Deep digital flexor tendon shortening as a treatment for distal interphalangeal joint hyperextension in a 2-year-old mare

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Summary
Shortening of the deep digital flexor tendon was performed by tenotomy, overlapping and anastomosis. The procedure was performed on a two-year-old Quarter Horse Mare with distal interphalangeal joint hyperextension with subluxation and metatarsophalangeal joint hyperextension. These problems originated from damage to the digital flexor tendons, presumably due to previous distal limb trauma. The procedure markedly improved the mare’s level of comfort, degree of amputation and limb conformation. Two years following surgery the mare was comfortable at pasture.

Keywords
Tendon shortening, equine, distal interphalangeal joint, deep digital flexor tendon

Case report
A two-year-old Quarter Horse Mare was admitted to the Veterinary Medicine Teaching Hospital (VMTH) College of Veterinary Medicine, University of Missouri for a six-month-old injury to the left hind limb. The original injury had been a puncture wound to the plantar aspect of the distal limb just proximal to the coronary band. The mare received minimal medical attention at the time of injury. Shortly thereafter she developed diffuse swelling and severe lameness of the affected limb. At that time medical therapy consisted of oral antimicrobials and phenylbutazone. During the weeks following the injury the mare’s lameness gradually improved, but during this time period at stance, the affected toe was gradually elevated off the ground, indicating potential rupture of the deep digital flexor tendon (DDFT) with resultant distal interphalangeal (coffin) joint hyperextension. In addition, the metatarsophalangeal (fetlock) joint was gradually sinking towards the ground, indicating loss of support from either the superficial digital flexor tendon (SDFT) or the suspensory apparatus resulting in fetlock hyperextension. Further treatment included short-limb cast application for approximately four weeks. Following cast removal, several attempts were made to place an elevated heel shoe but the mare kept pulling it off and eventually was left unshod. However, her level of lameness did not improve and the coffin and fetlock joints hyperextension continued to deteriorate. She was reported to be uncomfortable in pasture with a reluctance to move. Approximately six months following the original injury the mare arrived to the VMTH for evaluation and treatment.

Upon presentation the mare appeared bright and alert. Physical examination findings included marked conformational abnormalities in the left hind limb (Fig. 1). The toe was elevated above the ground while the fetlock was moderately dropped. Both abnormalities were evident in a standing position and were exaggerated at walk. Initial assessment was suggestive of loss of distal limb flexor tendons support, secondary to previous trauma. Ultrasonographic evaluation revealed a diffuse central hypoechoic lesion consistent with extensive fiber damage to the affected DDFT (Fig. 2). The lesion extended from just proximal to the fetlock to just distal to the proximal interphalangeal (paster) joint (13 cm in length). In addition, in the lesion’s periphery there was loss of fiber alignment. Similar but milder lesions were noticed in the SDFT (Fig. 2). Radiographs showed negative plantar angle and some dorsal displacement of the third phalanx, consistent with moderate coffin joint hyperextension and subluxation. Unfortunately, the lateral radiograph was obtained at incomplete weight bearing position hence the degree of coffin and fetlock joints hyperextension is underestimated (Fig. 3). Bony proliferation was evident at the abaxial and distal margins of both proximal sesamoid bones on the oblique views (not included). We believe that the latter abnormality was due to excessive strain on the suspensory apparatus, secondary to decreased fetlock support by the flexor tendons. The enthesiophytes at the abaxial surface indicates strain of the suspensory branches while the enthesiophytes at the distal margin indicates strain of the distal sesamoidean ligaments. At this stage primary diagnosis of coffin joint hyperextension due to DDFT laxity was confirmed.

Treatment options considered included: an experimental DDFT shortening procedure (1),
coffin joint arthrodesis (2–5) or conservative management including corrective trimming and shoeing (6). Distal limb amputation (7, 8) and euthanasia on humane grounds were also considered. We felt that shortening of the DDFT would be the best option for the horse. Conservative management had been previously attempted with unsatisfactory results. Techniques for coffin joint arthrodesis have been reported but none has shown consistent positive results. Distal limb amputation was not opted for due to the age of the horse and the limited average survival time reported for the technique. Both coffin joint arthrodesis and distal limb amputation were considered valid options for a salvage that could be used if the tendon shortening procedure failed.

