

Retrospective analysis of oblique and straight distal sesamoidean ligament desmitis in 52 horses

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Abstract

Background: Injuries to the oblique (ODSL) or straight (SDSL) distal sesamoidean ligaments are a recognised cause of distal limb lameness in the horse. However, there are only limited publications addressing common diagnostic features and prognosis.

Objectives: (a) Report findings on ultrasonography and standing low-field magnetic resonance imaging (sMRI) in horses with ODSL or SDSL injury; (b) Identify clinical variables associated with lesion type and (c) Identify factors associated with return to soundness in horses with ODSL or SDSL injury.

Study design: Retrospective case series.

Methods: Horses with a primary diagnosis of ODSL or SDSL injury confirmed with a combination of diagnostic analgesia and detection of a lesion on imaging (ultrasonographic ± advanced imaging) were included. Return to soundness and performance follow-up data were obtained.

Results: Fifty-one horses were included. SDSL injuries were more common in the forelimb (13/21, 62%), while ODSL injuries had equal frequency in fore- (15/30, 50%) and hindlimbs (15/30, 50%). ODSL injuries were more likely than SDSL injuries to affect the proximal third of the ligament (OR =13; 95% CI 2.3-74.3; $p = 0.004$) and often presented with periligamentar swelling (20/30;67%) and focal pain (22/28;79%). Lesions were frequently detected using ultrasonography (35/42;83%) and sMRI examination (18/25;72%). Only 27/49 cases (55%) returned to soundness, with only 15/49 (31%) returning to intended use. There were no significant associations between outcome and clinical features or treatment.

Main limitations: There was no comparative "gold standard" to validate lesions such as high-field MRI or histopathology.

Conclusions: In contrast to previous studies, ODSL and SDSL injuries were readily identified ultrasonographically using appropriate views, and with sMRI. Given the limited availability, cost and general anaesthetic risks associated with high-field MRI, more focus should be placed on optimising the ultrasonographic examination.

The abstract is available in German in the Supporting Information section of the online version of this article

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Owners of affected horses should be informed of the guarded prognosis for return to full use.

KEYWORDS

horse, lameness, distal sesamoidean ligament, ultrasonography, tenoscopy

1 | INTRODUCTION

The distal sesamoidean ligaments (DSL) consist of three paired (oblique distal sesamoidean ligament [ODSL], cruciate DSL [cDSL] and short DSL [sDSL]) and one single straight distal sesamoidean ligament (SDSL) that are the continuation of the suspensory apparatus in both fore- and hindlimbs, connecting the proximal sesamoid bones to the palmar/plantar aspect of the proximal (ODSL) or middle (SDSL) phalanx. The cDSL and sDSL are much smaller structures and have a reduced role in metacarpo/tarsophalangeal support and rarely are implicated in lameness. The lateral and medial ODSL form a V-shape and insert onto the distopalmar aspect (trigonum) of the proximal phalanx (P1). In certain individuals, this insertion is coupled with a sagittal fascicule. Injuries to the SDSL and ODSL are rare, but in recent years have become better defined by improvements in imaging.¹⁻⁶ However, ultrasonography of these structures can be technically challenging, and previous studies have detected lesions ultrasonographically in only 7% (2/27) and 20% (9/45) of cases, respectively, with the remainder diagnosed under general anaesthesia with the use of high-field (1-1.5T) MRI.¹⁻² However, both of these studies failed to describe specific ultrasonographic imaging planes optimised for detecting DSL injury.¹⁻²

Given the risks of general anaesthesia, limited availability and high costs of high-field MRI, sMRI would be the more clinically applicable, but only one study reports the use of low-field (0.27T) sMRI to diagnosis ODSL desmitis in just three racehorses.⁴ Furthermore, the prognosis for these injuries is also unclear, as the previously reported small case series have provided a highly variable (40%-76%) prognosis for a return to full athletic function.^{1,3,4} Previous studies have not attempted to identify factors associated with return to soundness or clinical variables associated with lesion type.

The objectives of this exploratory study were therefore to: 1) Report findings (lesion detection rate and common imaging abnormalities) on ultrasonography and sMRI in horses with ODSL and SDSL injury; 2) Identify clinical variables associated with lesion type (ODSL or SDSL) and 3) Identify factors associated with return to soundness in horses with ODSL and SDSL injury.

2 | MATERIALS AND METHODS

Case records from a single referral hospital over a 17-year period (2002-2018) were reviewed. Only horses with a primary diagnosis of unilateral ODSL or SDSL injury confirmed with a combination of diagnostic analgesia and detection of a lesion on imaging

(ultrasonographic \pm advanced imaging) were included in the study. Retrieved data included age, sex, breed, discipline, duration of lameness prior to admission, affected limb(s), lesion type, palpable abnormalities (periligamentar thickening/swelling \pm digital flexor tendon sheath/metacarpo/tarsophalangeal joint effusion), grade of lameness, response to distal limb flexion/palpation/diagnostic analgesia, ultrasonographic/sMRI/other imaging findings and treatment choice.

All clinical assessments were performed by one of three experienced clinicians (ACVS/ECVS diplomat) and sMRI examinations were analysed by a diagnostic imaging specialist (ECVDI diplomat/associate). Lameness was subjectively assessed using a standard 0-10 scale with 0 indicating the horse is sound and 10 indicating non-weight bearing lameness.⁷ More recent select cases (after 2012) were additionally examined using objective gait analysis (MTw; Xsens and The Mathworks). All horses underwent a combination of regional, intrathecal and intra-articular anaesthesia unique to each individual case. Treatment was categorised as conservative (rest and exercise management only) or including additional therapies (extracorporeal shockwave therapy, regenerative therapies and tenoscopic debridement).

