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Review Article

Farriery for the foal: A review part 2: Therapeutic farriery

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Summary

The extensive nature of this topic warrants this review paper to be divided into two parts: 'Basic trimming in foals' and 'Therapeutic farriery in foals'. Management of the feet and limbs during this juvenile period will often dictate the success of the foal as a sales yearling or mature sound athlete. Overall hoof care in the foal is often a joint venture between the veterinarian and the farrier. The orthopaedic disorders discussed in this paper that require input from the two professions are flexural limb deformities (FLD) and angular limb deformities (ALD). The concept of protecting the foot from the deleterious effects of mal-loading created by many FLDs and ALDs is just as important as using the symptomatology as an instrument to correct the deformity. This paper presents a review of the current information regarding the farriery for these two limb deformities while dispelling some of the anecdotal methodology, such as the use of toe extensions to treat flexural deformities, that presently exists. Considering the deficiency of information in the literature, segments of this text will be based on the author's extensive clinical practice, comprehensive clinical records and comparisons of case outcomes.

Evaluation of the feet and limbs

The reader is referred to the section 'Evaluating the foal' in Farriery for the foal: A review part 1: Basic trimming (O'Grady 2019). The importance of evaluating limb conformation, early recognition of changes in flight pattern, limb placement and foot loading patterns cannot be over emphasised. It is also important to recognise changes in overall body condition or accompanying developmental disorders as these may occur prior to the onset of an angular limb deformity.

Flexural deformities

Flexural deformities have been traditionally referred to as 'contracted tendons'. The primary defect is a shortening of the musculotendinous unit rather than a shortening of just the tendon portion, making 'flexural deformity' the preferred term (Adkins 2008; Hunt 2011; O'Grady 2012, 2014, 2017; Caldwell 2014, 2017). This shortening produces a functional length that is less than necessary for normal axial alignment of the digit; this results in fixed flexion of the various joints of the distal limb especially the distal interphalangeal joint (DIPJ) (O'Grady 2012, 2017).

Flexural deformities may be congenital or acquired. The outcome and prognosis will vary with the severity and subsequent treatment of the flexural deformity.

Congenital flexural deformities

Congenital flexural deformities are present at birth, may involve one or a combination of joints (e.g. carpal, metacarpophalangeal and distal interphalangeal joints) and are characterised by abnormal flexion of a given joint or all involved joints and the inability to extend the joint. Proposed aetiologies of congenital flexural deformities include mal-positioning of the fetus in utero, nutritional mismanagement of the mare during gestation, teratogens in various forages ingested by the mare and maternal exposure to influenza virus; it is also possible that the deformities could be genetic in origin (Hunt 2012; Caldwell 2014, 2017). Treatment of foals with a congenital flexural deformity varies with the severity and location of the deformity. It is not uncommon to see a foal born with a flexural deformity (generally bilateral) that involves a combination of joints in the forelimb such that the foal will stand and walk on the toe of the hoof capsule, is unable to place the heel on the ground and will assume a 'ballerina' stance with weight borne on the toes. A mild to moderate flexural deformity in which the foal can readily stand, nurse and ambulate is generally self-limiting and resolves with conservative treatment. Brief intervals of exercise for 1 h once or twice daily in a small paddock on firm footing for the first few days of life may be all that is necessary for the deformity to resolve. If the condition is unresponsive by the third day post-partum, i.v. administration of oxytetracycline (2–3 g), repeated every other day if necessary, is frequently beneficial (Madison *et al.* 1994; O'Grady 2012; Caldwell 2017). Although this treatment is in widespread use, caution must always be advised when administering this medication to a neonate. A variety of bandaging techniques and splints have been proposed, along with physical therapy to potentially stretch the involved soft tissue structures, thus possibly hastening recovery (Hunt 2011, 2012; Caldwell 2017). In the author's opinion, the traditional use of a toe extension is not indicated, as applying a toe extension will generally result in the neonate becoming 'clumsy', stumbling and being unable to ambulate. The 'lever arm' principal of the toe extension to stretch the tendon is unrealistic and does not come without a price which is the likelihood of damage to the hoof capsule (O'Grady 2017).

Foals with severe congenital flexural deformities of one isolated joint or multiple joints present at birth that prevent the foal from standing and ambulating, require therapeutic intervention early in the clinical course of the case. Treatments include aggressive physical manipulation and stretching of the legs in conjunction with a variety of forms of external coaptation aimed at fatiguing the muscular section of the musculotendinous unit. Bandaging, transient static splinting with PVC bracing or dynamic splinting with an articulating brace, application of a flexible tension band along the dorsal aspect of the limb and casting are accepted techniques when properly applied and managed. Application of a cast in a mildly extended position shortly

after birth will often improve a severe flexural deformity enough to allow splinting or bandaging until the condition fully resolves (Hunt 2011, 2012; Caldwell 2017).

