Aus der Klinik für Pferde, Allgemeine Chirurgie und Radiologie,
des Fachbereichs Veterinärmedizin
der Freien Universität Berlin

Non-septic tenosynovitis of the digital flexor tendon sheath in the equine distal limb: Diagnosis, long-term outcome and description of a surgical technique for tenoscopic resection of the manica flexoria

Inaugural-Dissertation
zur Erlangung des Grades eines
Doctor of Philosophy (PhD)
in Biomedical Sciences
an der Freien Universität Berlin

vorgelegt von
Andrea Cristina Noguera Cender
Tierärztin aus Valencia, Spanien

Berlin 2021
Journal-Nr.: 4312

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Dekan:	Univ.-Prof. Dr. Uwe Rösler
Erster Gutachter:	Univ.-Prof. Dr. Christoph Lischer
Zweiter Gutachter:	Univ.-Prof. Dr. Achim Gruber
Dritter Gutachter:	Univ.-Prof. Dr. Leo Brunnberg

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List of abbreviations

AAEP	American Association of Equine Practitioners
CI	Coefficient Interval
cm	Centimeter
DDAN	Distal digital annular ligament
DDFT	Deep digital flexor tendon
DFTS	Digital flexor tendon sheath
DLPMO	Dorsolateral-palmaromedial oblique
ECVS	European College of Veterinary Surgeons
MF	Manica flexoria
ml	Milliliter
PAL	Palmar/Plantar annular ligament
PDAN	Proximal digital annular ligament
PLDMO	Palmarolateral-dorsomedial oblique
PSB	Proximal sesamoid bones
SDFT	Superficial digital flexor tendon
OR	Odds Ratio

1. Introduction

Lameness is the most common reason of health issue in the horse and the leading cause of poor performance. Orthopedic pathologies account for the greatest economical losses for the equine industry. Very often lameness originates from pain localized at the distal part of the extremities, including the digital flexor tendon sheath.

The digital flexor tendon sheath (DFTS) is a complex synovial structure of the equine distal limb containing the superficial (SDFT) and deep digital flexor tendons (DDFT) in their pass along the palmar/plantar aspect of the fetlock joint. The palmar and plantar annular ligaments help to hold the flexor tendons in the DFTS at the level of the metacarpophalangeal and metatarsophalangeal joints. Lesions of the DFTS and its related structures often result in lameness.

The outcome after surgical treatment of the DFTS is variable and depends on the exact diagnosis. In general, lesions of the DDFT are associated with a poor outcome (Wilderjans et al. 2003), whereas tenoscopic removal of the manica flexoria (MF) is associated with a good prognosis (Findley et al. 2012), with 38% and 79% of horses returning to pre-injury level of ridden exercise, respectively. However, the number of studies evaluating the outcome following DFTS surgery is limited, and most studies focus on a specific structure, such as the DDFT or the MF.

Typical clinical features and prognosis for MF tears have only been reported in a limited case series (Smith and Wright, 2006 and Findley et al. 2012). Further, there is limited information available in the scientific literature about a comprehensive description of a technique for tenoscopic resection of the MF and its possible associated complications.

The aim of this work was, firstly, to describe and to evaluate a technique for tenoscopic resection of the MF. The second part of this study aimed to describe the prevalence of lesions identified by tenoscopy of non-septic DFTS tenosynovitis, evaluating their long-term outcome following surgical treatment as well as factors affecting diagnosis and outcome.

2. Literature

2.1 Anatomy of the equine digital flexor tendon sheath and related structures

The digital flexor tendon sheath (DFTS) is an important synovial structure in the equine limb containing two main structures, the superficial (SDFT) and deep digital flexor tendon (DDFT). The sheath runs on the palmar/plantar aspect of the limb beginning 4 to 7 cm proximal to the proximal sesamoid bones (PSB) and extending distally to the middle third of the second phalanx (Denoix, 1994). The palmar/plantar wall of the DFTS incorporates three annular ligaments (Figure 1): the palmar/plantar annular ligament (PAL), the proximal digital annular ligament and the distal digital annular ligament. These ligaments are local thickenings of the deep fascia and contribute to stabilize the flexor tendons in their course at the palmar or plantar aspect of the digit (Jordana, 2015; Budras, 2009). The PAL forms the wall of the sheath as it passes between the PSB and inserts on the palmar/plantar border of both PSB (Fraser et al. 2004). The proximal digital annular ligament resembles the letter „X“ and holds the flexor tendons against the distal sesamoidean ligaments. Its four corners insert on the medial and lateral borders of the proximal phalanx. The distal digital annular ligament originates from the medial and lateral borders of the proximal phalanx and descends to the distal phalanx between the DDFT and the digital cushion (Budras, 2009).

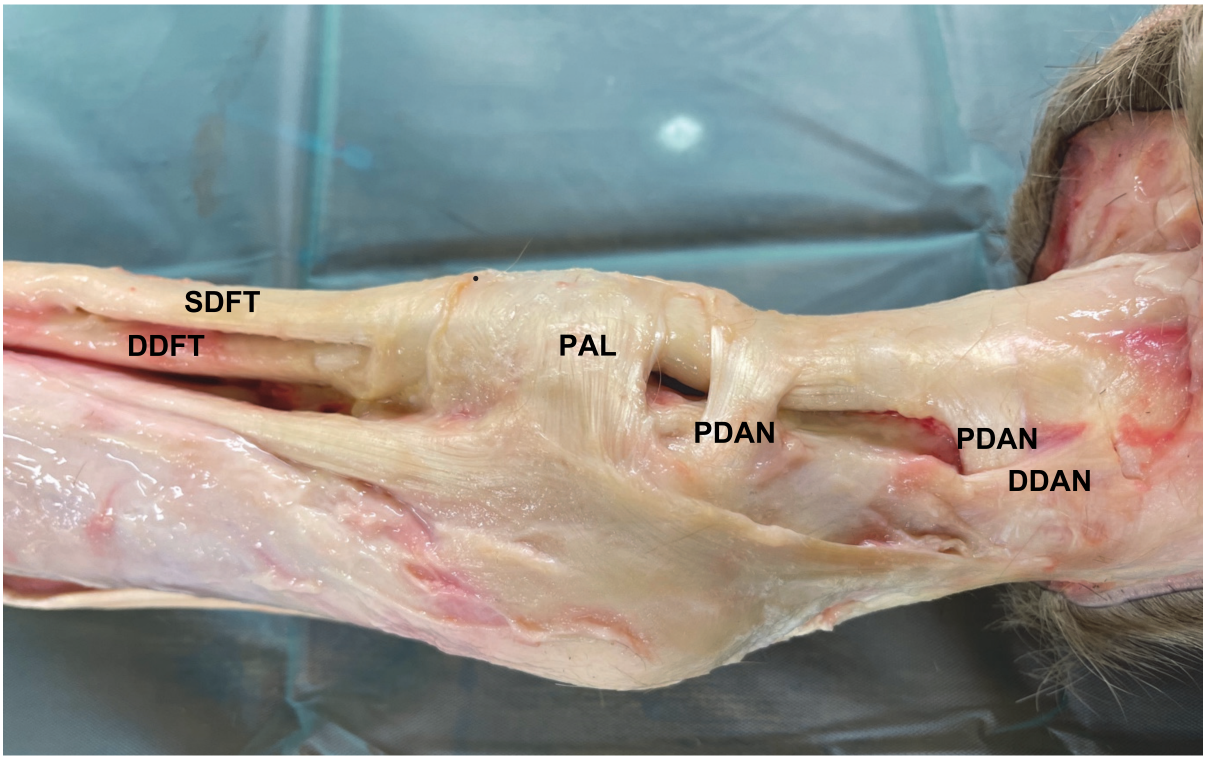

Figure 1: View of a distal forelimb with the skin and subcutis removed (the hoof is to the right). See the different annular ligaments at the palmar surface of the digital flexor tendon sheath. PAL = Palmar annular ligament; PDAN = Proximal digital annular ligament; DDAN = Distal digital annular ligament; DDFT = Deep digital flexor tendon; SDFT = Superficial digital flexor tendon. Image from Andrea C. Noguera Cender, 2021.

Proximally in the DFTS (Figure 2), the DDFT is surrounded by the manica flexoria (MF), a collar of tissue attached to the SDFT which wraps around the DDFT at the level of the metacarpo/metatarsophalangeal joints (Fraser et al. 2004, Findley et al. 2012). At the proximal border of the MF, there is a reflection of loose connective tissue that attaches the MF to the dorsal surface of the SDFT and the adjacent lining of the DFTS (Findley et al. 2017). The supposed function of the MF is to maintain the flexor tendons in alignment as they pass over the palmar/plantar aspect of the metacarpo/-tarso phalangeal joint (Denoix, 1994).

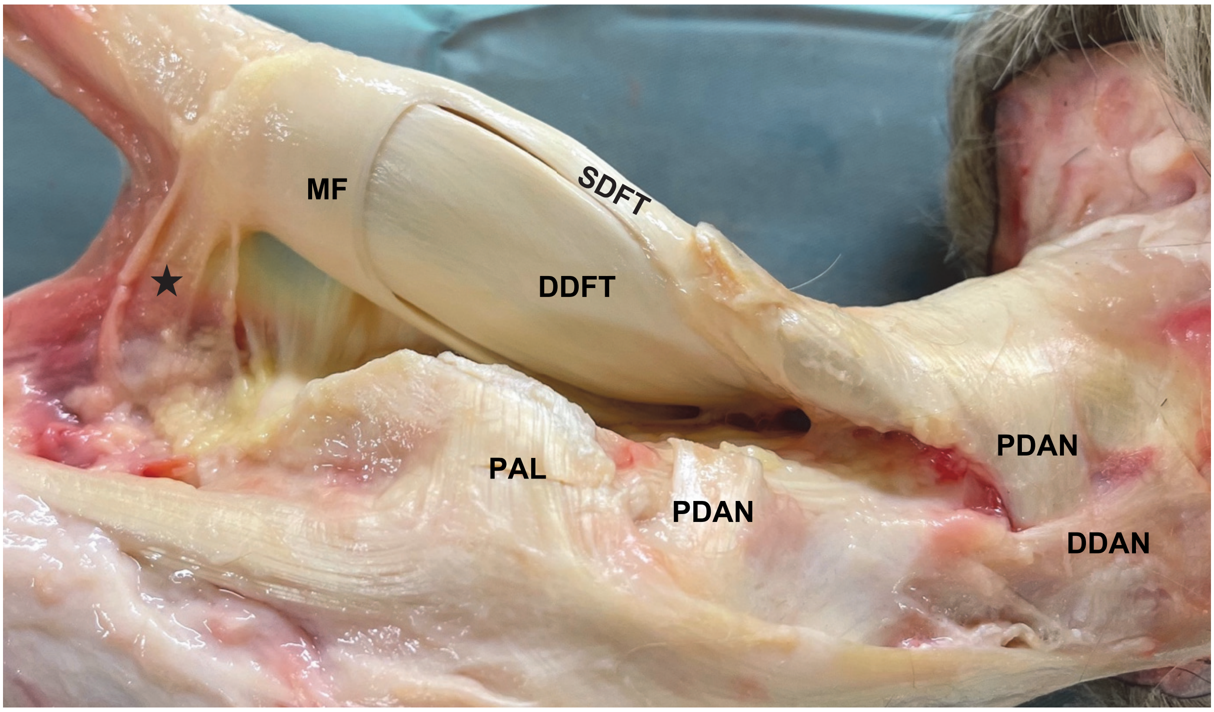

Figure 2: Lateral view of the structures within the digital flexor tendon sheath (DFTS). The synovial lining has been removed and the palmar annular ligament (PAL) and the proximal branch of the proximal digital annular ligament (PDAN) have been transected. The flexor tendons have been severed at the level of the proximal cannon bone and are rotated medially to allow visualization of the manica flexoria (MF). DDFT = Deep digital flexor tendon; SDFT = Superficial digital flexor tendon; DDAN = Distal digital annular ligament. The star represents the reflection of loose connective tissue attaching the MF to the adjacent lining of the DFTS. Image from Andrea C. Noguera Cender, 2021.

The DFTS has several synovial recesses (Fig. 3): a proximal recess, located proximal to the manica flexoria; the collateral recesses, located at the medial and lateral aspects of the pastern, between the flexor tendons and the distal sesamoidean ligament, and between the flexor tendons and the proximal digital annular ligament; and a distal recess, which extends between the middle phalanx and the dorsal aspect of the DDFT and presents a palmar pouch, palmar to the DDFT (Denoix, 1994; Jordana 2015).

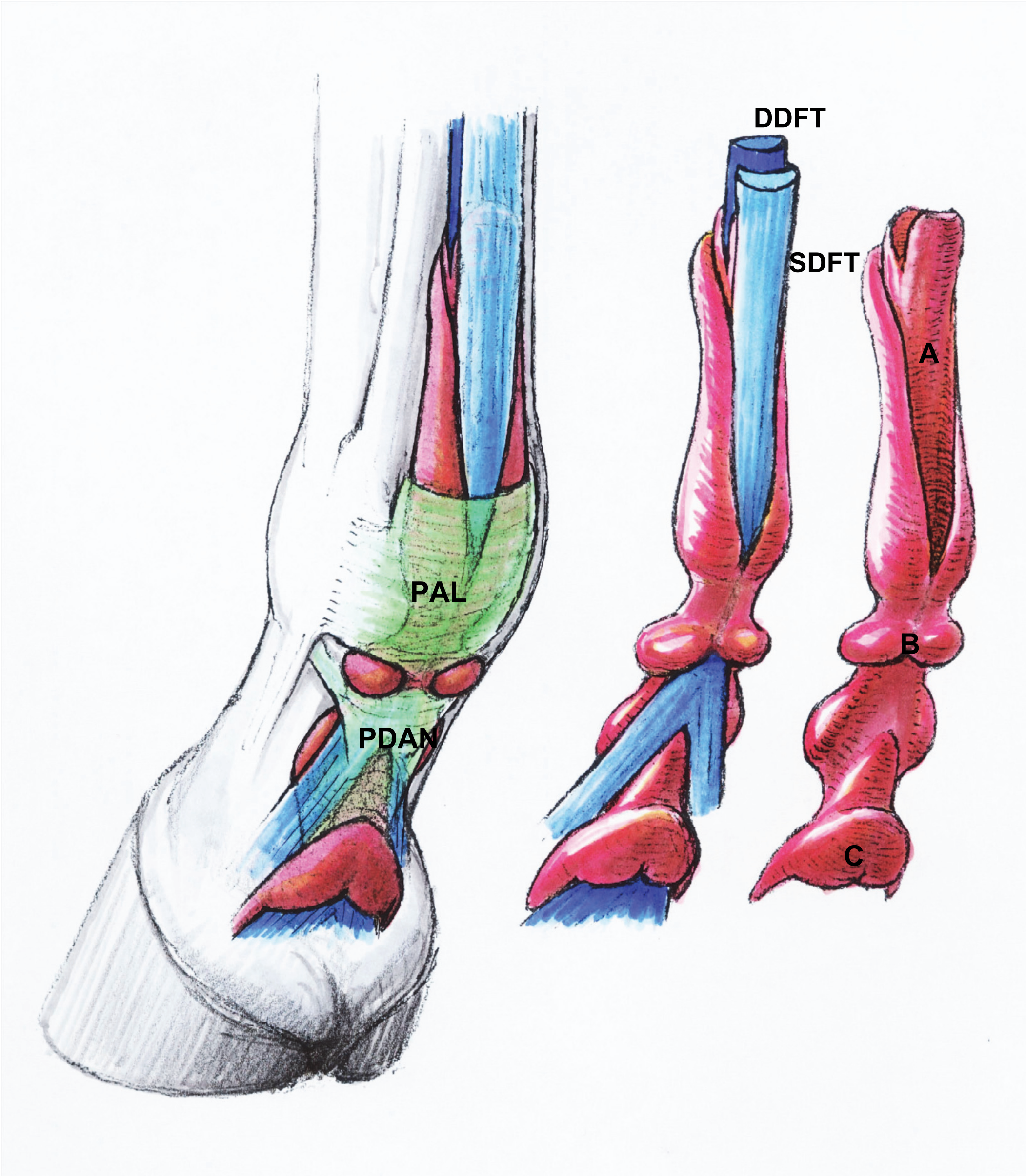

Figure 3: Drawing of a distal limb.

In red visible the different synovial recesses of the digital flexor tendon sheath (DFTS): A = Proximal recess; B = Collateral recess; C = Distal recess. Green: Palmar/plantar annular ligament (PAL) and proximal digital annular ligament (PDAN). Blue: Deep digital flexor tendon (DDFT) and superficial digital flexor tendon (SDFT). Image from Christoph Lischer, 2005. Illustration by Matthias Haab.

2.2 Pathology of the digital flexor tendon sheath

Synovial distension of the DFTS reflects the presence of tenosynovitis that can be caused by lesions of the sheath itself (primary tenosynovitis) or any of its related tendons or ligaments (secondary tenosynovitis). Primary non-septic tenosynovitis is unusual and it´s caused by an inflammation of the sheath wall, mostly caused by a single traumatic event that causes overstretching or compression of the DFTS (Jordana 2015). Secondary tenosynovitis is more common and has been associated to various lesions such as tears of the SDFT (McIlwraith et al. 2005) or DDFT (Wilderjans et al. 2003; Smith and Wright, 2006; Arensburg et al., 2011), desmitis of the palmar/plantar annular ligament (Fraser et al. 2004; Fortier, 2010) and tears of the manica flexoria (Smith and Wright, 2006; Findley et al. 2012).

Lesions can occur separately or in combination. The severity of the DDFT and SDFT lesions can be variable, depending on the size and depth of the lesion and the amount of tendon fibrillation, varying from surface fibrillation to large marginal tears extending into the center of the tendon (Figure 4).
DDFT lesions appear to be more frequent in fore limbs and the lateral borders seems to be more affected that the medial (Wilderjans et al. 2003; Smith and Wright, 2006; Arensburg et al. 2011).

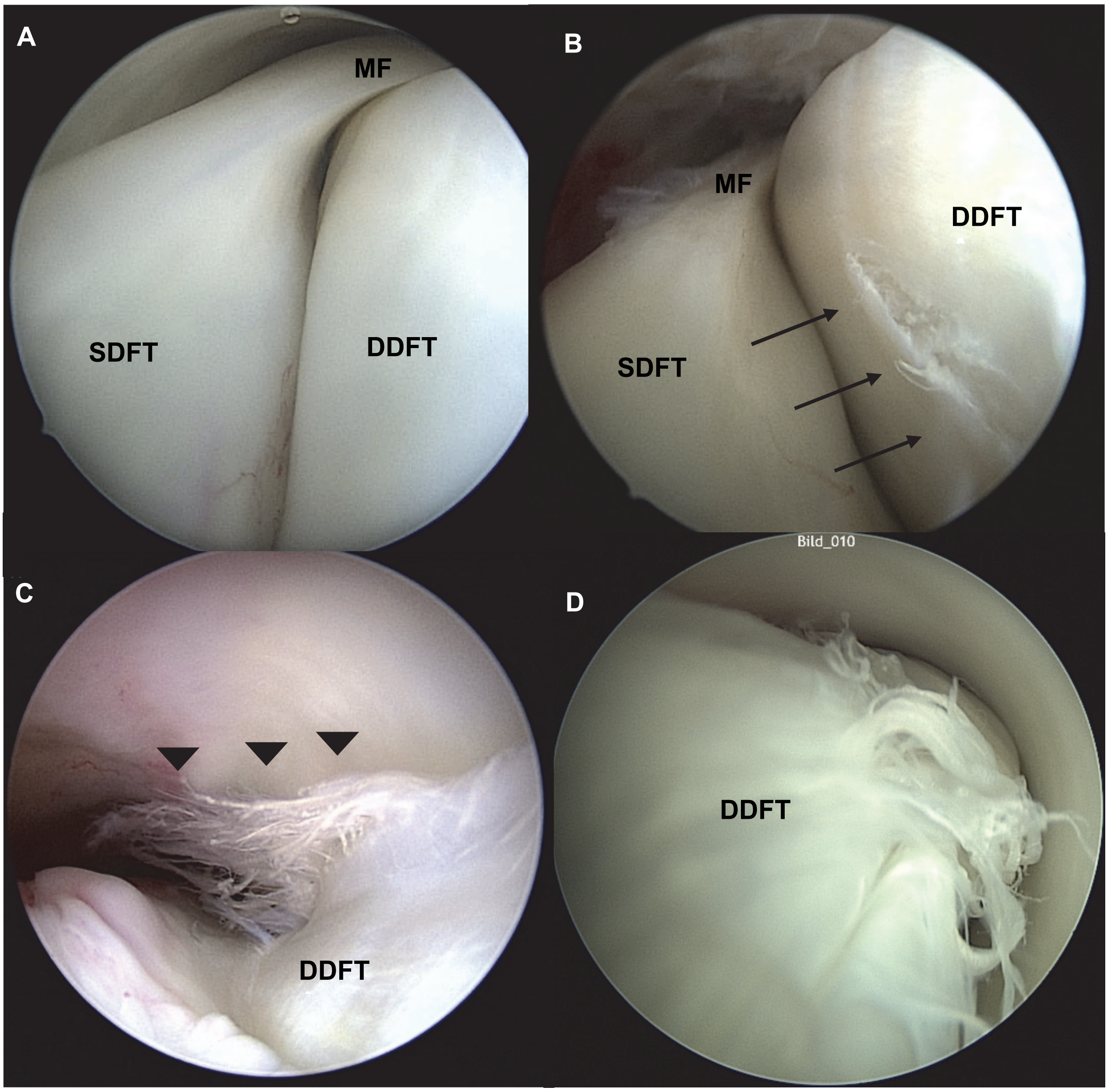

Figure 4: Tenoscopic view of the digital flexor tendon sheath (DFTS).

The arthroscope is inserted at the level of the base of the lateral proximal sesamoid bone and directed to the proximal pouch of the tendon sheath. Examples of variable degrees of lesions of the deep digital flexor tendon (DDFT). A) Normal appearance of the DDFT in the area distal to the manica flexoria (MF). B) Small superficial lesion at the plantar border of the DDFT (black arrows). Note also the mild fibrillation at the junction between the MF and superficial digital flexor tendon (SDFT). C) Longitudinal tear at the lateral border of the DDFT; note the tendon fibrils protruding into the DFTS (arrow heads). D) Deep longitudinal tear at the lateral border of the DDFT; note the severe tendon fibrillation and loss of normal tendon structure characterized by undulated fiber alignment. Image from Andrea C. Noguera Cender, 2020.

Most manica flexoria tears occur at the medial attachment of the manica to the SDFT or just adjacent to this site (Findley et al. 2012), and can be partial or complete, depending on the degree of disruption of the MF border from its attachment to the SDFT (Figure 5).
MF tears are more frequently associated to hind limbs (Smith and Wright, 2006); cobs and ponies seem to have a greater incidence compared to other breeds (Findley et al. 2012).