Preoperatively, the mare received intravenous broad spectrum antimicrobials (gentamicin [6.6 mg/kg, q 24h] and potassium penicillin G [22,000 IU/kg, q 6h]) and phenylbutazone (4.4 mg/kg, q 12h). Surgery was performed under inhalation anesthesia in lateral recumbency with the affected limb uppermost. A 10 cm long incision was made at mid-metatarsal region, on the lateral aspect of the flexor tendons. The paratenon was incised longitudinally, and the DDFT was exposed and severed. The proximal and distal tendon edges were overlapped by 15 mm and sutured together using two pairs of horizontal mattress sutures in 90 degrees to each other (Fig. 4). Suturing was performed using a new generation braided polyblend suture (Fiber-Wire©). In order to reduce tension on the repair following closure, a short limb cast was applied with the dorsal cortices of the phalanges aligned. Recovery from anaesthesia was uneventful and the mare used the limb well in the early post-operative period. The following day the treatment regimen was changed to potentiated sulphonamides (trimethoprim sulphadiazine 15 mg/kg, q 12h) and phenylbutazone (2.2 mg/kg q 12h). Oral antibiotics were discontinued six days following surgery. Ten days after surgery phenylbutazone administration was reduced, to once daily, and continued for additional 30 days. After four weeks the cast was removed under general anaesthesia, due to cast sores a new cast was not applied. The limb was placed in a commercially made metal splint (Leg Saver Splint©). In addition, the skin sutures were removed and the surgical site appeared to be healing well. Five days following splint application the affected limb was shod with a Patten bar shoe, with approximately 4.5 centimeter heel elevation and 3.5 centimeter caudal heel extension. Heel elevation resulted in dorsal hoof angle of 75° and plan...
tar hoof angle of approximately 25°. Over the next two weeks the mare was gradually weaned from the splint and was using the affected limb adequately.

At the time of discharge, the mare’s limb posture was significantly improved. The toe was no longer elevated off the ground at a stance, fetlock hyperextension was still noted but to a lesser degree than prior to surgery. Over the months following discharge from the hospital the heel elevation and caudal extension were gradually reduced. Two years following surgery the mare is comfortable at pasture but still shows some degree of fetlock hyperextension when weight-bearing on the limb.

**Discussion**

Coffin joint hyperextension is typically manifested in neonatal foals with congenital laxity of the DDFT and carries a favorable prognosis with conservative management (6). Treatment involves corrective trimming and in more severe cases caudal hoof extension. In most cases the deep digital flexor muscle gradually gains strength and normal limb conformation is attained within several weeks. Severe congenital distal limb hyperextension is uncommon and does not respond well to conservative management (1). Acquired coffin joint hyperextension is uncommon and presents typically secondary to DDFT rupture following navicular disease and neuritis but has been reported secondary to enzymatic dissolution of the DDFT due to chronic sepsis in the digital flexors tendon sheath (DFTS) (4, 5, 13). These acquired cases typically present with severe conformational changes and achieving long-term comfortable ambulation may require surgical management. In the current case, conservative treatment had been attempted prior to referral but was unsuccessful and was unlikely to succeed due to the age of the horse and the structural damage to the DDFT.

In this case, the history includes a penetrating wound at the plantar aspect of the distal limb, above the coronary band, followed by distal limb swelling, marked lameness and local pain reaction at the plantar aspect of the pastern region. The severe lameness, following such a small puncture wound is likely to be attributed to either synovial infection, a direct tendon penetrating injury or both. Sepsis of the DFTS commonly results from a penetrating injury (9, 10). Direct penetrating injuries leading to severe structural damage to the deep and superficial digital flexor tendons, without involvement of the DFTS, have been reported (11, 12). Additionally, chronic infection of the DFTS, occasionally results in infection of the tendon itself leading to structural damage and even complete rupture (9, 10, 13). The damage to the tendons, in cases of septic tendon sheath, results from enzymatic dissolution of collagen caused by bacteria as well as inflammatory cells (13, 14). The diffuse extensive hypoechic lesion in the DDFT and to a lesser degree in the SDFT, found upon ultrasonographic examination indicated severe structural damage along most of the flexor tendons within the DFTS. It is possible that partial laceration of the DDFT and SDFT occurred at the original injury and further deterioration, including potentially complete rupture, resulted in hyperextension of the coffin and the fetlock joints. Since we evaluated the horse six months following the original injury we can only make assumptions as to the most likely aetiology. Considering the history, clinical signs, radiographic and ultrasonographic findings it appears that the severe structural damage to the flexor tendons occurred at the time of the original injury or soon following it. The structural tendon damage was severe enough to cause marked loss of flexural function, resulting in coffin and fetlock joint hyperextension.

Reported surgical treatment options for coffin joint hyperextension include: coffin joint arthrodesis and flexor tendon shortening. Surgical arthrodesis of the coffin joint has been described (2–5). The surgery poses significant technical difficulties. The approach offers limited exposure due to the need to cause minimal damage to the coronary band, while avoiding the hoof wall. The proximity of the surgical site to the contaminated sole leads to increased risk of infection that can be devastating (3, 4). Arthrodesis eliminates coffin joint range of motion and increases the load on adjacent joints, especially the pastern, and may potentially result in severe osteoarthritis (3, 4). In addition, arthrodesis at best resolves the coffin joint hyperextension without resolution of the fetlock hyperextension.