2.1 | Ultrasonography

A 10-15 MHz linear transducer and ultrasound machine (GE Medical Systems Limited [various models]) was used for this study. Imaging protocol differed slightly between clinicians but involved subdividing the pastern region into four anatomical levels; proximal third (P1a), intermediate third (P1b) and distal third (P1c) of the proximal phalanx together with the proximal aspect of the middle phalanx (P2).⁸ The SDSL was examined both in transverse and longitudinal views using a palmar/plantar approach. Care was taken to avoid misinterpreting the normally present hypoechoic region seen within the SDSL on midline near its insertion on P2 as pathology, which is variable between animals and also visible on a number of MRI sequences.^{6,8-10} The ODSLs were also examined in transverse and longitudinal section using a palmaro/plantaro-lateral/medial approach. The most proximal images were obtained immediately distal to the proximal sesamoid bones (PSBs) from the palmaro/plantaro medial/lateral aspects of the limb with the transducer angled upwards so that the ultrasound beam was orthogonal to the DSL fibres. Longitudinal sections were aligned in an oblique abaxial (proximal) to axial (distal) from the same palmaro/plantaro-lateral/medial orientation (Figure 1). Doppler examination, when performed, was undertaken with the limb non-weight

FIGURE 1 (A) Ultrasound probe positioning to obtain a palmaro/plantaro-lateral/medial transverse image of the proximal third of the ODSL. NB: The probe is immediately distal to the base of the lateral proximal sesamoid bone. (B) Ultrasound probe positioning to obtain a palmaro/plantaro-lateral/medial longitudinal image of the proximal portion of the ODSL



bearing. Lesion location was reported as involving the proximal third, distal two thirds (along its attachment) or full length of the respective structure. In all cases, comparative images of the contralateral limb were obtained.

2.2 | Standing low-field MRI

A 0.27-Tesla dedicated equine sMRI system (Equine Limb Scanner; Hallmarq Veterinary Imaging, Ltd.) was used to obtain images of the pastern region in select cases since sMRI instalment in 2009. Imaging protocol differed between cases but usually included a combination of T1-weighted gradient recall echo (GRE), T2/T2*-weighted fast spin echo (FSE)/GRE and short tau inversion recovery (STIR) FSE sequences were acquired in the sagittal, frontal and transverse planes. Exclusion of artefacts, such as “magic angle” effect seen with imaging the proximal aspect of the ODSL,¹¹ was minimised by use of T2-weighted FSE sequences where possible.

2.3 | Other imaging modalities

Radiography of the distal limb (including contrast tenography), high-field MRI under general anaesthesia, nuclear scintigraphy and computed tomography were also performed in select cases.

2.4 | Treatment

2.4.1 | Rest and rehabilitation protocol

Typically, this consisted of 30-60 days of strict box rest, followed by a further 30-60 days of in-hand (controlled) walking that was gradually increased to 45-60 minutes daily, depending on clinical progress. Following this, a ridden exercise program was completed increasing from walk, to trot and canter. Small paddock turnout (10m x 10m) was advised 4-6 months after the diagnosis was

made. Serial clinical and ultrasonographic re-examinations were advised every 6-8 weeks throughout rehabilitation to adapt the program accordingly.

2.4.2 | Additional (non-surgical) treatments

In addition to rest and rehabilitation, some horses were treated with extracorporeal pressure wave therapy (EPWT), intralesional biological therapies (platelet-rich plasma (Veterinary Platelet Enhancement Therapy) (VBS Direct Limited) or mesenchymal stem cells (MSCs) or with intrathecal corticosteroid medication, depending on individual clinician's preference (Table S1).

2.4.3 | Surgery

Tenoscopic debridement was performed in cases where communication of the lesion with the digital flexor tendon sheath (DFTS) was suspected (Figure 2). The surgical approach, as described by Nixon (1990),¹² was similar in most cases, however, the main difference being some cases were positioned in dorsal rather than lateral recumbency (clinician-dependent).¹³ In all cases, tenoscopy was performed using a 4mm 25° forward oblique arthroscope (Karl Storz GmbH & Co.) initially introduced into the DFTS outpouching located between the palmar/plantar annular ligament (PAL) and proximal digital annular ligament immediately palmar/plantar to the palmar/plantar digital neurovascular bundle. Systematic evaluation of the proximal and distal aspects of the DFTS was performed to evaluate for any concurrent pathology. Additional arthroscopic and instrument portals were created as necessary and interchanged to optimise accessibility to lesions for assessment and treatment. Close evaluation of the dorsal aspect of the DFTS in the proximal pastern visualised the synovium overlying the SDSL centrally and the ODSL abaxially. Careful probing was performed to identify for any communication of the palmar/plantar DSL surface with the DFTS. Ligamentous defects



FIGURE 2 Tenoscopic appearance of a tear (arrow) with associated fibrillation (star) in the palmar aspect of the straight distal sesamoidean ligament (SDSL). The arthroscope has been directed distally from its portal immediately distal to the lateral proximal sesamoid bone between the deep digital flexor tendon (DDFT) and the SDSL

were debrided with a motorised synovial resector in an oscillating mode with or without suction applied (Dyonics/Smith & Nephew Endoscopy Inc.).

2.4.4 | Outcome

Outcome data relating to return to soundness and performance was obtained in the first instance from hospital clinical records and then from direct communication with both the referring veterinary surgeon and the owner via email and/or telephone. Both was achieved in all cases with follow-up. Follow-up was unstructured and the specific information collected related to (i) the veterinary assessment of return to soundness and (ii) the owner assessment of return to performance. A return to soundness was defined as a symmetrical gait (absence of a head nod in forelimbs and symmetrical movement of the tuber coxae in hindlimbs; lameness grade 0⁷) on repeat examinations performed either by the referring veterinary surgeons ($n = 23$) or at the referral institute itself ($n = 8$) with the time period taken to return to soundness sub-classified into < 6 months, 7-12 months and 13-18 months.

Performance outcome was assessed by owners and sub-classified as returned to the same level, reduced level, retired or subjected to euthanasia (related or unrelated to the injury) with a median follow-up period of 27 months (range 12-96 months).

One case (forelimb SDSL) was bilaterally affected and, because determination of a return to soundness would be problematical, this case was excluded from the study for the purpose of statistical analysis.

2.5 | Data analysis

Measurement variables are presented as categorical data. Descriptive statistical analysis was performed using Microsoft Excel (Microsoft Corporation). Associations between clinical variables and outcome (returning to soundness) were tested. This was also performed for associations with these variables with the lesion type (ODSL or SDSL). This involved univariable analysis with each of the individual variables with the outcome and then with lesion type by applying Pearson's chi-square and Fishers exact tests (for categories with < 5 cases). Variables with $p < 0.25$ were included in a multivariable logistic regression model (one model for return to soundness and one for lesion type), which was constructed using a manual backward elimination procedure. Odds ratios (OR) with 95% confidence intervals were calculated. A $p < 0.05$ was considered statistically significant. Data analysis was carried out in SPSS (Version 25) (IBM SPSS Statistics for Windows, Version 25.0.).