The less common variation of a flexural deformity that occurs in neonates is an isolated unilateral deformity of the DIPJ and does not correct with manual extension applied to the joint. The deformity occurs in all degrees but is often severe and difficult to manage. Again, toe extensions are not beneficial and typically cause the foal to stumble. Although it is difficult to apply, useful external coaptation to this area, articulating extension braces attached to a foot cuff, application of a cast or application of a flexible tension band with surgical tubing will provide appropriate mechanics to this region (Hunt 2012; Caldwell 2017).

Acquired flexural deformities

Acquired flexural deformities (AFD) involving the DIPJ are generally noted when the foal is between 2 and 4 months old and generally involves the DIPJ initially. It is commonly a unilateral condition but occasionally affects both forelimbs. The aetiology of this deformity is unknown, but speculative causes include genetic predisposition, improper nutrition (i.e. overfeeding, excessive carbohydrate [energy] intake, unbalanced minerals in the diet) and excessive exercise (Adkins 2008; Hunt 2011; O'Grady 2012, 2017; Caldwell 2017). A study looking at grazing patterns in a small number of foals showed that foals with long legs and a short neck tended to graze with the same limb protracted (van Heel *et al.* 2006). Fifty percent of the foals in this study developed mis-matched feet with a higher heel on the protracted limb leading the researchers to feel there may be a possible correlation between conformational traits and an acquired flexural deformity. It is the author's opinion that a large contributing factor to this syndrome is contraction of the muscular portion of the musculotendinous unit caused by a response to pain (Kidd and Barr 2002; Caldwell 2017). The source of such pain could be discomfort anywhere along the distal limb, including physeal dysplasia or trauma causing foot pain in foals exercising on hard ground. Rapid weight gain in the foal may result in physeal overload and pain. Discomfort may follow aggressive hoof trimming where excessive sole is removed, thus rendering the immature structures within the hoof capsule void of protection and prone to bruising (O'Grady 2012, 2017). The foal then becomes unwilling to bear full weight on the affected feet. Any discomfort or pain in the foot or lower portion of the limb coupled with reduced weight-bearing on the affected limb appears to initiate a flexor withdrawal reflex; this causes the flexor muscles proximal to the tendon to contract, leading to a shortened musculotendinous unit and an altered position of the DIPJ. This shortening of the musculotendinous unit shifts weight-bearing to the dorsal section of the foot causing inflammation of the lamellae in dorsal hoof wall, increased load on the dorsal sole, bruising of the sole, hoof wall separations, reduced hoof wall growth of the dorsal aspect of the hoof wall and excessive hoof wall growth at the heel to compensate for the shortening. As the flexural deformity may be secondary to pain in these cases, it is essential that possible sources of pain should be carefully identified and localised by physical examination and, if necessary, by regional analgesia and diagnostic imaging. The possibility of a genetic component should also be considered for acquired flexural deformities, as some mares consistently produce foals that develop a flexural deformity in the same limb as the dam or grand dam in which a similar deformity is present (Hunt 2012; Caldwell 2014; O'Grady 2017). It also appears that many individual foals have a propensity to acquire a flexural deformity as a group of foals can be fed the same ration, maintained in the same environment, have the same farriery and exercise routine yet only the odd foal will develop a flexural deformity (O'Grady unpublished data, 2012).

Mild acquired flexural deformities of the DIPJ

The initial clinical sign of a mild flexural deformity of the DIPJ may only be abnormal wear of the hoof at the dorsal toe, which is often discovered by the farrier during routine hoof care. Closer or subsequent investigation may reveal that the dorsal hoof wall angle is increased, a prominent coronary band may be present but the heels of the hoof capsule are still on the ground. However, after the heels of the hoof capsule have been trimmed to an appropriate length, the heels may no longer contact the ground. Most foals affected to this degree may already have a mildly broken forward hoof-pastern axis. Increased palpable digital pulse, heat in the affected foot and signs of pain may be noted when small hoof testers or even thumb pressure is applied to the solar aspect of the toe dorsal to the frog are not uncommon clinical findings. Hoof tester pain is generally due to lack of sole thickness, trauma and excessive weight-bearing on the dorsal toe. A recent method of classifying flexural deformities of the DIPJ using a grading system (Grade 1–4) has been proposed (Redden 2003). It is always beneficial to classify the severity of the flexural deformity to devise an appropriate treatment plan and monitor the response to a given therapy. It also becomes a useful part of the foal's record.

