of the ALD as a result of over-compression of the physis, leading to physeal dysplasia and cessation of growth, resulting in continued deviation due to collapse of the growth plate. Over-correction of the deformity may require intervention on the opposite side of the limb. Although an uncommon complication, there have also been reported cases of physitis of the distolateral radius after removal of transphyseal screws in older horses, leading to metaphyseal collapse and an angular limb deformity in the opposite direction (Carlson *et al.* 2012). Levet and Martens (2011) report on two cases of transphyseal screws in the distal radius failing to adequately correct a carpal valgus deformity due to the transphyseal screw pulling out of the epiphysis due to rapid growth at this location, screw sepsis or stripping of the threads; however, we had only one case of screw sepsis in our study.

Long-term follow-up after screw removal by personal owner or farm manager communication revealed no over-correction occurring after removal of the screw and excellent cosmetic results in all cases at the time of yearling sales.

One foal with bilateral carpal valgus deviations had radiographic evidence of medial physeal dysplasia at the distal radial physes (**Fig 1b**). Described treatment for cases such as this is a small transphyseal bone plate and screws

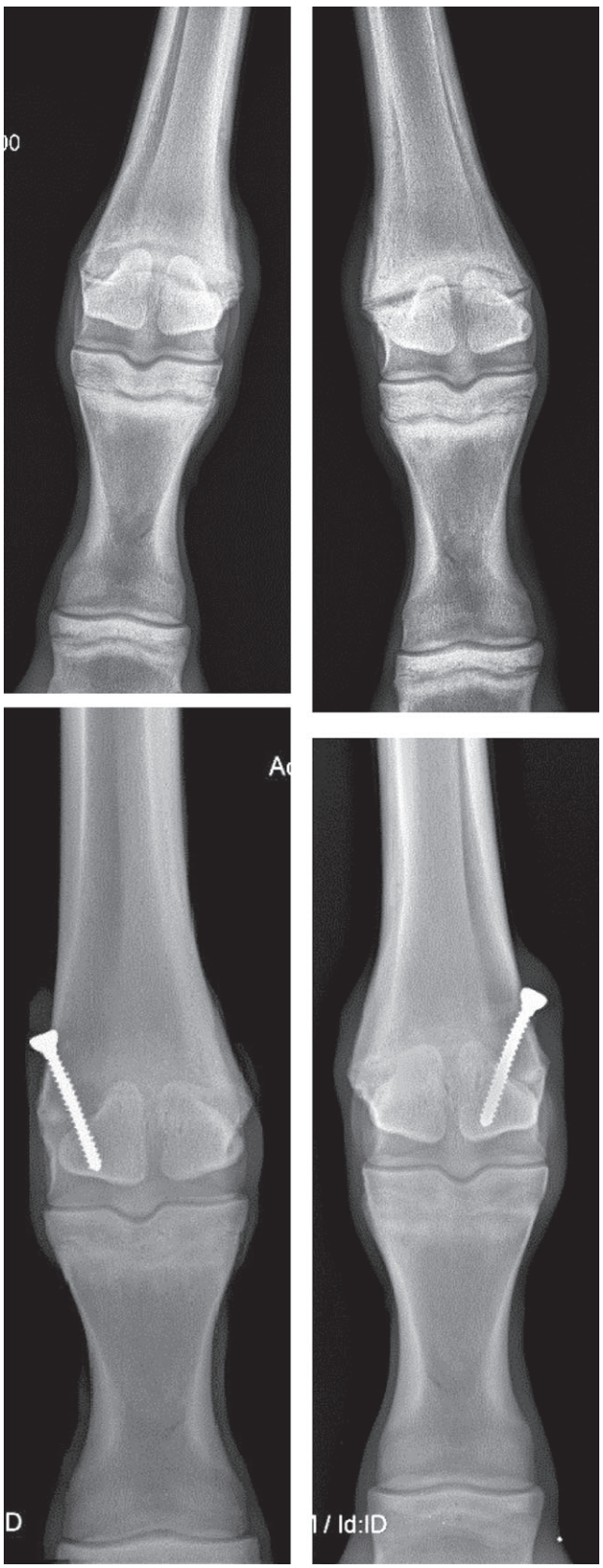

Fig 3: Radiographs of the front fetlocks of a Thoroughbred filly before screw placement and at time of screw removal, showing correction of varus deformity.

(Auer 2012); however, in this case, the foal was treated with single transphyseal screws across the medial physes of the distal radii. The angle of deviation corrected to an acceptable angle and the physeal dysplasia resolved.

One foal in our series failed to respond adequately to the single transphyseal screw due to implant infection. The screw was removed and a transphyseal bridge with two screws and wire was placed as an alternative in order to avoid the original, infected transphyseal screw tract. The angular limb deviation was corrected; however, there was a noticeable cosmetic blemish at the site of the screw and wire implant at the time of removal.

Angular limb deformities occur in all breeds and types of horses; however, tolerance of deviations from the ideal conformation is greater in some disciplines than in others. In the Thoroughbred breeding industry, there is greater pressure on breeders to produce horses with the perceived 'ideal' conformation, as some conformations have been shown to affect the athletic performance of a racehorse adversely (Anderson *et al.* 2004). This in turn has major implications on the value of individuals with less desirable conformational traits. While there is some debate about the ethical consideration of manipulating the horses' natural conformation, the described techniques are widely used, accepted and, ultimately, correcting undesirable conformational traits is in the best interest of the individual animal (Bramlage 1999). The procedures are also performed in cases as described above where severe deformity due to inappropriate development has and will occur if intervention is not performed (Auer 2011).

Few complications were observed in our series and no over-correction of deformities occurred. The use of the single transphyseal screw was effective in treating severe cases of angular limb deformities in both the fetlocks and the carpi. While single screws are widely used in treating fetlock deviations even in young foals (Adkins 2008; Roberts *et al.* 2009), many surgeons are still reluctant to place single screws into younger foals' carpi. Although favourable results were achieved in this case series, the effect of single transphyseal cortex screws in the distal radius of young foals needs to be further investigated in a greater number of cases.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

All animals included in this study were privately owned. Owners gave written consent for elective surgery performed and the use of the material generated.

Source of funding

No institutional, private or commercial funding was received for this work.

Authorship

A. Gray and P. Randleff-Rasmussen contributed to study design, study execution, data analysis and interpretation. All authors contributed to the preparation of the manuscript and gave their final approval of the manuscript.

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