3 | RESULTS

3.1 | Descriptive statistics (see also Tables S2 and S3)

3.1.1 | Signalment

Fifty-one horses (mean age 11.6 years; median age 12 years; range; 4-19 years) met the inclusion criteria. Thirty-three (65%) of the population were geldings and 18 (35%) were mares. Nineteen (37%) horses were ≤ 10 years old and 32 (63%) were ≥ 11 years old. Nine (17%) of the population were Thoroughbred-type, 4 (8%) were Warmblood-type, 8 (16%) were Irish sports horse-type (ISH), 5 (10%) were cob-type, 5 (10%) were pony-type and 20 (39%) were of unspecified breed. Thirty (59%) were used for general purpose and 21 (41%) for competition use.

3.1.2 | Clinical examination findings

Eighteen (35%) horses had been lame for < 2 months and 33 (65%) had lameness for > 2 months. Thirty-nine (76%) cases presented with unilateral limb lameness and the remaining 12 (24%) cases had concurrent mild chronic lameness on other limbs, ie most commonly osteoarthritis affecting the distal interphalangeal (3/13), proximal interphalangeal (2/13), metacarpophalangeal (1/13) and tarsometatarsal (2/13) joints. These were successfully managed with periodic intra-articular corticosteroid medication. All cases were diagnosed with ODSL or SDSL injury as the primary cause of the lameness. Thirty-one (61%) horses had mild (1-2/10), 15 (29%) horses had moderate (3-4/10) and 5 (10%) horses had severe ($\geq 5/10$) lameness recorded. The median (2/10) and range of lameness grades (1-7/10) were similar for both ODSL and SDSL injuries. Horses with ODSL injuries were focally painful during non-weight bearing examination of the metacarpo/tarsophalangeal region on palpation of the

space between the palmar/plantar aspect of the proximal phalanx and the DDFT in 22/28 (79%) cases, compared to 8/18 (44%) in the midline over the DDFT for SDSL injuries. In addition, ODSL injuries presented with palpable abnormalities (periligamentar swelling and/or MCP/MTP/DFTS effusion) in 20/30 (67%) cases compared to 7/21 (33%) of SDSL injuries. Distal limb flexion was performed in 43 cases, of which in 36/43 (84%) exhibited a marked response and 4/43 horses (9%) showed a partial response.

3.1.3 | Diagnostic analgesia findings

Table 1 summarises the diagnostic analgesia findings.

3.1.4 | Diagnostic imaging findings

Ultrasonographic examination was recommended in all cases. However, nine cases were referred for sMRI examination only (DSL injury diagnosis reached) and ultrasonography was declined. Thus, 42/51 (82%) cases had ultrasonography of the distal MCP/MTP and pastern regions performed. Of these, ultrasonographic abnormalities consistent with injury to either the ODSL or SDSL were identified in 35/42 (83%) cases. Ultrasonographic examination identified SDSL injuries (Figure 3) in 15/16 (94%) of cases and ODSL injuries (Figure 4) in 20/26 (77%) of cases. The most common ultrasonographic findings included enlargement (relative to the contra-axial ligament and the contralateral limb), focal or diffuse region of hypoechogenicity, periligamentar fibrosis, Doppler activity and enthesopathy. In 25 cases, the combination of clinical examination, diagnostic analgesia and ultrasonography conclusively localised and identified the lesion. In 10 cases, both ultrasonographic and sMRI examination were performed revealing abnormalities consistent with DSL injury in all 10 ultrasonographic studies and 4/10 sMRI studies. In three cases, ultrasonographic examination was within normal limits and horses were referred for MRI examination (2 cases sMRI and 1 case referred for high-field MRI under general anaesthesia due to excessive movement during sMRI examination preventing conclusive imaging) to confirm the presence of DSL injury. Four

cases underwent sMRI (3) and computed tomographic (CT) (1) examination because no diagnostic ultrasonographic images could be obtained due to their thick skin, revealing the presence of DSL injury in all four cases (Figure 5).

Standing low-field MRI examination was performed in both forelimb (19) and hindlimb (6) pastern regions in 25 cases. In 18 (72%) cases, MRI abnormalities consistent with ODSL (10/14, 71%) or SDSL (8/11, 73%) injury were identified. The most common findings consisted of increased signal intensity, enlargement, presence of periligamentar fibrosis and enthesopathy (Figure 6). Increased signal intensity was identified in all cases using T2/T2*-weighted GRE/FSE and T1-weighted GRE sequences. In addition, increased STIR signalling was identified in 8 cases.

Radiographic examination of the distal limb was performed in 41 (80%) cases. Only four cases (10%) had radiographic abnormalities consistent with ODSL injury (mild insertional enthesopathy). Nine (17%) cases had DFTS contrast tenography performed, in which, only two revealed communication of the lesion with the digital sheath (Figure 3). Two cases that underwent nuclear scintigraphic examination did not reveal any findings consistent with ODSL or SDSL injury. Native CT examination performed in one case revealed a lesion within the medial ODSL (MODSL) with periligamentar adhesion formation between both the MODSL and SDSL.

3.1.5 | Lesion type

Injuries to the ODSL (30/51, 59%) were more common than SDSL injuries. SDSL injuries were more common in the forelimb (13/21, 62%), whereas ODSL injuries were equally distributed between fore- (15/30, 50%) and hindlimbs (15/30, 50%). Overall, of the ODSL lesions, 18 (18/30, 60%), 8 (8/30, 27%) and 4 (4/30, 13%) were laterally, medially and biaxially located respectively. Thirteen of fifteen (87%) hindlimb ODSL lesions were within the lateral ODSL and 9/15 (60%) forelimb ODSL lesions were within the medial ODSL. Twenty-five of 30 (83%) ODSL injuries were located within the proximal third of the ligament with the remainder involving the full length (3/30, 10%), or being located in the distal two-thirds (2/30, 7%) of the ODSL. Fourteen of 21 (67%) SDSL injuries were located in the distal two thirds of the

