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Ex vivo study shows novel, rapid, suture-free tenotomy technique for the equine deep digital flexor tendon

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OBJECTIVE
To describe the feasibility of a novel thread-transecting technique for the tenotomy of the equine deep digital flexor tendon (DDFT).

ANIMALS
39 equine distal limb specimens.

METHODS
Under ultrasonographic guidance, a surgical thread was percutaneously placed around the DDFT through 2 needle punctures (lateral and medial) using a Tuohy needle in equine limbs (22 forelimbs, 17 hindlimbs). The DDFT was transected by a back-and-forth motion of the thread until the loop emerged from the entry puncture site. Each specimen was dissected and assessed for completeness of transection and iatrogenic damage under direct visualization. Descriptive statistics were reported.

RESULTS
Complete DDFT transection was achieved in all 39 limbs, taking an average of 8.6 minutes per procedure. Iatrogenic damage to surrounding structures occurred in 17 (44%) limbs, with 6 (15%) limbs having more than 1 structure damaged. Damage to the communicating branch of the palmar or plantar nerves was the most commonly seen.

CLINICAL RELEVANCE
DDFT tenotomy in equine limb specimens was effectively performed using a novel thread-transecting technique. The procedure is quick, and no suturing is needed, but damage to surrounding structures is possible. Further assessment of the procedure and clinical significance of its potential iatrogenic damage in clinical cases is needed.

Keywords: tenotomy, horses, deep digital flexor tendon, thread, laminitis

Deep digital flexor tendon (DDFT) tenotomy is a surgical procedure that is very familiar to surgeons in equine practice. The goal of transecting this tendon is to change the biomechanical forces within the foot by reducing shearing forces on the lamellar tissue of the dorsal hoof wall and pressure of the apex of the distal phalanx on the sole.[1–3] The procedure may be performed by transecting the DDFT at midmetacarpal/metatarsal or pastern levels. Both tenotomy procedures can be performed in the sedated standing horse with local anesthesia or in horses under general anesthesia.[4–7] DDFT tenotomy is most frequently performed in horses with laminitis, and it has historically been reserved for refractory cases that do not respond to medical treatment and supportive trimming or shoeing alone.[8–11] Without the palmar or plantar pull from the DDFT, more aggressive trimming can be performed that allows for realignment of the distal phalanx, also known as derotation.[9,10] DDFT tenotomy can also be used for the treatment of severe (stage II) flexural limb deformities of the distal interphalangeal joint, especially in cases that fail to respond to desmotomy of the accessory ligament of the DDFT.[4,12]

In recent decades, minimally invasive and standing procedures have become increasingly popular and currently are considered the gold standard approach for many equine surgeries.[13,14] While most of these procedures are performed in association with imaging technologies, ultrasound-guided

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surgeries in veterinary medicine are still limited when compared to the human surgical field.[4] Only a few reports have described the use of ultrasonography to guide equine orthopedic surgeries. Ultrasonography has been used in tendon surgeries, such as desmotomy of the palmar or plantar annular ligament, and medial patellar ligament splitting, as well as assisted in fracture fragment removal during arthroscopic surgery.[15–22] An ultrasound-guided equine DDFT tenotomy that can be performed standing or under general anesthesia has also been described.[4] However, a 1- to 2-cm surgical incision directly over the DDFT at the midmetacarpus/metatarsus or midpastern levels is still necessary to introduce Metzenbaum scissors.

Recently, a new minimally invasive percutaneous thread-transecting surgical technique for carpal tunnel and trigger digit release in humans has been described.[23–27] Under ultrasonographic guidance, a cutting thread is looped around the ligament using needles and the desmotomy is performed by applying a back-and-forth motion to the thread. This procedure can be performed without the need for an operating room, endoscopic equipment, or special blades or knives. Other benefits include fast wound healing, no risk of dehiscence, and earlier return to work. This percutaneous thread technique was effectively performed for desmotomy of normal palmar/plantar annular ligaments (PALs) in equine limb specimens with minimal iatrogenic damage to adjacent structures.[22]

To our knowledge, there are no studies describing a similar surgical technique for tenotomy of the DDFT in horses. This study aimed to develop an ultrasound-guided thread-transecting technique for tenotomy of the equine DDFT and describe the completeness of transection of the DDFT and potential damage to adjacent structures. We hypothesized that equine DDFTs can be completely transected without major damage to surrounding structures through a minimally invasive thread-transecting technique.