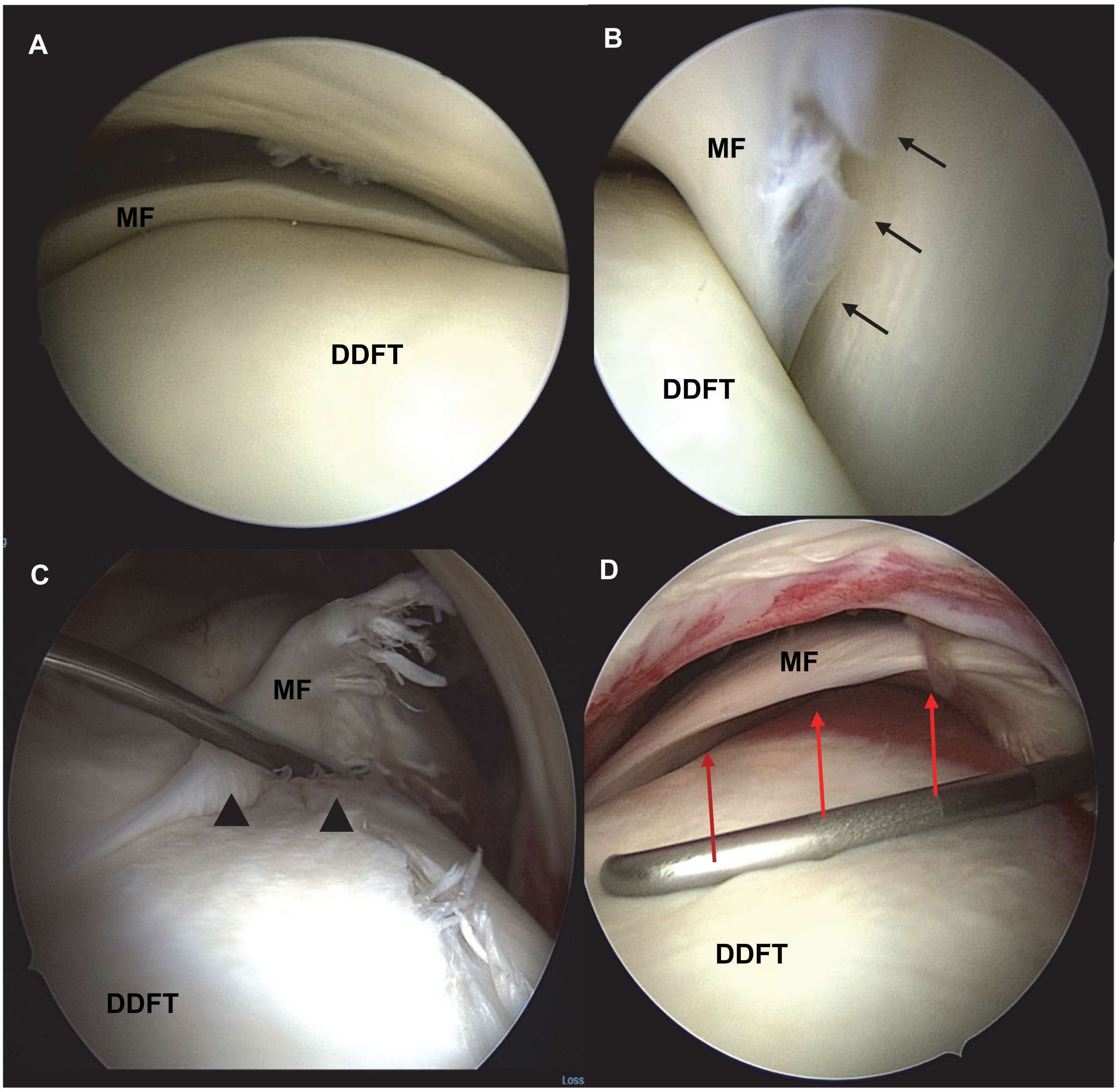

Figure 5: Tenoscopic view of the digital flexor tendon sheath (DFTS).
The arthroscope is inserted at the level of the base of the lateral proximal sesamoid bone and directed to the proximal pouch of the tendon sheath. Examples of variable degrees of lesions of the manica flexoria (MF). A) Normal MF. B) Mild fibrillation of the distal border of the MF (black arrows). C) Incomplete rupture of the lateral attachment of the MF (arrowheads) to the superficial digital flexor tendon (SDFT); note the concurrent superficial longitudinal tear of the deep digital flexor tendon (DDFT). D) Complete rupture of the medial attachment of the MF to the SDFT; due to the lack of tension medially the MF appears loosen and distanced from the DDFT (red arrows). Image from Andrea C. Noguera Cender, 2020.

Lesions of the DDFT and MF have been reported to be the most frequent causes for non-septic tenosynovitis of the DFTS, with a prevalence of 59% and 30%, respectively (Smith and Wright, 2006).

Oppositely, intrathecal tears of the SDFT have a reported lower incidence, compared to the DDFT (11/76 cases) and are commonly located at the lateral and proximal margins of the tendon (Smith and Wright, 2006).

2.3 Diagnostic procedures

Initial diagnosis of DFTS pathology is based on clinical examination followed by diagnostic analgesia to localize the source of pain. Generally, horses show a variable degree of distension of the DFTS and a moderate lameness when trotted. After lameness has been localized to the area of the digital flexor tendon sheath by perineural or intrasynovial anesthesia, ultrasonography and contrast radiography are performed.

Ultrasonography is the principal diagnostic method for investigation of lesions within the DFTS. Typically, fluid distension of the DFTS and in some cases presence of echogenic material within the tendon sheath can be seen in cases with DFTS tenosynovitis (Figure 6). Typical ultrasonographic changes indicative of DDFT and SDFT tears included hypoechoic areas, loss of the normal fiber alignment pattern and irregular surface of the affected area, as well as associated masses of echogenic material (Figure 7). Manica flexoria tears are suspected when the identification of one of the MF borders is not possible; or by the presence of echogenic material or irregular SDFT borders at the level of the MF (Figure 8A).

A width of the PAL larger than 2 mm measured in a transverse ultrasonographic image at the palmar/plantar aspect of the fetlock joint is categorized as PAL desmitis. This can be seen alone or in combination with subcutaneous fibrosis (seen as an increase in width and echogenicity of the tissue between the PAL and the skin) and/or poor definition of the palmar/plantar SDFT margin (Figure 8B).

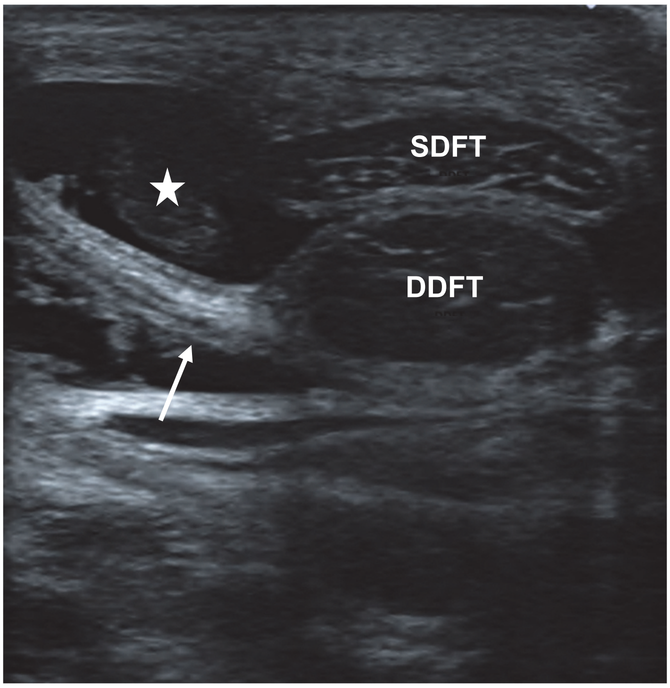

Figure 6: Transverse ultrasonographic image of the digital flexor tendon sheath (DFTS) obtained at the level of the proximal recess.
Note the severe fluid distension at the lateral recess of the DFTS, the presence of an hyperechogenic mass within it (star) and the thickening of the lateral mesotendineum of the deep digital flexor tendon (DDFT) (arrow). SDFT = Superficial digital flexor tendon. Image from Andrea C. Noguera Cender, 2020.

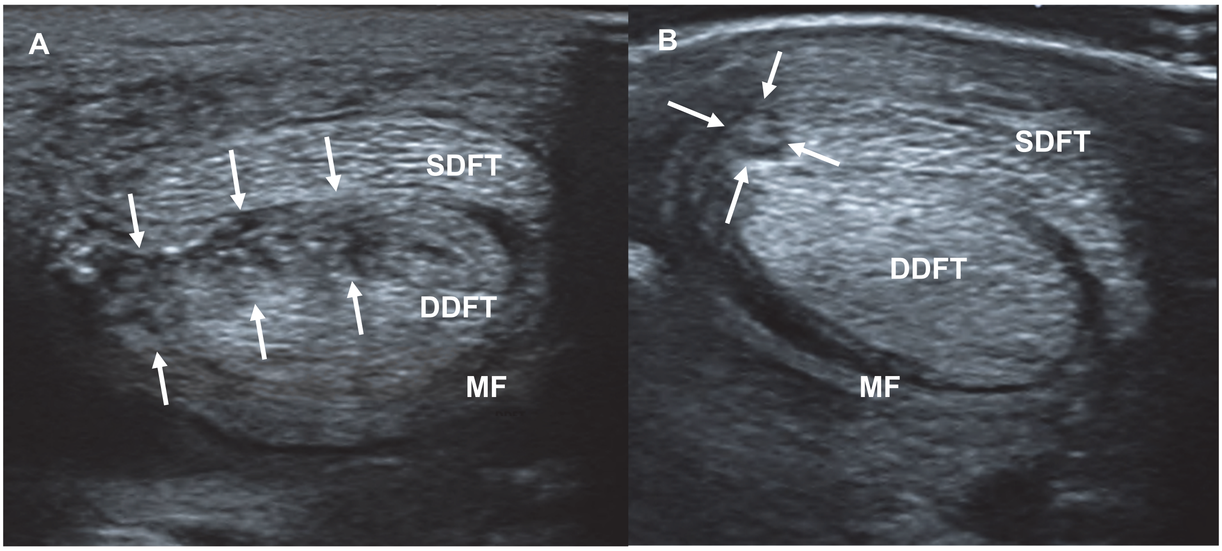

Figure 7: Transverse ultrasonographic image of the digital flexor tendon sheath (DFTS).
A) This image shows a severe lesion at the palmar border of the deep digital flexor tendon (DDFT) at the level of the manica flexoria (MF). (Note the irregular appearance of the palmar DDFT border with an area of decreased echogenicity (arrows). B: Ultrasonographic image of a longitudinal tear at the lateral border of the superficial digital flexor tendon (SDFT) at the level of the MF. Note the focal area of decreased echogenicity (arrows). Image from Andrea C. Noguera Cender, 2020.

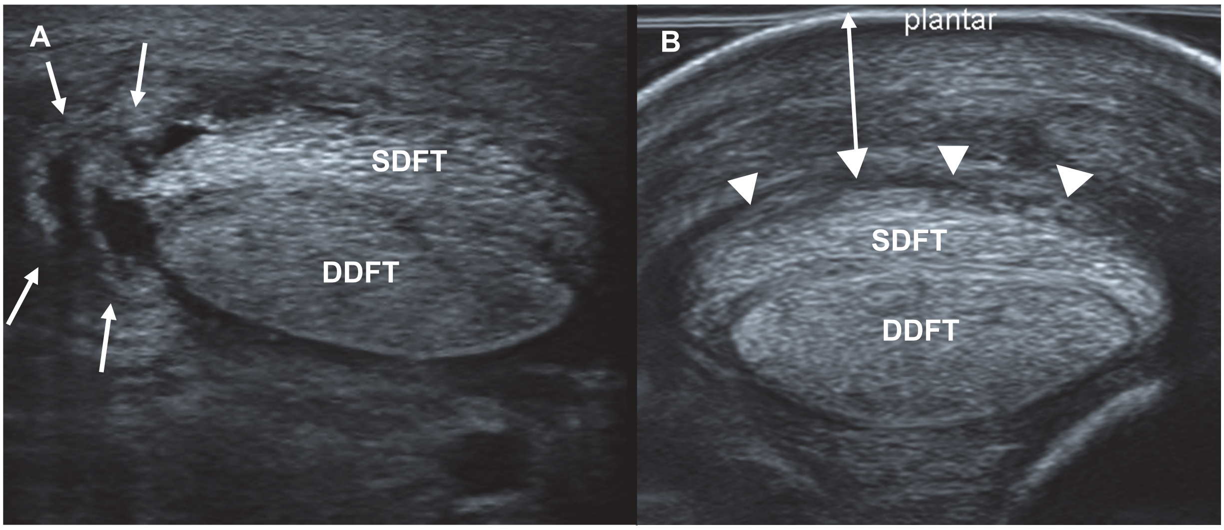

Figure 8: Transverse ultrasonographic image of the digital flexor tendon sheath (DFTS). A) Image obtained at the level of the manica flexoria (MF). Note the absence of the MF dorsal to the deep digital flexor tendon (DDFT) and the presence of echogenic material at the lateral border of the flexor tendons (arrows). This image is indicative of a complete rupture of the MF at its medial attachment to the superficial digital flexor tendon (SDFT), causing the MF to recoil laterally. B) Transverse ultrasonographic image of the DFTS at the level of the plantar annular ligament (PAL). Note the thickening of the subcutaneous tissue (arrow) and poor definition of the PAL and the plantar margin of the SDFT (arrowheads). Image from Andrea C. Noguera Cender, 2020.

Ultrasonography has been reported to have limited accuracy for diagnosis of intrathecal tendinous lesions such as MF lesions and DDFT lesions. Sensitivity and specificity were 38% and 92% for MF (Smith and Wright, 2006) and 63% and 76% for DDFT (Arensburg et al. 2011).

Contrast tenography was first described by Hago and Vaughan in 1986. This technique is performed at the same time as intrathecal analgesia by the sterile injection of combined local anesthetic solution (6-8ml) and radiodense contrast material (6-8ml) into the DFTS. Thereafter the horse is walked for a few steps to allow distribution of the injected substances within the DFTS and a lateromedial radiograph of the distal limb is performed (Figure 9).
According to the latest study (Kent et al. 2019) contrast radiography findings indicative of a MF tear include: an abnormal contrast accumulation dorsal to the DDFT at the level of the MF and/or the presence of one radiopaque line at the level of the MF instead of two (Fig 10A) and/or the dorsal of the two parallel lines not extending distally to meet the proximal border of the proximal sesamoid bones. Longitudinal DDFT tears are suspected if a longitudinally oriented accumulation of contrast is present within the outline of the DDFT, at the level of or

distal to the PSB (Figure 10B). These authors also reported a lack of of sensitivity and specificity for the detection of PAL constriction by this technique.

This method has significantly improved the diagnostic capacity for lesion detection in the DFTS, especially for MF tears, with a sensitivity of 92% and a specificity of 56% (Kent et al. 2019). Similarly, contrast enhanced ultrasonography has been reported to identify 90–100% of surgically created deep flexor tendon lacerations (Bertuglia et al. 2014).

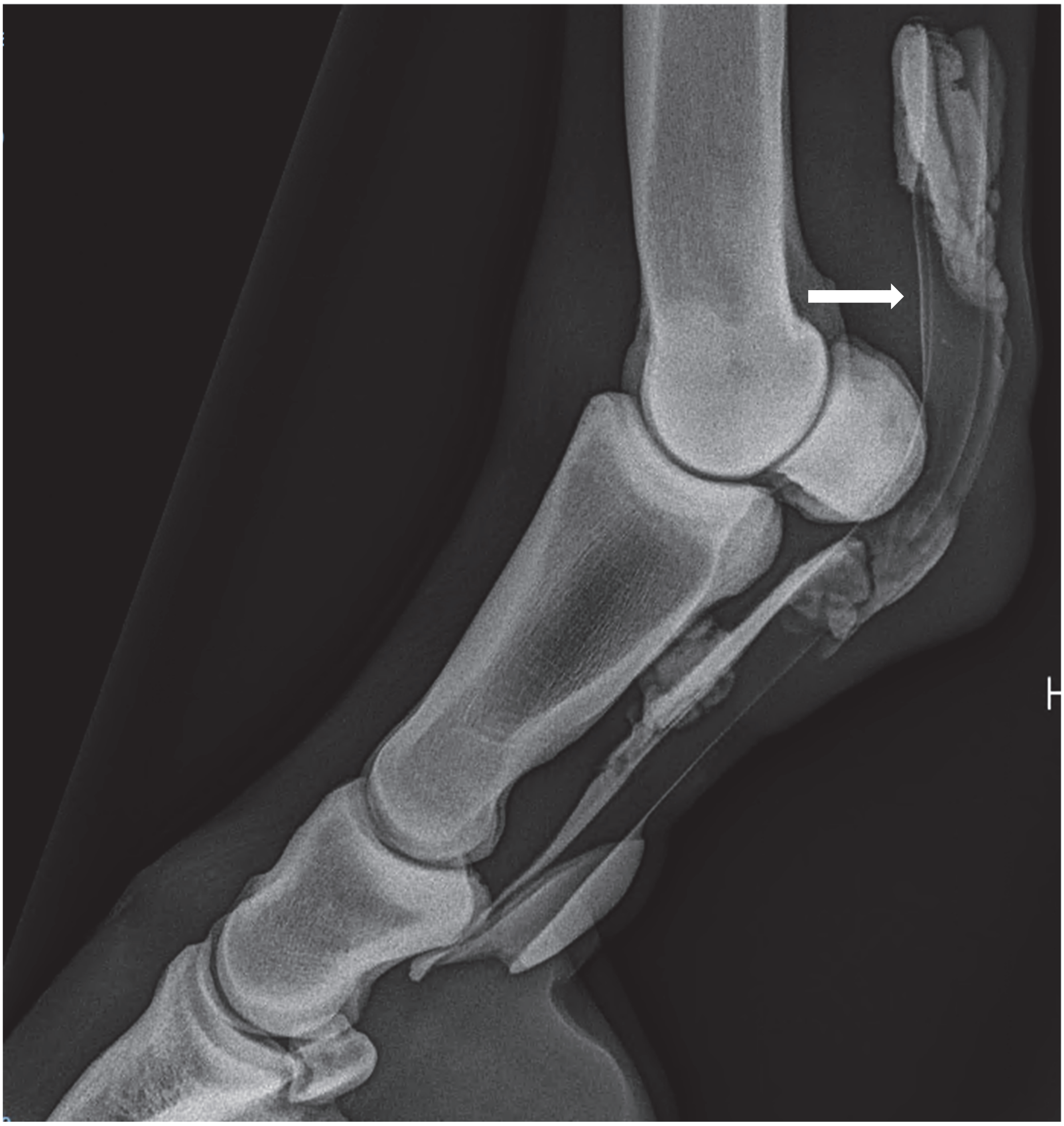

Figure 9: Normal contrast tenogram of the digital flexor tendon sheath.

Note 2 parallel lines delineating the manica flexoria (MF) (arrow). The most dorsal of the lines extends distally to meet the level of the proximal sesamoid bones. Image from Andrea C. Noguera Cender, 2020.

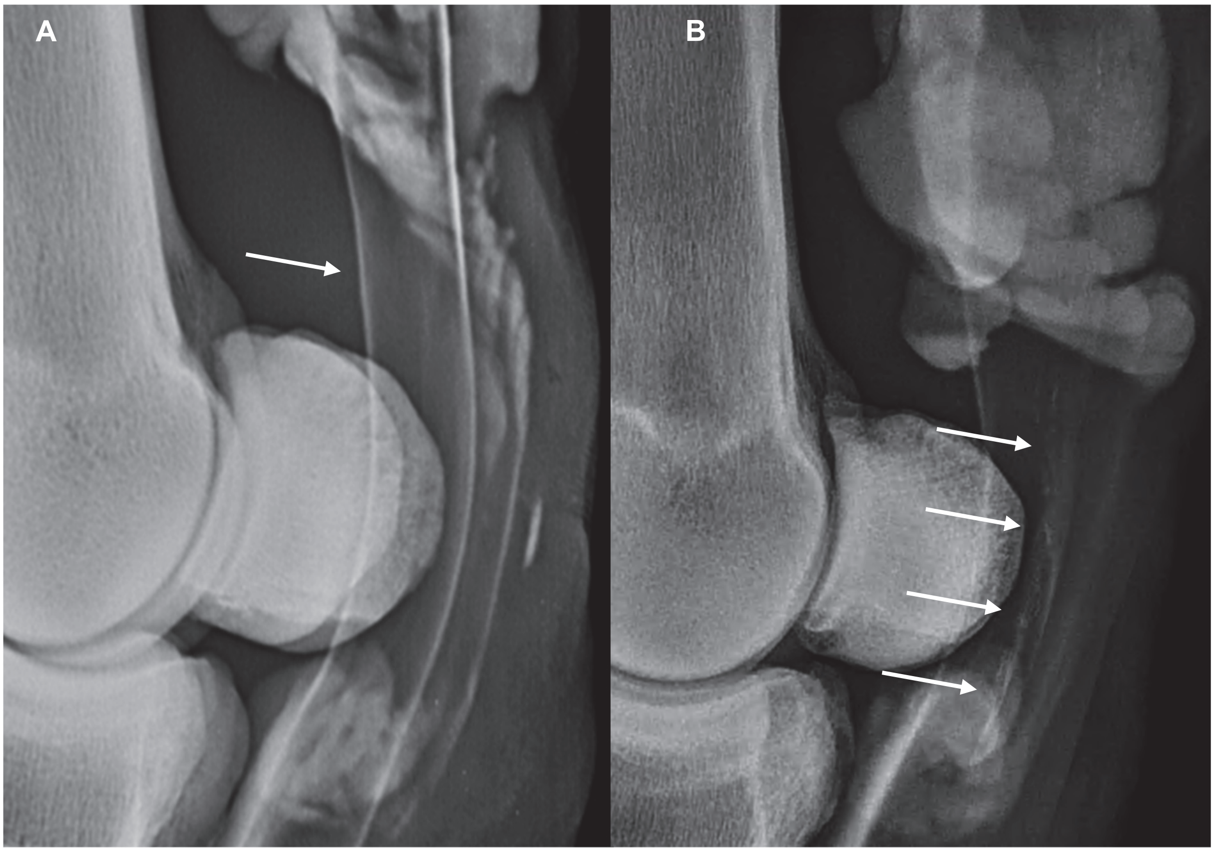

Figure 10: Contrast tenogram of the digital flexor tendon sheath (DFTS).
A) Image of a horse with a rupture of the manica flexoria (MF) at its medial attachment to the superficial digital flexor tendon. Note the MF is not present (only one line at the level of the MF proximal to the proximal sesamoid bones (PSB), instead of two) (arrow). B) Contrast tenogram of the DFTS of a horse with a severe longitudinal tear of the deep digital flexor tendon (DDFT). Note the longitudinally oriented accumulation of contrast (arrows) within the outline of the DDFT at the level of the PSB. Image from Andrea C. Noguera Cender, 2020.

In cases were radiographic and ultrasonographic examinations are inconclusive, high field magnetic resonance imaging (MRI) can be used for the diagnosis of soft tissue and bone injuries (King et al., 2012). MRI has been reported useful for the diagnosis of marginal tears of the SDFT or DDFT, PAL desmitis, and proximal or distal digital annular desmitis (Gonzalez et al., 2010; Dyson and Murray, 2011; King et al., 2012).
Computed tomography (CT) offers a method of viewing anatomy in three dimensions. Its use in combination with contrast solution (contrast enhanced computed tomography) has proved to be a valuable tool to visualize the structures within the DFTS (Agass et al. 2017), although further work is required to determine the utility of this technique in clinical cases with chronic DFTS tenosynovitis.

Further, the relative high costs of both imaging techniques and the need for general anesthesia makes these two diagnostic imaging modalities not the first choice for diagnosis of lesions in cases with DFTS tenosynovitis.

Diagnostic tenoscopy of the DFTS under general anesthesia is indicated in cases with tenosynovitis of the DFTS as a complementary diagnostic procedure. Further, tenoscopy allows immediate treatment of the lesions identified during surgery. The inner structure of the flexor tendons cannot be assessed with tenoscopy, but this technique is more sensitive for differentiating adhesions, longitudinal tears and superficial tendon fibrillations (Wilderjans et al. 2003; Edinger et al. 2005).

The results of a study comparing ultrasonography, MRI and tenoscopy in cases with chronic tenosynovitis of the DFTS performed in cadaver limbs suggested that ultrasound and MRI are the best techniques to assess synovial and ligament injuries, and that ultrasound is superior to assess tendon lesions in general, whereas tenoscopy is the only accurate technique to establish the diagnosis of peripheral lesions of the tendons (Thomas et al. 2009). These authors encouraged the use of ultrasound as the first-choice diagnostic technique in clinical cases because it´s easily available and does not require general anesthesia. However, they showed the importance of combining imaging techniques for complete assessment of digital chronic tenosynovitis, especially when peripheral lesions of the flexor tendons are suspected.

3. First project of this research study, its aims and hypothesis

Tears in the manica flexoria (MF) are the second more frequent lesion associated with non-septic tenosynovitis of the digital flexor tendon sheath (Smith and Wright, 2006). MF tears can be complete or partial and predominantly occur at or adjacent to the location where the MF attaches to the SDFT body. Complex lesions of the MF, wherein one margin of the MF is disrupted from its attachment to the SDFT, often require total resection of this structure.

The scientific literature and relevant textbooks offer limited information about a surgical procedure for tenoscopic MF resection and lack a comprehensive description of the method, its associated technical difficulties, intraoperative limitations, and the completeness of the achieved resection.

The aim of this study was therefore to establish, describe and to evaluate a technique for tenoscopic resection of the MF. We hypothesized that the technique described here would allow complete resection of the MF with minimal iatrogenic damage. Further, we hypothesized that this technique would be suitable for surgeons with varying levels of experience.

4. Second project of this research study, its aims and hypothesis

Pathology of the DFTS is a very common cause of lameness in the horse. The number of studies reporting about diagnosis and long-term outcomes after DFTS tenoscopy in large cases series is limited.

The aim of this study was to describe the prevalence of lesions associated with lameness due to non-septic DFTS tenosynovitis and their long-term outcome after surgical treatment in a German population of horses. Furthermore, we wanted to evaluate factors affecting the diagnosis and outcome after surgery, and to calculate the sensitivity and specificity of ultrasound and contrast tenography of the DFTS for the diagnosis of tendinous lesions.