TABLE 1 Frequency of responses (absolute numbers and percentages) to each diagnostic analgesia block with positive (70%-100%), partial positive (30%-70%) or negative (0%-30%) improvements seen. Note that although only one case was positive to a PDNB, 31% were partially positive. Only 17% were negative to the digital sheath, while a higher percentage was negative to a MCP/MTP joint

	PDNB	ASNB	L4/6	DIPJ	PIPJ	MCP/MTP	DFTS
Positive	1 (4%)	28 (78%)	15 (94%)	0	0	3 (21%)	10 (59%)
Partial positive	8 (31%)	4 (11%)	0	0	1 (10%)	2 (14%)	4 (24%)
Negative	17 (65%)	4 (11%)	1 (6%)	13 (100%)	9 (90%)	9 (65%)	3 (17%)
Total performed	26	36	16	13	10	14	17

Note: Abbreviations: ASNB, abaxial sesamoid nerve block; DFTS, digital flexor tendon sheath; DIPJ, distal interphalangeal joint; L4/6, anaesthesia of the lateral/medial palmar/plantar nerves; lateral/medial palmar/plantar metacarpal/tarsal nerves and dorsal metatarsal nerves (hindlimb); MCP/MTP, metacarpo/tarsophalangeal joint; PDNB, palmar/plantar digital nerve block; PIPJ, proximal interphalangeal joint.

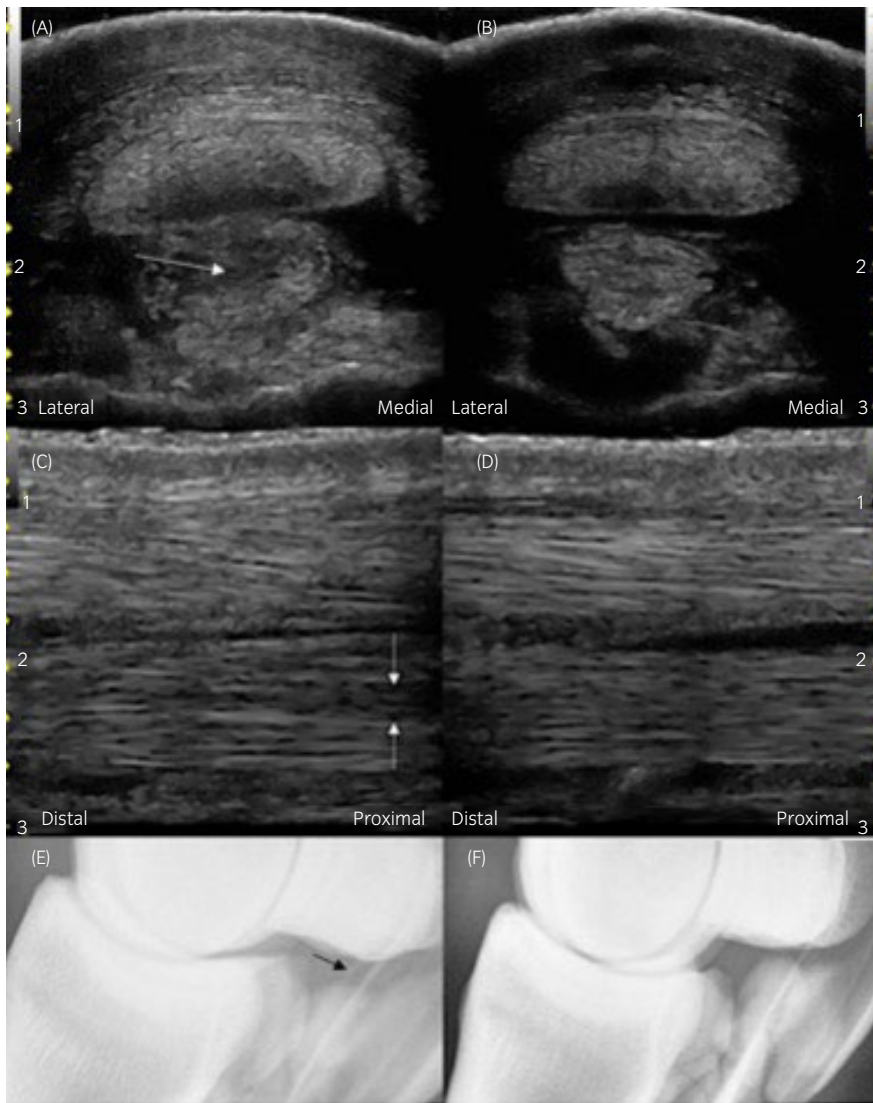


FIGURE 3 (A–D) Transverse (A) and longitudinal (C) ultrasonographic images using a palmar approach in the proximal half of the pastern region revealing a hypoechoic core lesion (arrows) within the lateral aspect of the straight distal sesamoidean ligament (SDSL). (B and D) normal appearance of the contralateral limb for comparison. (E) Contrast tenogram of the same case highlighting a small line of contrast exiting the sheath dorsally at the lesion location (arrow). (F) Normal comparison

ligament with the remaining being located in the proximal third (5/21, 23%) or involving the full length (2/21, 9%) of the SDSL (Figure 7).

3.2 | Factors associated with lesion type

Univariable screening identified four variables with potential association with ODSL relative to SDSL injury: lesion location (affect proximal third of the ligament; OR = 19.4; 95% CI 4.2-90; $p = 0.001$), focal pain on palpation (OR = 4.6; 95% CI 1.3-16.8; $p = 0.02$), presence of palpable abnormalities (periligamentar thickening/swelling \pm digital flexor tendon sheath/metacarpo/tarsophalangeal joint effusion; OR = 3.5; 95% CI 1.1-11.1; $p = 0.03$) and age (<11 years; OR = 2.0; 95% CI 0.6-6.7; $p = 0.2$) (Table S2). These variables were included in the final multivariable model with lesion location remaining the only significant independent predictor of lesion type: The odds of ODSL injuries affecting the proximal third of the ligament are 13 times (95% CI 2.3-74.3; $p = 0.004$) the odds of SDSL injuries (Table 2). Although the estimated OR is of high magnitude indicating

a strong association, the large width of the respective confidence interval indicates low precision of the estimated OR.

