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Proximal resection of the fourth metatarsal bone in combination with partial removal of metatarsal bone exostoses as alternative treatment for severe chronic proximal suspensory ligament desmopathy in a horse

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Summary: This case report describes the successful surgical treatment of a 9-year-old Warmblood gelding used for showjumping that presented with a 2/5 right hindlimb lameness, which had persisted for more than 2 years and was caused by chronic-active proximal suspensory ligament desmopathy and second and fourth metatarsal exostosis. Previous treatment methods including extracorporeal shockwave therapy, local corticosteroid injections and subsequent plantar fasciotomy and neurectomy of the deep branch of the lateral plantar nerve were unsuccessful. As the full extent, as well as the severity and location of the lesions could not be reliably determined using ultrasonography and radiography, computed tomography was helpful to delineate the extent of the pathology at the origin of the suspensory ligament. The horse was successfully treated by proximal resection of the fourth metatarsal bone in combination with partial removal of plantar metatarsal bone exostoses impinging on the suspensory ligament. The horse was sound 3 months following surgical treatment. It remained free of lameness at subsequent follow-up examinations at 6, 9, 12 and 18 months post-surgery, and was competing successfully 9 months after surgery. The favorable clinical outcome and rapid post-surgical recovery support the authors´ hypothesis that pressure reduction via proximal ostectomy of the fourth metatarsal bone and partial removal of metatarsal bone exostoses reduced osseous impingement on the suspensory ligament and created increased space for the pathologically altered soft tissue structures to heal.

Keywords: equine surgery, chronic proximal suspensory ligament desmopathy, enthesopathy, metatarsal bone exostosis, sclerosis

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Introduction

Proximal suspensory ligament desmopathy (PSLD) is a common cause of lameness in pleasure and performance horses (*Gibson* and *Steel* 2002, *Gomez* 2003, *Trump* et al. 2014) and occurs in both forelimbs and hindlimbs (*Dyson* 2000). The chronicity of some of these lesions when initially identified may be due to sub-clinical pre-existence and an associated unrecognized low grade lameness (*Dyson* 2000). Osseous impingement on the suspensory ligament (SL) and chronic pain have been described as sequelae to exostosis of the second or fourth metacarpal bones (MCII/MCIV) (*Owen* et al. 2019, *Zubrod* and *Kristek* 2019), however, there is debate on whether SL injury may precede bone exostosis (BE) or vice versa (*Butler* et al. 2009). Diagnosis is based on the results of lameness evaluation and diagnostic anesthesia, in combination with various imaging modalities including ultrasonography (*Dyson* 2000 and 2003, *Denoix* et al. 2010, *Labens* et al. 2010, *Zauscher* et al. 2013, *Denoix* and *Bertoni* 2015), radiography (*Dyson* 1991 and 2000, *Zekas* and *Forrest* 2003, *Trump* et al. 2014), nuclear scintigraphy (*Edwards* et al. 1995, *Dyson* et al. 2006, *Dyson* et al. 2007), computed tomography (CT) (*Müller-Kirchenbauer* et al. 2001) and/or magnetic resonance imaging (MRI) (*Zubrod* et al. 2004, *Brokken* et al. 2007, *Nagy* and *Dyson* 2012, *Barrett* et al. 2018, *Dyson* et al. 2018). There is a large variety of conservative treatment methods which include stall rest in combination with controlled exercise (*Dyson* et al.1995), extracorporeal shockwave treatment (*Brems* 2001, *Siedler* 2002, *Lischer* et al. 2006), radial pressure wave therapy (*Boening* et al. 2000, *Furlong* and *Revenaugh* 2001, *Löffeld* et al. 2002, *Crowe* et al. 2004) intralesional injection of bone marrow (*Herthel* 2001) and local administration of polysulfated glycosaminoglycans and corticosteroids (*Dyson* and *Genovese* 2003). Surgical therapies, such as osteostixis of the palmar/plantar aspect of the proximal third metacarpal (MCIII) or third metatarsal (MTIII) bones (*Müller-Kirchenbauer* 2001, *Launois* et al. 2003) and plantar fasciotomy and neurectomy of the deep branch of the lateral plantar nerve (DB-LPN) in hindlimbs have been described in cases unresponsive to conservative management (*Bathe* 2003, *Dyson* and *Murray* 2011). However, concurrent bony pathology may result in lameness of prolonged duration (*Dyson* et al. 2006), and horses with poor conformation or metatarsophalangeal joint hyperextension may not respond as favorably as those without (*Dyson* and *Murray* 2011). In cases where axial exostoses of splint bones (MTII/MTIV) impinge on the SL or where adhesions have formed, ostectomy of the affected structure proximal to the level of the exostosis and removal of the entire splint distal to the exostosis (*Milne* and *Turner* 1979) as well as segmental ostectomy of the affected splint bone have been reported (*Jenson* et al. 2004). This case report describes successful treatment of a horse with severe chronic-active PSLD and enthesopathy accompanied by axial splint BE in a hindlimb after unsuccessful conservative management and plantar fasciotomy and neurectomy. While surgical treatment of MCII exostoses in cases of suspensory ligament body desmitis (SLBD) has been described earlier (*Owen* et al. 2019), a case report describing MTIV resection and partial removal of plantarolateral metatarsal BE for treatment of chronic hindlimb PSLD has not been published previously to the authors´ knowledge.

Case report

A 9-year-old German Warmblood gelding used for showjumping was presented for further diagnosis and treatment of a chronic right hindlimb (RH) lameness of more than 2 years duration. One year prior to admission, a different veterinarian diagnosed the horse with right hind PSLD. Diagnosis was made based solely on improvement of the lameness after infiltration of the SL origin. Conservative treatment including extracorporeal shock wave therapy and local corticosteroid injections failed to improve the lameness, hence subsequent fasciotomy and neurectomy of the DB-LPN followed by stall rest for 6 weeks was performed. Digital radiographs or other diagnostic imaging modalities were not performed beforehand. The lameness grade of 3/5 on the AAEP lameness scale 18 months after initial surgery was worse than it had been before surgery (2/5). At that point, surgical removal of radiographically evident abaxial MTII bone exostoses (BE) was performed. After six months at pasture, the lameness grade returned to the grade prior to initial surgery (2/5).

Clinical findings

The gelding presented with a 2/5 RH (AAEP scale) lameness and mild soft tissue swelling of the lateral and plantaroproximal aspect of the metatarsus. There was surgical site scar related to the known fasciotomy and neurectomy. Palpation of the proximoplantar soft tissue structures provoked a pain response, slight edema and localized heat were evident. Distal limb flexion with pressure applied on the level of the proximal SL worsened the lameness. A low 6-point nerve block (plantar nerve, plantar metatarsal nerve, dorsal metatarsal nerves) and intra-articular analgesia of the tarsometatarsal joint (TMTJ) was performed to exclude pain arising from both the distal aspect of the limb and the TMTJ (*Dyson* and *Murray* 2011), but did not alter the lameness. The lameness was completely abolished 5 minutes after infiltration of 5 ml local anesthetic at the SL origin.