5. Research publications in peer-reviewed journals

5.1 Ex vivo evaluation of an alternative technique for resection of the proximal manica flexoria in horses

Authors: Andrea Noguera Cender; Kathrin Mählmann; Christoph J. Lischer

Publication: Veterinary Surgery. 2020; 49:401–408. DOI: 10.1111/vsu.13336
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Correspondence Address:

Andrea Noguera Cender
Klinik für Pferde
Fachbereich Veterinärmedizin
Freie Universität Berlin Oertzenweg 19B, 14163 Berlin
Phone: +49 30 838 622 99
Fax: +49 30 838 625 29
Email: andrea.noguera@fu-berlin.de

Authorship**:** Andrea Noguera Cender and Christoph Lischer conceived the surgical technique. All three authors performed the surgical technique in the cadaver limbs. Andrea Noguera Cender has collected, analysed and performed the statistical analysis of the data and has written the manuscript. Kathrin Mählmann has contributed to preparation of the manuscript. Christoph Lischer has contributed to prepare the manuscript and has given the final approval to it.

Ex vivo evaluation of an alternative technique for resection of the proximal manica flexoria in horses

Abstract

Objective: To describe and evaluate an alternative technique for tenoscopic resection of the manica flexoria (MF).

Study design: Descriptive study.

Sample Population: Equine cadaver fore- and hindlimbs (n = 36).

Methods: Each of 3 surgeons varying in experience resected the MF in 12 limbs. The procedure was divided into six steps, including resection of the lateral/medial borders of the MF with a hook knife and resection of the proximal border with a micro scalpel. Outcomes compared between surgeons included: completeness of resection; appearance of the margins of resection; appearance of the resected MF; collateral damage; time required for resection.

Results: The MF was successfully resected in all specimens, with a median time of 14:54 minutes (range, 06:42 – 43:33 minutes). 19/36 MF were categorized as symmetric, 11/36 as mildly asymmetrical, and 6/36 had unequal borders. No differences were detected between surgeons regarding the appearance of the MF and number of iatrogenic lesions. Five lesions were considered potentially clinically relevant, 3 caused by the arthroscope in the scutum (1) and the deep digital flexor tendon (DDFT, 2), and 2 consisting of DDFT damage caused by the micro scalpel.

Conclusion: The MF was successfully and symmetrically resected with minimal damage to adjacent structures by surgeons with varying levels of experience.

Clinical relevance: The results of this study justify further evaluation of the technique described here in live horses with rupture of the MF.

Introduction

Tears in the manica flexoria (MF) are lesions that are frequently associated with nonseptic tenosynovitis of the digital flexor tendon sheath (DFTS). Smith and Wright reported in 2006 a prevalence of 30% of MF tears in a mixed population of horses used for a variety of purposes undergoing routine DFTS tenoscopy.[1] While MF tears can occur at the medial or lateral attachment to the superficial digital flexor tendon (SDFT), the medial border seems to be affected more frequently. Similarly, the incidence appears higher in hind limbs than in fore limbs, and cob and pony breeds are over-represented. [2]

The MF is a collar of tendinous tissue attached to the SDFT at its medial and lateral borders. It surrounds the deep digital flexor tendon (DDFT) dorsally at the level of the metacarpo/metatarsophalangeal joint.[2,4] At the proximal border of the MF, there is a reflection of loose connective tissue that attaches the MF to the dorsal surface of the SDFT and the adjacent lining of the DFTS [3]. The supposed function of the MF is to maintain the flexor tendons in alignment as they pass over the palmar/plantar aspect of the metacarpo(tarso)phalangeal joint.[5] Histological studies of the MF have found that there is fibrocartilaginous metaplasia and a greater number of degenerated blood vessels within the palmar/plantar region of the MF.[3] Because fibrocartilaginous metaplasia is a normal response to the forces placed upon tendinous tissue, it remains unclear whether these changes represent a physiological adaptation or contribute to MF tears in this particular region. [3,6-10]

MF tears can be complete or partial and predominantly occur at or adjacent to the location where the MF attaches to the SDFT body. Partial tears at the distal edge are best managed by dissection of torn tendon tissue using an arthroscopic suction punch or arthroscopic scissors before removal with Ferris-Smith arthroscopic rongeurs,[11] but complex lesions, wherein one margin of the MF is completely disrupted, often require total resection.[1,11] Even though the biomechanical consequences after total resection of the MF remain unknown, the prognosis is good for a return to work after total resection.[2]

A technique involving the tenoscopic resection of the MF using a #12 scalpel blade or/and a suction punch in combination with the transection of the palmar/plantar annular ligament (PAL) has been described.[2] However, the scientific literature and relevant textbooks offer limited information about this surgical procedure and lack a comprehensive description of the method, its associated technical difficulties and intraoperative limitations, and the completeness of the achieved resection.

The aim of this study was therefore to describe and to evaluate an alternative technique for tenoscopic resection of the MF. We hypothesized that the technique described here would allow complete resection of the MF with minimal iatrogenic damage. Further, we hypothesized that this technique would be suitable for surgeons with varying levels of experience.

Materials and methods

Thirty-six distal limbs of skeletally mature warmblood horses were collected from the abattoir and included in the study. Ethical approval was obtained from the Institute of Animal Welfare, Animal Behavior and Laboratory Animal Science of the Free University of Berlin. Eighteen fore limbs and 18 hind limbs were collected and randomly assigned to 3 groups of 12 limbs each, and there was an equal distribution of fore limbs and hind limbs among the groups. Signalment and further case history details were not considered. The limbs were transected at either the carpometacarpal joint or the tarsometatarsal joint. After transection, the limbs were stored at -20°C and thawed at room temperature for 24 hours prior to surgery.

The surgical approach was performed by 3 surgeons with different levels of experience, including one boarded surgeon with many years of experience (surgeon 1), one recently boarded surgeon (surgeon 2) and one surgical resident (surgeon 3). Each surgeon performed the described technique in 12 randomly assigned cadaver limbs.

Surgical technique

The limbs were fixed to a table at the proximal extent of the metacarpal/metatarsal bone in a position imitating lateral recumbency using a custom made stainless steel clamp. The distal aspect of the limb was clipped, and the DFTS was distended by injecting it with tap water using an axial approach.[12] A stab incision was made using a #11 blade into the distended pouch between the palmar/plantar annular ligament and the proximal digital annular ligament at the base of the proximal sesamoid bone, 3 to 6 mm palmar/plantar to the digital neurovascular bundle.[11] Entry into the DFTS was confirmed by the egress of fluid. A cannula with a conical obturator was introduced into the DFTS in the proximal direction. The obturator was replaced with a 4 mm-diameter, 30° forward-angled arthroscope **(**Karl Storz Veterinary Endonscopy, Tuttlingen, Germany)**.**

The digital flexor tendon sheath and its internal structures were inspected. Limbs showing pathology of the flexor tendons or MF were excluded from the study.

The surgical technique used to resect the MF was performed in 6 steps, as follows (see videos of the different steps within the supplementary materials):

1) Resection of the first longitudinal lateral/medial MF border: The arthroscope was inserted in the DFTS and advanced into the *cul de sac* of the MF. A needle-guided instrument portal

was created proximally and ipsilaterally through the reflection of connective tissue (Figure 1) Then, an arthroscopic hook knife was placed through the portal and advanced distally until the distal margin of the MF was reached. The hook knife was placed at the junction between the SDFT and MF and pulled in a proximal direction under endoscopic control (Figure 2) in a straight line parallel to the lateral border of the SDFT until the most proximal aspect of the MF was reached.

2) Resection of the proximal border: The hook knife was replaced by an arthroscopic micro scalpel (#64 blade), and resection was performed through the proximal MF reflection of connective tissue, moving the scalpel in a latero-medial direction, from the contra-lateral to the ipsilateral side (Figure 3).
3) The micro scalpel was removed, and a curved Halsted-Mosquito forceps was introduced through the proximal instrument portal and used to grasp the free longitudinal margin of the MF to maintain tension on the tissue.
4) An additional portal was created for the arthroscope at the base of the sesamoid bone on the contralateral side. Then the arthroscope was removed from the first portal and placed in the new contralateral portal and a new ipsilateral instrument portal was created through the proximal reflection of the connective tissue of the MF, as described in step 1.
5) The second longitudinal lateral/medial MF border was resected with a hook knife under endoscopic guidance using the same technique described in step 1 (Figure 4).
6) The resected MF was removed through the first instrument portal using the Halsted-Mosquito forceps placed in step 3.

Evaluation of the technique

To evaluate the technique, each tenoscopic surgery was recorded prior to dissection of the limbs. The dissection protocol used for the limbs included removing the skin from the proximal metacarpal or metatarsal area to the second phalanx and transecting the palmar/plantar annular ligament at its lateral or medial border. After the DFTS was entered and the intrathecal structures were visualized, the SDFT and DDFT were transected 6 cm proximal to the reflection of connective tissue of the resected MF and 2 cm distal to the digital manica flexoria and then removed *en bloc*.

The criteria used to evaluate the surgical technique included the completeness of resection and appearance of the MF resection borders, the appearance of the resected MF, collateral damage to adjacent structures during surgery, and the time required for resection.

The MF was considered completely resected when both the longitudinal and the proximal margins were detached from the SDFT and proximal connective tissue, respectively, and subsequently exteriorized from the DFTS.

Both the longitudinal and the proximal resection margins of the MF were semiquantitatively analyzed. For this purpose, a four-point scale was established based on the evaluation of following parameters at the resection margins: the quality of the incision, its location accuracy and its straightness. The quality of the incision varied from a smooth and straight resection through the tissue (ideal) to the presence of variable levels of jagged or serrated borders. Location accuracy was defined as placement so that the longitudinal incision was started at the distal border of the MF and was considered ideal when the incision started abaxially at the junction between the MF and SDFT, whereas an axial deviation towards the midline was considered unsuccessful. When the location accuracy of the incision at the proximal MF border was analyzed, a resection through the proximal reflection of connective tissue that avoided a transection further distally through the tendinous MF tissue was considered ideal. Finally, the trajectory of the incision was considered ideal when the resection followed a straight line instead of showing a curved course. So accordingly, a score of 1 was given to resection margins showing the desired morphology, whereas deviations from the intended outcome were scored according to the severity (2=mild, 3=moderate, and 4=severe).

To evaluate the resected MF, a scale was created that contained 4 different categories. Category 1 represented the ideal morphology of the resected MF. This consisted of straight borders, abaxial location accuracy for both longitudinal borders and a proximal resection margin through the reflection of connective tissue. Deviations from the ideal outcome were scored according to their severity (2=mild asymmetry, 3=moderate asymmetry, and 4=severe asymmetry due to an inability to resect the MF *in toto*, resulting in its exteriorization from the DFTS in several pieces) (Figure 5). The level of asymmetry was evaluated using the same parameters that were used to evaluate the resection margins.

Information related to collateral damage to adjacent anatomical structures was documented during the procedure and the examination of the video records after surgery, and include the instrument causing the lesion and the affected structure. The severity assessment used to score such lesions were based on its endoscopic and macroscopic appearance and included the following classifications: mild, moderate or severe.

Further comments related to the technical difficulties and limitations experienced during the procedure were reported.

The time required to perform the resection of the MF was recorded. Counting was started when the arthroscope was introduced into the DFTS, and the complete exteriorization of the MF through the DFTS marked the end of the procedure. Each of the 6 steps was timed individually.

Once the surgical procedure was complete, the hoof length, hoof width and width of the heel bulbs of the operated limbs were measured and recorded. Hoof length was recorded as the length from the heel buttress line to the toe without including the heel bulbs. Hoof width was

measured across the widest part of the hoof sole. The width of the heel bulbs was measured as the distance between the abaxial margins of the medial and lateral bulbs.
Furthermore, the resected MF length was measured and recorded as the distance between the proximal connective tissue and the more distal margin of the MF.

Statistical analysis

A Kruskal-Wallis test was performed to compare the surgeons with regard for the appearance of the resected MF and the MF borders, the number of iatrogenic lesions and the time required for surgery. Spearman's rank correlation coefficient was calculated to determine the effects of hoof/heel size and MF length on surgery time, the quality of resection margins, the MF category and iatrogenic damage to associated structures. Differences between the fore and hind limbs were evaluated using the Mann-Whitney U-Test.

Results

Complete tenoscopic resection of the MF was accomplished in all 36 cadaver limbs: 19/36 MF were categorized as symmetric (category 1), 11/36 showed mild asymmetry (category 2), and 6/36 showed unequal borders (category 3) (table 2). No evident morphological alterations related to freeze-thaw artefacts were recognized in any of the cadaver limbs.

Iatrogenic damage to adjacent structures

A total of 27 iatrogenic lesions were identified in all 36 procedures (table 2). There were 7 lesions within the DDFT caused by the arthroscope (2 mild, 3 moderate and 2 severe (Figure 6)), one mild lesion was caused by the hook knife and 3 lesions were caused by the micro scalpel (1 moderate and 2 severe (Figure 7)). In the proximal scutum, 7 lesions were caused by the arthroscope (6 mild and 1 severe (Figure 8)), and 10 lesions were caused by the hook knife (7 mild and 3 moderate). No lesions were found in the SDFT.
All 27/27 lesions were recognized during a tenoscopic examination of the DFTS, whereas only 9/27 were visible during tenoscopy and macroscopic examinations performed after the limbs were dissected.
The appearance of lesions varied widely and depended on the nature of the responsible instrument. Lesions caused by cutting instruments, such as the hook knife or the micro scalpel, had smooth borders, no tissue fibrillation, and a variable cut depth and ranged from small and superficial to incisions that ran deep into the tissue. Conversely, lesions caused by blunt instruments, such as the conical obturator used to introduce the arthroscope into the DFTS,

or the arthroscopic sleeve, characteristically exposed different amounts of disrupted tissue fibers protruding into the tendon sheath and varied in severity from mild (superficial focal tissue fibrillation) to severe (lesions larger than 1 cm in which a large amount of tissue fibers protruded into the DFTS).

Time measurement

The total time required for resection of the MF varied substantially and ranged from 6:42 to 43:33 minutes. The median time to perform the procedure was 14:54 minutes (table 2).
The most time-consuming steps were both longitudinal resections of the MF (steps 1 and 5), which required a median time of 03:56 and 04:04 minutes, respectively. However, the resection of the proximal border (step 2) was a relative fast procedure requiring a median of 01:51 minutes. A scatter diagram was constructed to demonstrate the number of surgeries performed and the surgery times to determine whether surgery time improved as the surgeon gained experience with the surgical technique. However, the data seem to show that there is no real learning curve associated with the number of surgeries each surgeon had already performed.

Hoof and MF size measurements

Mean hoof length was 14.81 cm (range 11 - 17 cm), mean hoof width was 12.73 cm (10.30 to 15.50 cm), and the mean width of the heel bulbs was 8.53 cm (7 to 10.20 cm). The mean MF length was 4 cm (range 3 – 4.8 cm). We found no differences in the size of the hoof between the front and hind limbs. In contrast, the MF was significantly longer in the front limbs than in the hind limbs ($p=0.002$). There was also a positive correlation between hoof length and MF length ($p=0.004$), with animals with larger hooves having larger MFs.
Hoof size (hoof width, heel width and hoof length) and MF length did not have an influence in the appearance of the resection margins, the MF category or the number of iatrogenic lesions. However, many factors influenced surgery time, as follows: 1) hoof length ($p=0.009$), with larger hooves associated with longer surgery times; and 2) MF length ($p=0.02$), with longer MFs associated with longer surgery times.

Comparison of the results between surgeons

Table 1 shows the resection margin scores with mean values for every surgeon. Comparisons among surgeons regarding the category of MF, collateral lesions and surgery time are listed in Table 2. No differences in MF category were detected among the 3 surgeons ($p=0.366$).

Similarly, no differences in the number and severity of the iatrogenic lesions were detected between surgeons (p=0.694). The shape of the first longitudinal and the proximal resection border was not different among the surgeons. However, a variance was found in the quality of the cut in the second longitudinal border between surgeons 1 and 2 (p=0.038) and surgeons 1 and 3 (p=0.010), with surgeon 1 having a higher number of serrated borders (score 2.1, max. score 4). There was a difference in the time to complete the surgery between surgeons 1 and 3, with surgeon 3 being faster than surgeon 1 (p=0.001).

Discussion

The surgical technique described here allowed complete resection of the MF with minimal iatrogenic damage, by surgeons with varying levels of experience.

None of the mild and few of the moderate iatrogenic lesions were identified during a macroscopic examination of the limbs and were visible only during tenoscopy, potentially due to the effect of optical magnification. In our opinion, these lesions would therefore not be considered clinically relevant. Of the lesions visible after dissection on macroscopic examination, 5 were graded as severe. However, their clinical significance is unknown.

Three of the severe lesions were caused by the endoscopic sleeve and were located at the proximal scutum (1) or the DDFT (2). These lesions occurred during the surgical procedure and were most likely related to perceived difficulties encountered in maneuvering the endoscope within the fetlock canal by individual surgeons. It is difficult to assess objectively whether these lesions occurred as a result of a narrow fetlock canal or were the result of a less optimal placement of the arthroscopic portals, which can consequently led to difficulty in maneuvering the arthroscope within the DFTS, potentially increasing the likelihood of iatrogenic damage to adjacent structures.

In previous studies of MF resection, a PAL desmotomy was performed in all cases, suggesting that an initial transection of this ligament would make the subsequent surgery easier and less traumatic.[2] Thus, the authors of this study intend to determine whether it is necessary to perform a PAL transection in order to safely resect the MF tenoscopically. Despite the difficulty in objective assessment of a narrow fetlock canal related to PAL constriction, a desmotomy might be recommended in cases in which a constriction of this ligament is suspected as the cause of poor instrument maneuverability.

The remaining 2/5 severe lesions were in the DDFT and caused by surgeons 2 and 3 when the micro scalpel was being used to transect the proximal border of the MF. These lesions occurred because the surgeon achieved a poor orientation within the DFTS, resulting in the misplacement of the micro-scalpel so that it was inserted between the flexor tendons instead of over the dorsal aspect of the DDFT between the MF and the deep flexor tendon. One possible explanation for this could be a too palmar/plantar placement of the distal portal used to insert the arthroscope, which would make it more difficult for the arthroscopic sleeve to enter into the *cul de sac* of the MF.

The differences observed in surgery time were associated with technical difficulties experienced during surgery because of anatomical variations between limbs. For example, a surgical procedure was subjectively regarded by the performing surgeon as more difficult and more time-consuming when performed in horses with large hooves and/or a suspected narrowed fetlock canal, which often hinders the ability to maneuver the instruments placed in the distal portal during tenoscopy. In fact, there was a strong association between the total surgical time and hoof length. Furthermore, larger hooves had longer MFs, which was similarly associated with increased surgery times. One explanation for this association could be that longer MFs extend more distally than shorter ones within the DFTS; this could reduce the space available to maneuver and make it difficult to handle the instrument, thereby increasing the time needed to resect the MF.
The difference in median surgery time observed between surgeons 1 and 3 could be related to the fact that surgeon 3 was present in all surgeries, perhaps leading to an unaware learning experience, whereas surgeon 1 was present at only his own surgical procedures. Further, surgeon 1, the most experienced surgeon, tended to have longer surgical times and caused fewer iatrogenic lesions than were recorded for the other surgeons. He also seemed less affected by the fact that time was being counted during the surgical procedure.

The main limitation of this study is that this surgical procedure was evaluated in cadaver limbs without MF pathology, whereas the indication for performing the described procedure is the disruption of the MF at or adjacent to its attachment to the SFDT. Often, a rupture at the MF border is associated with thickening and recoil at the free MF margin,[11] which affects the normal anatomy and localization of this structure within the DFTS. This could potentially make the proposed surgery more difficult to perform. However, the technique described here has been performed in clinical cases (unpublished data) in which the pathological changes observed in the MF did not appear to impair the surgical technique. If one of the MF margins is disrupted, the surgical technique must be adapted, and the two remaining borders should be resected using the same steps that were used to resect a healthy MF. Performing this technique in healthy limbs provided us with a deeper understanding of DFTS anatomy and allowed the fast implementation of the technique in clinical cases.
We left it to the surgeon's inclination whether to start the surgical procedure medially or laterally, and this did not seem to affect outcomes. Surgeons 1 and 3 placed the first portals medially and started the resection of the MF at its medial border, whereas surgeon 2 started

the surgery laterally, beginning with the resection of the lateral MF border. There were no differences among the 3 surgeons with regard for the MF category or the appearance of the resection borders. We therefore assume that this technique could be used for any possible MF tear localization independent of the disrupted side of the MF.

For various reasons the authors decided to perform the technique using a medial and lateral portal, instead of performing the technique from one side, as described in previous reports.[1] The authors believed to have a better visualization of both longitudinal borders of the MF, which improved orientation and helped to achieve a good accuracy when dissecting the medial longitudinal MF border. In preparing for the project, the authors tried many different procedures and approaches, and concluded that crossing the instruments from the lateral to the medial side or vice versa decreases instrument maneuverability, specially working within the fetlock canal.

The authors decided to perform the surgery simulating lateral recumbency because it represents the routine positioning of the horse at their own clinic for this particular surgery. However, since the surgeon needs to access the medial and lateral aspect of the limb dorsal recumbency should be considered as a valuable alternative, too.

In conclusion, the technique described here allows the MF to be successfully resected with minimal collateral damage to adjacent structures and is suitable for surgeons with varying levels of experience.

Tables

Table 1: Scoring system used to evaluate all three resection margins of the MF according to the parameters described in the material and methods. A score of 1 represented the desired morphology, whereas deviations from the intended outcome were scored according to the severity (2=mild, 3=moderate, and 4=severe).

	Surgeon 1	Surgeon 2	Surgeon 3
Longitudinal Border 1			
Quality	1.8	1.5	1.2
Location accuracy	1.4	1.3	1.3
Straightness	1.4	1.4	1.1
Proximal Border			
Quality	1.3	1.7	1.4
Location accuracy	1.1	1.5	1.2
Straightness	1.6	1.5	1.4
Longitudinal Border 2			
Quality	2.1	1.3	1.3
Location accuracy	1.8	1.3	1.6
Straightness	1.4	1.7	1.3
Mean score	1.54	1.46	1.31

Table 2: Comparisons among surgeons regarding the appearance of the MF, collateral lesions and surgery time. Category 1 represented the ideal morphology of the resected MF. Deviations from the ideal outcome were scored according to their severity (2=mild asymmetry, 3=moderate asymmetry, and 4=severe asymmetry)

	Surgeon 1	Surgeon 2	Surgeon 3	Total
MF Category				
Category 1	6	6	7	19
Category 2	4	3	4	11
Category 3	2	3	1	6
Category 4	0	0	0	0
Lesions of the scutum				
mild	2	7	3	12
moderate	1	1	1	3
severe	1	0	0	1
Lesions of the DDFT				
mild	2	0	1	3
moderate	1	1	2	4
severe	0	2	2	4
Median surgery time	22:37	14:18	12:18	14:54
Range	(12:36-43:33)	(09:07-28:44)	(06:42-17:33)	(6:42-43:33)

Figure Legends

Figure 1: Dorsal view of the flexor tendons showing a visualization of the MF. The arthroscope is introduced within the cul-de-sac of the MF, and the first needle-guided instrument portal is created through the proximal reflection of connective tissue.

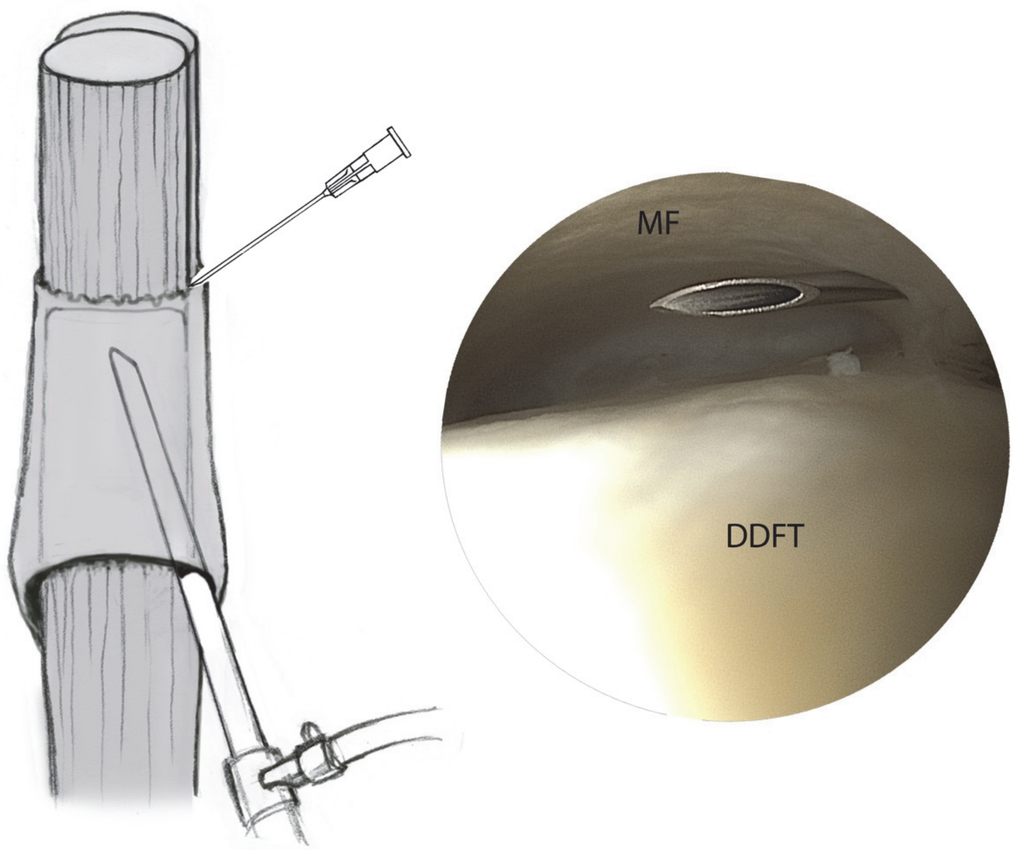


Figure 2: Dorsal view of the flexor tendons. The hook knife is introduced through the first instrument portal. For the resection of the first longitudinal MF border the hook knife is retracted in a disto-proximal direction under arthroscopic control.