Methods

Specimen collection and preparation

Thirty-nine distal limbs were collected from client-owned mature horses euthanized for reasons unrelated to orthopedic disease. Owner consent for inclusion in the study was obtained before euthanasia. Specimens from miniature horses, ponies, or draft horses were excluded from the study. Specimen collection, storage, and preparation are similar as previously described.[22] Before ultrasonographic examination and DDFT tenotomy, the specimens were thawed at room temperature for approximately 36 hours.

The palmar/plantar, palmaro/plantaromedial, and palmaro/plantarolateral aspects of all limbs were clipped from the proximal metacarpal or metatarsal region to the level of the coronary band. For the procedure, the limbs were held in a vertical position with the palmar/plantar surface of the foot parallel to the ground using a leg stand or jig to mimic a horse in a standing weight-bearing position **(Figure 1)**. The leg-jig unit was placed on a horizontal table with the

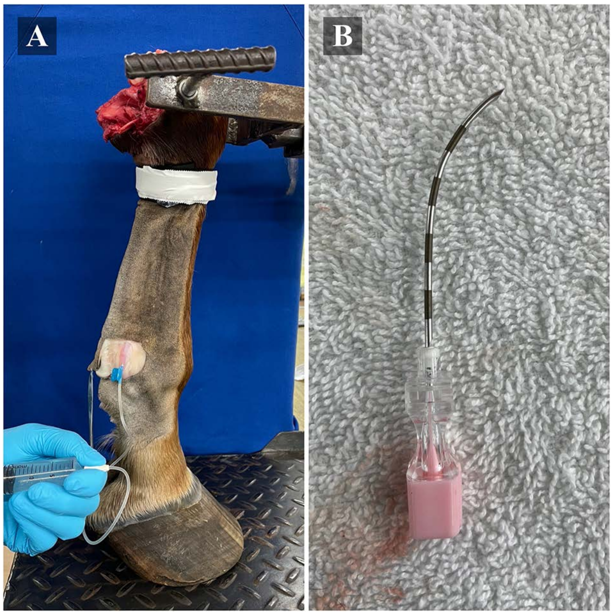

Figure 1—Preparation of the limb and equipment for tenotomy of the deep digital flexor tendon using a thread-transecting technique. (A) Leg-stand with a fixed forelimb. A medial skin flap was created to access the medial palmar artery for distension of the vessels using saline. (B) An 18-gauge, 2-inch Tuohy spinal needle was used for the placement of the transecting thread. A curvature was created at the needle middistal portion with the beveled surface facing the resulting concavity.

dorsal aspect of the metacarpus or metatarsus facing away from the surgeon for forelimbs and towards the surgeon for hindlimbs to mimic the safest position of a surgeon working in a standing live animal.

Surgical procedure

Ultrasonographic (US) examination of the DDFT, accessory ligament of the DDFT, superficial digital flexor tendon (SDFT), and suspensory ligament (SL) from the proximal to distal metacarpal or metatarsal region was performed by 1 operator (DG) using a linear array transducer (5 to 12 MHz; GE LOGIQ e Vet, Sound) to rule out any preexisting abnormality. For visualization of the surrounding palmar/plantar digital vessels with the ultrasound, a 1-inch-wide rubber tourniquet was placed at the most proximal aspect of the metacarpus or metatarsus. A 2 X 2 cm skin flap was then created on the lateral or medial aspect of the fetlock for exposure of the neurovascular bundle and insertion of a 25-gauge, 1.5-inch butterfly needle into the respective digital artery. A prefilled 35 mL syringe with sterile saline 0.9% was then attached to the needle and distention was performed until the palmar/plantar lateral and medial vessels adjacent to the proposed tenotomy site could be visualized by ultrasound (Figure 1).