Conservative treatment such as restricting exercise to reduce further trauma to the foot is paramount. Correcting the nutritional status of the foal (i.e. weaning the foal to avoid possible excessive nutrition from the lactating mare and/or decreasing carbohydrate intake), administering an anti-inflammatory agent (NSAID) to relieve pain, administering oxytetracycline to foals with acquired flexural deformities to facilitate muscle relaxation and carefully trimming the palmar section of the hoof are, in the author's opinion, is a reasonable starting point. The NSAIDs should be administered short-term and judiciously in foals due to the potential side effects, such as gastroduodenal irritation and nephrotoxicity. For analgesia, the author will administer firocoxib (0.1 mg/kg bwt q. 24 h) or flunixin meglumine (1.1 mg/kg bwt q. 24 h) combined with a gastric protectant. Hoof trimming is directed towards improving the hoof angle by lightly trimming the heels from the middle of the foot palmarly until the hoof wall at the heels and the frog are on the same plane. Over trimming of the heels should be discouraged as this will invariably cause the heels to lift off the ground which can be noted on firm footing. The bars can be thinned in this instance as an attempt to spread and possibly improve heel expansion. Additionally, the heels of the hoof capsule adjacent to the frog sulci may also be rasped to a 45° angle in an attempt to promote spreading. If the sole thickness is sufficient in the dorsal foot (does not deform with hoof testers or thumb pressure), breakover is moved palmarly by creating a mild bevel with a rasp, which begins just dorsal to the apex of the frog and extends to the perimeter of the dorsal aspect

of the hoof wall (**Fig 1**). If improvement is noted, this trimming regimen is continued and optimally performed at 2-week intervals. If the toe is constantly being bruised or undergoing abscessation, an acrylic or urethane composite (Equilox® or Vettec®) can be applied to the dorsal aspect of the sole and the distal dorsal aspect of the hoof wall to form a protective toe 'cap'. The acrylic composite-impregnated fibreglass combination or urethane composite used to form the toe cap will cover the solar surface with a thin layer of composite from the margin of the dorsal hoof wall to the apex of the frog, protecting that area from further damage and creating or exacerbating lameness. Caution is advised when a composite cap is applied as the sole-wall junction may be stretched or have separations/fissures present which make it susceptible to infection. Any separations should be explored and then packed with clay or other suitable material prior to the composite being applied. A bevel toward the toe can be created in the composite with a rasp or motorised burr (Dremel® tool) to facilitate breakover. If there is adequate integrity of the dorsal section of the hoof wall, the author believes the application of a toe extension to be unwarranted and contraindicated (O'Grady 2017).

The above treatment for a mild flexural deformity is often temporary as many foals will progress to a more severe deformity and thus the farriery appears to work best when initiated at the first sign of abnormal foot conformation before a marked flexural deformity is apparent. Whenever possible, the elimination of any possible or suspected inciting causes should be pursued. ***The farriery for a mild flexural deformity should always be combined with restricted exercise.*** If the affected foot continues to improve or does not regress, conservative treatment is continued. If a mild flexural deformity progresses in severity to the stage where a marked flexural deformity is present, the foal becomes a surgical candidate.

Fig 1: a) Grade 1 flexural deformity. b) After the foot is trimmed. Note the bevel created under the toe.

Severe acquired flexural deformities of the DIPJ

A mild acquired flexural deformity may progress in severity despite conservative treatment or a severe acquired flexural deformity may be acute in onset. A severe acquired flexural deformity is characterised by a foot with a hoof angle greater than 80°, a prominent fullness at the coronary band, a broken forward hoof-pastern axis, disparity in hoof wall growth distal to the coronet at the heel relative to growth at the toe and heels that fail to contact the ground (**Fig 2**). If the flexural deformity is allowed to persist, the foot eventually assumes a boxy, tubular shape due to the overgrowth of the heels to accommodate the lack of ground contact; heel

Fig 2: Grade 3 flexural deformity.

length will approach the length of the toe (**Fig 3**). Increased stress on the hoof wall at the toe will eventually cause a concavity along the dorsal surface of the hoof wall. Stress exerted on the sole-wall junction in the toe area will cause it to widen, allowing separations to occur.

Farriers have traditionally applied toe extensions to create a lever arm using a shoe or a composite to force the heel to the ground, but this will only exacerbate damage to the dorsal section of the foot, promote hoof wall separation and delay breakover (Hunt 2012; O'Grady 2017). As it is important to consider the use of a toe extension in biomechanical terms and to understand the effect of this leverage, it is necessary to briefly consider the moments about the distal interphalangeal joint. The moments about the DIPJ are the flexor moment and the extensor moment (a moment is equal to force x distance). At rest, the extensor moment is the product of the weight born by the limb (a force) and the horizontal distance from the point at which the ground reaction force GRF acts on the foot (centre of pressure CoP) and the centre of rotation of the distal interphalangeal joint (a distance). The flexor moment opposes the extensor moment and is the product of the force (tension) in the tendon and the shortest distance of the deep digital flexor tendon (DDFT) from the centre of rotation. Normally these two moments are balanced at rest, the GRF is dorsal to the centre of rotation of the joint and the heels are on the ground. In foals with a flexural deformity of the DIPJ, the tension in the tendon increases (as a result of the shortened musculotendinous unit), which increases not only the flexor moment but the opposing extensor movement which moves the CoP dorsally in the toe. At the point where the tension in the tendon increases such that the CoP is at the dorsal limit of the toe, any further increase in tendon tension cannot be balanced by movement of the CoP because it is already at the perimeter of the toe and can't move further dorsally, therefore, the heels lift off the ground (Eliashar 2012). Adding an extension to the toe of the foot allows the centre of pressure to move further dorsally in the toe in an attempt to counteract the tension in the tendon and force the heels to the ground. The ability of the toe extension to do this is dependent on the integrity of the tissues (hoof wall, lamellae), however, the tissues are not generally strong enough to withstand the additional stress and separation occurs within the dorsal hoof wall. Therefore, placing an extension or leverage on the dorsal hoof wall to counteract the forces in the shortened deep digital flexor muscle tendon unit is unrealistic and, in the author's opinion, contraindicated (**Fig 4**). Furthermore, extensions may contribute to lameness due to excessive stresses on the DDFT when the foal puts full weight on its foot and at the initiation of breakover.