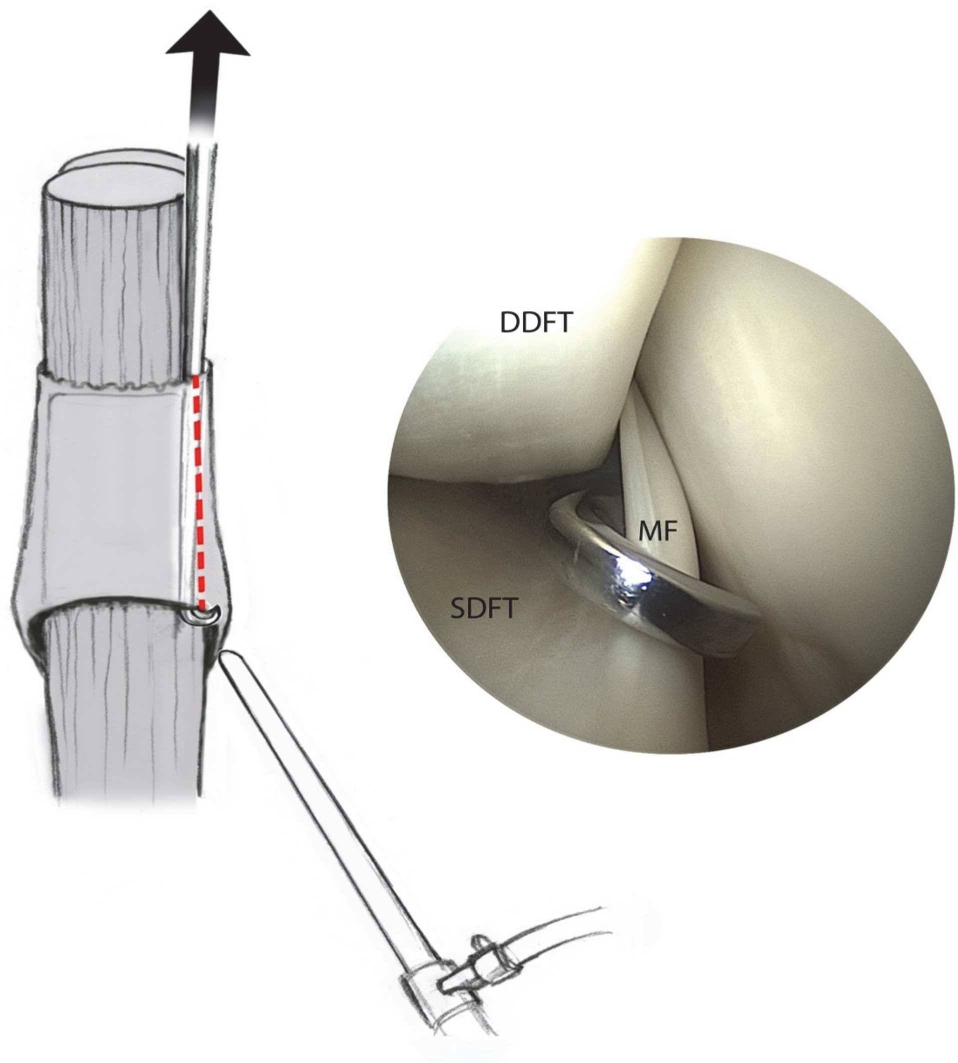


Figure 3: Dorsal view of the flexor tendons. A micro-scalpel is introduced into the instrument portal to resect the proximal MF border through the proximal reflection of connective tissue. Resection is performed moving the scalpel in the direction indicated by the arrow, from the contra-lateral to the ipsilateral side.

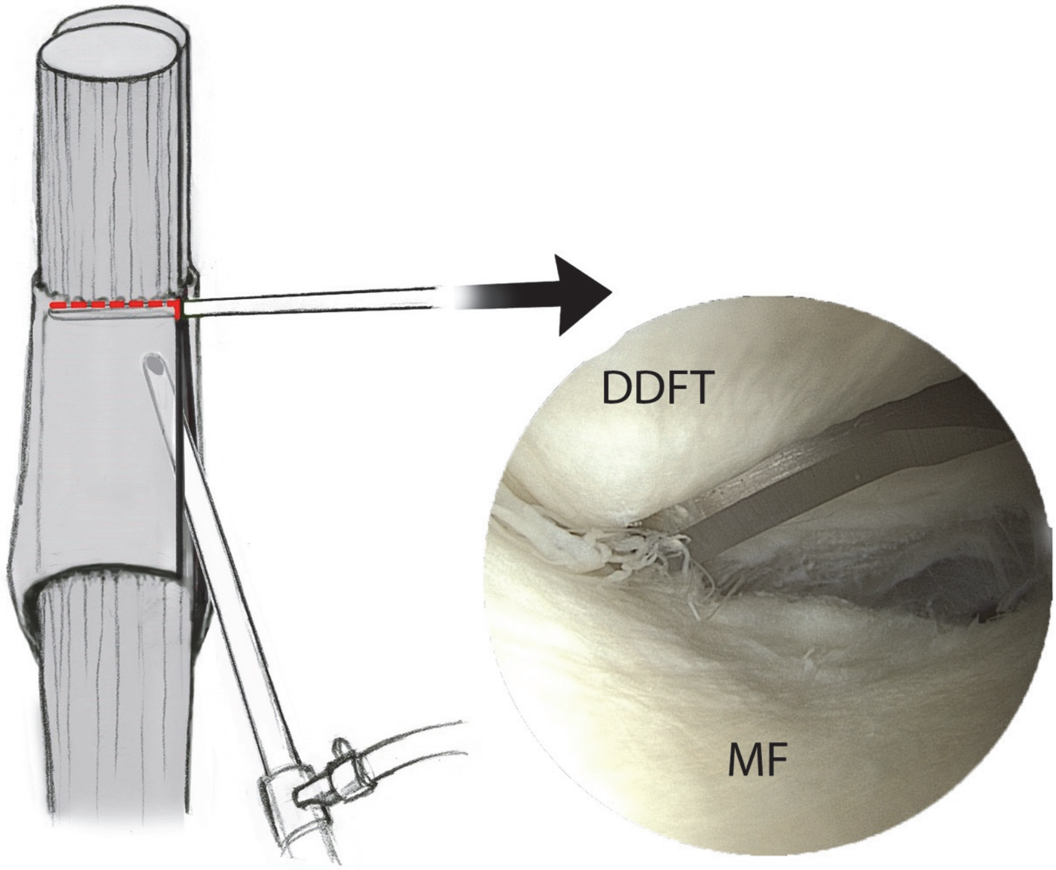


Figure 4: Dorsal view of the flexor tendons. The free MF border is held with a hemostatic forceps to maintain tension. New arthroscope and instrument portals are created in the contralateral side. The second longitudinal MF border is resected using a hook knife.

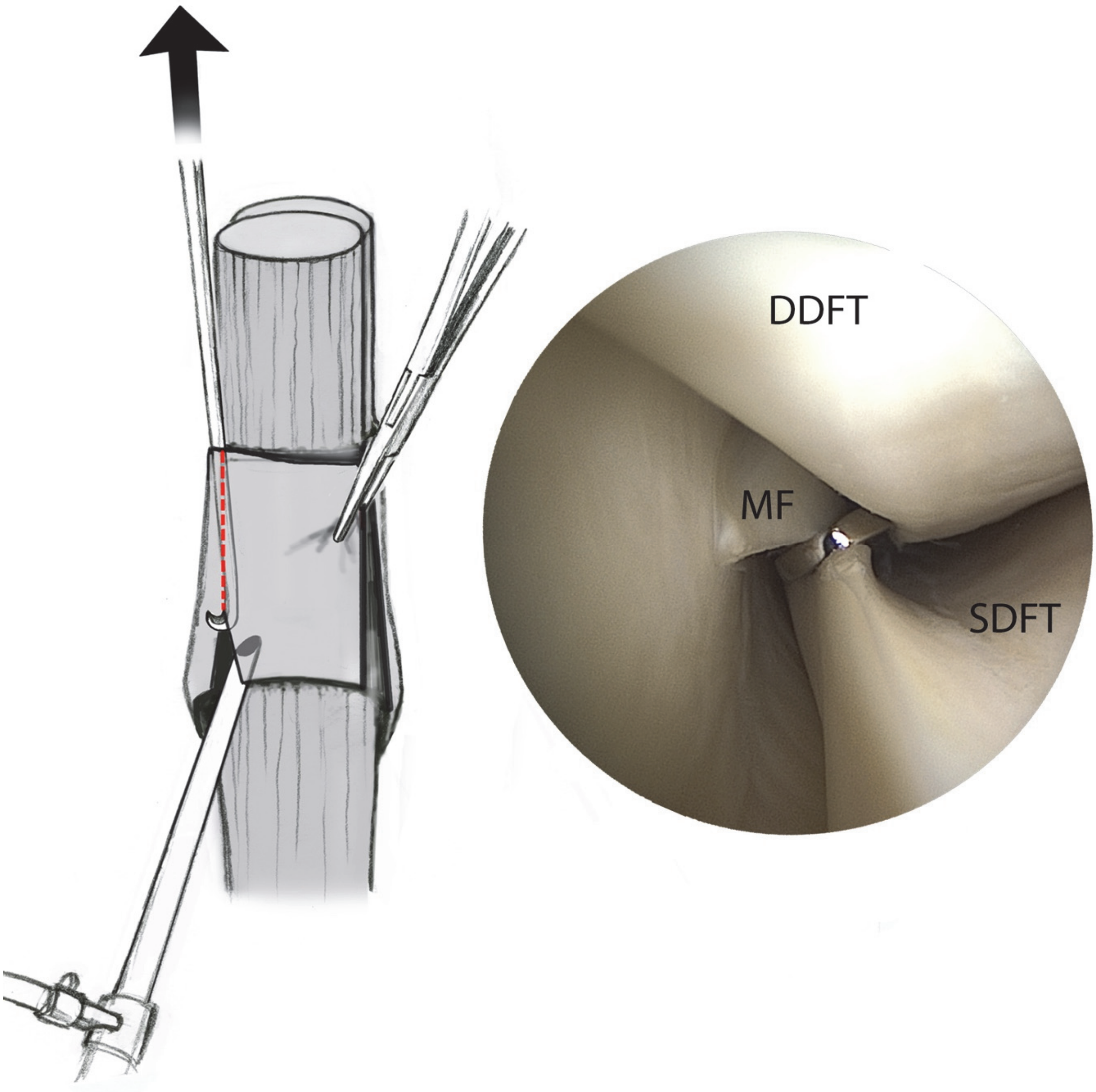


Figure 5. A: manica flexoria category 1: straight longitudinal resection margins, an abaxial location accuracy, and proximal resection through connective tissue; B: manica flexoria category 2: a curved and mild serrated longitudinal border and location accuracy slightly axial deviated; C: manica flexoria category 3: both longitudinal borders show a curved trajectory and moderate serrated incision margins.

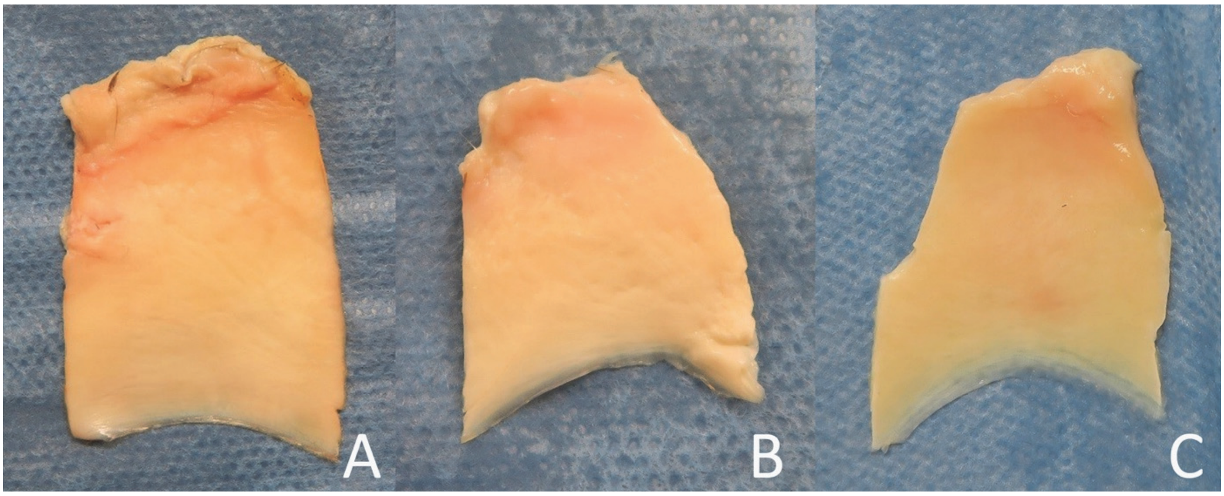


Figure 6: Macroscopic appearance of a lesion at the lateral DDFT border caused by the arthroscopic sleeve during the surgical procedure (white arrows); a: digital manica flexoria; b: proximal manica flexoria.

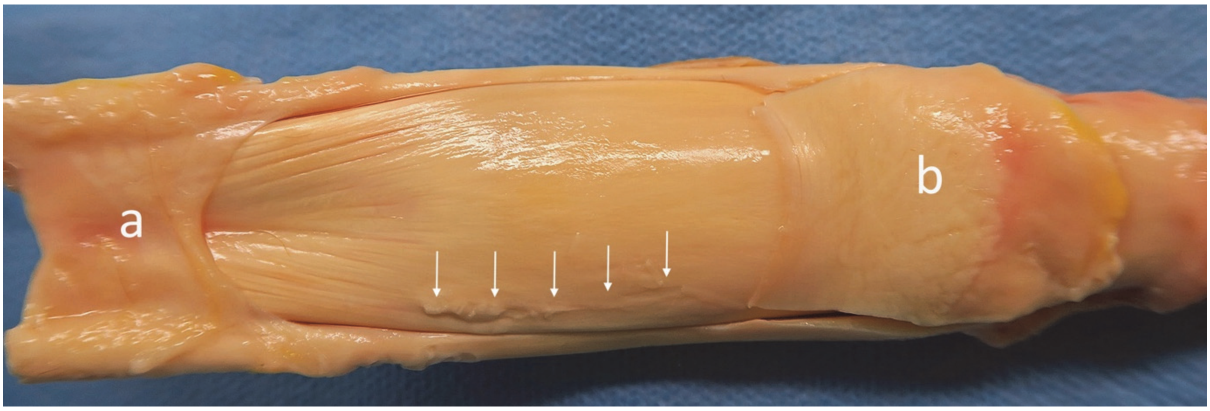


Figure 7: Macroscopic appearance of a lesion in the palmar/plantar surface of the DDFT caused by the micro scalpel during the surgical procedure (proximal is right and distal is left).

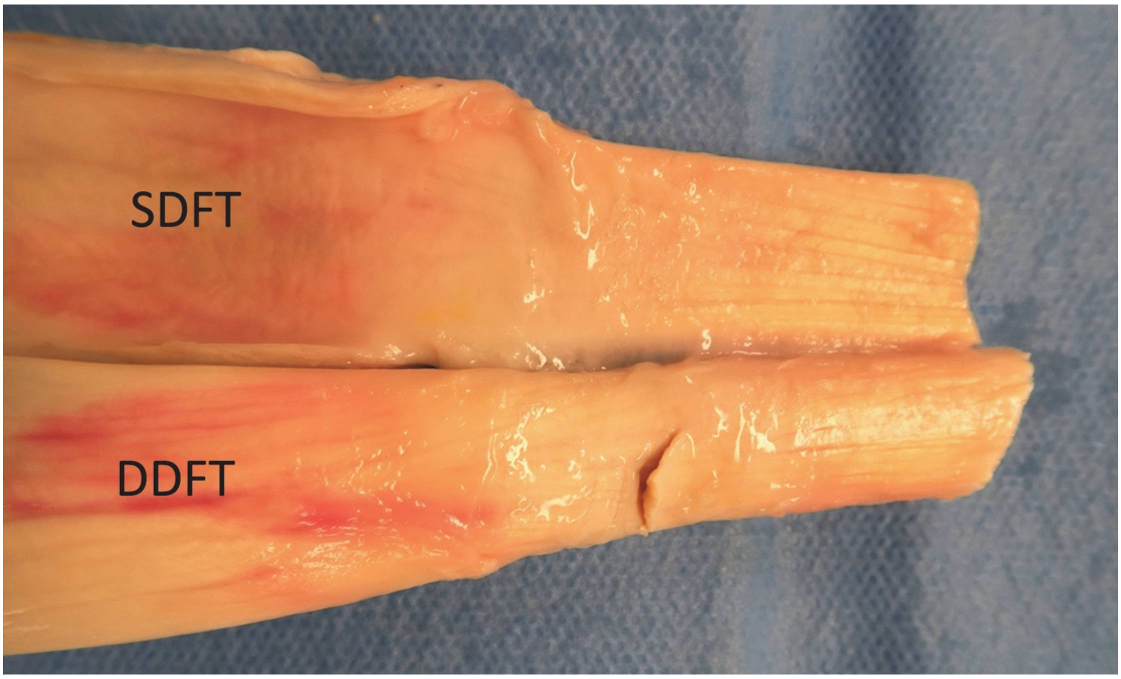
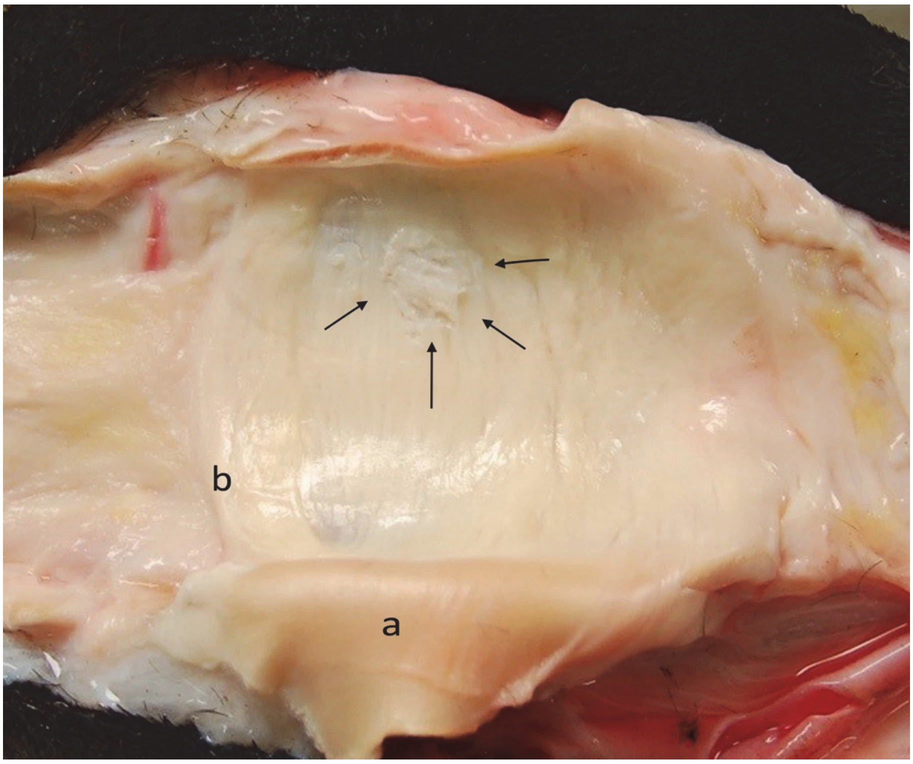


Figure 8: Macroscopic appearance of a lesion in the proximal scutum caused by the arthroscopic sleeve during the surgical procedure; a: Palmar/plantar annular ligament after transection; b: distal border of the proximal scutum.



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5.2 Diagnosis and outcome following tenoscopic surgery of the digital flexor tendon sheath in German sports and pleasure horses

Authors: Andrea Noguera Cender; Kathrin Mählmann; Anna Ehrle; Roswita Merle; Laura Pieper; Christoph J. Lischer

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Correspondence Address:

Andrea Noguera Cender
Klinik für Pferde
Fachbereich Veterinärmedizin
Freie Universität Berlin Oertzenweg 19B, 14163 Berlin
Phone: +49 30 838 622 99
Fax: +49 30 838 625 29
Email: andrea.noguera@fu-berlin.de

Authorship**:** Andrea Noguera Cender has collected and analysed the data and has written the manuscript. Roswita Merle and Laura Pieper have performed the statistical analysis of the data. Kathrin Mählmann and Anna Ehrle have contributed to preparation of the manuscript. Christoph Lischer has contributed to prepare the manuscript and has given the final approval to it.

Diagnosis and outcome following tenoscopic surgery of the digital flexor tendon sheath in German sports and pleasure horses

Background: Digital flexor tendon sheath (DFTS) pathology is an important cause of lameness in horses. The outcome after surgical treatment is variable and depends on the exact diagnosis.

Objectives: To (1) describe the prevalence of lesions associated with lameness caused by non-septic DFTS tenosynovitis in a large population of German horses; (2) determine the sensitivity and specificity of diagnostic imaging techniques for identifying lesions within the DFTS with tenoscopic-diagnosis being the gold-standard; (3) explore associations between tenoscopically-diagnosed lesions and signalment, purpose, and limb affected; and (4) describe the outcome following DFTS tenoscopy with non-septic DFTS tenosynovitis in this population.

Study design: Retrospective case series

Methods: Medical records of horses admitted for tenoscopic surgery of non-septic DFTS tenosynovitis between 2011 and 2020 were reviewed. Each surgical procedure was defined as the unit of analysis, thus horses in which tenoscopy was performed on two limbs or where it was repeated on the same limb, were defined as two units (two limbs). Follow-up information was obtained via telephone contact. Sensitivity and specificity of ultrasonography and contrast tenography were determined using tenoscopic diagnosis as gold standard and univariable analysis was used to explore associations between signalment, case history, and tenoscopic diagnosis.

Results: Medical records from 131 horses were retrieved, of which 8 horses had bilateral disease and 6 horses were presented for tenoscopy on two separate occasions (3 for tenoscopy in the same limb, 3 in a different limb), thus, making a total of 145 limbs. Lesions were most commonly diagnosed in the deep (DDFT, n=55 limbs) and superficial (SDFT, n=55 limbs) digital flexor tendons. Manica flexoria (MF) lesions were detected in 44 limbs and palmar/plantar annular ligament (PAL) constriction in 99 limbs. In 36 limbs, only one structure within the DFTS was injured, whereas in 109 limbs a combination of lesions was noted, the most common being the combination of a SDFT lesion with PAL constriction. All affected limbs were examined with diagnostic ultrasonography; contrast tenography was performed in 86 limbs. For diagnosis of MF and DDFT tears, tenography was more sensitive (89% (CI 65.4-95.2%); 72% (CI 46.4-89.3%) respectively) than specific (64% (CI 52.5-77.6%); 53% (CI 42.2-73.3%) respectively) whereas US was more specific (92% (CI 84.5-96.3%); 92% (CI 83.6-96.0%) with lower sensitivity (64% (CI 47.7-77.2%); 54% (CI 39.5-67.9%). For SDFT lesions, US was highly specific (94% (CI 86.9-97.9%) with lower sensitivity (66% (CI 51.3-77.4%). Follow-up information was obtained for 118 horses (132 limbs): 18 of 118 horses remained chronically lame, 40/118 performed at a reduced level and 60/118 performed at the same or higher level following rehabilitation after tenoscopy. Horses with DDFT lesions had the poorest outcomes.

Main limitations: Retrospective analysis of clinical records and subjective outcome assessment based on owner follow-up with potential recall bias. Findings on diagnostic imaging are impacted by many factors including equipment quality and operator expertise and experience.

Conclusion: Diagnostic imaging techniques were complimentary and contrast tenography was sensitive and ultrasonography was specific for the diagnosis of MF and DDFT lesions. Following tenoscopic surgery for non-septic tenosynovitis of the DFTS, approximately half the cases had a good outcome and were able to return to pre-injury level of exercise.