3.2.1 | Outcome

Follow-up was available for 49/51 (96%) cases. Lameness was assessed both subjectively and objectively with gait analysis (MTw; Xsens and The Mathworks) in the diagnosis (10/49 (20%) cases) and both diagnosis and follow-up in 4/49 (8%) cases. Twenty-seven of 49 (55%) cases returned to soundness within 12 months, of which 10/27 (37%) returned to soundness within 6 months. No further cases became sound between 13-18 months. Thirty-five cases (72%) returned to some form of work, but only 15/49 (31%) cases returned to their intended use and the remaining 20/49 (41%) cases returning to a reduced level of activity. Similar proportions of SDSL and ODSL injuries returned to soundness (55% and 56% respectively). Eighteen of 35 (51%) cases managed conservatively returned to soundness in comparison to 9/14 (64%)

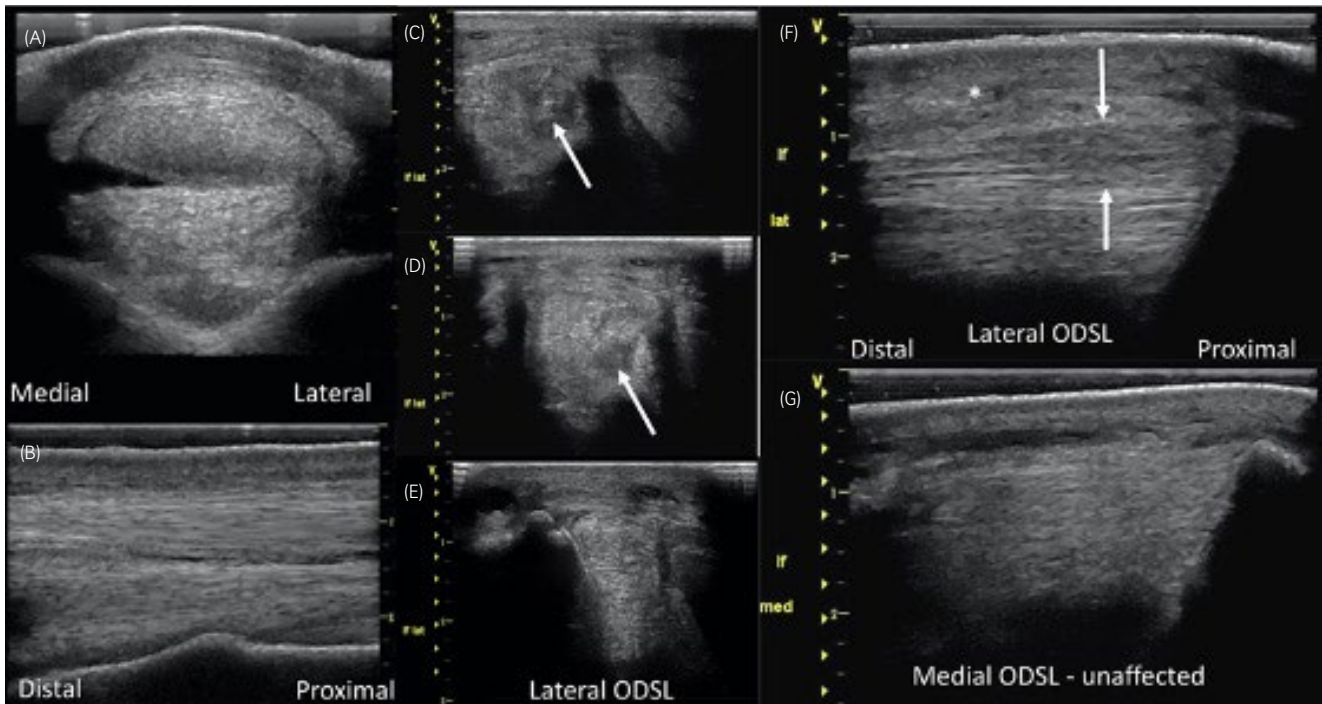
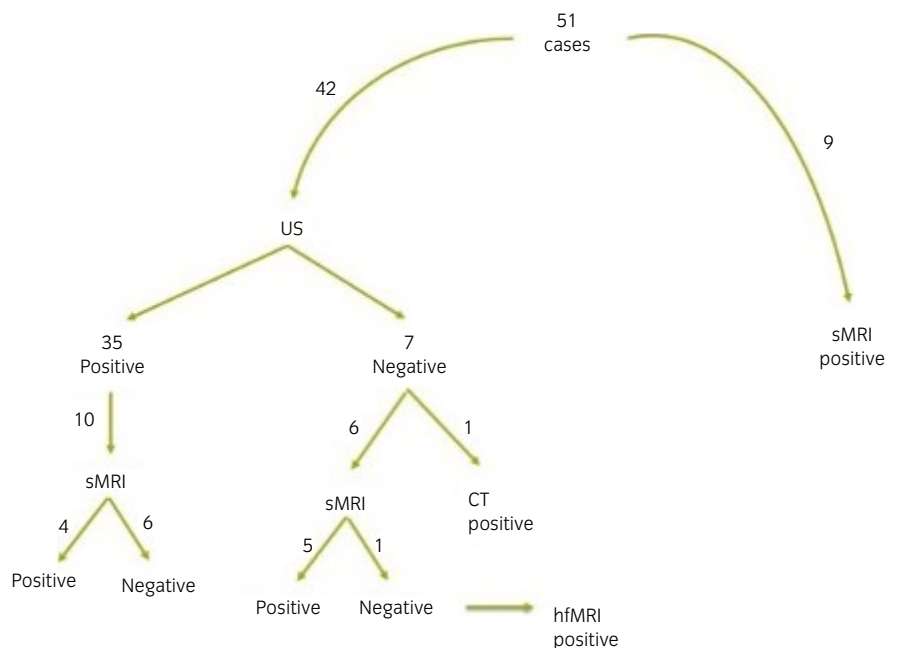


FIGURE 4 (A) (transverse) and (B) (longitudinal) images show the ultrasonographic appearance from the palmar aspect of the limb—no convincing pathology is evident. (C–E) are oblique transverse images over the damaged lateral oblique distal sesamoidean ligament (LODSL) from proximal (C) to distal (E). Note how the lesion (arrows) becomes less evident in a proximodistal direction. (F) is an oblique longitudinal image over the LODSL showing the loss of echogenicity and fibre pattern in the proximal portion of the ligament (arrows) with associated periligamentar fibrosis (asterisk). (G) shows the same view of LODSL in the contralateral limb for comparison