Fig 3: Chronic grade 3 flexural deformity in a 3-month-old foal that has acquired a tubular shape of the hoof capsule with the coronet becoming horizontal.

Radiographs should be used to assess changes in the joint and the integrity of the distal phalanx. The author will administer mild sedation (xylazine [0.33 mg/kg bwt, i.v.] combined with butorphanol [0.022–0.066 mg/kg bwt i.v.]) and place each of the foal's feet on separate wooden blocks of equal height, which allows normal or equal loading of both forefeet. The forelimbs are positioned such that the third metacarpal bone is perpendicular to the ground. Lateral-to-medial weight-bearing images of both forefeet should be acquired. The degree of flexion of the DIPJ, the angle of the dorsal hoof wall and abnormalities at the margin of the distal phalanx should be assessed (**Fig 5**). When a marked flexural deformity is noted during radiographic examination of the feet, conservative treatment and hoof trimming alone are generally unsuccessful in resolving the foot conformation. Elevating the heels has been advocated to reduce tension in the DDFT and to promote weight-bearing on the palmar section of the hoof. However, although elevating the heels will load the palmar section of the foot, improve the hoof-pastern axis and make the foal more comfortable initially, the

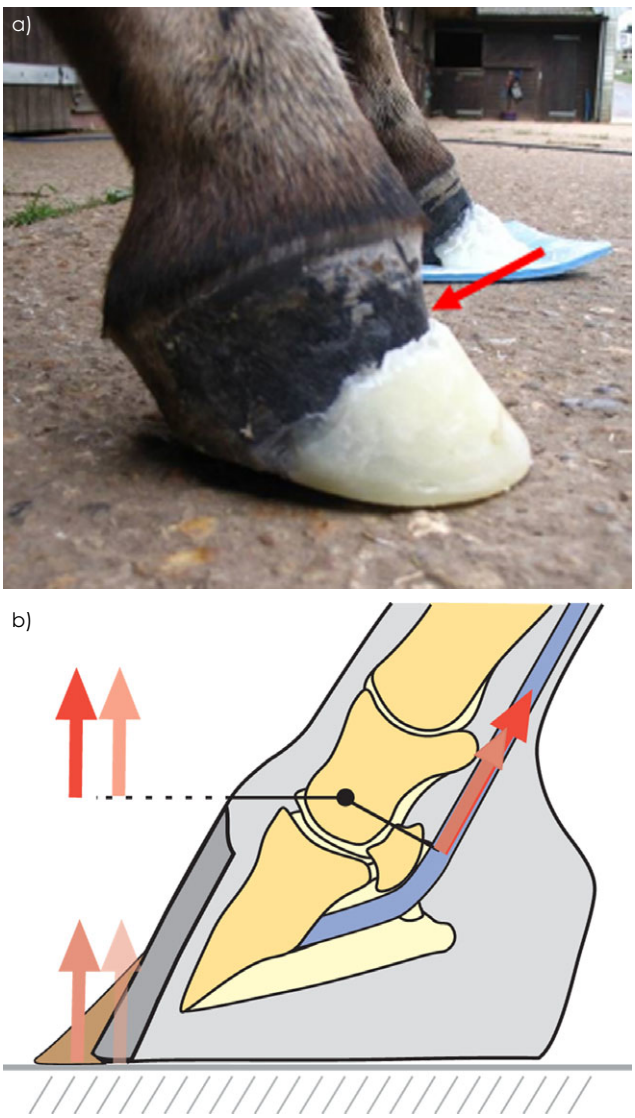

Fig 4: Photograph of toe extension shows the leverage on the hoof capsule and the point on the dorsal wall where the force is exerted (red arrow). Note the heel off the ground. Illustration of foot shows ground reaction force (GRF) is moving dorsally in the toe as the muscle tendon unit shortens and tension increases in the DDFT (Image courtesy of Andrew Parks).

author has not been able to subsequently lower the heel or remove the wedge and establish an acceptable hoof angle with the heel on the ground. Once a marked flexural deformity of the DIPJ with the heels of the hoof capsule lifted off the ground or a distorted hoof capsule characterised by a foot with a steep hoof angle, a prominent fullness at the coronet, a broken forward hoof-pastern axis, a disparity in the length of the heel relative to the toe of the hoof and some degree of concavity in the toe is apparent; the author recommends transection of the accessory ligament of the DDFT combined with the appropriate farriery.