Key words: tendon sheath, tenoscopy, contrast tenography, ultrasonography, lameness

Introduction

The digital flexor tendon sheath (DFTS) is an important synovial cavity in the equine distal limb extending from the middle third of the second phalanx to a level approximately 4 to 7 cm proximal to the proximal sesamoid bones.[1] The two main structures confined within the DFTS are the superficial (SDFT) and the deep digital flexor tendon (DDFT). The DDFT is surrounded by the manica flexoria (MF), a collar of tendinous tissue that is attached to the SDFT and wraps around the DDFT proximal to the metacarpo/metatarsophalangeal joint.[2,3,4] The palmar/plantar annular ligament (PAL) forms the wall of the DFTS as it attaches to the abaxial surface of the proximal sesamoid bones. [2]

Non-septic tenosynovitis of the DFTS may be associated with DDFT[3,5,6] or SDFT[7] tendonitis, manica flexoria tears[4,5,8,9] or PAL[2,10,11] desmitis.
With a prevalence of 59% and 30% respectively, DDFT and MF lesions are reported to be the most common causes of non-septic DFTS tenosynovitis in the horse.[5] MF tears are frequently diagnosed in hindlimbs with a greater incidence found in Cobs and ponies when compared to other breeds.[8,9] DDFT lesions appear to be detected in fore limbs more often.[3,5]

The initial diagnosis of DFTS pathology is usually based on diagnostic analgesia followed by ultrasonographic examination and contrast radiography of the DFTS. Ultrasonography has limited accuracy for the diagnosis of intrathecal tendinous lesions, with a particularly low sensitivity and specificity reported for the detection of MF and DDFT tears.[5,6] Contrast tenography offers added diagnostic value, especially for the detection of MF tears where a sensitivity as high as 96% and a specificity of up to 80% have been reported.[8,9] Magnetic resonance imaging (MRI) has been reported useful for the diagnosis of marginal tears of the SDFT or DDFT, PAL desmitis, and proximal or distal digital annular desmitis.[12,13]
Ultimately, tenoscopic examination of the DFTS under general anaesthesia appears to be the most reliable technique to confirm the presence of marginal tendon lesions associated with non-septic DFTS tenosynovitis. Tenoscopy additionally facilitates immediate treatment of lesions as detected during the surgical procedure. [3,5]

The prognosis for horses following DFTS tenoscopy is variable and depends on the affected structure and lesion severity. In general, tenoscopic removal of the MF is associated with a better prognosis when compared to longitudinal tears of the DDFT [3-6] However, the fact that specific lesions can occur separately or in combination, and the described predisposition of certain breeds and limbs might also impact on the prognosis.

The number of studies evaluating the diagnosis and the long-term outcome following DFTS surgery is limited. Thus, the aim of this study was to describe the prevalence of lesions associated with lameness caused by non-septic DFTS tenosynovitis in a large population of German horses and to evaluate the long-term outcome following surgical treatment of DFTS tenosynovitis as well as factors affecting diagnosis and outcome. The sensitivity and specificity of ultrasonography and contrast tenography of the DFTS for the diagnosis of tendinous lesions were also determined.

Materials and methods

Study population and clinical examination

Medical records were searched to identify surgeries in which DFTS tenoscopy was performed at the equine clinic between November 2011 and March 2020. All lesions diagnosed tenoscopically were noted and categorized as affecting DDFT, SDFT, MF, and/or PAL. Prior to tenoscopy, pain had been localized to the distal limb using diagnostic analgesia: low 4-point block in forelimbs, low 6-point block in hindlimbs or intrasynovial DFTS anesthesia. Horses undergoing tenoscopy for septic or contaminated DFTS tenosynovitis were excluded.

The following data were collected: sex (categorized as mare, gelding, stallion), age (range and median in years), breed (categorized as Warmblood, pony, Cob-type, Standardbred, and other), and purpose (categorized as showjumping, dressage, pleasure riding and other). The duration of lameness (months) and previous treatment was recorded. Clinical findings prior to each tenoscopy were described as the presence of DFTS effusion (categorized as mild-moderate or severe), any other swelling, degree of lameness using the AAEP grading system, and response to diagnostic analgesia.

Diagnostic imaging techniques

Preoperative diagnostic imaging included radiography, contrast radiography, and ultrasonography. All images were examined and classified by one clinician (ANC). Four standard radiographic views (lateromedial, dorsopalmar/dorsoplantar, dorsolateral-palmaro/plantaromedial oblique and palmaro/plantarolateral-dorsomedial oblique) were obtained to identify concurrent osseous abnormalities. For contrast tenography, mepivicaine hydrochloride (5-8 ml, Scandicain[c]) mixed with iopamidol contrast solution (5-8 ml, Solutrast 300[d]) was injected into the affected DFTS using a standard approach at the axial margin of the lateral sesamoid bone.[1] Radiographic findings were recorded and contrast tenograms were evaluated based on previous descriptions.[8,9] Briefly, contrast accumulation dorsal to the DDFT at the level of the MF and/or the presence of one instead of two radiopaque lines at the level of the MF and/or the dorsal of the two parallel lines not extending distally to meet the proximal border of the proximal sesamoid bones was indicative of a MF tear. Longitudinal DDFT tears were suspected if a longitudinally oriented accumulation of contrast was present within the outline of the DDFT, at the level of or distal to the proximal sesamoid bones.

Ultrasonographic images were obtained using a 7.5 or 10 MHz linear transducer (Esaote MyLab Five VET[a] or TOSHIBA Aplio500[b]). The presence of DFTS effusion, lesions of the DDFT, SDFT, MF and PAL were recorded. The ultrasonographic changes that were considered indicative for a lesion of the DDFT or SDFT included an irregular surface and intra-tendinous hypoechoic areas, reduced linear echo alignment and extra-tendinous hyperechoic material associated with the tendon. MF tears were suspected if it was not possible to identify the MF borders ultrasonographically; if the borders of the SDFT were irregular at the level of the MF or if there was hyperechoic material associated with the MF margins. PAL desmitis was defined as thickening of the PAL > 2mm.

Tenoscopy

Tenoscopy was performed by one of five ECVS board certified equine surgeons. Horses were anaesthesized and placed in lateral recumbency with the affected limb positioned upper- or lowermost, depending on the localization of the suspected lesion. Following aseptic preparation, the DFTS was distended by injection of sterile polyionic isotonic fluids (lactated Ringer's solution[e]) and a stab incision using an #11 blade was made into the distended lateral or medial pouch of the DFTS between the PAL and proximal digital annular ligament to introduce a 4 mm 30° forward oblique endoscope (Karl Storz Veterinary Endoscopy)[f].[15] An instrument portal was created in the ipsilateral proximal pouch of the DFTS under arthroscopic guidance and a hook probe was introduced to palpate the different structures within the DFTS. An Esmarch bandage was only applied in surgeries where excessive bleeding was present during surgery.

Tenoscopic findings and surgical treatment were recorded based on the surgery report and endoscopic images were reviewed by the one clinician (ANC) who classified tendon lesions subjectively as mild, moderate or severe, depending on the amount of tendon fibrillation, size (<2cm, 2-7cm and >7cm) and depth (<2mm, 2-5mm, >5mm) of the lesion. The hook probe was used as reference to measure the size and depth of the lesions. MF pathology was categorized as mild (localized fibrillation), moderate (focal tear) or severe (complete rupture of the MF border from its attachment on the SDFT) (Figure 1). PAL constriction was diagnosed in those surgeries were the surgeon had difficulty maneuvering the tenoscope inside the fetlock canal due to insufficient space.

Tendon lesions such as fibrillation or granulomas were debrided either with motorized synovial resectors (Shaver System Unidrive SIII Arthro SCB, Karl Storz[f]) (Figure 2) or manually using an arthroscopic suction punch. Arthroscopic rongeurs were also used to remove loose tendon fibers or to break down adhesions between the DFTS and the flexor tendons.
MF lesions classified as mild to moderate were locally trimmed with the arthroscopic punch whereas severe lesions were managed with total MF resection. Resection was accomplished by using a hook knife in combination with arthroscopic scissors and/or an arthroscopic micro scalpel, as described previously.[16] If judged necessary by the surgeon depending on the surgical findings, desmotomy of the PAL was performed under endoscopic guidance using a hook knife in a distoproximal direction.

Flunixin meglumine[g] (Flunidol, 1.1 mg/kg bwt. p.o.) was administered perioperatively; one dose before surgery and once daily for 2 to 5 days after surgery, depending on the level of comfort on the operated limb. Bandaging was maintained for 2 weeks after tenoscopy. Horses remained on box rest for 3 weeks, followed by 2 months of hand walking and/or paddock turnout. Horses were re-assessed 10 to 12 weeks after tenoscopy. Variable rehabilitation was individually adjusted based on the severity of the original lesion as well as clinical progress and ultrasonographic findings during repeated evaluation.

Outcome

Follow-up information was obtained from case records and a structured telephone conversation with the owner (Supplement 1). The first 6 months after tenoscopy were regarded as short-term follow-up. Long-term follow-up was defined as the period of time following 6 months after tenoscopy. Information about postoperative complications, period of convalescence, and current performance level of the horse was recorded. Outcome was described but not formally analyzed statistically. The pre- and post-operative performance was compared by the owner and outcome categories were defined as retired due to chronic lameness; returned to exercise at a lower level or returned to exercise at the same or higher level. Horses were considered lost to follow-up when the owner could not be reached after 4 attempts. Horses that were euthanized due to DFTS pathology were added to the “chronic lame” outcome group. Where horses were euthanized for reasons unrelated to DFTS pathology, they were considered to be lost to follow up. For horses which underwent bilateral tenoscopy during the same anaesthesia, for description of the impact of lesion on outcome, lesions were categorized on the basis of the most severely affected limb. The outcome of each horse was described once regardless of whether tenoscopy was performed unilaterally or bilaterally (i.e. using horse as unit for description not limb). Where horses underwent repeated tenoscopy during a later anaesthesia, these individuals were assigned to one of the three outcome groups based on their status immediately prior to the repeat procedure.

Data analysis

Data were analyzed using SPSS Version 25 Software (IBM SPSS Statistics for Windows. Armonk, NY: IBM Corp). The tenoscopically-diagnosed lesions of the DDFT, SDFT, MF and PAL were each dichotomized into affected and not affected. The sensitivity and specificity with 95% confidence intervals of ultrasonography and contrast tenoscopy for lesion detection (MF, & DDFT both imaging techniques; SDFT ultrasonography only) were calculated using the tenoscopic diagnosis as the gold standard. Lesion was used as unit of analysis regardless of whether it was identified unilaterally, bilaterally or prior to a repeated tenoscopy.

Fishers exact and Wilcoxon rank sum tests were performed for each tenoscopically-diagnosed lesion category to examine associations between each lesion category and age, sex, breed, purpose and affected limb (fore- vs. hindlimb). For this analysis, lesion category was dichotomized into affected and not affected. Breeds were also dichotomized, for example, pony breed or non-pony breed and Cob-type or non-Cob-type. Continuous data are presented as range and median and categorical data as percentages. The unit of analysis for determining the association between signalment, use, and fore versus hind limb was the lesion regardless of whether it was identified unilaterally, bilaterally or prior to a repeated tenoscopy.

Results

Study population and clinical examination

In total 131 horses with non-septic DFTS tenosynovitis underwent 145 surgeries (Figure 3). In 8 horses bilateral tenoscopy was performed during the same anaesthesia (i.e. accounting for 16 limbs). Six horses underwent DFTS tenoscopy on two separate occasions due to persistence or recurrence of lameness (12 limbs). In 3 of these horses, repeated tenoscopy was performed on a different limb 14, 16 and 18 months after the initial tenoscopy. In 3 horses repeated tenoscopy was performed on the same limb 17, 20 and 24 months after the initial tenoscopy. In these 3 horses, injury to a different structure was identified at the second surgery.

The cases included 75 mares, 53 geldings and 3 stallions aged 1–23 years (median age 13.2 years). Breeds consisted of 61 Warmbloods, 28 ponies, 17 Cob-type horses (Welsh Cob, Haflinger, Tinker and Norwegian horses), 4 Standardbreds and 21 horses categorized as “other” including American Quarter Horse, Appaloosa, Paint Horse, Pura Raza Española, Arabian and Draft horse breeds. Horses were used for the following purposes: showjumping (n=16), dressage (n=33), pleasure riding (n=70) and other purposes (n=12).

The duration of lameness prior to tenoscopy ranged from 1 to 24 months with a median of 4 months. In 33 horses it was less than 4 weeks, in 76 horses 5-16 weeks, in 11 horses 17-48 weeks and this information was not available for 11 horses. Rest and systemic administration of nonsteroidal anti-inflammatory drugs was the most common treatment horses had received prior to hospital admission (82 horses); 12 horses had intrasynovial medication with steroids alone or in combination with hyaluronic acid; 3 horses had previous surgery of the affected limb (extrasynovial PAL desmotomy performed at another clinic), 22 horses had not received any previous treatment and for 12 horses this information was not available.

On clinical examination, distension of the DFTS was identified in 103 limbs prior to tenoscopy, varying from mild-moderate (53 limbs) to severe (50 limbs). Prior to tenoscopy, there was a diffuse swelling at the level of the palmar/plantar fetlock in 28 limbs; the remaining limbs undergoing tenoscopy did not show any obvious abnormalities. All horses were lame at admission or had a history of lameness, with a median grade of 2/5, range 1/5 to 4/5. Lameness improved or resolved in all horses following a low 4-point or 6-point block or intrasynovial analgesia of the DFTS.

Diagnostic imaging

Radiographs of the fetlock area were available for 127 limbs. Bone remodeling and irregular new bone formation at the palmar/plantar aspect of the proximal sesamoid bones was detected in 28 limbs. Other findings including bone remodeling at the palmar/plantar aspect of the first or second phalanx or a longitudinal radiopacity palmar/plantar to the metacarpo/metatarsophalangeal joint corresponding with calcification of the soft tissues in 28 limbs. There were no radiographic abnormalities found in 71 limbs.

Pre-operative contrast DFTS tenography was performed in 86 limbs. The MF appeared to be intact in 50 limbs whereas 3 limbs had abnormal orientation of the MF and 33 limbs had one radiopaque line delineating the MF instead of two.[8,9] In 7 limbs linear contrast accumulation was found within the outline of the DDFT which was considered indicative of a DDFT tendinitis (Figure 4). The sensitivity of contrast tenography for detection of MF tears was of 89% (CI 65.4-95.2%) with specificity of 64% (CI 52.5-77.6%) and its sensitivity for diagnosis of DDFT tears was 72% (CI 46.4-89.3%) with specificity of 53% (CI 42.2-73.3%).

The ultrasonographic findings are listed in Figure 5 and included DDFT lesions (35 limbs), SDFT lesions (41 limbs), MF lesions (36 limbs), PAL desmitis (99 limbs) and distension of the DFTS (119 limbs). For the diagnosis of MF tears, ultrasonography had a sensitivity of 64% (CI 47.7-77.2%) and a specificity of 92% (CI 84.5-96.3%). For the diagnosis of DDFT lesions, ultrasonography had a sensitivity of 54% (CI 39.5-67.9%) and a specificity of 92% (CI 83.6-96.0%). For the detection of SDFT lesions, ultrasonography had a sensitivity was 66% (CI 51.3-77.4%) and specificity of 94% (CI 86.9-97.9%). PAL desmitis was seen alone or in combination with subcutaneous fibrosis and/or poor definition of the palmar/plantar SDFT margin (Figure 6).

Tenoscopy

Tenoscopy was performed on 47 forelimbs and 98 hindlimbs. Tenoscopic findings are summarized in Table 1. In 36/145 limbs, only one structure within the DFTS was injured. In 109/145 limbs a combination of lesions was noted (Figure 7), with the most common being the combination of a SDFT lesion with constriction of the PAL, found in 38 limbs. Most SDFT lesions were characterized by superficial fibrillation or a rough, hyperaemic palmar/plantar tendon surface at the level of the PAL (Figure 8). DDFT lesions mostly consisted of longitudinal tears at the tendon border (Figure 9).

The tenoscopic diagnosis did not appear to be biased by the horses' gender or discipline, however, a statistically significant association of the horses' age, breed as well as the affected limb was identified for several lesion types. Hindlimbs were less likely to be affected by a DDFT lesion compared to forelimbs (P 0.001, OR 0.23, CI 0.105-0.527). SDFT lesions were seen significantly more frequently in Cob-type horses when compared to non-Cob-type horses (P = 0.004, OR = 5.530, CI 1.568-19.500). MF lesions occurred more often in hindlimbs in this study population (P = 0.02, OR 2.94, CI 1.149-7.520). The likelihood of PAL constriction increased with age (P = 0.005, OR 1.156, CI 1.046-1.287); ponies were more affected than non-pony breeds (P = 0.004, OR = 23.85, CI 2.8-202.9) and hindlimbs were significantly more at risk of PAL constriction compared to forelimbs (P = 0.04, OR 2.287, CI 0.999-5.236).

Tendon lesions were debrided in 82 limbs. In 18 limbs, the injured MF was trimmed with the arthroscopic punch whereas in 26 limbs total resection of the MF was performed. Desmotomy of the PAL was performed under endoscopic guidance in 123 limbs. PAL desmotomy was performed using an extrasynovial open approach[17] due to severe PAL constriction, precluding the entry of the tenoscopic cannula and conical obturator into the DFTS in 2 limbs. In these two procedures, the surgical incision was closed following desmotomy and diagnostic tenoscopy of the DFTS was performed subsequently.

Outcome

One horse was euthanized intra-operatively due to the severity of the lesions detected during tenoscopy (severe SDFT lesion). No postoperative complications were recorded for the remaining 130 horses (144 tenoscopies) while hospitalized and all horses were discharged from the hospital.

Two horses developed septic tenosynovitis of the operated DFTS after they were discharged from hospital. Both cases were tenoscopically lavaged and received systemic and intrasynovial antimicrobial medication. In one of these horses, an extrasynovial approach for PAL desmotomy had been performed initially and the horse returned to the clinic 18 days after tenoscopy. This horse returned to its prior level of performance one year after a single DFTS lavage. The other horse had undergone minimally invasive MF resection, it was presented again 15 days after initial tenoscopy and subsequently two tenoscopic lavages were performed. The horse remained chronically lame and was thereafter used as a brood mare.

Nine horses were euthanized during the short-term follow-up period (mean 3.2 months, range 3 – 6 months): 6 for reasons other than pathology of the DFTS (1 proximal suspensory desmitis, 3 colic, 1 head trauma and 1 severe bilateral forelimb lameness of unknown etiology), whereas 3 were euthanized due to DFTS pathology on the operated limb (2 SDFT lesion and 1 DDFT lesion). For the purposes of description of long-term outcome, all the horses (3/9) euthanized because of DFTS pathology were added to the “chronic lame” outcome group. The remaining 6/9 dead horses were removed from the long-term follow-up group. Six horses were lost to follow up, leaving long-term outcome data for 118 horses (132 surgeries) (Figure 3) which completed rehabilitation. In these horses, the mean follow-up period was 3 years; range 6 months to 6 years. One horse was euthanized 14 months after tenoscopy due to worsening of the lameness on the operated limb. This horse had a DDFT lesion and for reporting outcome it was included in the “chronic lame” outcome group.

The time of convalescence and rehabilitation following surgery was less than 6 months in 55 surgeries, 7 to 12 months in 58 surgeries and more than 12 months in 16 surgeries. Long-term outcome for the diagnosed lesions after tenoscopy was as follows: 18/118 horses remained chronically lame and 100/118 horses were free of lameness and ridden again after tenoscopy, of which 40 performed at a reduced level and 60 at the same or higher level when compared to the pre-injury performance. Table 2 summarizes these cases depending on whether or not they had DDFT, SDFT and/or MF lesions. Descriptively, horses with DDFT lesions had a poorer long-term outcome compared to horses without a DDFT lesion.

Discussion

This is the first study evaluating the diagnosis and the long-term outcome following DFTS tenoscopy in a large population of German horses. Retrospective analysis of surgeries presented with non-septic DFTS tenosynovitis identified a particularly high prevalence of SDFT lesions in combination with PAL constriction in this horse population. Contrast radiography resulted in improved lesion detection for MF tears when compared to ultrasonography and the long-term prognosis was favorable for most lesions except for those affecting the DDFT.

DDFT lesions were mainly seen in forelimbs, and at a slightly lower prevalence that in previous reports.[3,5,18] In our population DDFT and SDFT were equally prevalent while previous reports suggest that SDFT lesions are less common than DDFT lesions and have been diagnosed with a prevalence of 14% in other studies.[5] In the current case series, mild lesions at the palmar/plantar aspect of the SDFT, characterized by superficial fibrillation or a rough surface at the level of the proximal sesamoid bones were common. It is suspected that this lesion is associated with narrowing at the level of the fetlock canal due to the pressure exerted by the PAL over the palmar/plantar tendon surface. SDFT and PAL injury was the most common lesion combination in our population and we speculate that the higher prevalence of SDFT lesions seen in the current case series compared to previous reports[5] might relate by the concurrent high level of PAL injury.

MF lesions occurred more frequently in hindlimbs, similar to the result of studies performed in British horses.[4,8,9] Kent et al. (2019)[8] showed that fetlock extension results in distal displacement of the MF. Since hindlimb fetlocks are often more extended,[19,20] these authors hypothesized that a more distal position of the MF in the hindlimb would increase the risk of this structure getting caught on the proximal scutum leading to MF tearing. Whilst Cob-type horses and ponies were significantly more affected by MF tears when compared to other breeds in the UK,[4,8,9] a similar breed predilection was not identified in the current study. The difference might be explained by the fact that Warmblood horses were over-represented in the German study population.

Owen et al. (2008),[21] diagnosed PAL constriction more commonly in hindlimbs of aged horses and hypothesized that a more distal position of the proximal sesamoid bones in hindlimbs when compared to forelimbs likely results in a different force distribution leading to increased tension on the PAL. Additionally, age-related loss of elasticity of the PAL may predispose this structure to injury.[10,21] Differentiation between primary desmitis of the PAL or PAL constriction secondary to an intrasynovial tendinous lesion is difficult. In the current study, diagnosis of primary PAL desmitis was based on ultrasonographic findings. During tenoscopy, where the surgeon had a subjective feeling of a narrow fetlock canal "PAL constriction" was diagnosed, which included both limbs with and those without ultrasonographically evident PAL desmitis. Due to the lack of sensitivity and specificity for the detection of PAL constriction previously described by Kent et al. (2019)[8], contrast tenograms were not used for detection of this pathology in our population.
Whilst a substantial number of horses were initially referred with the diagnosis of PAL desmitis for desmotomy, this lesion was rarely seen as a sole cause of DFTS tenosynovitis. As PAL pathology usually occurred in combination with flexor tendon or MF lesions, the outcome for the diagnosis "PAL constriction" was not examined separately. The DFTS should be assessed carefully for the presence of additional lesions when PAL desmitis is identified.
PAL desmotomy is indicated when PAL desmitis impairs the normal gliding of the flexor tendons within the fetlock canal and results in lameness that does not respond to conservative management.[22] Whilst several reports promote the advantages of surgical PAL desmotomy resulting in local decompression of the fetlock canal, a clear association with improved outcomes following PAL transection is lacking.[3,6,23] In the current study, PAL desmotomy was performed where the fetlock canal appeared narrowed during tenoscopy and potentially also in preparation for complex surgical procedures like the minimally-invasive resection of the MF, which required maximal space within the DFTS.

For reporting the outcomes, we decided not to include the horses which were euthanized during the first six months following tenoscopy for reasons unrelated to DFTS pathology, since they were not able to complete rehabilitation following tenoscopy, whereas those horses which

died because of lameness persistence or worsening related to the ongoing pathology in the DFTS were added to the “chronic lame” outcome group.
We decided to include the horses operated in two different limbs within the description of the outcome, since the contralateral pathology was in all cases a mild to moderate PAL desmitis. For outcome description in bilateral tenoscopy cases, the most severely affected limb was used for assigning lesion. For those cases that underwent repeat tenoscopy, to ensure that each horse’s outcome was categorized once only, the first tenoscopy was used for outcome categorization since in our opinion the second pathology will not have as much chance of a good outcome as a horse which had no previous pathology at all.