An 18-gauge, 2-inch Tuohy needle was manually curved at its middle and distal portions with the beveled surface facing the resulting concavity (Figure 1). The needle was inserted through the skin on the most lateral or most medial aspect of the DDFT at the midmetacarpal or metatarsal level. For the first 7 limbs, needle insertion and manipulation were performed by the surgeon using the right hand (dominant hand of the surgeon), either in a lateral-to-medial or medial-to-lateral direction depending on the leg. From limbs 8 to 39, the needle was inserted or manipulated in a medial-to-lateral direction for forelimbs, and in a lateral-to-medial direction for hindlimbs, to ensure a more accurate placement of the needle in the side of the limb where the neurovascular bundle is more prominent (medial aspect of forelimbs; lateral aspect of hindlimbs). Consequently, the right hand was used to insert and manipulate the needle when performing the procedure in the left fore and left hindlimbs, while the left hand was used for the right fore and right hindlimbs.

Once the needle was through the skin medial or lateral to the DDFT, it was advanced dorsally to pass in between the dorsal aspect of the DDFT and the palmar/plantar aspect of the SL **(Figure 2)** and directed to exit through the skin of the opposite side of the limb. This maneuver was performed under ultrasonographic guidance to ensure safe passage of the needle palmar or plantar to the neurovascular bundles. Hydro-dissection using a 3 mL syringe filled with sterile saline 0.9% injected through the Tuohy needle was used as needed to dissect the DDFT from the surrounding tissues and facilitate the needle passage (Figure 2).[22–26] The volume of saline used for hydro-dissection was recorded. A disposable surgical cutting thread (Loop & Shear, Ridge & Crest Company) of 0.23 mm in diameter and approximately 50 cm in length was passed through the needle and the needle was removed leaving the thread in position dorsal to the DDFT.

The same needle was then passed palmar/plantar to the DDFT (between the DDFT and SDFT) through the same skin entry and exit points used previously (Figure 2). This maneuver also was guided by US and the hydro-dissection was performed as needed. The end of the previously placed thread emerging adjacent to the needle was then passed through the needle from its bevel to the hub portion (Figure 2). The needle was then fully retracted leaving the thread looped around the DDFT with both ends exiting the same skin puncture site. This was followed by another US in longitudinal and transverse planes to ensure that the loop included only the DDFT (Figure 2). The tendon was then divided by a back-and-forth motion of the thread until the loop emerged from the initial skin puncture site (Figure 2; **Supplementary Video**). The transected tendon was digitally palpated and again evaluated by US for any remaining fibers (Figure 2). The skin needle puncture sites were not sutured or closed with tissue glue due to their small size. The surgical procedures as well as the ultrasound evaluations during the procedures were all performed by the same operator (DG).

The total duration of the procedure (defined as the time from the initial insertion of the Tuohy needle to the moment when the looped thread emerged from the skin puncture) and the number of attempts required for the correct needle placement were recorded. All limbs were carefully dissected and the