Diagnostic imaging

Radiography

Digital radiographs[a] of the tarsal and metatarsal region of the right limb were obtained comprising three views (dorsoplantar DP, dorso45°lateral plantaromedial oblique DLPMO and dorso45°medial plantarolateral oblique DMPLO). Subjective thickening of the plantar cortex and patchy increased opacity of the trabecular bone of the plantaroproximal aspect of MTIII (slightly more pronounced at the lateral aspect) could be seen (figure 1 and 2). Palisading, solid bone formation was visible at the plantar and suspected at the axial margin of the proximal portion of MTII (proximal to distal length approx. 5 cm; figures 1 and 2). Focal, solid and slightly palisading bone formation was noted at the abaxial aspect of the MTIV additionally (figures 1 and 2A). In conclusion, chronic PSLD and lateral and medial splint BE with suspicion of medial exostosis at MTII were diagnosed radiographically.

Ultrasonography

Ultrasonographic examination in transverse and longitudinal planes in weightbearing and non-weightbearing position using a 12 MHz linear probe (digital color doppler ultrasound system[b]) demonstrated marked enlargement and poor demarcation of the proximal part of the suspensory ligament (PSL) and the suspensory ligament body (SLB) and an irregular plantar contour of

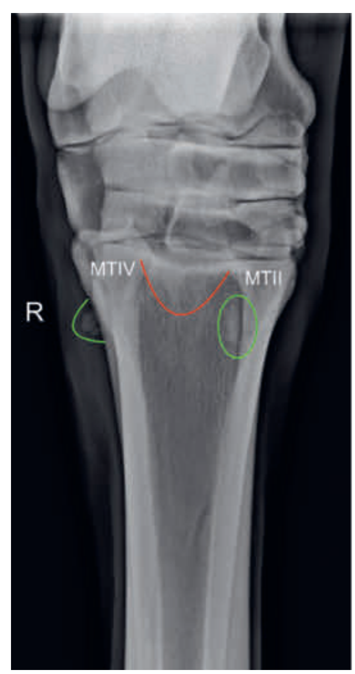

Fig. 1 Dorsoplantar view of the right tarsal and metatarsal region performed at the first presentation. Bone exostoses at MTII and MTIV are highlighted in green, subchondral sclerosis of the origin of the SL in red. | *Dorsoplantare Röntgenaufnahme der rechten Tarsal- und Metatarsalregion. Markierung der Exostosen an MTII und MTIV in grün zum Zeitpunkt der erstmaligen Vorstellung. Die subchondrale Sklerose am Fesselträgerursprung ist rot markiert.*

MTIII at the level of the proximal attachments of the SL. Loss of normal architecture in the fiber pattern and diffuse decrease in echogenicity, and evidence of significant mineralization within the PSL substance and within the SLB (hyperechogenic lines and stipples with distal acoustic shadowing) were noted (compare to figure 3, green circle). These findings extended to the distal third of the metatarsus being consistent with chronic suspensory desmopathy and enthesopathy with new bone formation at the proximal entheses. Additionally, a focal hypoechoic area was seen at the PSL origin; interpreted as a focal acute lesion. Doppler ultrasonography showed increased vascularity within the PSL and SLB suggesting an active component.

Computed Tomography

Computed tomography of the proximal metatarsal region including the distal tarsal joints to the level of the distal third of the metatarsus (figure 3) was performed. Physical examination was unremarkable and an intravenous catheter was inserted in the left jugular vein. Following sedation with xylazine[c] (1 mg/kg bwt IV) and butorphanol[d] (0.01 mg/kg bwt IV) the horse was anesthetized with ketamine[e] (2.2 mg/kg bwt IV) and diazepam[c] (0.05 mg/kg bwt IV). The gelding was positioned in right lateral recumbency with the affected limb within the isocenter of the CT gantry (longitudinal axis of the leg orientated perpendicular to the beam, i.e. parallel to the long axis of the table). A non-contrast study was performed with a 4-slice helical CT scanner[f]. Technical parameters were: 120 kV, 200 mAs; slice thickness 1 mm, pitch 1, rotation time 1 second; 38 cm field of view and matrix of 512 × 512). The images were reconstructed (increment of 0.8 mm; sagittal and dorsal planes) and interpreted using the DICOM medical imaging viewer Horos[g] in bone (window width, WW: 2500 HU, window level, WL: 450 HU) and soft tissue (WW: 350 HU, WL: 105 HU) algorithms. No contrast media was used for the examination.

CT data revealed marked osseous proliferation and roughening of the plantar aspect of the second, third and fourth tarsal bones (figures 4 and 5) associated with the proximal attachments of the proximal SL, most pronounced at the fourth tarsal bone and third metatarsal bone (figure 5A). Multiple pointed osteophytes associated with the plantar margins of the TMTJ and bridging bone formation between the third tarsal bone and MTIII (figure 5B) were evident. Small pointed bone projections were evident on the proximal margins of MTII and MTIV (figure 4). There was marked irregular endosteal thickening (sclerosis) of the plantar cortex and hyperattenuation of the trabecular bone, with loss of normal trabecular architecture of MTIII at the level of the PSL enthesis (figure 4). There was marked entheseous bone

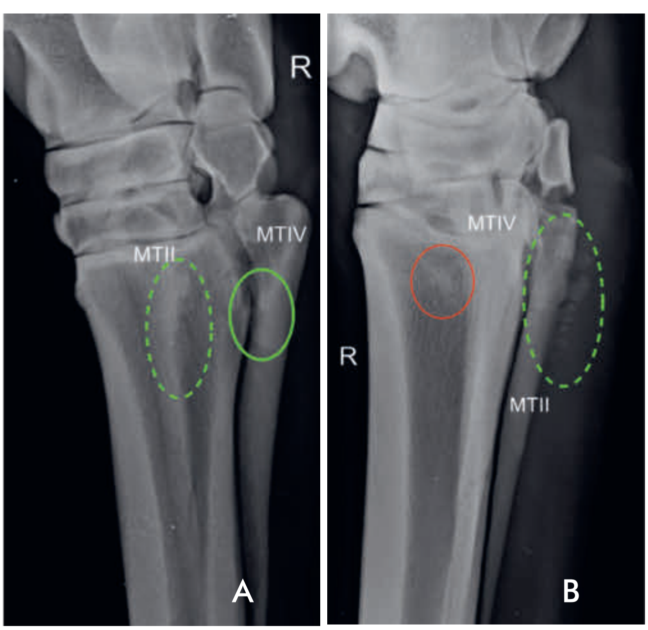

Fig. 2 Oblique views of the right tarsus/metatarsus: bone exostoses are highlighted in green (MT VI continuous line, MTII dashed line), subchondral sclerosis of the origin of the SL in red. A: D45°L-PMO view projecting the fourth metatarsal bone. B: D45°M-PLO view projecting the second metatarsal bone | *Schrägaufnahmen der rechten Tarsal-/Metatarsalregion: Exostosen sind grün markiert (MTIV durchgezogene Linie, MTII gestrichelte Linie), die subchondrale Sklerose im Bereich des Fesselträgerursprungs in rot. A: D45°L-PM-Schrägaufnahme, das laterale Griffelbein (MTIV) herausprojizierend. B: D45°M-PL-Schrägaufnahme, das mediale Griffelbein (MTII) herausprojizierend.*