The farriery is generally performed prior to the surgery either before or while the foal is anaesthetised to prevent manipulating the limb and handling the surgical site following the procedure. A toe extension is not used; rather an acrylic

Fig 5: Radiograph shows a marked flexural deformity involving the distal interphalangeal joint (red circle).

composite is applied to the solar region of the toe to create a reverse wedge (Stone and Merritt 2009; Hunt 2012; O'Grady 2012, 2017). The wedge affords protection for the toe region and appears to redistribute the load to the palmar aspect of the foot, thus mildly increasing the stresses on the DDFT, and appears to restore the concavity to the sole. The heels are lowered with a rasp from the point of the frog palmarly, until the sole adjoining the hoof wall (sole plane) at the heels becomes solid. This will generally place the hoof wall and the frog on the same horizontal plane. Any concavity or bending in the dorsal aspect of the hoof wall is removed with a rasp in order to redirect the forces directly under the coronet at breakover. The ground surface of the foot dorsal to the frog and the perimeter of the dorsal hoof wall are sanded and prepared for the composite wedge using a rasp or motorised burr (Dremel® tool). Deep separations in the sole-wall junction at the toe are explored and filled with clay, if necessary, to prevent tracts for infection beneath the composite. Foals undergoing this procedure are usually between 3 and 5 months old; therefore, due to their size and weight, reinforcing the composite with fibreglass is necessary to prevent excessive wear. A small section of fibreglass is separated into strands and mixed with the composite. The acrylic composite is applied to the solar surface of the foot beginning at the apex of the frog and extending to the perimeter of the hoof wall where a thin lip is formed around the perimeter of the dorsal hoof wall at the toe. The composite is moulded into a wedge starting at 0° at the apex of the frog and extending to 2° to 3° at the toe (Stone and Merritt 2009; O'Grady 2012, 2017) (**Fig 6**). If desired, a piece of 1/8-inch aluminium plate can be cut out in the shape of the dorsal aspect of the sole. Multiple holes are drilled in the plate, and it is gently placed into the composite. The aluminium is pushed down so that the composite material extrudes through the holes, and the aluminium plate is then covered with additional composite. This additional reinforcement allows the older foals to be walked daily or turned out in a small paddock without the foal wearing through the composite. The foal is placed under general anaesthesia, and the surgery is performed in a routine manner that is well described in the veterinary literature.

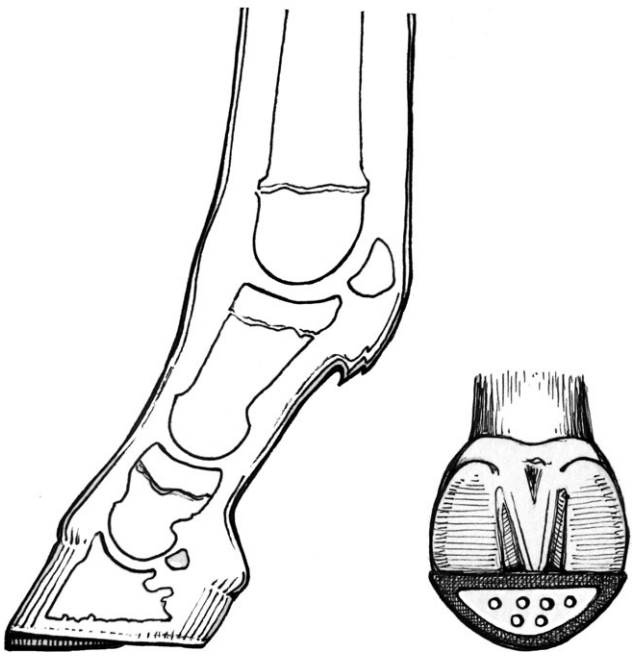

Fig 6: Reverse wedge created from a composite. An aluminium plate can be imbedded in the composite to prevent wear.

The surgical aftercare is at the discretion of the attending clinician. Oxytetracycline may be used with the surgery during the perioperative period to facilitate relaxation of other soft tissue structures secondarily involved (joint capsule, collateral ligaments) (Hunt 2012). Controlled exercise in the form of daily walking or turn out in a small paddock with firm footing such as a round pen is essential. There is the potential for pain with the initiation of exercise due to the shortening of soft tissue structures such as the joint capsule and suspensory ligaments to the navicular bone, requiring close monitoring of the foal, and exercise should be increased sequentially. The foal is trimmed at roughly 2-week intervals, based on the amount of hoof growth at the heels with the objective of establishing normal hoof capsule conformation. The composite wedge is removed one-month post-surgery. At subsequent trimmings, the heels are trimmed as necessary from the middle of the foot palmarly such that the frog and hoof wall are on the same plane and hoof wall at the toe is trimmed from the dorsal aspect of the hoof wall until the desired conformation is attained. No sole dorsal to the frog is removed. This type of trim promotes sole growth and creates approximate proportions on either side of the COR. When the desired foot conformation is reached, the foot is trimmed in a routine manner monthly. It is important to emphasise that when the hoof capsule returns to an acceptable conformation, only that portion of the sole that is shedding should be removed. This avoids causing discomfort in the dorsal solar section of the foot that can result in the foal redeveloping, to some degree, the original flexural deformity. The higher-grade clubfoot appears to have a tendency to revert back to the original deformity if not managed properly.