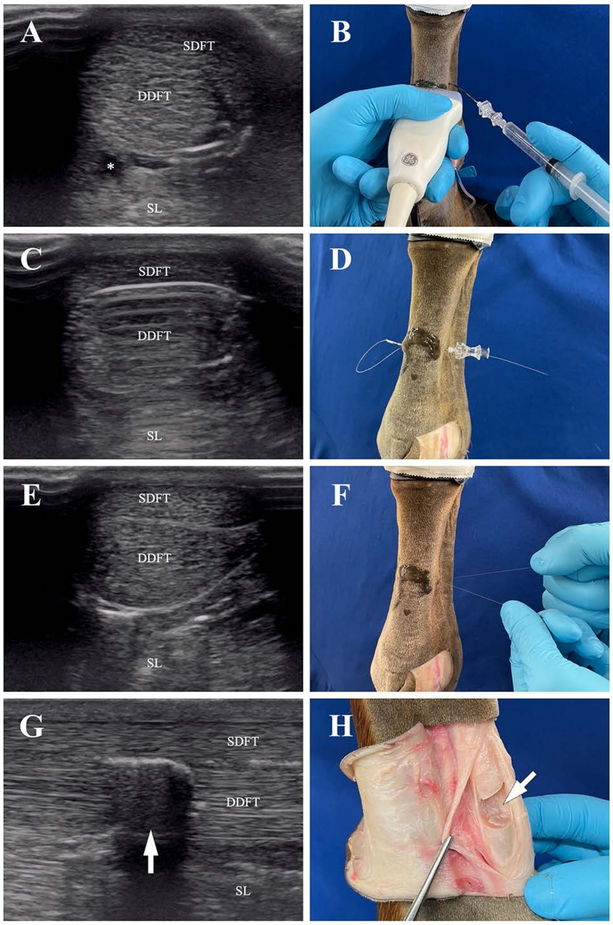

Figure 2—Insertion of the needle and placement of the transecting thread under ultrasound guidance for the tenotomy of the deep digital flexor tendon (DDFT) at the midmetacarpal level of a left forelimb. (A) Transverse ultrasound image demonstrating the passage of the Tuohy needle from medial to lateral between the dorsal surface of the DDFT and palmar surface of the suspensory ligament. Note a small area of hypoechogenicity next to the needle tip corresponding to the hydro-dissection. The * indicates a lateral palmar vessel distended with saline. (B) Hydro-dissection being performed while the needle is inserted as indicated by (A). Once the needle emerges on the lateral aspect of the leg, the cutting thread is inserted through the needle and the needle is removed leaving the thread just dorsal to the DDFT (not visible in this picture). (C) Transverse ultrasound image illustrating the passage of the Tuohy needle from medial to lateral between the palmar surface of the DDFT and the superficial digital flexor tendon. (D) The lateral end of the previously placed thread is inserted from lateral to medial through the Tuohy needle before needle removal. (E) Transverse ultrasound image demonstrating the cutting thread looped around the DDFT with both ends emerging medially. (F) The looped thread is held under tension and back-and-forth motion is applied to transect the tendon. (G, H) Transected DDFT was visualized using a longitudinal ultrasound image and after dissection. The arrows indicate the gap formed in the transection site. Please note that gas artifact prevents visualization of the suspensory ligament at this level. Medial is to the right, and lateral is to the left of the transverse ultrasound images. Proximal is to the left, and distal is to the right of the longitudinal ultrasound image. SDFT = Superficial digital flexor tendon. SL = Suspensory ligament.

structures adjacent to the surgical site (SDFT, SL, and palmar/plantar neurovascular bundles) were visually assessed for iatrogenic damage. The DDFT was thoroughly inspected for completeness of transection (Figure 2). The transected portion was subjectively classified as complete division, <25% remnant, 26% to 50% remnant, or >50% remnant.[15,22]

Data analysis

Variables of interest (saline volume used for hydro-dissection, number of attempts for correct Tuohy needle placement, hand used for needle placement, direction of needle placement, total duration of procedure, saline volume used for distension of the vessels, iatrogenic damage to structures associated with the palmar/plantar neurovascular bundle, and completeness of DDFT transection) were recorded and described on each limb. Descriptive statistics were reported with mean and SD for parametric data, and median and range for nonparametric data.

Results

Of the 39 distal limbs that were collected, 22 were forelimbs and 17 were hind limbs. The division of limbs was as follows: 12 left forelimbs, 10 right forelimbs, 9 right hind limbs, and 8 left hind limbs. The mean saline volume required for adequate distension of the palmar/plantar vessels was 21.6 mL (SD = 5.19). The mean amount used for hydro-dissection dorsal and palmar/plantar to the DDFT was 2 mL (SD = 0.70) and 1.1 mL (SD = 0.66), respectively. The number of attempts (partial withdrawal and redirection) for correct insertion or passage of the Tuohy needle dorsal to the DDFT was 1 (median, range = 1 to 2). Similarly, 1 attempt (median, range = 1 to 6) was required for the correct placement of the needle palmar/plantar to the DDFT. The mean duration of the procedure was 8.6 minutes (SD = 3.18).