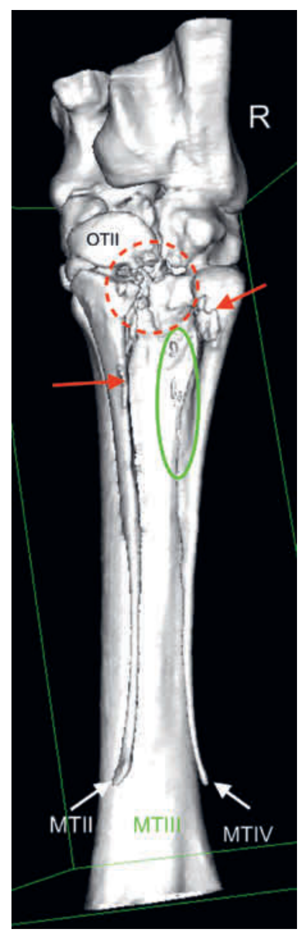

Fig. 3 Plantar view of a 3D reconstruction (surface rendering) of the right hind tarsal and metatarsal region. The green circle indicates multifocal mineralizations within the PSL. New bone formation is marked with the red dashed circle (MTII, MTIII and 2nd tarsal bone (OTII) as well 3rd and 4th tarsal bone) and red arrows (MTII and MTIV). | *Plantare Ansicht einer drei-dimensionalen Darstellung von Tarsus und Metatarsus rechts. Der grüne Kreis markiert multifokale Mineralisationen im Fesselträger. Knöcherne Zubildungen werden durch den rot-unterbrochenen Kreis (MTII, MTIII, Os tarsale II (OTII) sowie Ossa tarsalia III und IV) und rote Pfeile (MTII und MTIV) hervorgehoben.*

formation on the plantar aspect of MTIII associated with the PSL enthesis spanning from medial to lateral, with a largest one (13.5 mm length) evident at the medial plantar margin adjacent to MTII extending plantarly into the PSL (figure 4). The PSL was profoundly enlarged at the enthesis affecting both medial and lateral lobes, extending distally into the SLB with no apparent normal internal hypodense (fat/muscle/connective tissue) architecture in either lobe (figures 4 and 6). Additionally, numerous regions of linear mineralization were evident in the substance of the PSL and within the SLB (small foci to strands of up to 3 cm in length; figures 3 and 6). Marked bridging bone formation between the proximal thirds of MTIII and MTIV and overlying soft tissue swelling of the lateral aspect of the limb was noted as well as entheseous bone formation on the axial aspect of MTII projecting to the PSL margins (figures 5). In summary, CT revealed 1) severe PSLD, enthesopathy and dystrophic mineralization extending into the SLB, and marked MTIII plantar cortical thickening without evidence of plantar cortex fracture, 2) chronic BE of the third-fourth metatarsal bones, 3) moderate degenerative joint disease of the TMTJ and enthesopathy of the plantar tarsal soft tissue entheses onto the distal tarsal bones. The horse made a good recovery from general anesthesia following CT examination.

The severity of imaging findings in combination with a lack of clinical improvement to conservative and standard PSLD therapies over the past 2 years indicated a novel treatment approach. The potential risks of TMTJ instability subsequent to further surgical intervention and general anesthesia risks were discussed with the owner and the decision was made to proceed with surgery.

Surgical treatment

The aim of the proposed novel approach was to heal chronic PSLD via proximal segmental MTIV ostectomy in combination with partial removal of proximal lateroplantar MTIII BE pressing on the PSL. Our hypothesis was that the surgical procedure would reduce pressure on the soft tissues and allow more space for the profoundly swollen PSL to heal outside the rigid borders formed by the proximal splint bones.

Clinical examination and presurgical bloodwork including complete blood cell count and chemistry were unremarkable. A catheter was placed in the right jugular vein for administration of perioperative gentamicin[h] (6.6 mg/kg bwt IV SID, for 24 h) and phenylbutazone[i] (4.4 mg/kg bwt IV BID, for 24 h). Benzylpenicillin procain[j] (22.000 I.U./kg bwt BID for 24 h) was given intramuscularly. The gelding was sedated and anesthetized as described above (section "Computed tomography"), and placed in left lateral recumbency. Surgical anesthetic plane was maintained with isoflurane[c] and oxygen administered via a large animal breathing circuit. Proximal resection of MTIV was performed as described

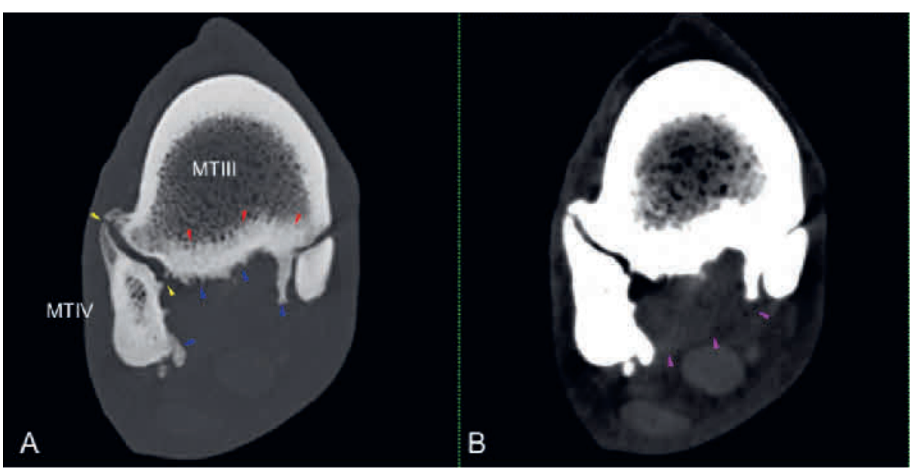

Fig. 4 Transverse CT images of the right hind metatarsal region in bone (A) and soft tissue algorithm (B) approximately 1 cm distal to the tarsometatarsal joint. Red arrowheads indicate plantar cortical sclerosis, blue arrows large enthesophytes at the plantar aspect of MTIII, yellow arrows remodeling of the fourth metatarsal bone and bridging bone to the third metatarsal bone and purple arrowheads indicates the thickened SL. | *CT-Bild in Transversalebene in Knochen- (A) und Weichteil-Algorithmus (B) ca. 1 cm distal des Tarsometatarsalgelenks. Die roten Pfeile zeigen plantare kortikale Sklerosierungen, die blauen Pfeile große Enthesophyten, die gelben Pfeile Umbauvorgänge am MTIV und Knochenbrücken zum MTIII und die lila Pfeile die kaudale Kontur des verdickten Fesselträgers.*