DDFT tears, which were typically longitudinal at the lateral border of the tendon[6] in forelimbs, had the poorest outcome after tenoscopy. Similarly, Wilderjans et al. (2003), Smith et al. (2006) and Arensburg et al. (2011) found lesions of the DDFT, especially longitudinal tendon tears, had a poorer prognosis compared to other intrasynovial pathologies.[3,5,6]

Overall, the results of this case series show that only 60/118 (51%) of horses were able to return to the same or higher level of exercise compared to pre-injury. In contrast to previous reports, the majority of horses included in the current study were used for general purpose riding rather than high level competitive athletic activity. Therefore, horses returning to their proposed use were not intended to pursue a high level of athletic performance and owner expectations may have been fairly easy to meet and some owners may have been cautious about workload due to fear of re-injury. Reliance on owner description of outcome is a limitation of the current study.
Our results are comparable to the outcome documented by Thuenker et al. (2019), who reported 47.5% (19/40) of the horses treated tenoscopically returning to their original level of performance. Further research is needed to assess adjunctive treatment options, such as corrective shoeing[23] or different types of postoperative intrasynovial medications (such as hyaluronic acid, platelet-rich plasma, autologous conditioned serum, mesenchymal signaling cells) in order to improve the outcome after tenoscopy.

Synovial sepsis following DFTS tenoscopy occurred in two of 145 surgeries in this study and in one of 90 surgeries in the report of Smith et al. (2006).[24] The open approach for PAL desmotomy (first case) and the tenoscopic resection of the MF (second case), which resulted in a longer and potentially more traumatic surgery likely led to an increased risk of infection.

Similar to previous reports, the sensitivity of ultrasonography for the prediction of DDFT and MF lesions was low. [5,6] This may be related to several factors such as the operators experience or the skin thickness of the horse. Holding the limb in a semi-flexed position during ultrasound examination may improve visualization of marginal tears of the flexor tendons. With this position, the lower tension in the tendon allows some opening of the tear making it easier to detect the lesion.[25]

Contrast tenography performed in line with intrasynovial analgesia improved the diagnostic capacity, especially for the identification of MF tears. Kent et al. (2019) reported a sensitivity of 92% and specificity of 56% for the detection of MF tears and a sensitivity of 54% and specificity of 73% for DDFT tears, similar to the values obtained in this study.[8] The results of both studies provide evidence to encourage the use of contrast tenography as a routine part of a lameness investigation in horses with suspected tenosynovitis of the DFTS. Nevertheless, tenoscopy of the DFTS should be considered the gold standard for diagnosis of soft tissue lesions associated with digital flexor tenosynovitis.

The main limitations of this study are its retrospective nature, the lack of a control group and reliance on owner-reported information for outcome assessment. The diagnosis of specific lesions and the recognition of the exact localization and severity on the basis of recorded patient data might have introduced some bias. Additionally, a large proportion of horses included in the study were used for general purpose riding and long-term follow up was obtained via conversations with the owners, so the level of athletic activity pre- and post-tenoscopy was not objectively assessed. Although our study population was fairly large, the large variation in lesion types and combinations, precluded more formal analysis of outcome and this was limited to description only.

In conclusion, the overall prognosis for horses with non-septic tenosynovitis of the DFTS following tenoscopy is fair, with DDFT lesions having the poorest outcome. Intrasynovial lesions of the DDFT and MF were not consistently predicted during ultrasonographic examination but the addition of DFTS contrast tenography as part of a routine investigation in horses with DFTS pathology improves the likelihood of lesion identification, particularly for the diagnosis of MF tears.

Manufacture’s Addresses:

[a]Esaote, Köln, Germany

[b]TOSHIBA, Düsseldorf, Germany

[c]AstraZeneca GmbH, Wedel, Germany

[d]Bracco Imaging Deutschland GmbH, Konstanz, Germany

[e] Braun GmbH, Marktheidenfel, Germany

[f] Karl Storz Veterinary Endonscopy, Tuttlingen, Germany

[g] CP-Pharma Handekges. mbH, Burgdorf, Germany

Table 1: Tenoscopic diagnosis in 145 limbs with non-septic tenosynovitis of the digital flexor tendon sheath. Lesions of the deep digital flexor tendon (DDFT); superficial digital flexor tendon (SDFT); manica flexoria (MF) and palmar/plantar annular ligament (PAL) are listed as number and as percentage of the total number of affected limbs. The occurrence of lesions in forelimb vs. hindlimb is listed below. P value represents the association between lesion and fore- or hindlimb. Note that the percentage of DDFT[1] lesions is significantly higher in forelimbs, whereas MF[2] lesions and PAL constriction[3] occur predominantly in hindlimbs.

	DDFT Lesion	SDFT Lesion	MF Lesion	PAL Constriction
Present n (%)	55 (38%)	55 (38%)	44 (30%)	99 (68%)
Mild	23 (16%)	23 (16%)	11 (8%)	48 (33%)
Moderate	18 (12%)	18 (12%)	7 (5%)	38 (26%)
Severe	14 (10%)	14 (10%)	26 (18%)	13 (9%)
Not present n (%)	90 (62%)	90 (62%)	101 (70%)	46 (32%)
Forelimb n (%)	26 (55%)[1]	21 (45%)	9 (19%)	26 (55%)
Forelimb not present	21 (45%)	26 (55%)	38 (81%)	21 (45%)
Hindlimb n (%)	24 (24%)	34 (35%)	35 (36%)[2]	73 (75%)[3]
Hindlimb not present	74 (76%)	64 (65%)	63 (64%)	25 (25%)
P	0.001	0.5	0.02	0.04

Table 2. Long term outcome for 118 horses which underwent tenoscopy for management of non-septic tenosynovitis with a range of additional lesions.

	Deep digital flexor tendon lesion (n = 41)	Superficial digital flexor tendon lesion (n = 41)	Manica flexoria lesion (n= 36)	All cases n (%) in outcome category
Lameness persisted N (% of lesion group)	8 (19.5%)	5 (12.2%)	5 (13.8%)	18 (15.3%)
Returned to work at lower level N (% of lesion group)	18 (43.9%)	11 (26.8%)	11 (30.5%)	40 (33.8%)
Returned to work at same or higher level N (% of lesion group)	15 (36.6%)	25 (61%)	20 (55.5%)	60 (50.8%)

Figure legends:

Figure 1: A: Tenoscopic view of the digital flexor tendon sheath (DFTS); the tenoscope is inserted at the level of the base of the lateral proximal sesamoid bone and directed to the proximal pouch of the tendon sheath. View of a minor fibrillation seen at the distal margin of the manica flexoria (MF); this lesion was classified as mild. B: Tenoscopic view of a case with complete rupture of the MF, categorized as severe. Note the complete separation of the MF (arrow) from its medial attachment. DDFT = deep digital flexor tendon. C: Contrast tenogram of the DFTS corresponding with the case shown above with a rupture of the MF. Note the manica flexoria is not present (only one line, instead of two, at the level of the MF proximal to the proximal sesamoid bones) (arrow).

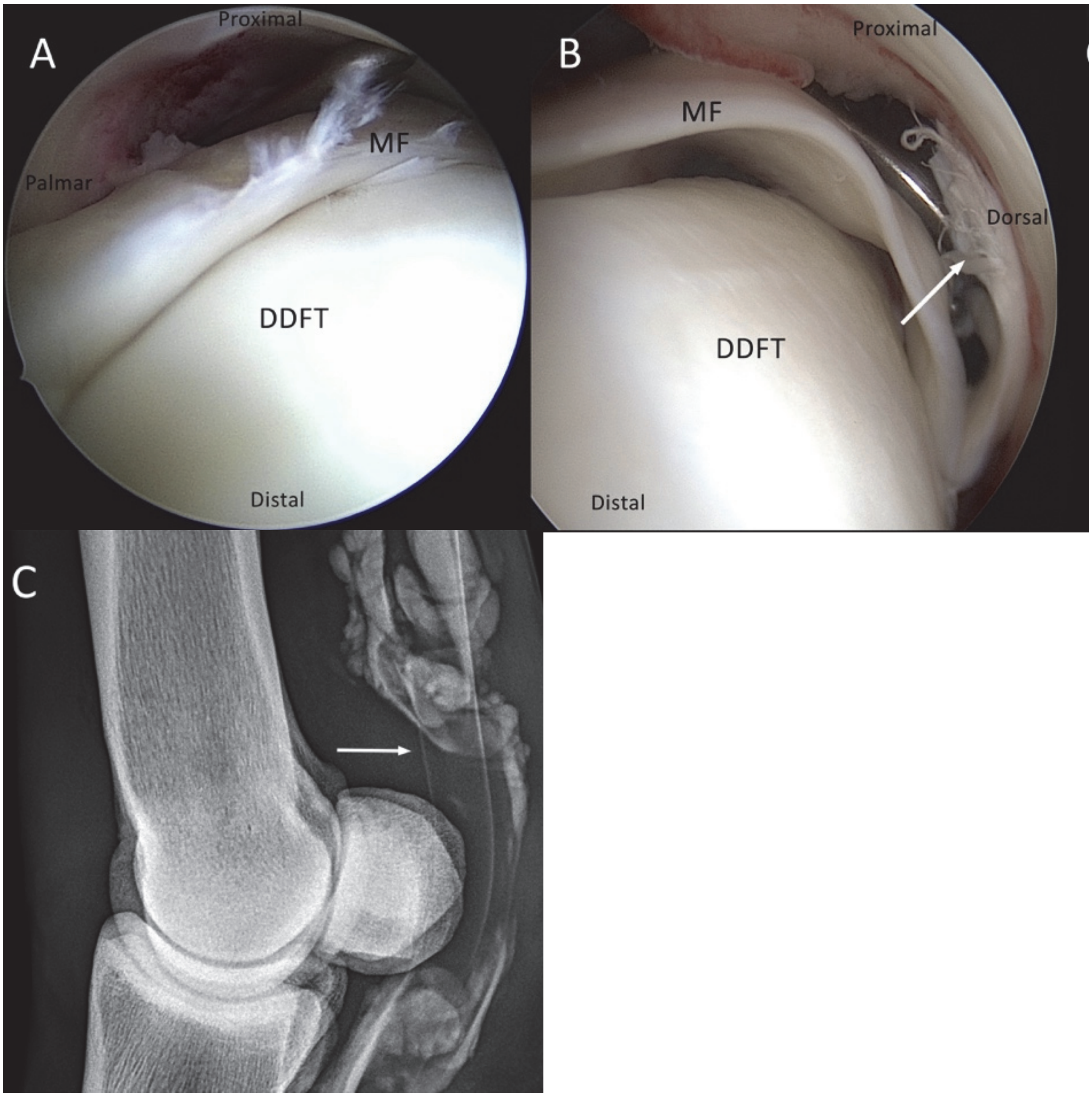


Figure 2: A: Tenoscopic view of a severe longitudinal tear at the lateral margin of the superficial digital flexor tendon (SDFT) distal to the level of the manica flexoria. The tenoscope is inserted at the level of the base of the lateral proximal sesamoid bone and directed to proximal. Torn tendon fibers can be seen protruding into the lumen of the digital flexor tendon sheath. B: Motorized synovial resector (SR) was introduced via an ipsilateral proximal instrument portal for debridement of the torn tendon fibers. Transection of the palmar annular ligament (PAL) was additionally performed. C: Tenoscopic view of the same SDFT lesion after debridement. DDFT = palmar border of the deep digital flexor tendon.

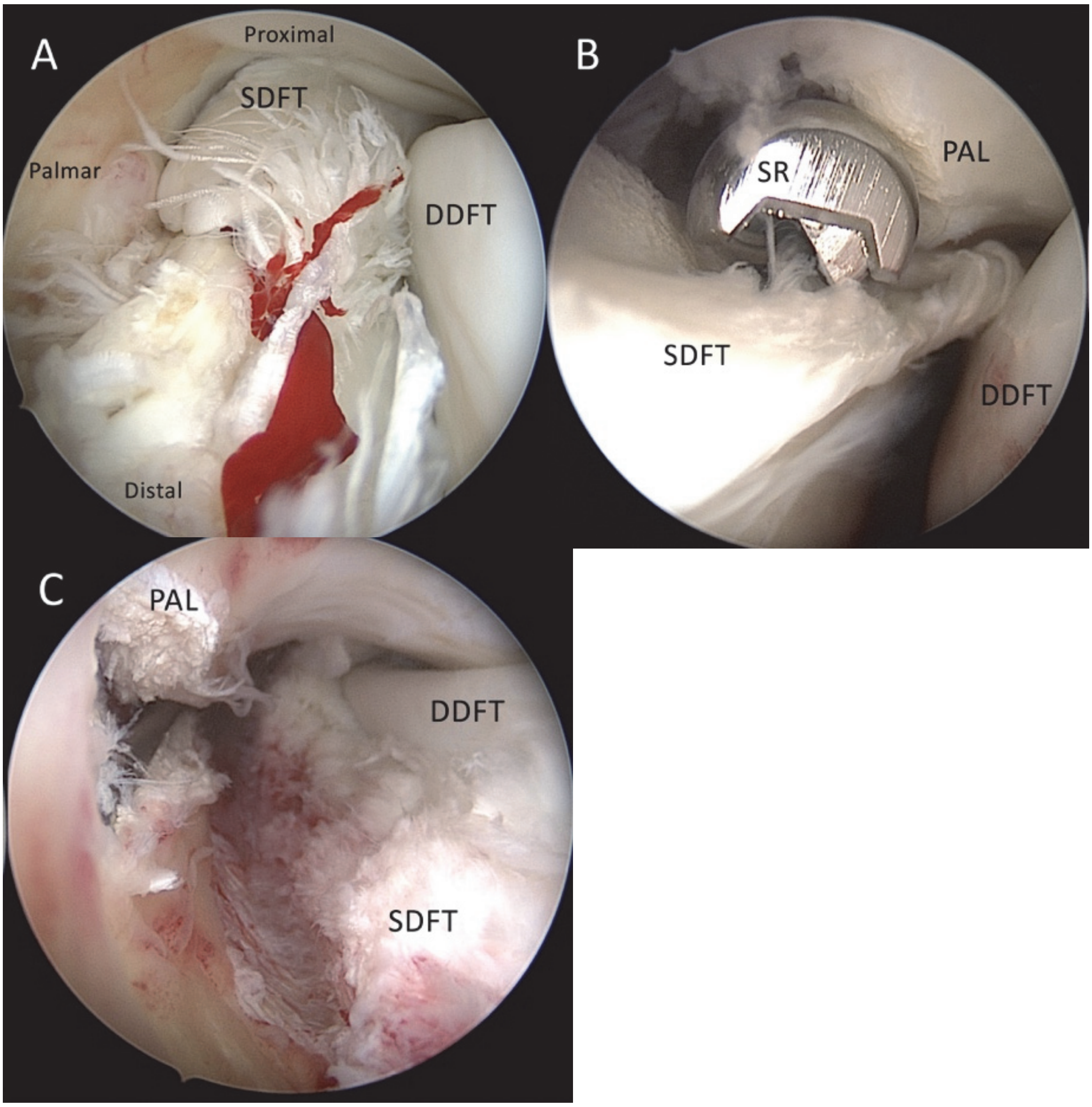


Figure 3: Flow chart illustrating case inclusion, follow-up and outcome after tenoscopy.

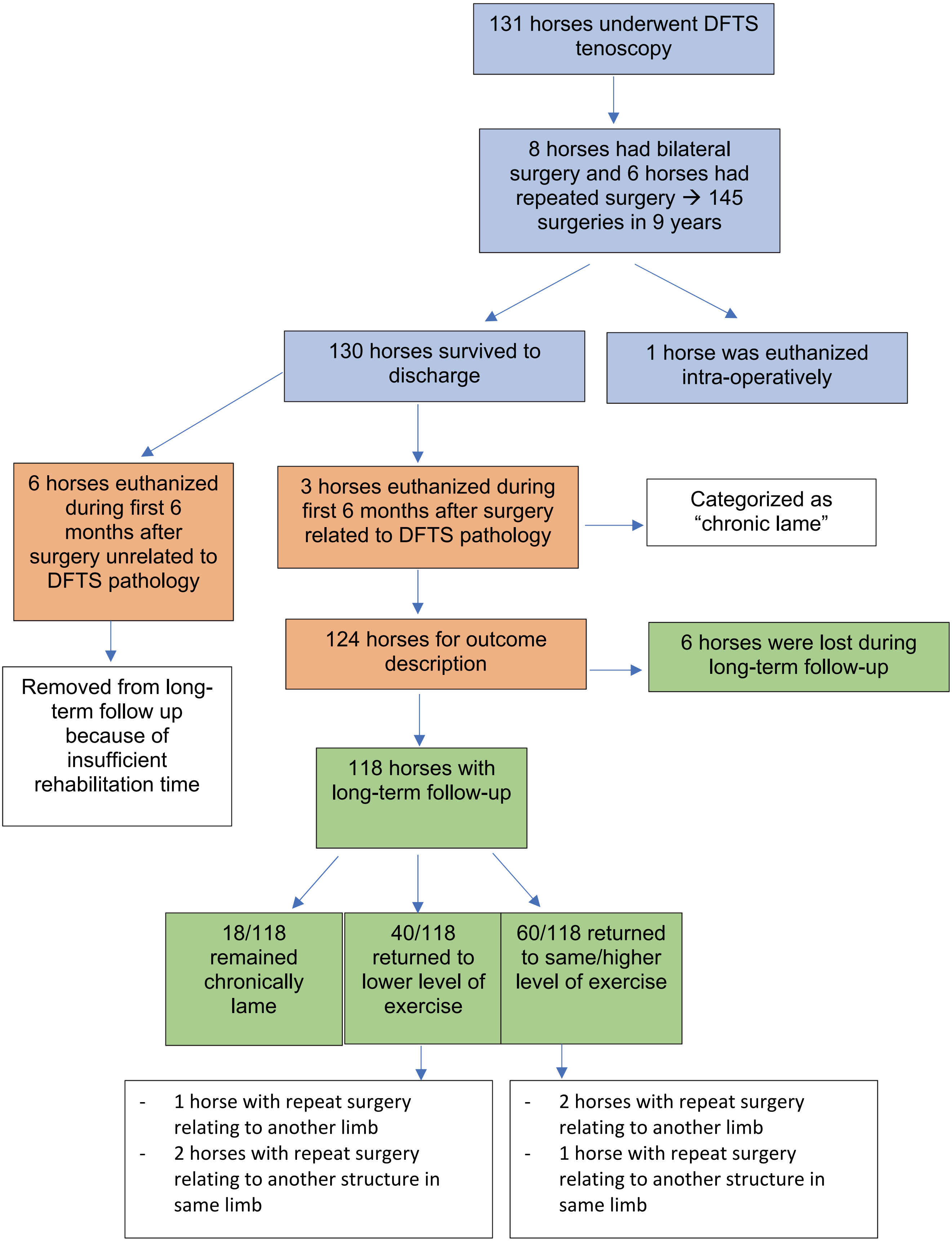


Figure 4: Contrast radiography of the digital flexor tendon sheath of a horse with a longitudinal tear at the deep digital flexor tendon (DDFT). See the linear contrast accumulation within the outline of the DDFT (arrow).

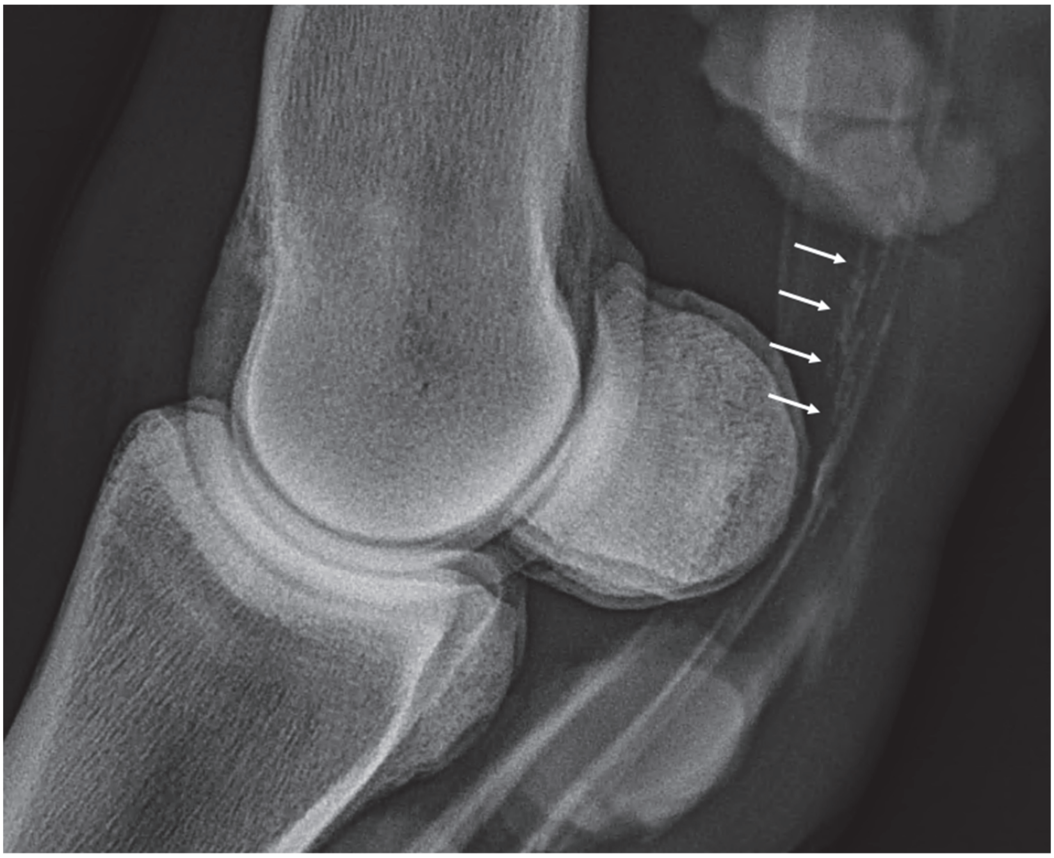


Figure 5: Distribution of the different digital flexor tendon sheath (DFTS) pathologies as detected during pre-operative ultrasonographic examination. Lesions of the deep digital flexor tendon (DDFT); superficial digital flexor tendon (SDFT); manica flexoria (MF) and palmar/plantar annular ligament (PAL) are listed as percentage of the total number of cases.

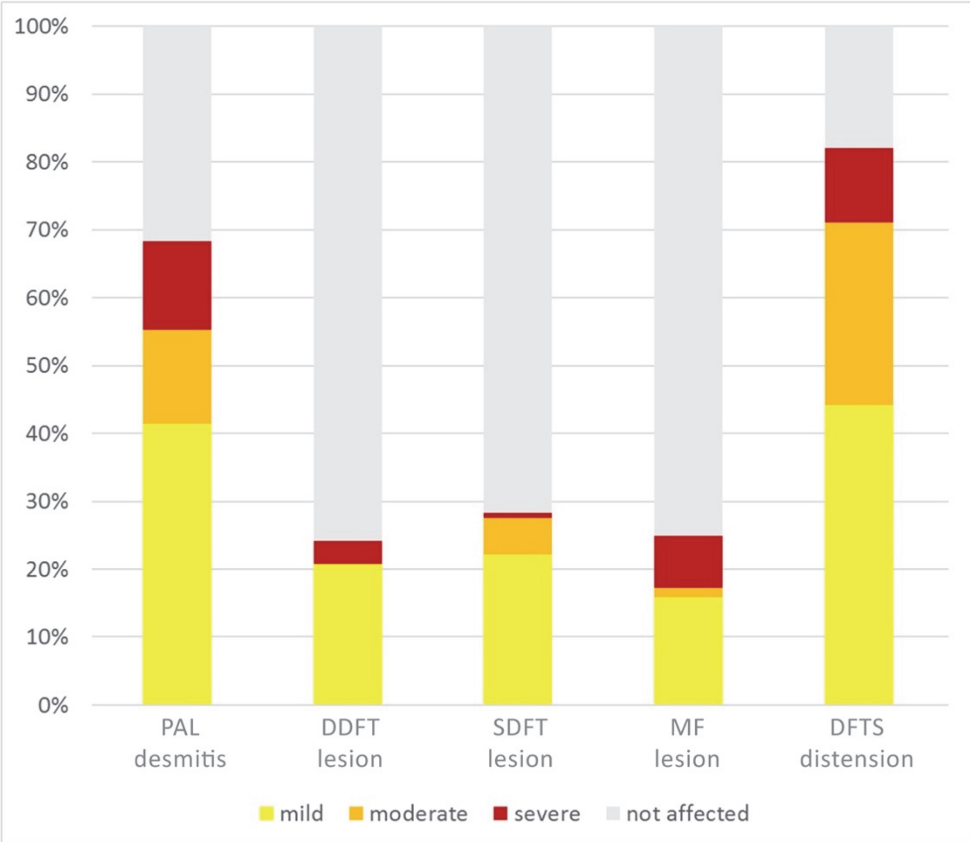


Figure 6: Transverse ultrasonographic image of the digital flexor tendons at the level of the plantar annular ligament (PAL). Note the thickening of the subcutaneous tissue (arrow) and poor definition of the PAL and the plantar margin of the superficial digital flexor tendon (arrowheads).