The DDFT was completely transected in all 39 limbs. In 35/39 (90%) limbs, the first attempt was successful in transection of the DDFT. More than 1 attempt to transect the tendon was necessary in 4/39 (10%) limbs. In 2 of these cases, the thread broke during the procedure necessitating replacement. After thread breakage, a third attempt was needed due to thread displacement (1 end of the thread slipped from the operator's hand into the surgical site) in 1 of these 2 cases. The other 2 cases involved a partial transection of the DDFT or thread displacement into the surgical site necessitating replacement. Replacement of the routing needles and thread was accomplished easily; however, ultrasonographic visualization of the limbs where the thread breakage occurred was impaired by air entering the surgical site. All 4 tendons were successfully transected in the second or third attempt.

The right hand was used in 23 limbs, and the left was used in 16 limbs for needle passage and thread around the DDFT. The right hand was used in the first 7 limbs before the distinction was made as to which hand to use as described in material and methods. For these 7 limbs, the division was as follows: 3 left forelimbs, 2 right hindlimbs, 1 right forelimb, and 1 left hindlimb. For the remaining 32 limbs, the right and left hands performed the procedure in 16 limbs each. The left hand was used in 9 right forelimbs and 7 right hindlimbs. The right hand was used in 9 left forelimbs and 7 left hindlimbs.

Iatrogenic damage to surrounding structures was noted in 17/39 (44%) limbs, with 6/17 (35%) limbs having more than 1 structure damaged. Four of these limbs had superficial fiber disruption to the medial or lateral edge of the superficial digital flexor tendon (SDFT). Superficial disruption to the suspensory ligament (SL) was also seen in 1 limb. The medial palmar/plantar nerve was completely transected in 3 limbs and partially damaged in 2 limbs. Complete transection of the lateral palmar/plantar nerve occurred in 2 limbs, while partial transection occurred in 1 limb. The communicating branch between the medial and lateral palmar/plantar nerve was transected in 10 limbs. One case had a transection of the lateral plantar artery.

Of the 17 limbs with damage, 10 (59%) were performed with the right hand and 7 (41%) with the left hand. In the first 7 limbs where no distinction of left or right hand was made, 6/7 (86%) of them had damage to 1 or more structures. These limbs were all performed with the right hand and multiple attempts were made for redirection of the needle in all limbs. In the remaining 32 limbs, a distinction was made on which hand to use for the procedure, and in only 10/32 (31%) limbs multiple attempts for placement of the needle were necessary. Once the procedure was changed with a distinct method, 4/32 (13%) limbs with damage were performed with the right hand and 7/32 (22%) limbs with damage were performed with the left hand. Of the 11 limbs with damage in this group, 7 (64%) had damage to the communicating branch only. A detailed table with the variables of interest and the respective data from each limb is presented in the supplementary materials section **(Supplementary Material Table 1)**.

Discussion

To the best of our knowledge, this is the first description of the novel ultrasound-guided thread-transecting technique being applied for the tenotomy of the equine DDFT. The results indicate that the transection of DDFTs in equine limb specimens is quick and feasible. However, it is important to note that a learning curve is to be expected, as it is common with all minimally invasive procedures, especially since ambidexterity and proficient ultrasonographic skills are required.

A complete transection of the DDFT was achieved in 100% of the limbs effectively. In 90% of the limbs, complete transection was achieved with 1 attempt; however, in 10% of the limbs, a second or third attempt was necessary. These results are comparable to other studies of DDFT tenotomy in which complete transection was visualized.[5,6,8,10,11] Conversely, we recently reported a lower success rate when applying the thread-transecting technique for the desmotomy of PALs, with 81% of complete transections.[22] This difference in outcome can be attributed to the shape and location of the transected anatomical structures. The DDFT exhibits a more prominent and rounded shape at the midmetacarpal level (Figure 1) making it readily identifiable through digital palpation and US. In contrast, the visualization of the PAL posed recognition challenges due to the thin distal margin of the ligament. In addition, the leg has a straight appearance at the midmetacarpal level and the Tuohy needle travels a short distance that facilitates the placement of the thread. Inversely, the PAL is wider and has a flat shape requiring the needle to travel through a longer distance, and in a curved portion of the leg. These differences make the described thread technique a suitable surgical option with more favorable results for DDFT than PAL transection.[22]