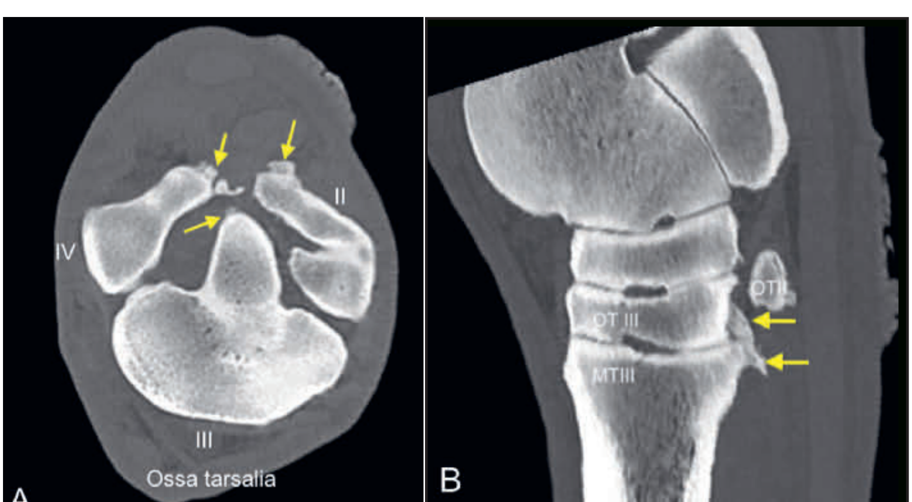

Fig. 5 Transverse (A) and sagittal (B) reformatted CT images of the right tarsus on the level of the distal tarsal bones (A) respectively in a medial paramedian plane (B) in bone algorithm. Yellow arrows indicate new bone formation at 2nd, 3rd and 4th tarsal bone (A, B) and bridging new bone formation between 3rd tarsal (OTIII) and 3rd metatarsal bone (MTIII; B). | *Transversale (A) und sagittale (B) reformatierte CT-Bilder des rechten Tarsus auf Höhe der distalen Tarsalknochenreihe (A) bzw. in einer leicht medial gelegenen paramedianen Ebene (B) im Knochenalgorithmus. Gelbe Pfeile markieren knöcherne Zubildungen an den Ossa tarsalia II, III und IV (A) und überbrückende Zubildungen zwischen Os tarsale III (OTIII) und Os metatarsale III (MTIII; B).*

previously (*Baxter* et al. 1992): To facilitate haemostasis, a wide rubber tourniquet was placed proximal to the tarsus. After aseptic preparation of the surgery site, a vertical skin incision was created over the junction between MTIII and MTIV extending from the proximal third of MTIV to the level of the TMTJ space, which was identified by placement of a 20 gauge, 3.3 cm needle. After blunt dissection of the subcutaneous tissues, the proximal third of MTIV was obliquely ostectomized with an osteotome. MTIV and its periosteum were elevated from the surrounding tissues and sharply dissected from MCIII. Tissues were manipulated carefully in order to avoid accidental injury of the metatarsal artery. Periosteal elevators and an osteotome were used to separate the abnormally adhered SL from the axial border of MTIV. Proximal ligamentous attachments including the long lateral collateral and long plantar ligament were sharply transected and the MTIV head was disarticulated from its articulation with the fourth tarsal bone. The proximal third of MTIV was removed with the distal two-thirds of the MTIV left in situ. The tarsal fascia at the attachment to MTIV appeared thickened and there was substantial bone remodeling at the plantarolateral margins of MTIII. After removal of bony fragments and incision lavage with Ringer's lactate solution; periosteal elevators were used to palpate the region of bone proliferation and to partially separate the plantarolateral SL from the irregular lateral border of MTIII to create access to the region of interest. Curettage was performed to remove the impinging new bone formation at the lateral aspect of MTIII located about 3 cm distal to the TMTJ. The method has been described previously by *Launois* et al. (2009). Adhesions identified between the abaxial surface of MTIII and the SL were sharply transected with a ligament knife. Subsequently, reactive bone bridging between third tarsal bone and MTIII resp. between MTIII and former position of MTIV as well as the smaller spurs at the proximal aspect of MTIII were resected with chisels and periosteal elevators. The surgical site was lavaged prior to primary incision closure. Subcutaneous tissue was closed in two layers with a simple continuous pattern using 2/0 absorbable monophilic suture material. The skin was closed with a simple interrupted pattern using 2/0 non-absorbable monophilic suture material. A padded bandage with full-length hindlimb cast including the hoof and extending to the proximal tibia was applied for recovery and for the 10 days postoperatively to minimize the risk of possible subsequent instability or luxation of the TMTJ (*Jackson* and *Auer* 2012). The horse recovered uneventfully from general anesthesia.

Post-operative care, follow-up and outcome

Following recovery, phenylbutazone[i] was continued every 12 h (2.2 mg/kg bwt p.o.) for 7 days after surgery and then reduced to every 24 h administration (2.2 mg/kg bwt p.o.) for 7 days. The full-length limb cast was removed 10 days post-surgery due to the development of pressure sores. At 14 days post-surgery, skin sutures were removed. The patient was fully weight-bearing and discharged 14 days following surgery with instructions to keep both hindlimbs bandaged for another 4 weeks; changed at regular intervals whilst on strict stall rest for 4 weeks, followed by 4 weeks of stall rest combined with hand-walking at 5 minutes twice daily increasing by 5 minutes weekly (*Owen* et al. 2019). Two months post-surgery, light work at trot was commenced. Before introduction of ridden exercise, the gelding was turned out on a small paddock with continued hand-walking for 15–20 minutes twice daily. On recheck examination 6 weeks post-surgery, palpation of the proximal plantar soft tissue structures was not painful and limb flexion with pressure applied over the PSL did not result in lameness at the trot. The gelding was sound at walk and trot in a straight line on firm ground. A DLPMO follow-up radiograph of the metatarsal region was obtained 6 weeks post-surgery (figure 7). The proximal contour of the remaining distal two thirds of MTIV was smoothly delineated with a thin sclerotic line closing the medullary cavity of MTIV. In the proximal plantar metatarsus, small structures of mineral opacity (variable shape, from stipples to irregular linear shape) were noted within the soft tissues and presumed to be dystrophic mineralization at the surgery site within the SL noted on CT, or the surrounding soft tissues (figure 7). Non-weightbearing Doppler ultrasonography 3 months post-surgery revealed minimal evidence of intraligamentous PSL and SLB blood flow (markedly reduced compared to pre-operative images). Since no ultrasonographic signs of increased vascularity were apparent 6 months post-surgery, the horse was re-introduced to ridden work and remained sound. Another DLPMO follow-up radiograph 9 months post-surgery indicated new bone formation and bone modelling at the surgery site (figure 8 compared to figure 7): structures of mineral opacity increased in size with rounded margins were noted. 18 months post-surgery, the