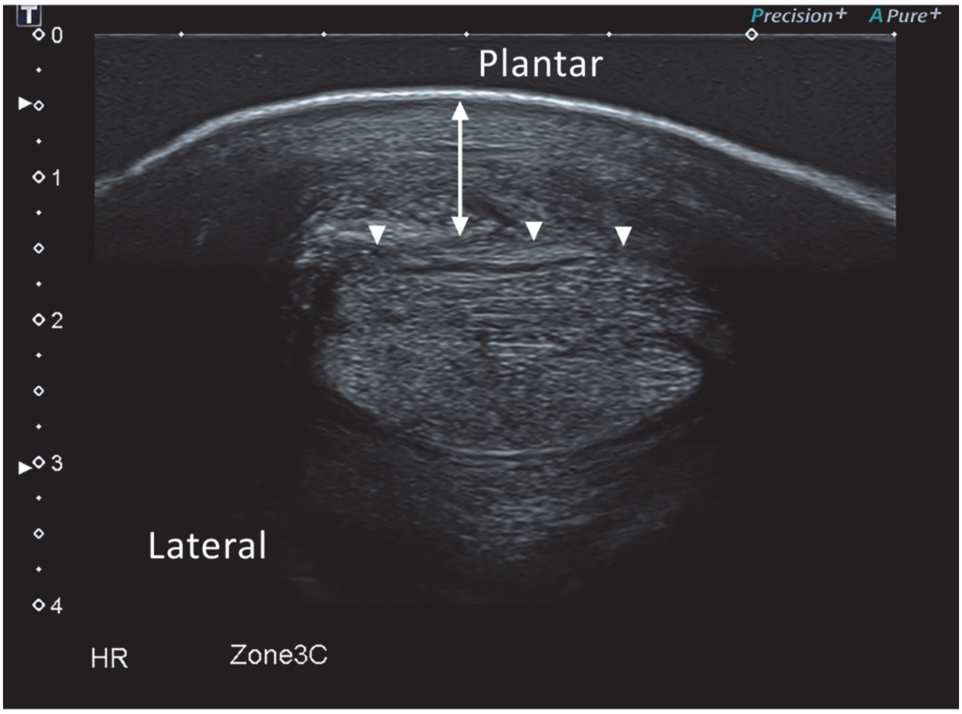


Figure 7: Combinations of lesions of the deep digital flexor tendon (DDFT), superficial digital flexor tendon (SDFT), manica flexoria (MF) and palmar/plantar annular ligament (PAL) as detected during tenoscopic surgery of the digital flexor tendon sheath in 145 cases.

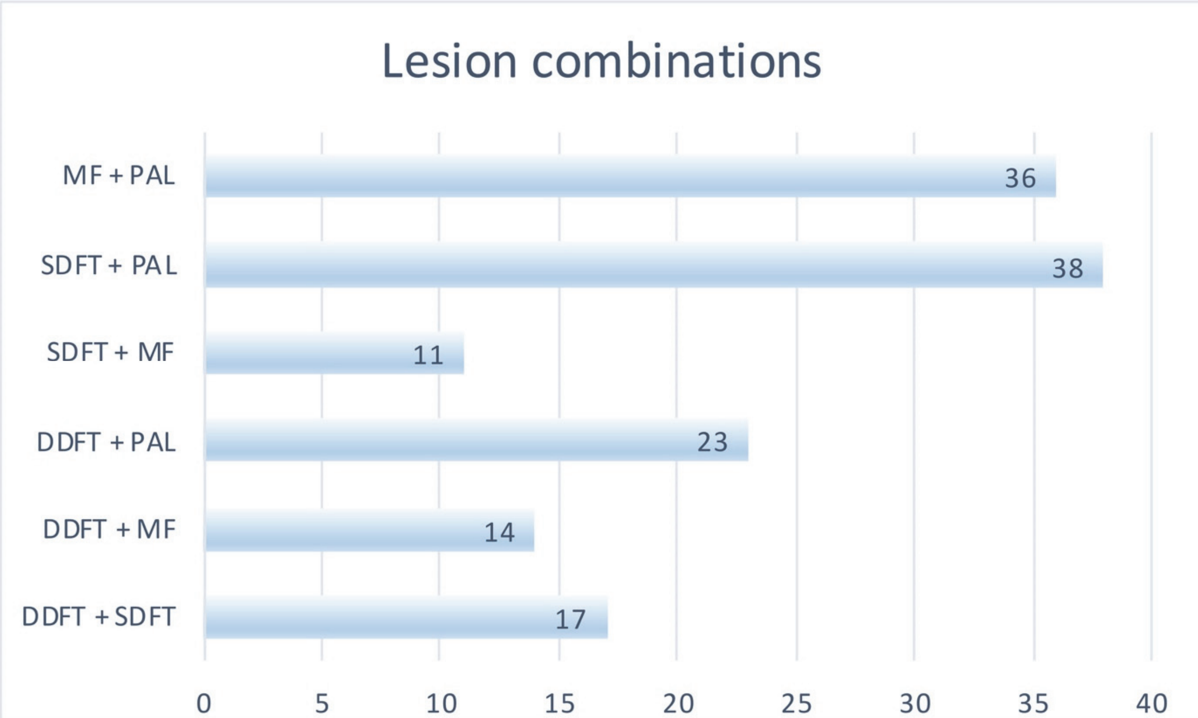


Figure 8: Tenoscopic visualization of the digital flexor tendon sheath of a typical lesion seen at the plantar aspect of the superficial digital flexor tendon (SDFT) in a case with a concurrent plantar annular ligament (PAL) constriction; the tenoscope is inserted at the level of the base of the lateral proximal sesamoid bone and directed to proximal. The PAL has been transected using a hook knife. Left in the image the plantar surface of the SDFT can be seen; note the marked superficial fibrillation and hyperemic surface of the tendon in the area in contact with the PAL.

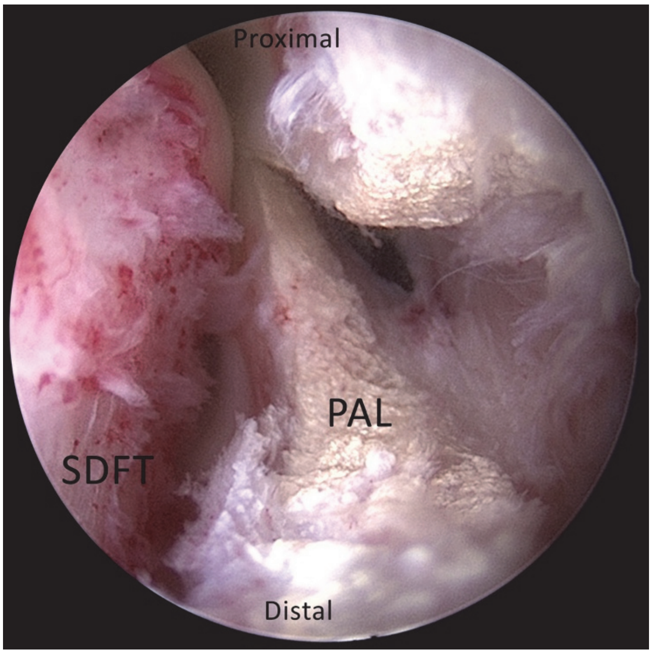
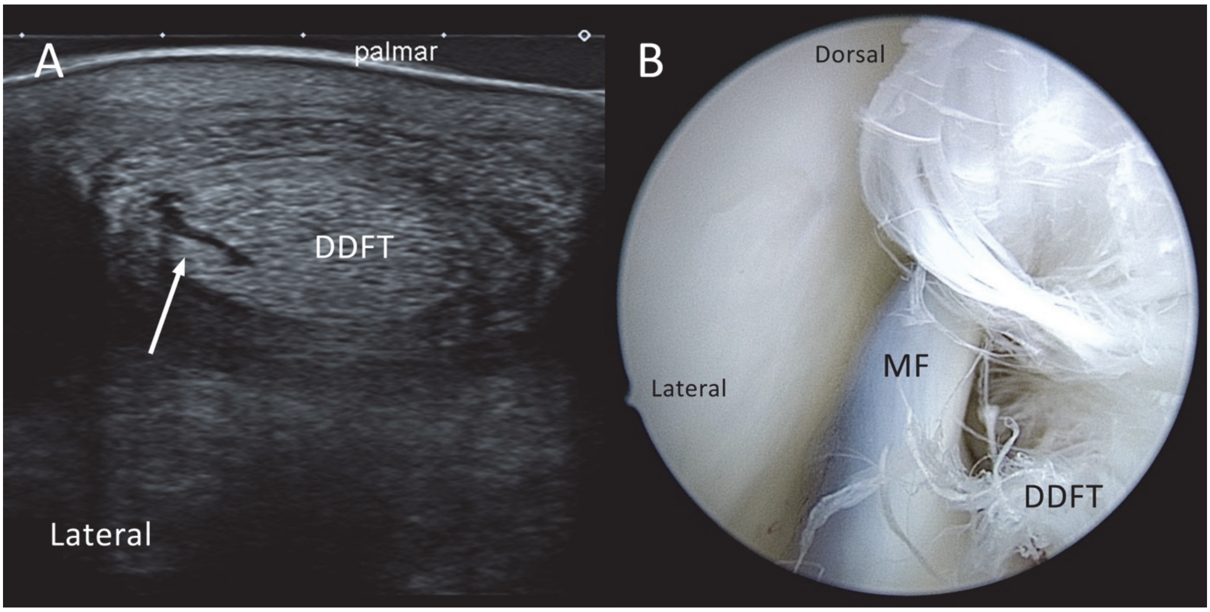


Figure 9: A: Ultrasonographic image of a longitudinal lesion at the lateral border of the deep digital flexor tendon (DDFT) at the level of the manica flexoria (MF). (Note the irregular appearance of the lateral DDFT margin with an area of decreased echogenicity (arrow). B: Tenoscopic view of the same DDFT lesion. The tenoscope is inserted at the level of the base of the lateral proximal sesamoid bone and directed to proximal. Note the significant tendon fibrillation along the lateral edge of the tendon, the case was classified as severe.



Supplementary file 1:

Owner´s telephone questionnaire

1. Do you still own the horse?

2. Is the horse still alive, if not, what was the cause of euthanasia?

3. What is the intended use/discipline of the horse?

4. What is the cosmetic appearance of the distal limb, compared to before surgery?

5. Is the horse currently lame, if yes, how severe is the lameness, when compared to pre-injury level?

    a. The horse is sound
    b. The horse is lame
        i. Less lame than before surgery
        ii. Equally lame
        iii. Lameness has worsened after surgery

6. Current performance level of the horse, compared to pre-injury:
    a. Better or equal
    b. Reduced level
    c. Retired due to chronic lameness

7. Duration of convalescence period:

8. Did the horse suffer any post-operative complications after discharge from the hospital?

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6. Discussion

Pathology of the digital flexor tendon sheath is an important cause of lameness in the horse. Lesions of the manica flexoria are often involved in tenosynovitis of the DFTS. Minor lesions of the MF at the distal edge are managed by trimming of the manica using an arthroscopic punch; in contrast, complex lesions, defined as a complete separation of the MF from one or both SDFT borders, required total resection of the MF.

A technique involving the tenoscopic resection of the MF using a #12 scalpel blade or/and a suction punch in combination with the transection of the PAL has been described (Findley et al. 2012). However, the scientific literature and relevant textbooks offer limited information about this surgical procedure and lack a comprehensive description of the method, its associated technical difficulties and intraoperative limitations, and the completeness of the achieved resection.
The objective of the first study was to describe and to evaluate an alternative technique for tenoscopic resection of the MF. The surgical procedure we explained in the first paper (Noguera et al. 2020) was divided into six steps, including resection of the lateral/medial borders of the MF with a hook knife and resection of the proximal border with a micro scalpel. We thereafter compared the outcomes between the different surgeons involved, including completeness of resection, appearance of the margins of resection, appearance of the resected MF, collateral damage and time required for resection.

The surgical technique we described allowed a complete resection of the MF with minimal iatrogenic damage, by surgeons with varying levels of experience.
A total of 27 iatrogenic lesions were identified in all 36 procedures. Most iatrogenic lesions caused during the surgical procedure were visible only during tenoscopy, most likely due to the effect of optical magnification. In our opinion, these lesions would therefore not be considered clinically relevant. Only 9/27 lesions were visible during tenoscopy and at the macroscopic examination of the limbs performed after surgery. Of these lesions, 5 were graded as severe. However, their clinical significance is unknown. Three of the severe lesions were caused by the endoscopic sleeve and were located at the scutum (1) and the DDFT (2). These lesions occurred during the surgical procedure and were most likely related to difficulties when maneuvering the endoscope through the fetlock canal. It is difficult to assess objectively whether these lesions happened as a result of a narrow fetlock canal or a misplacement of the arthroscopic portals. Comparing the iatrogenic lesions between a group

with and one without desmotomy of the PAL prior to the MF resection could have helped to identify the PAL constriction as factor for iatrogenic lesions. Perceived suboptimal placement of the arthroscopic portals has the potential to increase the likelihood of iatrogenic damage to adjacent structures as well, but the shape and the size of the hoof may also lead to difficulty in maneuvering the arthroscope or the instruments within the DFTS.
The remaining 2/5 severe lesions were in the DDFT and happened when the micro scalpel was being used to transect the proximal border of the MF. These lesions occurred because the surgeon achieved a poor orientation within the DFTS during surgery, resulting in the misplacement of the micro-scalpel, so that it was inserted between the flexor tendons instead of over the dorsal aspect of the DDFT between the MF and the deep flexor tendon. One possible explanation for this could be a too palmar/plantar placement of the distal portal used to insert the arthroscope, which would make it more difficult for the arthroscopic sleeve to enter into the *cul de sac* of the MF.

The main limitation of this study was that the surgical procedure was evaluated in cadaver limbs without MF pathology. In clinical cases with a disruption of the MF at or adjacent to its attachment to the SFDT, the MF often recoils at the free margin, which affects its normal localization. This could potentially make the proposed surgery more difficult to perform. However, the technique described here has been performed in all cases with MF rupture since 2016 (approximately 30) and the pathological changes observed in the MF did not appear to impair the surgical procedure. If one of the MF margins is disrupted, the surgical technique was adapted, and the two remaining borders were resected using the same steps that were used to resect a healthy MF. Performing this technique in healthy cadaver limbs provided us with a deeper understanding of three-dimensional anatomy of the DFTS and allowed the fast implementation of the technique in clinical cases.

In conclusion we can confirm our initial hypothesis: the technique described here allowed a complete resection of the MF with minimal iatrogenic damage and was suitable for surgeons with varying levels of experience.

The second part of this work aimed to describe intrathecal lesions seen within the digital flexor tendon sheath (DFTS) during tenoscopy and to report their long-term outcome after surgery.
There are comparable studies in the literature reporting about DFTS tenoscopic findings and outcome, however, most of them are focused on a particular lesion, such as MF (Findley et al. 2012) or DDFT tears (Wilderjans et al. 2003 and Arensburg et al 2011).

The most common lesions recorded in the literature are lesions of the deep digital flexor tendon (DDFT) and manica flexoria (MF) (Smith and Wright 2006, Arensburg et al. 2011, Wilderjans et al. 2003).
Specific lesion association to a breed and/or limb predilection have been reported. MF tears are frequently diagnosed in hind limbs with a greater incidence found in Cob horses and ponies when compared to other breeds (Findley et al. 2012).
In our study we did not have a breed association to tears of the MF, probably because our population was over-represented by warmblood horses and we do not have many Cobs in this area of Germany compared for example to other regions in the UK.
However, we did find more MF tears in hindlimbs as well. The reason for this limb predilection is not fully understood yet. Kent et al. (2019) showed that by fetlock extension the MF displaces slightly distally. Since hindlimb fetlocks are more extended, these authors hypothesized that a more distal position of the MF in the hindlimbs increases the risk of this structure getting caught in the proximal scutum and being torn. However, further research is needed to prove the displacement of the MF in relation to the proximal scutum during flexion and extension of the distal limb.

Marginal tears of the DDFT within the DFTS appeared more frequently in front limbs and were seen in a higher proportion in Warmblood horses, with the forelimb being more likely to be affected. This correlates with previous results in the literature (Wilderjans et al. 2003, Arensburg et al. 2011).

Wilderjans et al. (2003) and Smith et al. (2006) observed tears of the DDFT to be the principal cause of noninfected tenosynovitis of the DFTS in 68% and 59%, respectively.
However, in the present series, intrathecal superficial digital flexor tendon (SDFT) lesions had a prevalence as high as DDFT tears. To our knowledge SDFT lesions have never been reported to be as frequent as lesions in the deep digital tendon. Most of the SDFT lesions in our study were characterized by a superficial fibrillation or a rough and hyperemic surface in the palmar/plantar aspect of the tendon at the level of the PAL (Figure 11), whereas DDFT lesions were mostly longitudinal tears at the tendon border. The type of lesion seen at the SDFT may be associated with narrowing in the fetlock canal due to exerted pressure of the PAL over the palmar/plantar surface of the tendon. SDFT and PAL was the most common lesion combination in our study, which may explain the high prevalence of SDFT lesions seen in the current series.

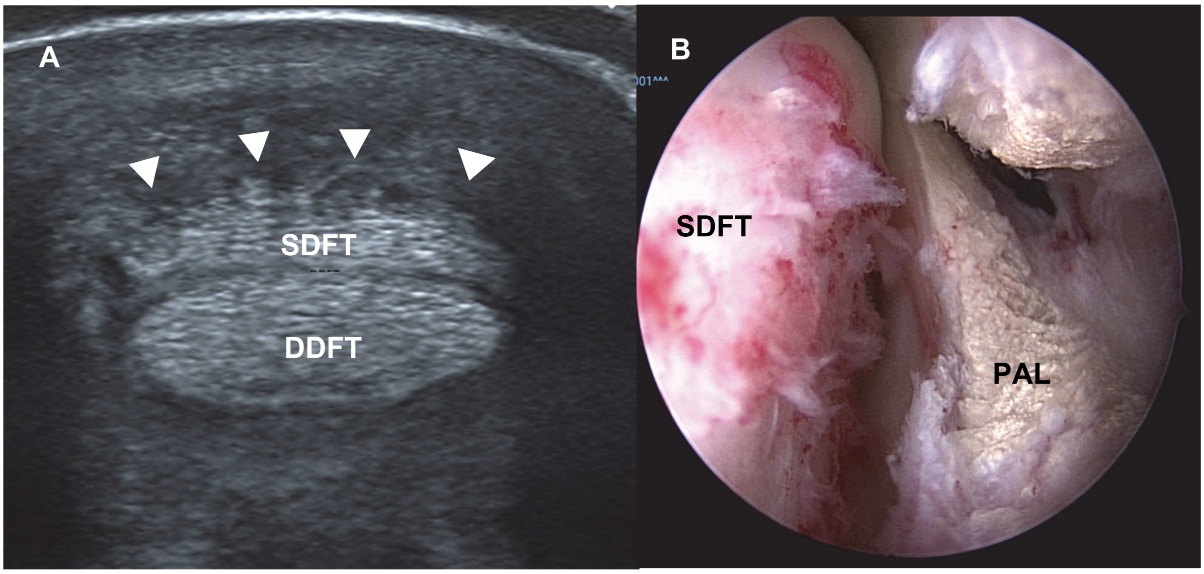

Figure 11: Ultrasonographic and corresponding tenoscopic image of a case with a lesion at the plantar border of the superficial digital flexor tendon (SDFT).

A) Transverse ultrasonographic image of the digital flexor tendons in a hind limb at the level of the plantar annular ligament (PAL). Note the thickening of the subcutaneous tissue and poor definition of the PAL and the plantar margin of the superficial digital flexor tendon (SDFT) (arrowheads). B) Tenoscopic visualization of the digital flexor tendon sheath of the same patient; the arthroscope is inserted at the level of the base of the lateral proximal sesamoid bone and directed to the proximal pouch of the tendon sheath. The PAL has been transected using a hook knife. Left in the image the plantar surface of the SDFT can be seen; note the marked superficial fibrillation and hyperemic surface of the tendon in the area in contact with the PAL. Image from Andrea C. Noguera Cender, 2020.

Type of lesion was a determining factor influencing the outcome after surgery. DDFT tears, especially longitudinal tears seen typically in forelimbs, mostly at the lateral border of the tendon (Arensburg et al. 2011), were associated with a guarded prognosis, with a higher number of cases (28%) remaining chronically lame after surgery. Wilderjans et al. (2003), Smith and Wright (2006) and Arensburg et al. (2011) similarly associated lesions of the DDFT, especially longitudinal tendon tears with a worse prognosis compared to other intrathecal lesions.

Oppositely, tears of the MF and SDFT had a relatively good prognosis, with 80% and 83% of the horses, respectively, going back to their intended use. These results agree with Findley et al (2012), who reported 79% of the patients with MF tears returning to pre-injury level of ridden exercise after tenoscopic resection of the MF.

Even though the biomechanical consequences after removal of the MF remain unknown, the prognosis in this case series was good for a return to work after total resection.

In contrast to previous reports, the majority of horses included in the current study were used for general purpose riding rather than high level competitive athletic activity. Most horses therefore returned to their proposed use as they were not intended to pursue a high level of athletic performance. Additionally, telephone follow up revealed that some owners were cautious about re-injury and elected to continue at a lower level of exercise once the horse had returned to soundness in order to prevent future orthopaedic injury. This explains, in part, the high number of cases performing at a lower level after surgery compared to pre-injury.

In the present study the accuracy of ultrasound for predicting lesions of the DDFT and MF was low, which accords to similar results reported in the literature. In a retrospective analysis of 76 cases of noninfected tenosynovitis, tears of the MF were predicted with a sensitivity of 38% compared with DDFT tears, which were predicted with a sensitivity of 71% (Smith and Wright, 2006).

There are several factors which can negatively influence the accuracy of ultrasound, such as a thick skin of the horse, which may compromise the image quality. Also, the experience of the operator plays an important role on the ability to diagnose marginal tendon tears or MF lesions. Holding the limb in a semi-flexed position during ultrasound examination may improve visualization of marginal tears of the flexor tendons or the MF. With this position, the lower tension in the tendon allows some opening of the tendon split making it easier to detect the tear (Bertuglia et al., 2014; Cauvin and Smith, 2014).
To help the operator in the interpretation of ultrasonographic images, it is recommended to always evaluate and compare the findings with the contralateral limb.

Contrast tenography, performed at the same time as diagnostic analgesia, has improved the diagnostic capacity, especially for detection of MF tears. Kent et al. (2019) reported a sensitivity of 92% and specificity of 56% for MF tears and a sensitivity of 54% and specificity of 73% for DDFT tears, which is similar to the values obtained in this study. Injection of contrast solution into the DFTS followed by radiography of the distal limb and identification of the two lines delineating the MF and their normal orientation was performed easily and allowed accurate identification of MF tears with a sensitivity of 89%, which exceeds that of ultrasonography. These results should encourage the use of this technique as a routine part of a lameness investigation in horses with tenosynovitis of the DFTS.

In conclusion, the overall prognosis for horses with non-septic tenosynovitis of the DFTS following tenoscopy is favorable, with the exception of marginal tears of the DDFT. Intra-thecal lesions of the DDFT and MF are not consistently predicted during ultrasonographic examination but the addition of DFTS contrast tenography as part of a routine investigation in horses with DFTS pathology adds accuracy, particularly for the diagnosis of MF tears.

7. Zusammenfassung

Aseptische Tendovaginitis der Fesselbeugesehnenscheide beim Pferd: Diagnose, Langzeitprognose und Beschreibung einer Technik zur tenoskopischen Resektion der Manica flexoria

Hintergrund: Entzündung der Fesselbeugesehnenscheide (FBSS) ist eine häufige Ursache für Lahmheit beim Pferd. Die Langzeitprognose nach chirurgischer Behandlung ist abhängig von der Ursache und hängt somit von der exakten Diagnose ab. Es sind nur wenigen Studien verfügbar, die in einer größeren Pferdepopulationen über die Prognose nach FBSS Tendovaginoskopie berichten. Läsionen in der Manica flexoria (MF) wurden in den letzten Jahren vermehrt als Lahmheitsursache erkannt, aber eine konkrete Beschreibung und eine Evaluation einer Technik zur tenoskopischen Resektion der MF fehlt in der Literatur.

Das Ziel des ersten Teiles dieser Arbeit war es eine chirurgische Technik zur tenoskopischen Resektion der MF zu entwickeln und zu evaluieren. Im zweiten Teil war das Ziel anhand einer retrospektiven Studie in einer deutschen Pferdepopulation die Prävalenz der Läsionen zu dokumentieren, die mit Lahmheit auf Grund einer aseptischen Tenovaginitis der FBSS einhergehen und deren Langzeitprognose nach chirurgischer Versorgung zu evaluieren.