Angular limb deformities

Angular limb deformities (ALD) are common in foals and require early recognition and treatment (Greet 2000; Hunt 2000; Greet and Curtis 2003; Auer 2006; Witte and Hunt 2009; Garcia-Lopez 2017; O'Grady 2017). This subject receives tremendous attention in any discussion of foal conformation and it refers to a lateral or medial deviation in axial alignment of the limbs when the animal is viewed from the frontal plane. It is understood that a certain amount of deviation can be normal in young foals and does not require any special farriery or surgical intervention (Hunt 1998, 2000; Auer 2012; O'Grady 2017). Objective data is lacking regarding the dynamics involved in the development of acquired angular limb deformities, however, it is recognised that many foals change axial alignment during various stages of their development. Serial evaluation and treatment of limb deviations is an integral component of management on most breeding operations.

Angular limb deformities may occur anytime during the animal's life but are most commonly treated from birth through the yearling growth period. The primary lesion appears to be an imbalance of physeal growth; for assorted reasons, growth proceeds faster on one side of the physis vs. the other. Although this is described as a discrepancy of limb length of the medial vs. lateral side from an imbalance of physeal growth; another discrepancy in loading the limb with lack of soft tissue support may also create an 'apparent' ALD. Angular limb deformities can be further classified into two categories; valgus deformities occur when the deviation occurs lateral to the axis of the limb distal to the affected joint (away from the midline) and varus deformities occur when the deviation is medial to the axis of the limb distal to the affected joint (toward the midline) (**Fig 7**). The most common location of valgus angular limb deformities is the carpus and tarsus while varus deformities are most often seen at the fetlock and to a lesser extent at the carpus.

Fig 7: Carpal valgus. Note the limb below the carpus deviates away from the midline (red line).

Limb alignment of young foals should be observed standing and walking without restriction on the head and neck (not leaning) toward and away from the examiner. Overall body development and maturity should be noted. It is important to take note of foot placement especially when working with distal limb deviations. This will determine the necessity for corrective measures on the feet such as trimming or placement of a composite extension on the hoof capsule to alter the forces on the physis and change the rotation of the limb on contact with the ground. This practice is especially beneficial with a fetlock varus deviation with inward rotational deformities in foals 2–4 weeks of age in which there is a limited time frame for correction.

Carpal/tarsal valgus

It is apparent that a mild carpal valgus of 2–5 degrees offers the newborn foal a comfortable stance while nursing and eating off the ground and is considered acceptable. If the deviation exceeds 5–8 degrees then it becomes a concern and should be monitored (Hunt 1998, 2000; Auer 2012). A few days of stall confinement on firm bedding or limited exercise in a small paddock (2–3 times a day) is a rewarding, cost-effective treatment for early carpal or tarsal valgus (Garcia-Lopez and Parente 2011).

It may be helpful to digress and briefly mention routine hoof care before discussing treatment of angular limb deformities. The technique for using farrier tools when trimming foals was discussed under the trim in Part 1 of this review. The veterinary and farriery literature abounds with various trimming methods that are thought to affect the various limb conformations; however, none of these methods have been substantiated or documented to be efficacious. The author trims the heels such that the heels of the hoof wall and the frog are on the same plane, visualises a line across the middle of the foot (located just dorsal to the COR) and then reduces the toe to make the foot proportional on either side of the line across the widest part of the foot. When the trim is complete, the solar surface of the foot will be level rather than having the lateral to medial orientation of the foot changed by rasping one side of the foot more than the other (**Fig 8**). Farriery texts describe trimming a foal lower on the outside of the foot when the foot turns out and trimming the foal on the inside of the foot when the foot turns in; however, remembering that a toe-out or toe-in stance originates from the limb, this practice will do nothing more than place excessive stress on one side of the hoof capsule.

If the angular limb deformity is greater than 5–8 degrees or shows no improvement in the first few days of life, radiographs should be part of the physical examination of a foal with ALD (Garcia-Lopez and Parente 2011; Garcia-Lopez 2017).

Occasionally, osseous abnormalities such as hypoplastic carpal/tarsal bones will preclude correction of the problem without splints or a cast. Radiographs will also reveal the site and degree of deviation which will allow comparison later. Carpal valgus deformities of less than 10 degrees are generally handled successively with conservative treatment (Garcia-Lopez and Parente 2011; Garcia-Lopez 2017).

