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Surgical Anatomy for Desmotomy of the Superior and Inferior Check Ligaments in Donkeys

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ABSTRACT

Literature lacks sufficient information regarding anatomical features and surgical approach of the superior check ligament (SCL) and inferior check ligament (ICL) in donkeys. We hypothesized that desmotomy techniques of horses may not be applicable in donkeys due to species differences. This study aimed to explore the anatomical and morphometric features and surgical approaches of desmotomy of SCL and ICL in donkeys (*Equus asinus*). The Anatomical and morphometric aspects of SCLs and ICLs were conducted on the donkey cadavers (Group A, n. = 4). The desmotomy study was conducted on twelve clinically healthy adult donkeys, which were allocated randomly into four groups (each of 3 donkeys); groups (B) and (C) for surgical exploration of SCLs and ICLs, respectively, and groups (D) and (E) for conducting modified desmotomy techniques of SCLs and ICLs, respectively. The study reported the anatomical and morphometric features of SCL and ICL in donkeys, and reliable landmarks for the surgical approach and desmotomy of SCL and ICL in donkeys, which were somewhat different from that of horses. Moreover, the study developed modifications in the desmotomy techniques of SCL and ICL, which could enhance outcomes and reduce adverse effects of these techniques in donkeys.

Introduction

The flexor tendons of forelimbs are important weight-bearing structures at rest and during locomotion in equines (O`Sullivan, 2007). The flexural deformity has been defined as a shortening of the superficial digital flexor tendon (SDFT) and deep digital flexor tendon (DDFT) or inability to keep the limb flat on the ground or restriction of the joint in a flexed position and inability to extend the joint completely. This may occur either congenital or acquired (Adams and Santschi, 2000; Tamilmahan and Prabhakar, 2018). The flexural deformities mostly observed in neonates and affect the flexor tendons of fetlock and pastern joints, which become a common orthopedic problem (Adams and Santschi, 2000; Tamilmahan and Prabhakar, 2018). In an early report, Crowe and Swerczek (1985) have reported that 20% of 608 fetuses and newborn foals submitted for necropsy suffered from miscellaneous limb contracture.

The surgical method is routinely used for correction of more severe deformity of limbs or when the failure of other methods of treatment. This may include desmotomy of one or more of the following: the inferior check ligament (ICL), DDFT, superior check ligament (SCL), or SDFT (O`Grady, 2012; Carlier *et al*., 2016; Getman, 2011; Ghurashi *et al*., 2014; Tamilmahan and Prabhakar, 2018). The desmotomy of ICL has been used to treat foals with flexural deformity of the distal interphalangeal joint and adults with chronic desmitis of ICL (Stick *et al*., 1992; Yiannikouris *et al*., 2011; Humbach and Gutierrez-Nibeyro, 2018). It has also been proposed as a potential treatment option for equines with deep digital flexor tendinopathies that do not respond to conservative therapy (Schramme, 2011; Humbach and Gutierrez-Nibeyro, 2018). Additionally, ICL desmotomy may decrease pain and lameness caused by the navicular bone degeneration (Turner and Rosenstein, 1992; Humbach and Gutierrez-Nibeyro, 2018). The desmotomy of ICL has been described in horses through the standard open approach (Adams and Santschi, 2000; Auer, 2006; O`Grady, 2012) or minimally invasive approach (White, 1995; Tnibar, 2010).

The desmotomy of SCL is a surgical treatment for tendinitis and desmitis of SCL and flexural deformities of the metacarpophalangeal joint (Bramlage, 1986; Genovese, 1992; Ross, 1997; Adams and Santschi, 2000). Transection of SCL should be performed when this tendon was tighter during manipulation (Soennichsen, 1982; Jennings, 1984). The SCL has been approached either cranial to the flexor carpi radialis muscle or

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through the tendon sheath of the flexor carpi radialis (Jennings, 1984; Wagner *et al*., 1985; Jann *et al*., 1986). In severe cases, the accessory ligaments of both the deep and superficial digital flexor tendons are transected (Wagner et at., 1985).

Currently, the literature lacks sufficient information regarding anatomical features, as well as surgical approach of SCL and ICL in donkeys. We hypothesized that the described techniques for horses may not be applicable in donkeys due to the presence of anatomical differences between different species (Stanek, 2020). Therefore, the main goal of this study was to explore the anatomical and morphometric features and surgical approaches for desmotomy of the SCL and ICL in donkeys (*Equus asinus*). Also, the study developed modifications in desmotomy techniques of SCL and ICL that could enhance outcomes and reduce adverse effects of these techniques.