FIGURE 5 Diagnostic imaging flow chart diagram allocating each individual case to the imaging modality used to diagnose the oblique (ODSL) or straight distal sesamoidean ligament (SDSL) injury. Abbreviations: Positive = diagnosis made, negative = no diagnosis made. US = ultrasonography, sMRI = standing low-field magnetic resonance imaging (MRI), CT = computed tomographic examination under general anaesthesia, hfMRI = high-field MRI under general anaesthesia



cases that received additional treatments (5 EPWT, 2 biological therapies, 7 tenoscopy) (Table S1). Tenoscopic debridement of intra-thecal lesions was effective in 4/7 (57%) cases but two of three cases with unsuccessful outcomes following surgery were subjected to euthanasia before completion of rehabilitation for reasons unrelated to injury. Three of the surgical cases also had

concurrent intralesional injection of biological therapy (MSC in 2 SDSL cases, PrP in 1 ODSL case) under tenoscopic and ultrasonographic control. Surface fibrillation was identified and debrided tenoscopically in both cases with SDSL injury and four ODSL cases. No obvious sheath-lining defect was noted in one ODSL case treated with PrP.

3.3 | Factors associated with returning to soundness

Univariable screening identified four variables with potential association with return to soundness: time from onset of lameness (<2 months; OR = 2.1; 95% CI 0.6-7.1; $p = 0.2$), limb affected (forelimb; OR = 2; 95% CI 0.6-6.4; $p = 0.2$), lesion location (proximal third of the ligament; OR = 7.2; 95% CI 0.7-73.5; $p = 0.1$) and those horses with concurrent lameness issues (OR = 0.4; 95% CI 0.1-1.5; $p = 0.2$) (Table S3). No significant association was found between any of these variables with return to soundness in the final multivariable model (Table 3), although lesion location justifies consideration given that the small numbers leads to low precision in the estimated OR.

4 | DISCUSSION

In agreement with Sampson *et al.* (2007),¹ lesions were more commonly seen in the ODSL than in the SDSL, but this difference was less evident in this study (58% vs. 67%).¹ In contrast, Smith *et al.*

(2008)² previously reported a higher prevalence of SDSL lesions in their study using high-field MRI. However, the majority of horses with obvious structural abnormalities detected ultrasonographically by Smith *et al.* (2008)² did not undergo MRI, which may therefore only reflect a subset of DSL injuries. The results of this study matched the most common lesion locations for both ligaments described by Sampson *et al.* (2007)¹ with the ODSL affected more commonly proximally and the SDSL within the body of the ligament. With respect to the limb affected, an equal proportion of forelimb and hindlimb ODSL injuries were present in our study compared to 67% in hindlimbs described previously.¹ Our data on the frequency

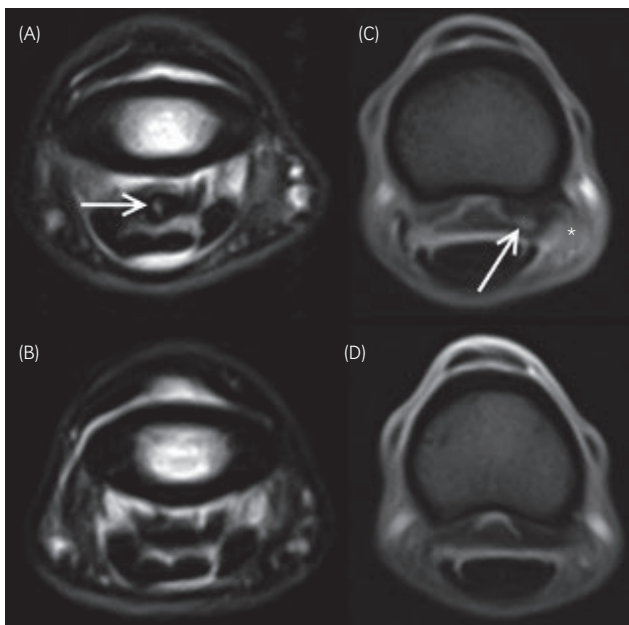


FIGURE 6 (A) Transverse standing magnetic resonance image (sMRI) T2-weighted fast spin echo image at the level of the body of the straight distal sesamoidean ligament (SDSL) revealing increased signal intensity (arrow) within the centre and enlargement of the SDSL extending from the level of the proximal aspect of the proximal phalanx to the insertion on the middle scutum. (B) normal appearance of the contralateral limb. (C) Transverse sMRI T2*-weighted gradient recall echo image at the level of the proximal phalanx revealing enlargement of the lateral oblique distal sesamoidean ligament (LODSL) compared with the MODSL. There is a focal well-delineated, oval area of increased signal intensity (arrow) seen in the LODSL. N.B. the extensive subcutaneous/periligamentar fibrosis around the affected ligament (star) which is what is often palpable. (D) Normal appearance of the contralateral limb. Right is lateral in all images