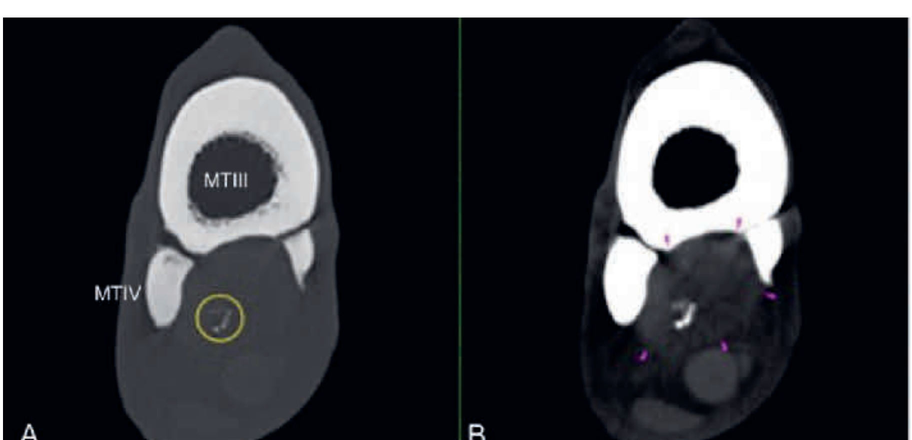

Fig. 6 Transverse CT images on a bone (A) and soft tissue algorithm (B) approx. 6 cm distal to the TMTJ. Yellow circle indicates mineralization of the PSL, which is markedly enlarged (purple arrowheads). | *Transversale CT-Bilder in Knochen- (A) und Weichteil-Algorithmus (B) ca. 6 cm distal des Tarsometatarsalgelenks. Der gelbe Kreis zeigt die Mineralisierung des proximalen Fesselträgers, der deutlich vergrößert ist (lila Pfeile).*

horse remained sound and was competing successfully as a show jumper at international events.

Discussion

Various analgesic techniques have been described to localize pain arising from the PSL including local analgesic PSL infiltration and block of the DB-LPN, but none of the techniques are specific (*Wheat* and *Jones* 1981, *Ford* et al. 1989, *Stashak* 2002, *Castro* et al. 2005, *Bassage* and *Ross* 2002). In the present case, local infiltration of the SL origin was chosen after pain arising from the TMTJ and SLB were excluded beforehand. Diffusion of local anesthetic and inadvertent penetration into adjacent synovial structures is a common problem when diagnosing proximal metatarsal pain (*Leelamankong* et al. 2018, *Hughes* et al. 2007). Anesthesia of the DB-LPN would have been helpful to address the question if neurectomy of the DB-LPN resulted in complete resection of the nerve or if reinnervation occurred. However, DB-LPN block is not specific either for lesions of the SL origin or for conditions in the proximal metatarsal region (*Labens* et al. 2010). Furthermore, DB-LPN block can result in inadvertent anesthesia of the lateral plantar nerve which can lead to pathological conditions of the distal lateral limb responding to the DB-LPN block, thus providing a misleading result as to lameness origin (*Hinnigan* et al. 2014). The fast resolution of lameness after SL infiltration in combination with a negative response to low 6-point block at mid metatarsal level and TMTJ block prior to SL infiltration suggest that the pathological changes at the level of the SL origin are the most significant factors leading to chronic lameness history in this case. According to this blocking pattern, only the proximal PSLD was addressed with the attempted surgical approach even though both, ultrasonography and CT revealed substantial chronic PSLD as well as desmopathy of the SLB.

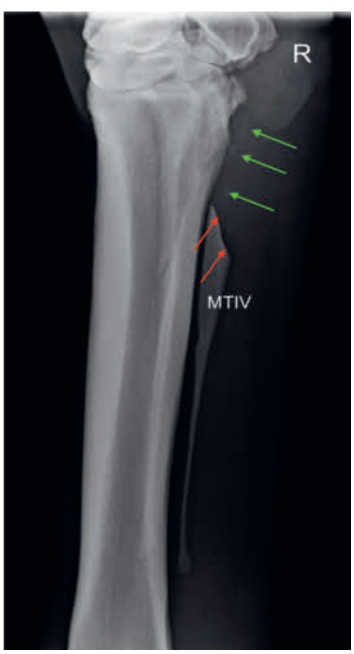

Fig. 7 D45°L-PMO view of the right tarsus/metatarsus: status approx. 6 weeks after surgical removal of the proximal third of MTIV. Smooth delineation of the proximal contour of the remaining part of MTIV with a thin sclerotic line closing the medullary cavity of MTIV (red arrows). Small structures of mineral opacity (variable shape, from stipples to irregular linear shape) within the soft tissues at the surgery site (green arrows). | *D45°L-PM-Schrägaufnahme von rechtem Tarsus/Metatarsus etwa 6 Wochen nach chirurgischer Entfernung des proximalen Drittels von MTIV. Gut abgrenzbare proximale Kontur des verbleibenden, distalen Anteils des lateralen Griffelbeins. Eine feine sklerotische Linie weist auf den Verschluss der Markhöhle von MTIV hin (rote Pfeile). Kleine mineraldichte Strukturen unterschiedlicher Form sind in den Weichteilen im Operationsgebiet zu erkennen (grüne Pfeile).*

Though a high level of success (77.8%) has been described for plantar fasciotomy and neurectomy (*Dyson* and *Murray* 2011), a prerequisite for successful management is recognition of concurrent comorbidities which could reduce treatment efficacy (*Dyson* 1994, 1995 and 2007, *Dyson* and *Genovese* 2010). Radiography and ultrasonography were helpful diagnostic modalities in the present case, however, conclusive diagnosis and detailed surgical planning was only obtained with CT, as the size and extent of osseous and soft tissue lesions became apparent.

A limitation of the CT study is that administration of intra-arterial contrast media was not performed. A post-contrast study would have been beneficial to determine the extent of neovas-

Fig. 8 D45°L-PMO view of the right tarsus/metatarsus: status approx. 9 months after surgical removal of the proximal third of MTIV. Solid new bone formation with irregular, but smooth margins plantarolaterally at the fourth tarsal bone and MTIII bridging the TMTJ (yellow arrows), less pronounced at the plantarolateral contour of MTIII (red arrows), within the soft tissues (green arrows) and proximally at the resection site of MTIV (bridging to MTIII; dashed red line). | *45°L-PM-Schrägaufnahme von rechtem Tarsus/Metatarsus etwa 9 Monate nach chirurgischer Entfernung des proximalen Drittels von MTIV. Solide, das Tarsometatarsalgelenk (TMTJ) überbrückende Knochenneuformationen mit unregelmäßigen, aber glatten Rändern sind plantarolateral am Os tarsale IV und MTIII zu sehen (gelbe Pfeile), weniger auffällige Neubildungen an der plantarolateralen Kontur von MTIII (rote Pfeile), in den Weichteilen (grüne Pfeile) und proximal an der Resektionsstelle von MTIV mit Brückenbildung zu MTIII (gestrichelte rote Linie).*

cularization and thus potentially the extent of active pathology present within the soft tissues. However, ultrasonographic examination of the limb with use of Doppler technique has been described to detect neovascularization in chronic tendon injuries in horses and man (*Kristoffersen* et al. 2005) and was performed prior to CT in this case. High-field MRI, described as a definitive method to visualize the axial splint bone margins (*Zubrod* et al. 2004) and to provide detailed information about the soft tissue structures of the proximal metatarsal region of the hindlimb (*Labens* et al. 2010, *Dyson* et al. 2017), was not available for this case.