Materials and methods

Animals

From October 2018 to March 2021 four donkey cadavers (n = 4), obtained from the prosector of the Anatomy, Histology, and Embryology Department, Faculty of Veterinary Medicine, Assiut University, Assiut, Egypt, and twelve clinically healthy adult donkeys (*Equus asinus*) (n. = 12) of both sexes (six males and six non-pregnant, non-lactating females), aged 3 – 4 years and weighing 120 - 150 kg body weight (BW), with no orthopedic abnormalities, , obtained from Assiut Veterinary Teaching Hospital, Faculty of Veterinary Medicine, Assiut University, Assiut, Egypt.

Anatomical and morphometric aspects of SCLs and ICLs were conducted on four donkey cadavers (Group A, n. = 4). Donkeys were allocated randomly into four groups (each of 3 donkeys); groups (B) and (C) were used for surgical exploration of SCLs and ICLs, respectively, and groups (D) and (E) were subjected for conducting modified desmotomy techniques of SCLs and ICLs, respectively.

The Ethical Committee at Faculty of Veterinary Medicine, Assiut University, Egypt, has approved all the procedures in this study in accordance with the Egyptian bylaws and OIE animal welfare standards for animal care and use in research and education.

The anatomical and morphometric aspects of SCL and ICL in donkeys

The skin was removed over the thoracic limbs of the donkey cadavers. The flexor muscles were carefully dissected at the forearm region to expose SCL as it originates from the distal extremity of the radius. The proximal region of the manus was dissected to expose ICL distal to the carpal joint. A detailed anatomic description and features of SCL and ICL were recorded with special regard to its origin, insertion, and topography. SCL and ICL were photographed in situ using Olympus (C-5060).

The superficial digital flexor and deep digital flexor muscles with their tendons and SCL and ICL were dissected out and photographed using an Olympus (C-5060) camera for further analysis by the ImageJ software (National institutes of health company, USA). Each ligament was divided into three parts; the attached part (A), which attaches to the caudo-medial aspect of the radius in case of SCL and the carpal palmar ligament in case of ICL, the connecting part (C), which connects the attached part to the tendon, and the fused part (F), which fuses with the tendon for a certain distance until its fiber intermingled with the tendon fibers (Fig. 1). The attached parts were measured in situ (cm). The connecting parts were measured using a measuring tape (cm). The ligamentous fibers that fuse with its corresponding tendon were traced by analyzing the cross-sections. The endpoint of the ligament, where their fibers intermingled with their corresponding tendons was determined and the length of the fused part was then calculated. The total length of each ligament starting from its origin to its endpoint with its tendon was determined by the summation of the length of the attached, connecting, and fused parts.

Superior check ligaments and ICLs were sectioned transversely at different levels along their lengths. These sections were individually transferred onto an opaque plate of the stereomicroscope (Leica S6D) and photographed sequentially using the Olympus camera (C-5060) connected with adaptor to the microscope. Using a segmented area tool of the imageJ software to draw the area around the cross-section profile, the cross-section area (CSA) and the circular index (CI) were measured. The (CI) measures the circularity of the cross-section. When the CI equals 1.0 indicates a circle, while when it approaches 0, it indicates elongated polygonal shape.

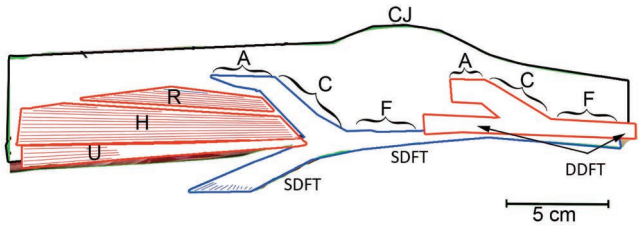

Fig. 1. A diagram illustrating the superior check ligament (SCL) and inferior check ligament (ICL). Each of them is considered divided into three parts; the attached part (A) to the skeleton of the forelimb, the connecting part (C), which connects between the skeleton and the corresponding flexor tendon, and the fused part (F), which fuses with the tendon. The superficial digital flexor muscle (SDFM), radial head (R), humeral head (H), and ulnar head (U) of the deep digital flexor muscle (DDFM), superficial digital flexor tendon (SDFT), deep digital flexor tendon (DDFT), Carpal Joint (CJ) and metacarpal bone (MB).