Conservative therapy for the management of many mild to moderate congenital angular limb deformities may be successful in the newborn foal. Restricted exercise would be either strict stall confinement or brief periods of turnout (1 h two times daily) in a small area with firm footing. This allows the physis to be stimulated but prevents stress, fatigue and compression on the overloaded side of the growth plate from excessive exercise. If the carpus can be corrected by applying pressure with one hand on the inside of the carpus and counter pressure with the other hand applied to the outside of the fetlock, some form of coaptation such as support tape, splints, dynamic splints or tube casts may be helpful. The author uses a splint made from polyvinylchloride (PVC) pipe, cut in half and fitted from the elbow to below the fetlock applied for a few hours 1–2 times daily. It is labour intensive, but the splints must be removed and replaced periodically to prevent laxity. A full-length thick cotton bandage is applied to the entire limb, and then the PVC pipe is placed on the outside of the limb and secured to the bandage with elastic tape. This will distract the carpus laterally and load the limb more proportionally. The splint is often the most cost-effective treatment available but must be applied with caution, paying strict attention to the details of application. Meticulous attention to applying the splint is essential to prevent focal pressure and the propensity of the foal to develop decubital ulcers. As the foal improves, brief periods of turnout in a small area with firm footing can be considered.

Fig 8: Two-month-old foal trimmed to show the proportionality of the foot on either side of a line drawn across the widest part of the foot. Note the hoof wall at the heels and the frog trimmed to the same plane.

Acquired carpal/tarsal valgus deformities can be graded from one to four according to severity (**Fig 9**). Mild to moderate carpal valgus will generally respond to restricted exercise and the use of a composite extension applied to the medial side of the foot while the more severe cases require surgical intervention combined with farriery (Hunt 1998, 2000; Greet 2000; Auer 2006; Witte and Hunt 2009; Garcia-Lopez

Fig 9: Grade 3 carpal valgus in a 2-month-old foal.

2017; O'Grady 2017). Various clinicians have described trimming the lateral side of the foot aggressively when there is a valgus deformity in an attempt to increase the ground surface on this side of the foot (Greet and Curtis 2003). However, it is this authors' opinion that the foal does not grow sufficient horn at this age to make an appreciable difference and changing the medial to lateral orientation of the foot may have detrimental effects on the immature hoof capsule as well as the physis. Using some form of extension to increase the ground surface of the foot and change the forces on the physis seems to be more beneficial (Cheramie and O'Grady 2003; Greet and Curtis 2003; O'Grady 2017).

Periosteal elevation is a controversial surgery that is routinely performed on foals with mild to moderate angular limb deformities (Garcia-Lopez 2017). However, the author has not referred a foal for this surgery in 20 years as the author saw no difference when compared with foals that had controlled exercise (brief turnout in a small paddock with firm footing) and the application of a hoof extension (O'Grady unpublished data, 2014). If stall confinement is used initially, the mare and foal should be bedded on firm footing (such as a thin layer of sawdust) for the foot extensions to be effective. Initially, the author prefers using some form of extension to increase the ground surface area of the foot on a given side and change the forces on the affected joint. Some type of composite applied to the hoof wall is preferred rather than a cuffed shoe that is attached with glue as this type of shoe appears to restrict movement of the hoof capsule and contracts the foot especially the heels. As noted previously in Footcare in foals: A review part 1, the author will not apply a composite to a foal's foot before 3 weeks of age because of the potential detrimental effects of the excessive heat.

For carpal valgus, the composite extension is placed on the medial side of the hoof and toward the heels which appears to redirect the forces on the physis on the overloaded side of the limb by moving the axis of weight bearing towards the centre of the limb (**Fig 10**). The extension also appears to promote centreline breakover. The extension is made from an acrylic composite mixed with fibreglass strands or a urethane composite applied directly to the foot and shaped to the desired width. Properly applied for maximum results, the extension should begin at the contact point of the heel and feather up most of the length of the wall. It should not extend dorsally beyond the junction of the quarter and toe to be of any benefit. Also, it should not be built up on the sole but only tapered along the sole toward the frog. The extension should be no wider than a vertical line drawn from the coronet to the ground. If the extension is too wide, it applies leverage on the attached side that will invariably distort the hoof capsule. The extension should be removed every 2–3 weeks for 1–2 days to allow the hoof wall to dry out and not break up. Also, with chronic use, there may be a restriction of hoof wall growth which may contribute to long-term distortion of the wall. Strict controlled exercise as described above is essential for this conservative approach to be successful. In severe cases of carpal valgus or cases that have not responded to conservative therapy, surgery such as a transphyseal screw or staple or a wire transphyseal bridge placed across the distal radial physis may be necessary (Garcia-Lopez 2017; McCarrel 2017). The author likes to combine a medial extension with the surgery, however, it may affect the clinician's ability to assess the limb to accurately determine the time for implant removal (A. Parks, personal communication, 2012). In many cases, a surgical procedure may be performed too early before conservative therapy has allowed sufficient time to correct

Fig 10: Urethane extension placed on medial side of hoof on foal in Figure 9.

the problem. It appears that valgus angular limb deformities involving the carpus will respond to transphyseal bridge surgery up to 14 months of age, resulting in full correction (Garcia-Lopez 2017; McCarrel 2017). Obviously, if the valgus deformity renders the carpus unstable, then surgery will be required sooner.