In this horse, excision of the proximal third of MTIV was undertaken due to severe chronic proximal MTIV BE and marked PSL swelling causing impingement of the SL. The technique has been chosen in spite of generally accepted considerations that not more than the distal two-thirds of a splint bone should be removed in order to maintain TMTJ stability (*Jackson* et al. 2007). Despite the fact that the majority of large spurs were located at the axial aspect of MTII in the present case, MTIV was removed instead of MTII as removal of a splint bone including TMTJ exarticulation is exclusively recommended for MTIV. This procedure has been described for treatment of multi-fragment fractures of the proximal portion of this bone (*Baxter* et al. 1992). Though the articulation between MTIV and the fourth tarsal bone is small in size (*Baxter* et al. 1992, *Jackson* and *Auer* 2012) providing minimal weight transfer (*Baxter* et al. 1992), there is a potential risk of instability or luxation of the TMTJ (*Jackson* and *Auer* 2012) as proximal ligamentous attachments including the long lateral collateral and long plantar ligament have to be transected in order to perform segmental MTIV ostectomy (*Baxter* et al. 1992). In order to reduce these risks in our patient, a full-length hindlimb cast was applied for recovery and maintained for another 10 days post-surgery. *Jackson* and *Auer* (2012) recommend to leave a full-length hindlimb cast in place for 4 weeks after complete MTIV resection, but since our patient developed pressure sores, the cast had to be removed after 10 days. Yet, further recovery of the horse was uneventful.

The significant mineralization within the SL substance was most likely dystrophic secondary to chronic desmopathy. Furthermore, the marked bony changes at the proximal entheses resulting in large bony spicules projecting into the ligament, plantar cortical remodeling and sclerosis were likely major contributors to the chronic lameness and failure of primary performed treatments (fasciotomy and neurectomy, removal of axial MTII BE). There remains the possibility that a significant bone marrow lesion may have been present in the third metatarsal bone, which could have only been detected using MRI, this could also have responded to the period of rest that the horse undertook following surgery. It is possible that inadvertent iatrogenic damage of plantar metatarsal nerve fibers during segmental ostectomy and partial plantar metatarsal curettage may have contributed to the fast postsurgical recovery. As multiple surgical procedures were performed in this horse, contribution of each procedure to the improvement in lameness is unknown (*Launois* et al. 2009).

The attempt to remove plantarolateral MTIII BE and hence probable iatrogenic fiber disruption at the origin of the SL included the risk of weakening SL integrity. Doppler ultrasonography 6 months post-surgery however did not show evidence of active lesion within the SL or at the site of plantar metatarsal curettage. A follow-up contrast CT scan would have been interesting to monitor the activity of pathological and look for possible iatrogenic lesions, but would have significantly increased the costs and required another general anesthesia and the gelding was sound and clinically doing well upon recheck-examinations, therefore, being unjustifiable.

The current case report describes the first attempt to perform segmental ostectomy of a splint bone opposing to the majority of MTIII BE in combination with partial removal of MTIII BE as possible treatment method for chronic PSLD. The novel approach described in this case report aimed 1.) to allow more space for the PSL to heal outside the rigid borders formed by the proximal splint bones and hence to remove impingement on the PSL, 2.) to remove MTIII BE pressing on the PSL and 3.) to avoid the risks described for proximal MTII resection (*Baxter* et al. 1992). Surgical removal of MTIII/MCIII BE in combination with osteostixis has been described as a successful treatment method in horses with chronic PSLD (*Launois* et al. 2009) and osteostixis in combination with plantar fasciotomy was found to be successful in horses with chronic proximal metatarsal pathology (*Müller-Kirchenbauer et al*. 2001). It is debatable whether additional proximal metatarsal osteostixis (*Launois* et al. 2003) could have provided further therapeutic benefits in this case, however, rapid post-surgical return to athletic function support the success of the described novel technique. As mentioned above, it remains a possibility that in the initial surgery the neurectomy component was unsuccessful as a confounding factor. Therefore, it would have been an option to re-open the metatarsal fascia and to verify complete resection of the DB-LPN visually during surgery.

While the marked bridging bone formation between the proximal thirds of MTIII and MTIV as well as between the third tarsal bone and MTIII, the small pointed bone projections associated with the proximal margins of MTIV and lateral plantar MTIII BE were successfully removed, complete removal of MTIII entheseous bone formation and large bony projections at the plantaromedial margin adjacent to MTII was not possible due to their anatomic location. Since additional proximal MTII resection could have had fatal consequences for TMTJ instability or luxation, this option was ruled out. Radiographic examination 9 months post-surgery revealed solid bone formation at the former surgery site as well as changes indicating TMTJ arthrosis. Reinjury of PSLD is common (*Dyson* and *Murray* 2011) and given the fact that leaving a portion of the exostosis can potentially provide a nidus for adhesion formation and recurrent exostosis (*Zubrod* and *Kristek* 2019), the gelding remains at risk of reinjury and subsequent lameness. Further complications such as worsened TMTJ arthrosis has previously been described as potential consequence of TMTJ instability (*Jackson* et al. 2007) and was encountered in this specific case; though osteophytes were evident prior to surgical intervention. However, unsuccessful standard PSLD treatment methods and chronicity of lameness provided indication for a novel approach. The rapid post-operative recovery suggests that the currently described technique reduced SL impingement and contributed to the resolution of the chronic lameness.

Conclusion

Proximal resection of MTIV in combination with partial removal of plantar metatarsal BE resulted in successful resolution of chronic lameness in a horse with severe chronic PSLD, enthesopathy and MTII/MTIV BE after failure of previous fasciotomy and neurectomy of the DB-LPN. The described technique is rapid and easy to perform given the fact that accurate diagnostic imaging preceded the procedure. CT examination provided vital information with regards to exact extent of the lesions facilitating detailed surgical planning to shorten anesthesia duration. However, additional studies involving a larger number of horses with a study design clarifying the described uncertainties are necessary to confirm the successful outcome of the present case.

Manufacturer's addresses

- [a] FujiFilm wireless DR system FDR D-EVO G35i, FujiFilm Europe, Germany
- [b] SonoScape Digital Color Doppler Ultrasound System E2V, SonoScape Medical Corporation, China
- [c] Ecuphar, Germany
- [d] Zoetis, Germany
- [e] Medistar, Germany
- [f] Siemens Somatom, Siemens Healthcare GmbH, Germany
- [g] Horos Viewer v3.3.6, www.horosproject.com
- [h] CP-Pharma, Germany
- [i] Vetoquinol, Germany
- [j] Livisto, Germany

Conflict of interest

No conflict of interest has been declared.