Surgical exposure for desmotomy of SCL and ICL in donkeys

Surgical sites were clipped, shaved, and scrubbed several times with 10% povidone-iodine solution (BETADINE, El- Nile Co. for Pharmaceutical and Chemical Industries, Egypt) and then draped except for the operative sites. Surgical procedures were performed under the effect of intravenous (IV) 1.1 mg/kg 2% xylazine HCl (Xyla-Ject, ADWIA Co., SAE, Egypt) and 2.2 mg/kg 5% ketamine HCl (Ketamine, Sigma-tec Pharmaceutical Industries, SAE, Egypt) (Moradi *et al*., 2013). 10 ml of 2% lidocaine HCl (Dibucaine, Sigma-Tec Pharmaceutical Industry Co., Egypt) were infiltrated subcutaneously at the anticipated incision site.

Surgical exposure for desmotomy of SCL

The donkey was positioned laterally with the operated limb was the down most. The above thoracic limb was tied caudally using a rope. Based on the earlier anatomical findings, caudal to the radius, a 7–8 cm linear skin incision was conducted medially 4–5 cm distal to the chestnut and proximal to the carpal joint (Fig. 2 A & B). Subcutaneous tissue was carefully dissected exposing the cephalic vein (Fig. 2C). The cephalic vein branch that pierces the antebrachial fascia was double ligated and transected between the ligatures (Fig. 2D). The cephalic vein was then carefully dissected and retracted caudally (Fig. 2 E & F). The antebrachial fascia was carefully transected. SCL was identified attaching to the radius caudomedially 6 – 7 cm distal to the chestnut. SCL was elevated on a curved scissor and transected by a sharp scalpel (Fig. 2 G & H). The site of the operation was checked for any bleeding. The subcutaneous tissue was closed in a continuous fashion

using 2 – 0 polyglactin 910 (EGYSORP, TAISIER-MED, Egypt). The skin was closed with simple interrupted sutures using 2 – 0 polyglactin 910 (Fig. 2 I).

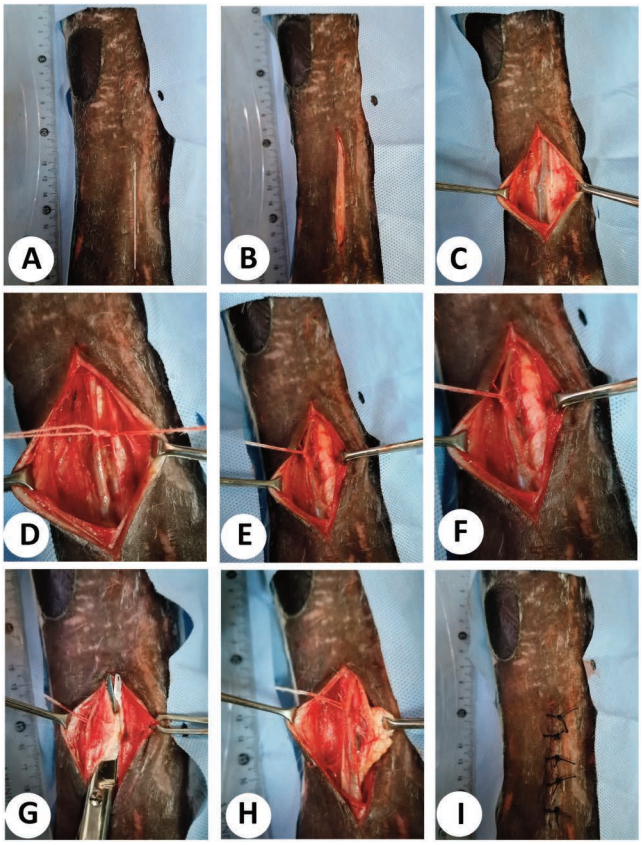

Fig. 2. Surgical approach of the superior check ligament (SCL) in donkeys; the anticipated site (line) of incision (A), incision of the skin and subcutis (B), exposure of the cephalic vein (C), dissection and double ligation of the cephalic vein branch (D), transecting the cephalic vein branch between the ligatures and retraction of the cephalic vein caudally (E), magnification to (E) (F), exposing of SCL (G), desomtomy of SCL (H), Closure of the subcutis and skin (I).