Overall, the duration of the current procedure (mean 8.6 min) is quick since the size of the skin punctures eliminates the need for suture placement. In humans, this advantage of the percutaneous thread-transecting technique allows for faster healing, better cosmetic appearance, and less risk for incisional infections.[23,26] The procedural time for the DDFT tenotomy is similar or shorter to the surgery time reported for other thread-transecting techniques in horses and humans.[22,23,25]

Iatrogenic damage to surrounding structures was visualized in 44% of the limbs with 6 limbs having more than 1 structure damaged. The damage was mainly seen in the first 7 limbs when the right hand was used, and no distinction was made on which side of the limb the needle should enter first. Once that distinction was made, damage to anatomical structures was decreased and the damage to structures was very similar for the left and right hand. Damage to vessels and nerves during DDFT tenotomy has been reported in the literature.[8,9] It usually affects only the medial side, because the surgical incision is made lateral, and no visualization of the medial vascular/nerve bundle is possible. With the thread-transecting technique, visualization of the vascular/nerve bundle is only possible with ultrasound since the surgical entry/exit points are very small. Damage can potentially occur on the lateral side, medial side, or both sides. In our study, damage was noted on either the lateral or medial side, but never on both sides. If damage occurs on only 1 side during surgery, it should not affect the overall innervation and circulation since these can be supplied to the entire foot by the remaining structures.[9]

In the current study, the observed damage to tendons/ligaments was always superficial to paratenon and superficial fibers. This raises the question of whether such damage would have any clinical implications for the horse. Nerve damage as the sole damage, specifically the communicating branch between the lateral and medial palmar/plantar nerve, was noted in most cases and only in 1 case was the lateral artery transected. Assessing this nerve branch with ultrasound proves challenging, and any damage appears to be linked to needle placement. The authors suspect that the clinical significance of the damage to this communicating branch would be minimal to none since the main lateral and medial palmar/plantar nerves are still intact to supply sensory innervation to the distal limb. If the communicating nerve branch is identified during ultrasound examination, we recommend needle/thread placement proximal or distal to that location to prevent nerve damage. In addition, other DDFT tenotomy techniques might cause damage to surrounding structures, but it may go unnoticed.

Iatrogenic damage might be decreased by lifting the limb in a flexed position to facilitate the placement of the needle with no tension on the surrounding structures in the limb. Nevertheless, lifting a limb in a nonweight-bearing position in a sedated horse can cause movement of the limb and can create more lamellar damage to the contralateral foot in laminitis cases. Therefore, the authors wanted to develop a technique that mimicked the clinical situation in a standing weight-bearing position.[7–10]

The authors believe this minimally invasive surgical thread technique has many potential advantages. The cost is low, and the equipment needed, such as ultrasound, is usually available to most equine practitioners. The cutting threads are commercially available as well as the Tuohy needles. Regular spinal needles can potentially be used instead of Tuohy needles with some caution. The tip of spinal needles is sharper, and no curvature is present compared to a Tuohy needle increasing the risk of damage to the surrounding structures during placement. Hydro-dissection also facilitates the placement of the Tuohy needle by separating the surrounding structures from the DDFT. Although the amount of hydro-dissection used appeared to have been adequate, additional hydro-dissection may potentially prevent some of the iatrogenic damage seen. This new technique may also facilitate a repeat tenotomy just proximal or distal to the initial tenotomy site avoiding the risks associated with a second tenotomy at the pastern level, such as entering the flexor tendon sheath, adhesion formation, and increased risk of subluxation of the distal interphalangeal joint.[6,7,10]

This procedure needs to be investigated to determine if it is feasible in live animals such as horses with laminitis or severe flexural limb deformities of the distal interphalangeal joint. The selected limbs used for this study also came from horses with no orthopedic diseases and maintenance of tension on the tendon as in a clinical situation was not possible. The limbs were positioned in a leg stand/jig in a neutral weight-bearing position with the fetlock locked to mimic a tendon under tension, but the ex-vivo nature does not entirely reflect the clinical situation.