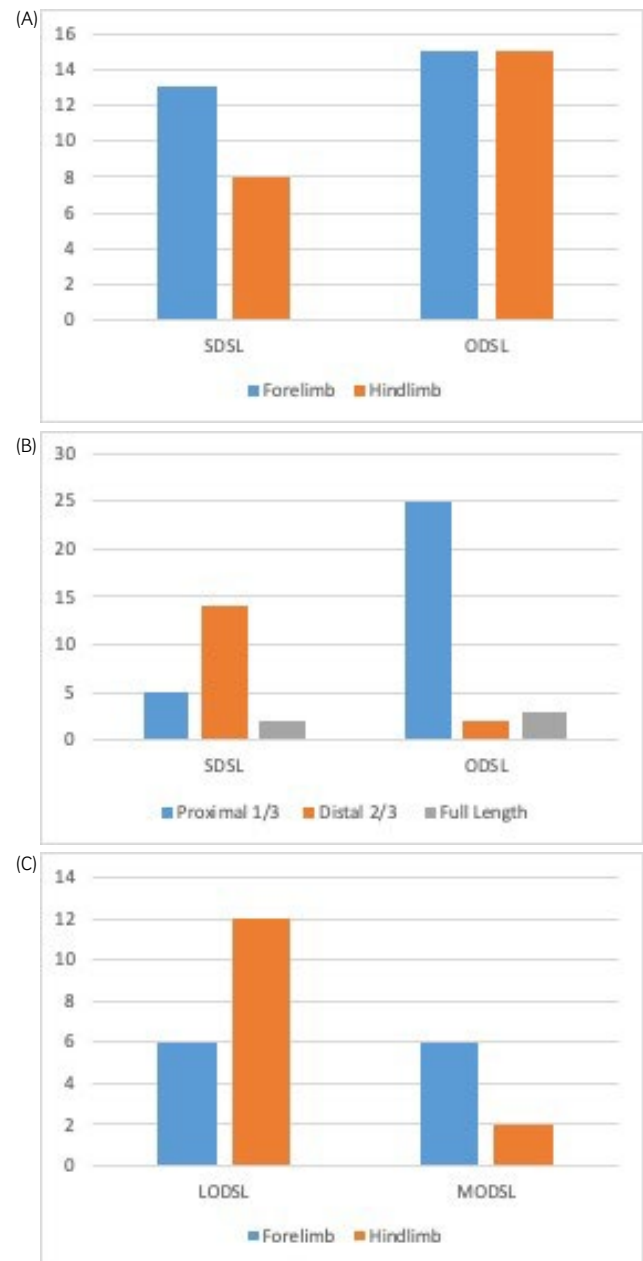


FIGURE 7 Distribution of straight (SDSL) and oblique distal sesamoidean ligament (ODSL) lesions. (A) Forelimb versus hindlimb involvement. (B) Lesion location. (C) Medial and lateral ODSL in fore- and hindlimbs

of medial and lateral ODSL injuries were also similar to that reported previously; the medial ODSL was affected in the forelimb in 60% of cases compared to 87% described previously and 87% affected the lateral ODSL in the hindlimb compared to 71% reported previously.¹ Biomechanical asymmetry during loading may explain the cause of medial over-representation in the forelimbs and lateral in the hindlimbs as this reflects the loading patterns in these limbs. This is supported by the reported higher frequency of medial suspensory ligament branch injuries in the forelimbs in racehorses,¹⁴⁻¹⁵ although a study in Warmbloods showed no significant association with laterality.¹⁶

Unlike previous studies, palpable abnormalities (periligamentar swelling \pm effusion) and focal pain on palpation were associated with ODSL injury, likely due to their abaxial and more superficial location in comparison to the SDSL which is located deep to the DDFT.¹⁻³ Due to the high prevalence shown in our study, swelling and pain in the palpable groove located biaxially immediately distal to the basilar aspect of each proximal sesamoid bone and immediately palmar/plantar to the medial and lateral edges of the proximal phalanx appears to be a key diagnostic feature of ODSL injuries. This is best appreciated during non-weight bearing examination of the metacarpus/tarsophalangeal region and can be easily overlooked.

Seventy-eight per cent of our cases were positive or partially positive to DFTS diagnostic analgesia consistent with the previously reported high frequency of response of DSL injuries to DFTS diagnostic analgesia, although not necessarily in every case or completely.¹ Just over half of blocks were considered fully positive in this study, where response was graded subjectively in percentages based on evaluation in both a straight line and on the lunge, which might account for the lower percentage considered a positive response. It is not clear why this response occurs: it is unlikely due to disruption of the palmar/plantar surface of the ligament establishing

a communication with the sheath cavity as this was evident in only a minority of cases. The most likely explanation is either that the local anaesthetic diffuses through the very thin layer of synovium overlying the ligament (Figure 2) or diffuses locally to anaesthetise the regional nerves as described for foot diagnostic analgesic techniques.¹⁷ Only 1/26 (4%) cases was fully positive to a palmar/plantar digital nerve block although approximately a third of cases showed some response (30%). Abaxial sesamoid and low 4-point nerve blocks most frequently abolished the lameness, consistent with previous studies.¹⁻² As with all regional diagnostic analgesia, a negative result to these blocks can be the result to ineffectively performed blocks.

Ultrasonography was a useful diagnostic tool in this study with 86% of ultrasonographic examinations showing abnormalities, in contrast to previous reports of 7%-20% of lesions detected with ultrasonography alone.¹⁻² Ultrasonography of the proximal third of the ODSL requires palmaro/plantaro-medial or lateral positioning of the transducer at the base of the proximal sesamoid bones in both longitudinal and transverse planes to identify lesions in the proximal ODSL which was where the majority of the lesions were located. This view is, however, challenging because the ODSLs are affected by off-incidence artefacts and horses with thick skin significantly compromises obtaining diagnostic quality images in this plane.¹⁰ Combining the common ultrasonographic changes of ligament disease (enlargement and altered longitudinal pattern) with additional signs such as periligamentar fibrosis and enthesopathy at the ligament's insertion sites contribute to improved confidence in diagnosis. Cross-sectional areas (CSAs) of both the SDSLs and ODSLs have only been published in the literature from MRI images.^{1,2,5} The CSA of the SDSLs and ODSLs reduces in size in a proximodistal direction giving rise to variation in size. Furthermore, our previous ultrasonographic CSA measurements

TABLE 2 Multivariable logistic regression model of clinical variables associated with oblique (ODSL) relative to straight (SDSL) distal sesamoidean ligament desmitis

Variable	Odds ratio (OR)	Lower 95% CI	Upper 95% CI	P value
Lesion location				
Proximal 1/3	13.1	2.3	74.4	0.004
Distal 2/3	ref			
Full length	4.5	0.4	54.9	0.2
Focal pain				
Yes	3.5	0.6	20.5	0.2
No	Ref			
Palpable abnormalities				
Yes	1.9	0.4	9.9	0.4
No	Ref			
Age				
0-10 years	0.3	0	1.7	0.2
>11 years	Ref			

TABLE 3 Multivariable logistic regression model of factors associated with return to soundness in 49 horses (2 lost to follow-up) diagnosed with oblique (ODSL) or straight (SDSL) distal sesamoidean ligament desmitis

Variable	Odds Ratio (OR)	Lower 95% CI	Upper 95% CI	P value
Time from onset of lameness				
<2 months	1.8	0.5	7	0.4
>2 months	ref			
Limb affected				
Forelimb	2.1	0.6	7.4	0.2
Hindlimb	ref			
Lesion location				
Proximal 1/3	7.7	0.7	81.3	0.09
Distal 2/3	4.9	0.4	57	0.2
Full length	ref			
Concurrent lameness				
Yes	0.4	0.1	1.5	0.2
No	ref			

have indicated that the SDSL in the hindlimb is smaller than in the forelimb and that the lateral ODSL is marginally larger than the medial ODSL (unpublished data). Because of this variation, the most reliable assessment of enlargement is a comparison with the contralateral limb at the same level, as we have shown that bilateral injury is extremely rare (1/52 cases). We believe that the improved detection rate using ultrasonography in this study reflects the addition of the described key oblique views during the examination and assessing these additional ultrasonographic signs.