Surgical exposure for desmotomy of ICL

The donkey was positioned laterally with the operated limb was the upper most. Based on the earlier anatomical findings, a 6 - 7 cm linear skin incision was created laterally at the proximal third of the manus and proximally extended over the flexor tendons (Fig. 3 A & B). The subcutaneous tissue was bluntly dissected and the paratenon incised. ICL was identified at its insertion in the DDFT at the proximal fourth of the metacarpus. The ICL was elevated out of the incision using a curved scissor and severed with a sharp scalpel (Fig. 3 C & D). The subcutaneous tissue and skin were closed as described before (Fig. 3 E).

Modified techniques for desmotomy of SCL and ICL in donkeys

Modified technique for desmotomy of SCL

In this modified technique, SCL was detected based on the previous anatomical and surgical findings (6–7 cm distal to the chestnut) and its hard attachment texture to the radius during down pressure with a tenotome through the antebrachial fascia, caudal to the radius (Fig. 3F). A puncture incision was made with the scalpel at the anticipated site proximal to SCL. The tenotome was then introduced at this point and transected SCL distally (Fig. 3G). Polypropylene material piece (3 × 1 cm) was inserted in the incision caudal to the radius (Fig. 3H). The antebrachial fascia was closed with simple continuous sutures using 2–0 polyglactin 910 (Fig. 3 I). The subcutaneous tissue and skin were closed as described before.

Modified technique for desmotomy of ICL

In this modified technique, the cutting bud of ICL was covered by polypropylene material and fixed with four interrupted sutures using 2-0 polygalactin 910 (Fig. 3 J & K). The covered ligamentous bud was then returned in situ (Fig. 3L). The subcutaneous tissue and skin were closed as described before.

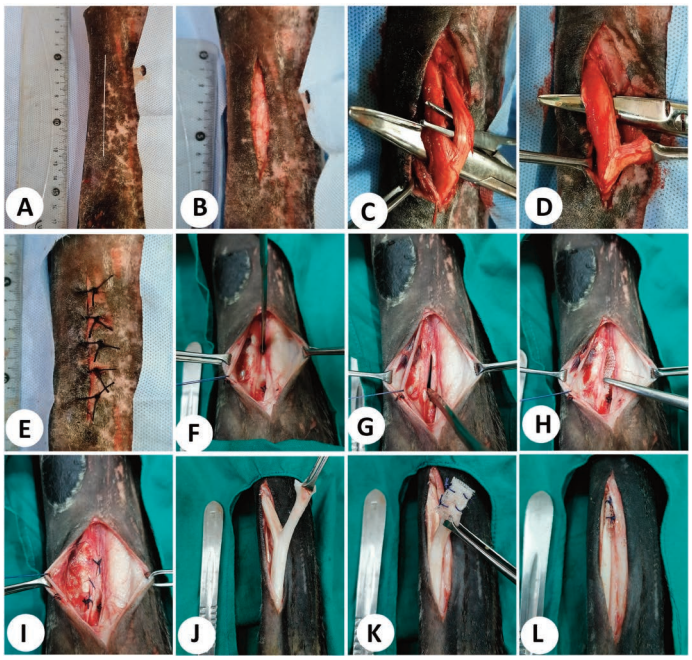

Fig. 3. Surgical approach of the inferior check ligament (ICL) and modified desmotomy techniques of SCL and ICL in donkeys; the anticipated site of incision (A), incision of the skin and subcutis (B), exposing of the ICL (C), desmotomy of the ICL (E), closure of the subcutis and skin (D), identification of SCL (hard texture on down pressure with the tenotome through the antebrachial fascia) (E), transecting of SCL with tenotome (F), inserting the propylene mesh in the incision site (G), closing the antebrachial fascia (H), the cutting bud of the ICL (I), covering the cutting bud of ICL with the propylene mesh (J), the cutting bud of ICL in situ (K).