Fetlock varus

Varus deformities involving the fetlock are common in either the front or hindlimb of newborn foals (**Fig 11**). This deformity can be congenital or acquired within the first week of life. Fetlock varus is often confused with a foal that has a toe-in conformation. The digit will deviate axially (toward the midline) relative to the fetlock with fetlock varus; a foal with a toe-in conformation will have a rotational deformity at or above the fetlock but the digit will follow the axial alignment of the limb. However, both conditions may occur concurrently. A fetlock varus deformity requires early detection and treatment since functional closure of the distal physis of the third metacarpal/metatarsal bone is approximately 8 weeks of age. Foals with fetlock varus should have their exercise restricted and will generally respond to an extension applied to the lateral side of the foot to change the forces on the lateral side of the physis. The window of opportunity for treatment is small and the extension should be applied at 1–3 weeks of age. As stated previously, the author is reluctant to apply a composite to a foal's foot before 3 weeks of age. Alternatively, the author uses a firm impression material (Equilox Pink®), moulds it to the solar surface of the foal's foot forming an extension on the lateral side (**Fig 12**). The impression material is moulded into the concavity of the sole and the sulci of the frog which holds it in place; it is then secured by covering the foot with kling gauze and then taping the extension in place with 2-inch elastic tape. Between 3–6 weeks of age, a composite extension can be applied to the lateral wall as described above; however, the results are better if correction is started shortly after birth. In severe cases, surgical intervention will be necessary combined with a lateral extension. If the foal is presented for treatment after 6 weeks of age, treatment becomes difficult and surgery will be necessary for correction with the overall treatment being less effective and not as cosmetic. Many fetlock varus deformities are not evident until 8–10 weeks or even later and obviously not addressed until that time. With the exception of a severe fetlock varus deformity; it may be ill-advised to place a transphyseal screw at less than 6 weeks of age because of rapid correction at this early age which necessitates early removal of the implant (R. Hunt, personal communication, 2018).

Fig 11: Left forelimb fetlock varus in a 2-week-old foal. Note the varus deformity combined with the toe-in conformation of the digit.

Fig 12: Impression material is formed to match the concavity of the sole and hold it in place. Impression material can be trimmed to the desired width of the lateral extension (red arrow).

Carpal varus deviations are also recognised in young foals and weanlings. Foals that develop carpal varus from birth to 1–2 months of age often have an 'over at the knee' appearance and buckle forward when standing. These foals typically worsen with exercise and improve with rest. Dietary control is important as is the judicious use of analgesics and controlled exercise. Lateral extensions placed on the foot may be useful but surgical intervention may be necessary if the varus deformity is severe. Weanlings that develop carpal varus are typically offset at the carpus, sometimes pigeon toed and often have accompanying physeal dysplasia. If the physeal dysplasia is kept under control; the deviation will often resolve. If the condition fails to respond, surgery such as transphyseal bridging or placement of a transphyseal screw in the physis of the distal lateral radius may be necessary. In general, valgus deviations are far easier to manage and are more prone to spontaneously correct and appear much more forgiving from a soundness standpoint than varus deviations.

Conclusions

The concept of protecting the foot from the deleterious effects of mal-loading created by many FLDs and ALDs is just as important as using the symptomatology as an instrument to correct the deformity. Flexural and angular limb deformities are often controversial and have a multitude of purported treatments; it is therefore essential that appropriate communication occur among the responsible parties to avoid any misunderstanding and unnecessary or job threatening miscommunications. Management of limb deformities in foals, irrespective of the type, severity or origin, are best managed through a coordinated effort between the owner, farm manager, farrier and veterinarian. When treating valgus and varus limb deformities especially fetlock

varus, prompt early recognition and treatment is best for consistent correction. Most veterinarians are not able to perform the farriery required to address foot and limb issues in foals, so their reliance on a farrier becomes obvious. A veterinarian not well versed in farriery should familiarise themselves with good basic farriery and have a working knowledge of this discipline. An avenue of communication between the professions is not only necessary but mandatory. Hoof care in the first few months of life is serious business and should never be taken lightly. Appropriate farriery combined with medical/surgical input from the veterinarian is essential when confronted with orthopaedic disorders related to the limbs. Farriery plays a vital role in both the development of the hoof and the conformation of the limb. A planned foot care programme is time consuming whereas assembly-line trimming is quick and easy, but the former thoughtful approach is much more rewarding with a better outcome.

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