Im Rahmen dieser Arbeit wurde eine Technik entwickelt, um die Manica flexoria minimalinvasiv tenoskopisch zu resezieren. Zur Beschreibung und Evaluation der Operationsmethode wurden 6 Teilschritte definiert, welche im Wesentlichen die Platzierung der Portale sowie die Durchtrennung des medialen und lateralen Randes der MF mit einem Hakenmesser und die Resektion vom proximalen Rand mit einem Mikroskalpell umfassten.
Drei Chirurgen mit unterschiedlichen Erfahrungsstufen resezierten die MF von je 12 Kadaver Gliedmaßen gemäss der vorgegebenen Operationsmethode. Nach Abschluss der Operation wurden am Kadaverbein folgende Parameter erfasst und bewertet: Vollständigkeit der Resektion, Erscheinung der Resektionsränder, Erscheinung der resezierten MF, Kollateralschäden und benötigte Zeit für die Resektion.
Die MF wurde bei allen Gliedmaßen komplett reseziert. Die durchschnittliche Operationszeit betrug 14:54 Minuten (06:42 - 43:33 Minuten). Bezüglich der Erscheinung der MF nach Resektion und der Anzahl an iatrogenen Läsionen konnten keine signifikanten Unterschiede zwischen den Chirurgen erkannt werden. Fünf von 27 Läsionen wurde als potenziell klinisch

relevant eingestuft, 3 davon wurden durch das Arthroskop im Skutum (1) und in der TBS (2) verursacht und in 2 Fällen wurde die tiefe Beugesehne durch das Mikroskalpell beschädigt.
Die Krankheitsgeschichten von Pferden, die zwischen 2011 und 2020 an der Klinik für Pferde der Freien Universität Berlin wegen einer FBSS Entzündung tenoskopiert wurden, wurden ausgewertet. Informationen über den postoperativen Verlauf wurde durch einen telefonischen Fragebogen gesammelt. Mittels einer logistischen Regression wurde die Relation zwischen Signalement, Vorgeschichte, tenoskopischer Diagnose und Outcome analysiert. Die retrospektive Analyse von 145 Fällen identifizierte in 110 Fällen (76%) Läsionen der Beugesehnen. Die tiefe Beugesehne (TBS) und die oberflächliche Beugesehne (OBS) waren mit je 38% gleich häufig betroffen. In 30% der Fälle wurde eine Läsion an der MF festgestellt und in 68% der Fälle wurde eine Desmopathie des Fesselringbandes (FRB) diagnostiziert.
Die Prognose nach Tenoskopie der FBSS ist günstig bei MF und OBS Läsionen. Circa 80% der Fälle mit MF und OBS Läsionen waren nach der Operation wieder einsetzbar. Randläsionen der TBS hatten jedoch eine signifikant ($p = 0.04$) schlechtere Prognose. Insgesamt 28% der Pferde mit Läsionen an der TBS blieben nach der Operation chronisch lahm.

Mit der Sonographie alleine konnten nicht alle intrathekalen Läsionen der TBS und MF zuverlässig diagnostiziert werden. Die Kontrastradiographie der FBSS als Teil der Routineuntersuchung bei Patienten mit Tendovaginitis der FBSS erhöht die diagnostische Sicherheit, insbesondere bei Läsionen der MF.

Zusammenfassend kann die Prognose für Pferde mit einer aseptischen Tendovaginitis der FBSS nach Tendovaginoskopie als günstig eingeschätzt werden. Läsionen der TBS haben die schlechteste Prognose. Läsionen der MF konnten in 30% der Fälle identifiziert werden. Die hier beschriebene Operationsmethode zur tenoskopische Resektion der MF ermöglicht eine vollständige Resektion der MF mit minimalen Kollateralschäden und kann von Chirurgen mit unterschiedlichen Erfahrungsstufen ausgeführt werden.

8. Summary

Non-septic tenosynovitis of the digital flexor tendon sheath in the equine distal limb: Diagnosis, long-tern outcome and description of a surgical technique for tenoscopic resection of the manica flexoria

Background: Digital flexor tendon sheath (DFTS) pathology is an important cause of lameness in horses. The long-term outcome is variable and depends on the exact diagnosis. Studies about the prognosis after DFTS tenoscopy in large horse populations are sparse. Lesions of the manica flexoria (MF) have recently been identified as an important cause of DFTS pathology, but a comprehensive description and evaluation of a surgical technique for tenoscopic resection of the manica flexoria (MF) is not available.

The first part of this thesis aimed to establish and evaluate a technique for tenoscopic resection of the MF and the aim of the second part was a retrospective analysis of the prevalence of lesions associated with lameness due to non-septic DFTS tenosynovitis and their long-term outcome after surgical treatment in a German population.

A technique for tenoscopic resection of the manica flexoria was described and evaluated. The surgical procedure was divided into six steps, including placement of portals, resection of the lateral/medial borders of the MF with a hook knife and resection of the proximal border with a micro scalpel.

Each of 3 surgeons varying in experience resected the MF in 12 cadaver limbs. Outcomes compared between surgeons included: completeness of resection; appearance of the margins of resection; appearance of the resected MF; collateral damage and time required for resection.

The MF was successfully resected in all specimens, with a median time of 14:54 minutes (06:42 - 43:33 minutes). No differences were detected between surgeons regarding the appearance of the MF and number of iatrogenic lesions. Five of 27 lesions were considered potentially clinically relevant, 3 caused by the arthroscope in the scutum (1) and the deep digital flexor tendon (DDFT, 2), and 2 consisting of DDFT damage caused by the micro scalpel.

Medical records of horses admitted to the Equine Clinic of the Freie Universität Berlin for tenoscopic surgery of non-septic DFTS tenosynovitis between 2011 and 2020 were reviewed.

Follow-up information was obtained via telephone questionnaire. Logistic regression was used to evaluate associations between signalment, case history, tenoscopic diagnosis and outcome. The review of 145 cases identified flexor tendon lesions in 110 (76%) cases; both tendons, deep digital flexor tendon (DDFT) and superficial digital flexor tendon (SDFT) were affected in the same frequency of 38%. Manica flexoria lesions were present in 30% and palmar/plantar annular ligament (PAL) constriction in 68% of the cases. Overall, the prognosis for horses with non-septic tenosynovitis of the DFTS following tenoscopy is favorable, with the exception of marginal tears of the DDFT, which were significantly associated with a poor long-term outcome (P = 0.04) and had the highest proportion of cases remaining chronically lame (28%). Approximately 80% of cases with MF and SDFT lesions went back to their intended used after surgery.
Intra-thecal lesions of the DDFT and MF are not consistently predicted during ultrasonographic examination but the addition of DFTS contrast tenography as part of a routine investigation in horses with DFTS pathology adds accuracy, particularly for the diagnosis of MF tears.

In conclusion, the overall prognosis for horses with non-septic tenosynovitis of the DFTS following tenoscopic surgery is favorable. Longitudinal tears of the DDFT carry the worst long-term outcome. Tears of the MF were present in 30% of the cases. The surgical technique for tenoscopic resection of the MF allowed a complete resection of the MF with minimal iatrogenic damage, by surgeons with varying levels of experience.

9. Literature

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Figures:

Figure 1: Unpublished image of a dissection study of a cadaver limb performed in 2021.

Figure 2: Unpublished image of a dissection study of a cadaver limb performed in 2021.

Figure 3: Unpublished illustration courtesy of Christoph Lischer. Handout “Erkrankungen der Fesselbeugesehnenscheide“ year 2005, Zürich. Illustration by Matthias Haab.

Figure 4: Unpublished image obtained during surgery of the digital flexor tendon sheath in a patient, year 2020.

Figure 5: Unpublished image obtained during surgery of the digital flexor tendon sheath in a patient, year 2020.

Figure 6: Unpublished image obtained during an ultrasonographic examination of a patient, year 2020.

Figure 7: Unpublished image obtained during an ultrasonographic examination of a patient, year 2020.

Figure 8: Unpublished image obtained during an ultrasonographic examination of a patient, year 2020.

Figure 9: Unpublished image obtained during a radiographic examination of a patient, year 2020.

Figure 10: Unpublished image obtained during a radiographic examination of a patient, year 2020.

Figure 11: Unpublished image obtained during an ultrasonographic examination of a patient. Image obtained during tenoscopy of the digital flexor tendon sheath of the same patient, year 2020.

10. Appendix

10.1 Table of signalment from the study “Diagnosis and long-term outcome following tenoscopic surgery of the digital flexor tendon sheath in 145 cases”

Case Number	Year	Age	Breed	Gender	Purpose
1	2011	11	O	F	P
2	2011	14	C	F	P
3	2011	11	W	M	P
4	2012	8	W	M	S
5	2012	9	W	M	P
6	2012	18	O	M	P
7	2012	21	P	F	P
8	2012	16	P	M	P
9	2012	16	P	M	P
10	2012	11	W	F	S
11	2012	11	W	F	S
12	2012	11	O	F	P
13	2012	13	W	F	P
14	2012	8	W	F	S
15	2012	16	C	F	P
16	2013	5	W	M	D
17	2013	10	W	F	S
18	2013	17	W	F	P
19	2013	14	C	F	P
20	2013	7	W	F	P
21	2013	16	W	M	S
22	2013	9	W	F	S
23	2013	22	O	F	O
24	2013	6	W	F	D
25	2013	12	C	M	O
26	2014	13	W	F	P
27	2014	12	W	M	D
28	2014	6	W	M	D
29	2014	16	C	F	O
30	2014	14	W	F	D
31	2014	10	W	F	D
32	2014	10	w	F	D

33	2014	14	P	M	P
34	2014	15	W	M	D
35	2014	18	W	M	D
36	2014	15	P	F	P
37	2014	9	W	M	S
38	2014	11	P	M	P
39	2014	22	P	F	P
40	2014	22	P	F	P
41	2014	7	W	F	D
42	2014	8	O	F	P
43	2014	12	W	M	D
44	2014	18	W	F	P
45	2014	1	C	F	O
46	2014	5	W	F	D
47	2014	15	O	M	P
48	2014	15	O	M	P
49	2014	12	P	M	P
50	2015	20	C	F	P
51	2015	13	W	F	D
52	2015	19	P	M	P
53	2015	14	C	M	P
54	2015	18	C	F	P
55	2015	14	P	F	P
56	2015	10	W	M	D
57	2015	13	C	M	P
58	2015	13	W	F	S
59	2015	10	W	M	P
60	2015	10	W	F	D
61	2015	14	C	F	D
62	2015	15	W	M	P
63	2016	9	W	M	D
64	2016	9	W	M	D
65	2016	16	P	F	P
66	2016	15	O	F	O
67	2016	12	P	F	P
68	2016	12	P	F	P
69	2016	23	C	M	P
70	2016	6	W	F	S
71	2016	10	W	F	P
72	2016	8	W	M	D

73	2016	8	C	M	P
74	2016	16	P	M	P
75	2016	14	P	M	O
76	2016	14	W	M	P
77	2016	10	W	M	D
78	2016	14	W	F	P
79	2016	7	O	M	O
80	2016	17	P	M	P
81	2016	12	W	F	D
82	2016	16	W	M	P
83	2016	12	W	M	S
84	2016	18	P	M	P
85	2016	14	C	M	P
86	2017	10	P	M	P
87	2017	15	P	F	P
88	2017	13	P	M	P
89	2017	9	O	M	P
90	2017	23	P	M	P
91	2017	12	C	F	P
92	2017	9	W	M	D
93	2017	10	O	F	0
94	2017	11	O	F	P
95	2017	19	P	M	P
96	2017	13	W	M	S
97	2017	15	W	F	S
98	2017	10	W	M	D
99	2018	11	W	F	D
100	2018	21	C	F	P
101	2018	20	W	M	D
102	2018	18	W	F	S
103	2018	10	P	F	D
104	2018	8	W	F	P
105	2018	9	W	F	D
106	2018	19	P	F	P
107	2018	18	O	F	P
108	2018	13	O	M	P
109	2018	15	W	F	S
110	2018	13	O	F	O
111	2018	13	O	F	P
112	2018	5	W	M	D
113	2018	7	P	F	P

114	2018	10	W	M	O
115	2018	18	W	F	P
116	2018	15	C	M	P
117	2018	18	P	F	P
118	2018	9	W	F	S
119	2018	15	W	F	D
120	2018	10	O	M	P
121	2019	11	P	F	O
122	2019	22	O	M	P
123	2019	12	W	F	D
124	2019	19	P	M	P
125	2019	14	O	M	P
126	2019	12	O	F	P
127	2019	10	W	M	D
128	2019	14	O	F	P
129	2019	17	C	M	P
130	2019	14	O	F	P
131	2019	8	W	F	P
132	2019	17	C	F	D
133	2019	19	O	F	P
134	2019	18	P	M	P
135	2019	6	O	F	O
136	2019	14	O	F	P
137	2019	18	W	F	P
138	2019	18	w	F	P
139	2019	18	C	M	P
140	2019	18	W	F	P
141	2019	18	W	F	P
142	2020	13	W	M	D
143	2020	11	W	F	P
144	2020	6	W	F	O
145	2020	14	P	F	P

Table legend and abbreviations: Signalment

Breed	W (Warmblood)	P (Pony)	C (Cob like)	O (Other)	
Gender	M (male)	F (Female)			
Purpose	P (Pleasure)	D (Dressage)	S (Show jumping)	O (Other)	
	No distension	Mild-moderate	Severe	Others	
DFTS distension	0	1	2	3	
	No lameness	≤ 4 weeks	17-48 weeks	> 48 weeks	n.a.
Previous lameness	0	1	2	3	4
	No prev. Treatment	Cntr. exercise + NSAID	Intrathecal medication	Surgery	n.a.
Previous treatments	0	1	2	3	4

10.2 Table of tenoscopic diagnosis from the study "Diagnosis and long-term outcome following tenoscopic surgery of the digital flexor tendon sheath in 145 cases"

Case Number	Diagnosis PAL	Diagnosis DDFT	Diagnosis SDFT	Diagnosis MF	Limb
1	1	0	3	0	Forelimb
2	1	0	1	1	Hindlimb
3	0	2	0	0	Hindlimb
4	0	2	0	0	Forelimb
5	0	3	0	1	Forelimb
6	2	0	0	3	Forelimb
7	1	0	0	0	Hindlimb
8	1	1	0	1	Forelimb
9	1	3	0	2	Forelimb
10	1	0	3	0	Hindlimb
11	1	0	0	2	Hindlimb
12	0	1	0	0	Forelimb
13	0	1	3	0	Hindlimb
14	1	2	2	0	Hindlimb
15	0	1	1	3	Hindlimb
16	0	1	0	0	Forelimb
17	2	0	2	0	Hindlimb
18	1	2	0	1	Forelimb
19	1	2	0	3	Hindlimb
20	1	0	3	0	Hindlimb
21	0	3	2	0	Forelimb
22	0	0	0	0	Hindlimb
23	0	1	1	0	Hindlimb
24	0	1	1	0	Hindlimb
25	1	0	2	0	Hindlimb
26	0	0	0	0	Hindlimb
27	1	2	2	0	Forelimb
28	0	0	2	0	Forelimb
29	0	3	1	0	Forelimb
30	1	0	0	0	Hindlimb
31	1	0	0	0	Hindlimb
32	1	0	0	0	Hindlimb
33	3	0	0	0	Hindlimb
34	1	0	2	1	Hindlimb

35	0	1	1	0	Hindlimb
36	2	0	2	2	Forelimb
37	1	0	0	3	Hindlimb
38	2	0	1	1	Hindlimb
39	2	2	3	0	Hindlimb
40	1	0	0	0	Hindlimb
41	0	0	0	0	Hindlimb
42	0	2	0	0	Forelimb
43	0	0	3	0	Hindlimb
44	1	1	0	0	Forelimb
45	0	0	0	0	Forelimb
46	0	2	0	0	Forelimb
47	1	0	0	3	Hindlimb
48	1	0	0	2	Hindlimb
49	1	1	0	0	Hindlimb
50	1	0	2	0	Hindlimb
51	0	3	0	0	Forelimb
52	1	0	0	3	Hindlimb
53	1	0	3	1	Forelimb
54	1	0	1	0	Forelimb
55	1	0	2	0	Hindlimb
56	1	2	0	2	Hindlimb
57	1	0	1	2	Hindlimb
58	1	0	1	3	Hindlimb
59	1	0	0	1	Hindlimb
60	1	0	0	0	Hindlimb
61	2	0	1	0	Hindlimb
62	0	2	1	0	Forelimb
63	1	1	0	0	Hindlimb
64	1	0	0	0	Hindlimb
65	2	0	0	0	Forelimb
66	1	2	0	0	Forelimb
67	1	0	0	0	Hindlimb
68	2	0	0	0	Hindlimb
69	0	0	2	0	Forelimb
70	1	0	3	0	Hindlimb
71	1	0	0	0	Hindlimb
72	1	3	0	2	Forelimb
73	0	3	2	0	Forelimb
74	1	2	0	3	Hindlimb
75	2	0	0	0	Hindlimb

76	0	0	0	0	Hindlimb
77	0	0	0	3	Hindlimb
78	1	3	0	0	Forelimb
79	1	3	0	0	Forelimb
80	2	0	2	3	Hindlimb
81	0	1	0	1	Hindlimb
82	0	0	0	0	hindlimb
83	0	0	3	0	forelimb
84	2	0	2	0	hindlimb
85	2	0	1	0	hindlimb
86	2	0	0	0	hindlimb
87	3	0	0	1	hindlimb
88	3	0	0	1	hindlimb
89	0	0	0	0	hindlimb
90	2	0	0	3	hindlimb
91	3	0	0	0	hindlimb
92	0	2	0	3	forelimb
93	3	0	1	0	hindlimb
94	2	0	0	3	hindlimb
95	3	0	1	0	hindlimb
96	0	1	3	0	forelimb
97	1	0	0	0	hindlimb
98	2	0	1	3	hindlimb
99	0	3	0	0	hindlimb
100	2	2	0	3	hindlimb
101	0	3	0	0	hindlimb
102	2	0	0	0	forelimb
103	1	0	0	3	hindlimb
104	0	2	0	0	forelimb
105	0	0	0	0	hindlimb
106	2	0	3	0	forelimb
107	3	0	3	0	hindlimb
108	3	1	0	3	hindlimb
109	0	0	0	0	hindlimb
110	2	0	0	0	hindlimb
111	1	0	0	3	hindlimb
112	2	0	0	0	hindlimb
113	2	0	0	3	hindlimb
114	0	2	0	0	hindlimb
115	2	0	0	3	hindlimb
116	2	0	0	0	forelimb

117	2	0	0	3	hindlimb
118	0	0	0	0	hindlimb
119	1	0	2	0	forelimb
120	0	0	0	3	hindlimb
121	0	2	0	0	forelimb
122	0	1	0	3	hindlimb
123	0	3	2	0	forelimb
124	2	3	2	0	hindlimb
125	2	0	0	0	forelimb
126	1	1	3	0	hindlimb
127	2	0	0	0	hindlimb
128	3	0	1	0	hindlimb
129	3	1	1	0	forelimb
130	3	0	0	3	hindlimb
131	2	0	0	0	hindlimb
132	2	0	1	0	forelimb
133	3	0	1	0	hindlimb
134	3	2	2	0	forelimb
135	2	0	0	0	hindlimb
136	0	0	1	3	hindlimb
137	2	1	1	0	hindlimb
138	0	0	1	0	forelimb
139	2	0	3	0	forelimb
140	2	0	0	3	hindlimb
141	2	0	0	0	hindlimb
142	2	3	0	0	forelimb
143	0	3	0	0	hindlimb
144	2	1	0	0	forelimb
145	2	0	0	0	hindlimb

0 = not affected

1 = mild lesion

2 = moderate lesion

3 = severe lesion

10.3 Table of survival and outcome after surgery from the study "Diagnosis and long-term outcome following tenoscopic surgery of the digital flexor tendon sheath in 145 cases"

Case Number	Short term survival	Long term survival	Outcome
1	1	1	3
2	1	1	3
3	1	4	2
4	1	1	3
5	1	1	1
6	1	1	3
7	1	1	1
8	1	1	2
9	1	1	2
10	1	1	2
11	1	1	2
12	1	4	2
13	2	0	0
14	1	1	3
15	1	1	1
16	1	1	1
17	1	1	2
18	1	1	2
19	1	1	2
20	1	1	2
21	1	1	2
22	1	1	2
23	1	1	2
24	1	1	2
25	1	4	3
26	1	3	0
27	1	3	0
28	1	1	1
29	1	1	2
30	1	1	2
31	1	1	3
32	1	1	1
33	1	1	3
34	1	1	2
35	1	1	3
36	1	1	3

37	1	1	3
38	1	1	3
39	1	1	2
40	1	1	2
41	1	1	2
42	1	1	2
43	1	2	3
44	1	1	3
45	1	1	3
46	1	1	1
47	1	4	4
48	1	4	4
49	1	1	2
50	1	1	2
51	1	1	1
52	1	1	3
53	1	1	2
54	1	1	2
55	1	1	2
56	1	1	3
57	1	1	3
58	1	1	3
59	1	1	2
60	1	4	3
61	1	1	3
62	1	2	0
63	1	1	3
64	1	1	3
65	1	1	3
66	1	1	2
67	1	1	3
68	1	1	3
69	1	3	0
70	1	1	3
71	1	1	1
72	1	1	1
73	1	1	1
74	1	1	3
75	1	1	3
76	1	1	1
77	1	1	1
78	1	1	2
79	1	1	2

80	1	1	1
81	1	1	1
82	1	1	3
83	1	1	1
84	1	1	3
85	1	3	0
86	1	1	2
87	1	1	3
88	1	1	2
89	1	1	3
90	1	1	4
91	1	1	1
92	1	1	1
93	1	1	3
94	1	1	3
95	1	1	2
96	1	1	3
97	1	1	1
98	1	1	3
99	1	1	2
100	1	1	2
101	1	1	1
102	1	1	3
103	1	1	1
104	1	3	0
105	1	1	2
106	1	1	4
107	1	2	0
108	1	1	3
109	1	1	2
110	1	1	3
111	1	1	3
112	1	1	3
113	1	1	2
114	1	1	2
115	1	1	3
116	1	1	3
117	1	1	2
118	1	1	3
119	1	1	2
120	1	1	3
121	1	1	1
122	1	1	2

123	1	2	0
124	1	1	4
125	1	1	2
126	1	1	3
127	1	1	3
128	1	1	1
129	1	3	0
130	1	1	3
131	1	1	3
132	1	1	3
133	1	1	4
134	1	1	3
135	1	1	2
136	1	1	3
137	1	1	2
138	1	1	1
139	1	1	2
140	1	1	2
141	1	1	2
142	1	1	2
143	1	1	1
144	1	1	3
145	1	1	2

Legend of the table:

	Survived discharge	**euthanasia related to DFTS pathology**	**euthanasia related to other causes**		
short term survival	1	2	3		
	Survived x months after discharge	euthanasia related to DFTS pathology	euthanasia related to other causes	n.a.	not alive
long term survival	1	2	3	4	0
	Chronic lame	< level	> or same level	n.a.	not alive
Outcome	1	2	3	4	0

11. List of publications and oral presentations

1. Ex vivo evaluation of an alternative technique for resection of the proximal manica flexoria in horses. Andrea Noguera Cender; Kathrin Mählmann; Christoph J. Lischer. Veterinary Surgery. 2020; 49:401–408.
2. Diagnosis and outcome following tenoscopic surgery of the digital flexor tendon sheath in 145 limbs. Andrea Noguera Cender; Kathrin Mählmann; Anna Ehrle; Roswita Merle; Laura Pieper; Christoph J. Lischer. Accepted for publication at the Equine Veterinary Journal in June 2021.

3. Abstract: “Evaluation of an alternative technique for tenoscopic resection of the manica flexoria in an equine cadaver model” submitted for presentation at the ECVS Annual Scientific Meeting 2018, Athens, Greece.

4. Oral presentation “Evaluation of an alternative technique for tenoscopic resection of the manical flexoria in an equine cadaver model“ at the ECVS Annual Scientific Meeting 2018, Athens, Greece.

   - Award: “Best large animal presentation, Residents Forum”: First place at the ECVS Annual Scientific Meeting in Athens, 2018.

5. Oral presentation “Evaluation of an alternative technique for tenoscopic resection of the manical flexoria in an equine cadaver model“ at the ACVS Annual Scientific Meeting 2018, Phoenix, USA (Residents Award Presentation).

6. Oral presentation “Pathology of the fetlock area, diagnosis and treatments”, Baltic Forum of Veterinary Medicine and Food Security, 2018, St. Petesburg, Russia.
7. Oral presentation “Contrast tenography of the digital flexor tendon sheath”, Presentation „on demand“, BPT-Kongress Digital 2020.
8. Oral Presentation “Pathology of the digital flexor tendon sheath”, Ciclo de conferencias de extension universitaria, University of Vetrinary Medicin, Río Cuarto, Argentina.

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14. Competing Interests

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15. Selbstständigkeitserklärung

Hiermit bestätige ich, dass ich die vorliegende Arbeit selbstständig angefertigt habe.
Ich versichere, dass ich ausschließlich die angegebenen Quellen und Hilfen in Anspruch genommen habe.

Berlin den 4. Juli 2021 Andrea Cristina Noguera Cender

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