Postoperative care

Donkeys were administered intramuscular 1 ml/kg procaine penicillin and dihydrostreptomycin sulphate (Pen & Strep, 1 ml contains procaine penicillin 200 mg and dihydrostreptomycin sulphate 250, Norbrook Laboratories Limited, Newry) and intravenous phenylbutazone 1,1 ml/50 kg (Phenyl-D 20%, 1 ml contains phenylbutazone 200 mg, DELTA PHARMA, veterinary sector, Egypt) for 5 successive days, postoperatively. The surgical sites were aseptically dressed with sterile non-adherent dressing pads secured by sterile elastic bandages and outer elastic adhesive bandages. These dressings were aseptically changed daily until the stitches were removed 10–12 days postoperatively. During the first two postoperative weeks the donkeys were permitted only limited exercise to promote good soft tissue healing.

Results

Anatomical features of SCL and ICL in donkeys

Anatomical features of SCL

Superior check ligament originates from the caudo-medial surface of the radius at its distal half and blends with the SDFT. The SDFT originates from the connective tissue of the superficial digital flexor muscle (SDFM) of the forelimb. It passes distally through the carpal canal to the palmar aspect of the metacarpus and inserts on the proximal eminencies of the middle phalanx. The SDFM originates from the medial epicondyle of the humerus and is located in the middle of the flexor group of muscle between the flexor carpi ulnaris muscle (FCUM) and DDFM (Fig. 4).

Topographically, SCL is bordered by the flexor retinaculum medially and there is an attachment between SCL and tendon sheath of the flexor carpi radials (FCRM) muscle medially (Fig. 5A). Laterally, there is an attachment between SCL and the radial head of the DDFM (Fig. 5B). Regarding the vasculature, the FCRM is the landmark for large blood vessels and nerves passing through the forearm (Fig. 5C). The cephalic vein passes superficially along the forearm between the FCRM and radius (Fig. 5C). Just beneath the FCRM, the median artery and nerves distally pass until reaching the carpal joint, where they pass together with the SDFT and DDFT through the carpal canal (Fig. 5C). A large nutrient artery, the palmar branch of the median artery, pierces the SCL between the attached and connecting parts (Fig. 5D).

Anatomical features of ICL

Inferior check ligament originates from the palmar fibrous joint capsule of the carpus. It courses distally between the suspensory sesamoedean ligament and DDFT and inserts on the dorsal surface of the DDFT in the proximal fourth of the metacarpal region (Fig. 6A). Deep digital flexor tendon originates from the union of tendons of the three heads of the deep digital flexor muscles, which appear deep to the SDFM (Fig. 5A). The first (the largest) head of the DDFM is the humeral head, which originates from the medial epicondyle of the humerus and runs to the caudal surface of the radius and almost completely covered by the SDFM. The second head is the ulnar head, which has a short triangular fleshy part proximally, which continues as long strip-like tendon. The fleshy part superficially lies between the flexor carpi radialis and extensor carpi ulnaris muscles. The tendon passes distally along the forearm between the humeral head and extensor carpi ulnaris muscle. Finally, it joins the main tendons proximal to the carpus. The third (the smallest) head is the radial head, which arises as a flat muscle belly from the caudo-medial aspect of the radius at the middle third of the forearm. Its tendon blends with the chief tendon near the distal end of the radius. The three tendons constitute the DDFT, which passes