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References

Barrett M. F., Manchon P. T., Hersman J., Kawcak C. E. (2018) Magnetic resonance imaging findings of the proximal metacarpus in Quarter Horses used for cutting: Retrospective analysis of 32 horses 2009–2012. Equine Vet. J. 50, 172–178; DOI 10.1111/evj.12746

Bassage L., Ross M. (2002) Diagnostic analgesia. In: Diagnosis and management of lameness in the horse. Saunders, Philadelphia, 105–106

Bathe A. P. (2003) Plantar metatarsal neurectomy and fasciotomy for treatment of hindlimb proximal suspensory desmitis. Vet. Surg. 32, 480

Baxter G. M., Doran R. E., Allen D. (1992) Complete excision of a fractured fourth metatarsal bone in eight horses. Vet. Surg. 21, 273–278; DOI 10.1111/j.1532-950x.1992.tb00063.x

Boening K.-J., Löffeld S., Weitkamp K., Matuschek S. (2000) Extracorporeal Shock Wave Therapy for Chronic Insertion Desmopathy of the Suspensory Ligament. Proceedings of the 53rd AAEP Convention. San Antonio, Texas, 203–207

Brems R. (2001) Shock wave therapy: principles and technique, application and comparison with other therapeutic techniques. Proceedings of the 7th Congress on Equine Medicine and Surgery. Geneva, Switzerland

Brokken M. T., Schneider R. K., Sampson S. N., Tucker R. L., Gavin P. R., Ho C. P. (2007) Magnetic resonance imaging features of proximal metacarpal and metatarsal injuries in the horse. Vet. Radiol. Ultrasound 48, 507–517; DOI 10.1111/j.1740-8261.2007.00288.x

Butler J. A., Colles C., Dyson S. J., Kold S. E., Poulos P. W. (2009) Clinical Radiology of the Horse. 3rd edn. Wiley-Blackwell, Hoboken, New Jersey

Castro F. A., Schumacher J. S., Pauwels F., Blackford J. T. (2005) A new approach for perineural injection of the lateral palmar nerve in the horse. Vete. Surg. 34, 539–542

Crowe O. M., Dyson S. J., Wright M., Schramme M. C., Smith R. K. W. (2004) Treatment of chronic or recurrent proximal suspensory desmitis using radial pressure wave therapy in the horse. Equine Vet. Educ. 36, 313–316; DOI 10.2746/0425164044890562

Denoix J.-M., Bertoni L. (2015) The angle contrast ultrasound technique in the flexed limb improves assessment of proximal suspensory ligament injuries in the equine pelvic limb. Equine Vet. Educ. 27, 209–217; DOI 10.1111/eve.12303

Denoix J. M., Coudry V., Jacquet S. (2010) Ultrasonographic procedure for a complete examination of the proximal third interosseous muscle (proximal suspensory ligament) in the equine forelimbs. Equine Vet. Educ. 20; DOI 10.2746/095777308X282381

Dyson S. J. (2000) Proximal Suspensory Desmitis in the Forelimb and the Hindlimb. Proceedings of the 46th Annual AAEP Convention. 46, 137–142; DOI 10.3920/978-90-8686-577-2

Dyson S. J., Pinilla M. J., Bolas N., Murray R. (2018) Proximal suspensory desmopathy in hindlimbs: Magnetic resonance imaging, gross post-mortem and histological study. Equine Vet. J. 50, 159–165; DOI 10.1111/evj.12756

Dyson S. J. (1991) Desmitis of the accessory ligament of the deep digital flexor tendon: 27 cases. (1986–1990). Equine Vet. Educ. 23, 438–444; DOI10.1111/j.2042–3306.1991.tb03757.x

Dyson S. J. (1994) Proximal suspensory desmitis in the hindlimb: 42 cases. Brit. Vet. J. 150, 279–291; DOI 10.1016/S0007-1935(05)80008-9

Dyson S. J. (1995) Proximal suspensory desmitis in the hindlimb. Equine Vet. Educ. 7, 275–278

Dyson S. J, Arthur R. M., Palmer S. E., Richardson D. (1995) Suspensory ligament desmitis. Vet. Clin. North Am. - Equine Pract. 11, 177–215

Dyson S. J. (2003) Proximal metacarpal and metatarsal pain: a diagnostic challenge. Equine Vet. Educ. 15, 134–138; DOI 10.1111/j.2042-3292.2003.tb00231.x

Dyson S. J. (2007) Diagnosis and management of common suspensory lesions in the forelimbs and hindlimbs of sport horses. Clin. Techn. Equine Pract. 6, 179–188; DOI 10.1053/j.ctep.2007.08.004

Dyson S. J., Blunden A., Murray R. (2017) Magnetic resonance imaging, gross postmortem, and histological findings for soft tissues of the plantar aspect of the tarsus and proximal metatarsal region in non-lame horses. Vet. Radiol. Ultrasound 58, 216–227; DOI 10.1111/vru.12444

Dyson S. J., Genovese R. L. (2003) The suspensory apparatus. in *Ross*, M. W. and *Dyson*, S. J. (eds) Lameness in the Horse. 1st edn., Saunders, Philadelphia, USA, 654–672

Dyson S. J., Genovese R. L. (2010) The suspensory apparatus. in *Ross M.* and Dyson S. J. (eds) Diagnosis and Management of Lameness in the Horse. 2nd edn. Elsevier, St. Louis, 738–760

Dyson S. J., Weekes J. S., Murray R. (2006) How Useful Is Nuclear Scintigraphy in the Diagnosis and Management of Proximal Suspensory Desmitis in the Horse. Proceedings of the 52nd AAEP Convention. San Antonio, Texas, 405–411

Dyson S. J., Weeks J. S., Murray R. C. (2007) Scintigraphic evaluation of the proximal metacarpal and metatarsal regions of horses with proximal suspensory desmitis. Vet. Radiol. Ultrasound 48, 78–85; DOI 10.1111/j.1740-8261.2007.00208.x

Dyson S., Murray R. (2011) Management of hindlimb proximal suspensory desmopathy by neurectomy of the deep branch of the lateral plantar nerve and plantar fasciotomy: 155 horses. (2003–2008). Equine Vet. J. 44, 361–367; DOI 10.1111/j.2042-3306.2011.00445.x

Edwards R. B., *Ducharme N. G.*, *Fubini S. L.*, *Yaeger A. E.*, *Kallfelz F. A.* (1995) Scintigraphy for diagnosis of avulsions of the origin of the suspensory ligament in horses: 51 cases. (1980–1993). J. Am. Vet. Med. Assoc. 207, 608–611; PMID 7649776

Ford T. S., *Ross M. W.*, *Orsini P. G.* (1989) A comparison of methods for proximal palmar metacarpal analgesia in horses. Vet. Surg. 18, 146–150; 10.1111/j.1532-950x.1989.tb01059.x

Furlong B., *Revenaugh M.* (2001) Radial Shock Wave Therapy for the Treatment of Insertion Desmopathies in Performance Horses. Proceedings of the British Columbia Veterinary Medical Association Meeting. Vancouver, British Columbia, 101–105

Gibson K. T., *Steel C. M.* (2002) Conditions of the suspensory ligament causing lameness in horses. Equine Vet. Educ. 14, 39–50; DOI 10.1111/j.2042-3292.2002.tb00137.x

Gomez J. H. (2003) Proximal suspensory desmitis in the hind limb. Proceedings - The North American Veterinary Conference, Large Animal. Gainsville, Florida, 148–149

Herthel D. J. (2001) Enhanced Suspensory Ligament Healing in 100 Horses by Stem Cells and other Bone Marrow Components. Proceedings of the 47th Annual AAEP Convention, 319–321

Hinnigan G., *Milner P. I.*, *Talbot A.*, *Singer E. R.* (2014) Is anaesthesia of the deep branch of the lateral plantar nerve specific for the diagnosis of proximal metatarsal pain in the horse? Vet. Comp. Orthop. Traumatol. 27, 351–357; DOI 10.3415/VCOT-13-12-0146