Clinically the mare was admitted with two abnormalities, a dropped fetlock or moderate fetlock hyperextension and severe coffin joint hyperextension. These clinical problems are a manifestation of loss of normal DDFT and SDFT function. Thus, bio-mechanically, re-establishing tension in the DDFT by shortening appeared to be the most reasonable solution to the case. In humans, it was shown that tendon shortening, as the sole treatment or as an adjacent procedure, for chronic tendon rupture, provides good results and may offer a better outcome than joint arthrodesis (15–17). The primary limitation of tendon shortening is that healing of a flexor tendon typically occurs with gap healing which is counterproductive to the goal of shortening of the tendon. Even in ideal experimental conditions healing of appositionally sutured equine DDFT occurs with a gap (18). Extended external support to prevent loading of the tendon and to minimize gap formation is an essential part of post-operative management of equine flexor tendon tenorrhaphy (19). Tendon healing within the DFTS is limited. In experimental conditions, tenorrhaphy followed by pro-

**Fig. 4** Intra-operative photograph, showing overlapping of the proximal and distal ends of the Deep Digital Flexor Tendon.

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longed rehabilitation including six weeks in a short-limb cast, resulted in 50 mm gap at six months without direct healing between the proximal and the distal edges. Both DDFT edges adhered with fibrous tissue to the SDFT (20). In this case, in order to achieve optimized healing and to avoid sheath related complications, we transected the tendon at mid-metatarsal region, an area lacking a tendon sheath. The paratenon at this area provides adequate blood supply and thus promotes healing (21, 22).

Among the techniques utilized in human studies were V-Y tenoplasty and a flap from the distal end of the proximal tendon, looped transversely through the distal end, turned back proximally and sutured upon itself and the proximal tendon. A modification of the latter technique could potentially be utilized in the DDFT. We projected that V-Y tenoplasty would not provide adequate shortening. A recent experimental study in horses showed tenorrhaphy using bioabsorbable plates to be superior to traditional three-loop-pulley technique. The plating technique would have eliminated the need to overlap the tendon edges and may be advantageous. However, so far the technique has only been reported on cadavers and the plates were not commercially available (23).

We considered several techniques for tendon shortening (Fig. 5). Performing tenectomy by end to end anastomosis may result in a large gap formation that would negate the surgical goal (Fig. 5A). Tenectomy and longitudinal splitting of both DDFT and SDFT followed by individual anastomosis of each tendon unit (Fig. 5B) was performed by Fackelman et al. (1) but a follow-up was provided. Longitudinal splitting offers increased tendon surface area for healing but we preferred not to further weaken the tendon by longitudinal incisions. Folding the tendon upon itself and suturing while keeping it intact does not offer incised tendon surface areas that promote healing (Fig. 5D). Tendon folding avoids the potential for achieving tendon elongation which is an inherent risk with all techniques that involve incising the tendon but results in excessive bulging that interferes with wound closure. Due to the weaknesses of the abovementioned techniques, transecting the DDFT followed by overlapping the desired length to be shortened was the technique selected in the current case (Fig. 5C, Fig. 6).

Typical suture materials used for equine tenorrhaphy include large diameter (# 2) absorbable or non-absorbable synthetic monofilament sutures (24, 25). In the current case we used a new generation synthetic non-absorbable braided polyblend suture (FiberWire). This suture was shown to have extreme durability and strength and compared favorably in cycling loading with equal size synthetic braided suture materials (26, 27). We felt that due to the known difficulty with achieving initial adequate strength in equine tenorrhaphy, using a mechanically superior material would be advantageous.

The goal of the surgery was to salvage the mare for pasture soundness, prevent continuous conformational deterioration and to improve weight bearing on the affected limb. Complete resolution of clinical signs enabling athletic activity was not achieved in this mare. However, the mare was pasture sound two years following surgery and the owners were satisfied with the mare’s level of comfort and conformation.

It is likely that shortening the tendon beyond 15 mm would have resulted in a better distal limb conformation. One factor that limited the degree of DDFT shortening was the resultant laxity of the superficial digital flexor tendon (SDFT). However, another potential consideration was concurrent shortening of the SDFT. Combined shortening of the flexor tendons was performed on a foal with severe congenital coffin joint hyperextension with no reported long term follow up (1).

Shortening of the DDFT tendon in the horse as a treatment for distal limb hyperextension abnormalities is a novel approach. In the current case, positive results were attained by using this technique. We believe that in selected cases of DDFT laxity, DDFT shortening may be a viable option for salvaging the horse.

Fig. 5 Illustration depicting several tendon shortening techniques: A) Tenectomy with simple appositional end-to-end anastomosis; B) Longitudinal transaction of both SDFT and DDFT followed by suturing the tendon strips end to end; C) Transverse tendon transaction followed by overlapping and suturing; D) Folding the tendon, overlapping and suturing without transecting.

Fig. 6 Illustration depicting the DDFT biplanar tenorrhaphy technique used with the tendon edges overlapping 15 mm. Two pairs of horizontal mattress sutures were placed in 90 degrees to one another. Bold and grey lines represent individual horizontal mattress sutures in the same plane, the grey is slightly narrower and shorter than the bold.
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References

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