The distension of vessels with saline was very helpful for visualization, but leakage around the needle or from the vessels due to the cadaveric nature of the study impaired the recognition of the palmar/plantar vessel in some limbs. In live animals, blood flow and naturally distended blood vessels might facilitate the visualization with ultrasound with or without Doppler and decrease the risk of damage to surrounding structures.

In conclusion, a complete tenotomy of the equine DDFT with the ultrasound-guided thread-transecting technique is a feasible surgical procedure. The surgical procedure is quick with incisions that do not require suturing. While damage to the surrounding structures is possible, its relevance in clinical cases requires additional investigation. A learning curve is expected with this procedure and further investigation of the procedure in clinical cases is needed.

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None reported.

Disclosures

The authors have nothing to disclose. No AI-assisted technologies were used in the generation of this manuscript.

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References

1. Pollitt CC, Dyson SJ, Collins SN, et al. Laminitis. In: Ross MW, Dyson SJ, eds. *Diagnosis and Management of Lameness in the Horse.* 2nd ed. Saunders, 2011:366–386.
2. Fürst AE, Lischer CJ. Foot. In: Auer JA, Stick JA, Kummerle JM, Prange T, eds. *Equine Surgery.* 5th ed. Elsevier, 2019:1543–1587.
3. Wagner IP, Heymering H. Historical perspective on laminitis. *Vet Clin North Am Equine Pract.* 1999;15(2):295–309. doi:10.1016/S0749-0739(17)30146-3
4. Tnibar A. Ultrasound-aided tendon and ligament surgery in the horse. *Equine Vet Educ.* 2007;19(8):435-443. doi:10.2746/095777307X229471
5. Burba DJ, Hubert JD, Beadle R. How to perform a mid-metacarpal deep digital flexor tenotomy on a standing horse. Abstract in: *Proceedings of American Association of Equine Practitioners Annual Convention*; San Antonio, TX; 2006:547–550.
6. Allen Jr D, White NA, Foerner JF, Gordon BJ. Surgical management of chronic laminitis in horses: 13 cases (1983–1985). *J Am Vet Med Assoc.* 1986;189(12): 1604–1606. ISSN:0003-1488, 1943-569x
7. Waguespack RW, Caldwell F. How to perform a modified standing deep digital flexor tenotomy at the level of the proximal interphalangeal joint. Abstract in: *Proceedings of American Association of Equine Practitioners Annual Convention*; Las Vegas, NV; 2009:230–237.
8. Hunt RJ, Allen D, Baxter GM, Jackman BR, Parks AH. Mid-metacarpal deep digital flexor tenotomy in the management of refractory laminitis in horses. *Vet Surg.* 1991;20(1):15–20. doi:10.1111/j.1532-950x.1991.tb00300.x
9. Waguespack RW. Deep digital flexor tenotomy. In: Belknap JK, Geor RJ, eds. *Equine Laminitis.* 1st ed. John Wiley & Sons; 2017:382–390.
10. Morrison S. Long-term prognosis using deep digital flexor tenotomy and realignment shoeing for treatment of chronic laminitis. *J Eq Vet Sci.* 2011;31(2):89–96. doi:10.1016/j.jevs.2010.12.008
11. Eastman TG, Honnas CM, Hague BA, Moyer W, Von der Rosen HD. Deep digital flexor tenotomy as a treatment for chronic laminitis in horses: 35 cases (1988–1997). *J Am Vet Med Assoc.* 1999;214(4):517–519. ISSN:0003-1488, 1943-569x