Hughes T. K., *Eliashar E.*, *Smith R. K.* (2007) In vitro evaluation of a single injection technique for diagnostic analgesia of the proximal suspensory ligament of the equine pelvic limb. Vet. Surg. 36, 760–764; 10.1111/j.1532-950X.2007.00333.x

Jackson M., *Fuerst A.*, *Hässig M.*, *Auer J.* (2007) Splint bone fractures in the horse: a retrospective study 1992–2001. Equine Vet. Educ. 19, 329–335; DOI 10.2746/095777307X207169

Jackson M. A., *Auer J. A.* (2012) Vestigial metacarpal and metatarsal bones. in *Auer*, J. A. and Stick, J. A. (eds) Equine Surgery. 4th edn. P. Rudolph, St. Louis, Missouri, 1339–1347

Jenson P. W., *Gaughan E. M.*, *Lillich J. D.*, *Bryant J. E.* (2004) Segmental ostectomy of the second and fourth metacarpal and metatarsal bones in horses: 17 cases. (1993–2002). J. Am. Vet. Med. Assoc. 224, 271–274; DOI 10.2460/javma.2004.224.271

Kristoffersen M., *Ohberg L.*, *Johnston C.* (2005) Neovascularisation in chronic tendon injuries detected with colour Doppler ultrasound in horse and man: implications for research and treatment. Knee Surg. Sports Traumatol. Arthrosc. 13, 505–508; DOI 10.1007/s00167-005-0648-3

Labens R., *Schramme M. C.*, *Robertson I. D.*, *Thrall D. E.*, *Rich Redding W.* (2010) Clinical, magnetic resonance, and sonographic imaging findings in horses with proximal plantar metatarsal pain. Vet. Radiol. Ultrasound 51, 11–18; DOI 10.1111/j.1740-8261.2009.01614.x

Launois M. T., *Vandeweerd J.-M.*, *Perrin R.*, *Brogniez L.*, *Desbrosse F.*, *Clegg P. D.* (2009) Use of computed tomography to diagnose new bone formation associated with desmitis of the proximal aspect of the suspensory ligament in third metacarpal or third metatarsal bones of three horses. J. Am. Vet. Med. Assoc. 234, 514–518; DOI 10.2460/javma.234.4.514.

Launois T., *Desbrosse F.*, *Perrin R.* (2003) Percutaneous osteostixis as a treatment for avulsion fractures of the palmar/plantar third metacarpal/metatarsal bone cortex at the origin of the suspensory ligament in 29 cases. Equine Vet. Educ. 15, 126–131; DOI 10.1111/j.2042-3292.2003.tb00229.x

Leelamankong P., *Estrada R. J.*, *Rungsri P.*, *Stäcker W.*, *Müller C.*, *Lischer C. J.* (2018) Objective evaluation of the response to perineural analgesia of the deep branch of the lateral plantar nerve and intraarticular analgesia of the tarsometatarsal joint in horses with suspected proximal metatarsal pain using body-mounted inertial sensors. J. Equine Vet. Sci. 70, 91–95; DOI 10.1016/j.jevs.2018.07.004

Lischer C. J., *Ringer S. K.*, *Schnewlin M.*, *Imboden I.*, *Fuerst A.*, *Stoeckli M.*, *Auer J.* (2006) Treatment of chronic proximal suspensory desmitis in horses using electrohydraulic shockwave therapy. Schweiz. Arch. Tierheilk. 148, 561–568; DOI 12.1024/0036-7281.148.10.561

Löffeld S., *Boening K.-J.*, *Weitkamp K.*, *Stadler P.* (2002) Radial extracorporeal shock wave therapy for horses with chronic insertion desmopathy of the proximal suspensory ligament - a controlled study. Pferdeheilkunde 18, 147–154; DOI 10.21836/PEM20020203

Milne D. W., *Turner A. S.* (1979) An Atlas of Surgical Approaches to the Bones of the Horse. Edited by W. B. Saunders. Philadelphia, USA

Müller-Kirchenbauer D. (2001) Osteostixis and fasciotomy as a treatment for proximal avulsion fracture on the third metatarsal bone in a horse. Pferdeheilkunde. 17, 477–481; DOI 10.21836/PEM20010509

Nagy A., *Dyson S.* (2012) Magnetic resonance imaging findings in the carpus and proximal metacarpal region of 50 lame horses. Equine Vet. J. 44, 163–168; DOI 10.1111/j.2042-3306.2011.00422.x

Owen K. R., *Hinnigan G. J.*, *Smith C. E.*, *Smith M.* (2019) Surgical treatment of a second metacarpal bone exostosis with associated desmitis of the body of the suspensory ligament in a horse. Equine Vet. Educ. 32, 223–229; DOI 10.1111/eve.13117

Siedler C. (2002) Proximal suspensory desmitis in the horse: Extracorporeal shock waves compared to injections according to Dr.Müller-Wohlfahrt. A field study. University of Vienna

Stashak T. S. (2002) Examination for lameness. In: *Stashak, T. S.*, ed. Adams′ Lameness in horses. Lippincott Williams & Wilkins, St. Louis, 113–183

Trump M., *Siegenthaler E.*, *Kircher P. R.*, *Fuerst A.*, *Theiss F.* (2014) Comparison of radiographic changes of the proximal third metacarpal and metatarsal bones in horses with and without proximal suspensory desmitis. Pferdeheilkunde 30, 671–676; DOI 10.21836/PEM20140606

Trump M., *Fuerst A.*, *Theiss F.* (2014) A retrospective study of the prevalence of injuries to the suspensory ligament, digital flexor tendons and associated structures in a non-racehorse referral-hospital population. Vetsuisse Fakultät Universität Zürich; DOI 10.5167/uzh-109107

Zauscher J. M., *Estrada R.*, *Edinger J.*, *Lischer C. J.* (2013) The proximal aspect of the suspensory ligament in the horse: How precise are ultrasonographic measurements? Equine Vet. J. 45, 164–169; DOI 10.1111/j.2042-3306.2012.00597.x

Wheat J. D., *Jones K.* (1981) Selected techniques of regional anesthesia. Vet. Clin. North America - Large Animal Practice 3, 223–246

Zekas L. J., *Forrest L. J.* (2003) Effect of perineural anesthesia on the ultrasonographic appearance of equine palmar metacarpal structures. Vet. Radiol. Ultrasound 44, 59–64; DOI10.1111/j.1740-8261.2003.tb01451.x

Zubrod C. J., *Kristek J. W.* (2019) Metacarpal bone exostosis and associated desmitis and adhesions: A review. Equine Vet. Educ. 32, 572–574; DOI 10.1111/eve.13140

Zubrod C. J., *Schneider R. K.*, *Tucker R. L.* (2004) Use of magnetic resonance imaging identify suspensory desmitis and adhesions between exostoses of the second metacarpal bone and the suspensory ligament in four horses. J. Am. Vet. Med.l Assoc. 224, 1815–1820; DOI 10.2460/javma.2004.224.1815