We have also observed that sMRI was a useful diagnostic tool with 72% of sMRI studies showing abnormalities. A recent study by Ellis *et al.* (2019) utilising high-field MRI and histopathological evaluation concluded that increased cross-sectional area and changes in signal intensity are significantly associated with ODSL pathology.⁵ These were also the most common findings in our horses examined with sMRI. Similar to ultrasonography, the presence of additional abnormalities, such as periligamentar fibrosis and enthesopathy, was used to support the diagnosis. We acknowledge that there is a risk that the six cases diagnosed ultrasonographically but were normal on sMRI examination could represent false positive diagnoses, however, with convincing ultrasonographic and clinical abnormalities consistent with DSL injury, together with a lack of other significant pathology strongly supported the diagnoses. Lower image resolution associated with sMRI images could explain why some pathologies are not detected on sMRI.

It is not possible from these data to conclusively determine whether sMRI or ultrasonography is superior for detecting DSL pathology as both imaging modalities were not used in every case. In addition, there were unavoidable complicating factors such as non-availability of sMRI in the first half of the study timeframe and also improvements in our ability to differentiate pathology from artefacts in both sMRI and ultrasonography over the years. However, the high frequency at which DSL pathology was detected using specific ultrasonographic techniques supports our conclusion that the first line imaging modality in cases of DSL injury should be ultrasonography, but if findings are inconclusive or non-diagnostic, sMRI should be considered. However, it is also recognised that not all DSL injuries will be visible with sMRI, in part due to potential susceptibility to magic angle effect within the proximal aspect of the ODSL and lower resolution images acquired with sMRI which may underestimate the extent of the injury.¹¹ In addition, movement (particularly with hindlimb sMRI scans) and individual horse temperament issues can interfere with the overall quality of image acquisition. Thus, high-field MRI should also be considered for some cases.¹⁸

There was no significant difference in outcome between conservative management alone (51%) and additional therapies (64%). Although the relatively small case numbers reduce the power of the study to predict more effective treatments, the limited difference suggests more intense treatments do not impact outcome in a major way. Unlike in previous studies,^{1,3} intrathecal corticosteroid medication and ligament splitting was not frequently performed in our cases.

Clinicians should be aware of the possibility of extension of palmar/plantar injuries into the DFTS cavity due to the ligaments' close

proximity to the DFTS in this region (Figure 2) which thereby offer the prospect of surgical debridement. We were able to identify this opening into the sheath cavity pre-operatively in two of our surgical cases using a combination of ultrasonography and contrast tenography. Only a limited number of cases underwent surgery, which prevents any valid statistical analysis, but the success rate was high (80%) if the two horses who did not survive for other reasons are excluded, which encourages further evaluation of this therapeutic approach for such cases.

Limitations of this study include its retrospective nature and insufficient subject numbers to determine which treatments were the most effective. A 'gold standard' was lacking for validating the presence of injury (such as high-field MRI or histopathology), although we believe that the combination of clinical and diagnostic features made the diagnoses sufficiently robust. Potential reasons for the lack of significant association with return to soundness following multivariable analysis are explained by the relatively small study number and low statistical power to detect such potential associations. There is a possibility of misclassification of return to soundness due to the inherent subjectivity of lameness assessment performed by various referring veterinarians (greater interobserver variation) with only four cases assessed with concurrent objective gait analysis both at the time of diagnosis and at follow-up. In addition, as mentioned previously, although certain ORs are of a high magnitude, the wide confidence intervals obtained in the multivariable analyses indicate low precision of the estimated ORs. Consequently, statistical conclusions drawn from this observational study must be interpreted with caution because of the small sample size. It could be argued that the varied outcomes seen between the current and largest previous study¹ are a result of differences in imaging modalities, where the previous study used a more sensitive imaging modality (high-field MRI) and diagnosed less severe injuries which translated to improved outcomes.^{y1}

We believe that the prognosis for a return to soundness calculated in this study can be used reliably because it is based on the largest case numbers to date. We acknowledge that this is limited to the population of horses within the referral practice area and shortcomings of imaging modalities used. Owners of horses with SDSL or ODSL injuries should therefore be advised of the guarded prognosis to return to full athletic function.

ACKNOWLEDGEMENTS

We thank all the referring veterinary surgeons for their case contributions, Ms Nancy Brown (nee Ellis) for her work on ultrasonographic assessment of the cross-sectional area of oblique and straight distal sesamoidean ligaments and Dr Ruby Chang for her statistical advice.

CONFLICT OF INTERESTS

No competing interests have been declared.

AUTHOR CONTRIBUTIONS

A. Hawkins was the principal author and contributed to study design, data collection and analysis and manuscript preparation.

L. O'Leary contributed to study design and data collection. D. Bolt and A. Fiske-Jackson contributed cases to the study and revision of the manuscript. D. Berner contributed to preparation and revision of the manuscript. R. Smith was the senior author and contributed to overall study design, data analysis and preparation of the manuscript. All authors gave their final approval to the manuscript.

ETHICAL ANIMAL RESEARCH

Research ethics committee oversight not required by this journal: retrospective analysis of clinical data.

INFORMED CONSENT

Explicit owner informed consent for inclusion of animals in this study was not stated.

PEER REVIEW

The peer review history for this article is available at <https://publons.com/publon/10.1111/evj.13438>.

DATA ACCESSIBILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Hawkins A, O'Leary L, Bolt D, Fiske-Jackson A, Berner D, Smith R. Retrospective analysis of oblique and straight distal sesamoidean ligament desmitis in 52 horses. *Equine Vet J.* 2021;00:1–11. <https://doi.org/10.1111/evj.13438>