12. Fackelman GE, Auer JA, Orsini J, von Salis B. Surgical treatment of severe flexural deformity of the distal interphalangeal joint in young horses. *J Am Vet Med Assoc.* 1983;182(9):949–952. ISSN:0003-1488, 1943-569x
13. Martens A, Pader K, Prange T, Ortved KF, Richardson DW. Minimally invasive surgical techniques. In: Auer JA, Stick JA, Kummerle JM, Prange T, eds. *Equine Surgery.* 5th ed. Elsevier; 2019:214–233.
14. Bonomelli N, Bonilla AG. Standing surgery among equine board certified surgeons: survey regarding current use and trends. *Equine Vet J.* 2023;55(6):1045–1057. doi:10.1111/evj.13920
15. Espinosa P, Nieto JE, Snyder JR, Galuppo LD, Katzman SA. A novel ultrasonographic assisted technique for desmotomy of the palmar/plantar annular ligament in horses. *Vet Surg.* 2017;46(5):611–620. doi:10.1111/vsu.12630
16. Henninger RW, Bramlage LR, Bailey M, Bertone AL, Weisbrode SE. Effects of tendon splitting on experimentally-induced acute equine tendinitis. *Vet Comp Orthop Traumatol.* 1992;5(1):01–09. doi:10.1055/s-0038-1633122
17. Rose PL, Penninck D. Use of intraoperative ultrasonography in six horses. *Vet Surg.* 1995;24(5):396–401. doi:10.1111/j.1532-950x.1995.tb01350.x
18. White NA. Ultrasound-guided transection of the accessory ligament of the deep digital flexor muscle (distal check ligament desmotomy) in horses. *Vet Surg.* 1995;24(5):373–378. ISSN:0161-3499
19. Tnibar MA. Medial patellar ligament splitting for the treatment of upward fixation of the patella in 7 equids. *Vet Surg.* 2002;31(5):462–467. doi:0.1053/jvet.2002.34660
20. Piccot-Crezollet C, Cauvin ERJ. Treatment of a second carpal bone fracture by removal under ultrasonographic guidance in a horse. *Vet Surg.* 2005;34(6):662–667. doi:10.1111/j.1532-950X.2005.00103.x
21. Barrett EJ, Rodgerson DH. Ultrasound assisted arthroscopic approach for removal of basilar sesamoid fragments of the proximal sesamoid bones in horses. *Vet Surg.* 2014;43(6):712–714. doi:10.1111/j.1532-950X.2014.12180.x
22. De Gasperi D, Guo D, Guo D, Lu Y, Brounts SH. Ex vivo evaluation of a percutaneous thread-traansecting technique for desmotomy of normal palmar/plantar annular ligaments in horses. *Vet Surg.* 2023;52(3):388–394. doi:10.1111/vsu.13932
23. Guo D, Tang Y, Ji Y, Sun T, Guo J, Guo D. A non-scalpel technique for minimally invasive surgery: percutaneously looped thread transection of the transverse carpal ligament. *Hand.* 2015;10(1):40–48. doi:10.1007/s11552-014-9656-4
24. Guo D, Guo D, Guo J, Malone DG, Wei N, McCool LC. A cadaveric study for the improvement of thread carpal tunnel release. *J Hand Surg Am.* 2016;41(10):e351–e357. doi:10.1016/j.jhsa.2016.07.098
25. Guo D, Guo D, Guo J, McCool LC, Tonkin B. A cadaveric study of the thread trigger finger release: the first annular pulley transection through thread transecting technique. *Hand.* 2018;13(2):170–175. doi:10.1177/1558944717697433
26. Guo D, Guo D, Guo J, Schmidt SC, Lytie RM. A clinical study of the modified thread carpal tunnel release. *Hand.* 2017;12(5):453–460. doi:10.1177/1558944716668831
27. Park J, Kim IJ, Park HY, Heo DJ, Kim JM. A clinical study of thread carpal tunnel release with a newly developed thread: a retrospective pilot study. *PLoS ONE.* 2022;17(10):e0276630. doi:10.1371/journal.pone.0276630

Supplementary Materials

Supplementary materials are posted online at the journal website: avmajournals.avma.org