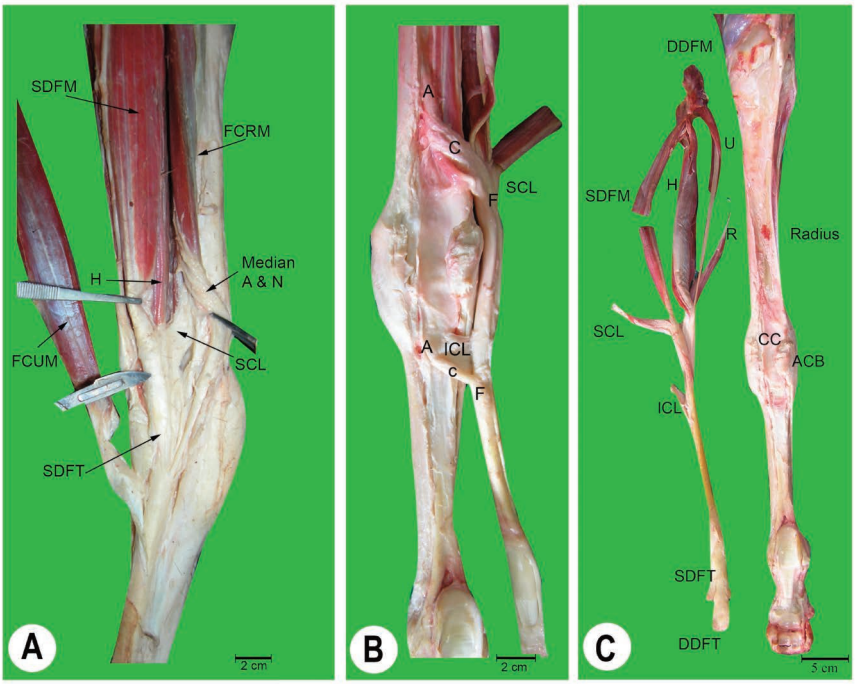

Fig. 4. Dissection and the anatomical features of SCL. (A) The superficial digital flexor muscle (SDFM) located in the middle of the flexor group of muscle between the flexor carpi ulnaris muscle (FCUM), which is reflected to the left and the humeral head of the deep digital flexor muscle (DDFM). The superior check ligament (SCL) could be found in the distal forearm just proximal to the carpal joint emerge between the flexor carpi radialis muscle (FCRM) and the SDFM. (B) The three parts of SCL and ICL; the attached part (A) to the caudal surface of the radius, the connecting part (C), which connects between the radius and the corresponding SDFT, the fused part (F), which fuses with SDFT. (C) After dissection SDFT and DDFT outside the forelimb, the opened carpal canal (CC) appears on the palmar aspect of the carpal joint through which SDFT and DDFT pass distally. The CC is bounded laterally with the accessory carpal bone and its ligaments (ACB).

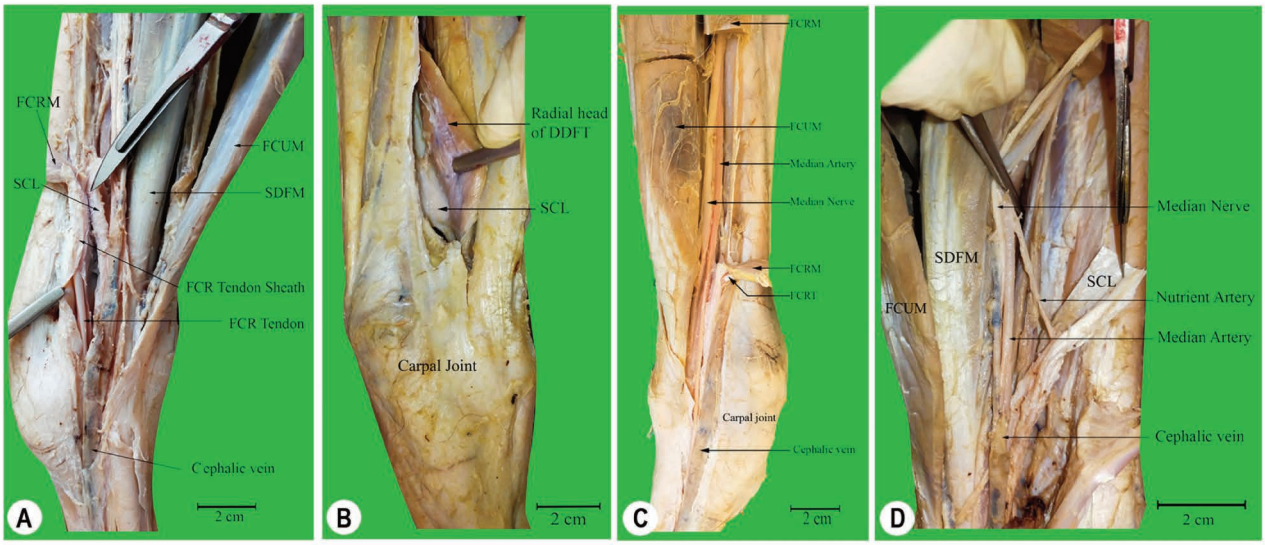

Fig. 5. The topography and main vessels and nerves associating SCL. Superior check ligament is attached to the tendon sheath of the flexor carpi radials muscle (FCR) medially (A) and to the radial head of DDFM laterally (B). (C) The cephalic vein passes superficially along the forearm between the FCRM and the radius large blood vessels and nerves passing through the forearm. The median artery and nerves are passing below the FCRM and pass together with SDFT and DDFT through the carpal canal. (D) A large nutrient artery, the palmar branch of the median artery, pierces SCL between the attached and connecting parts.

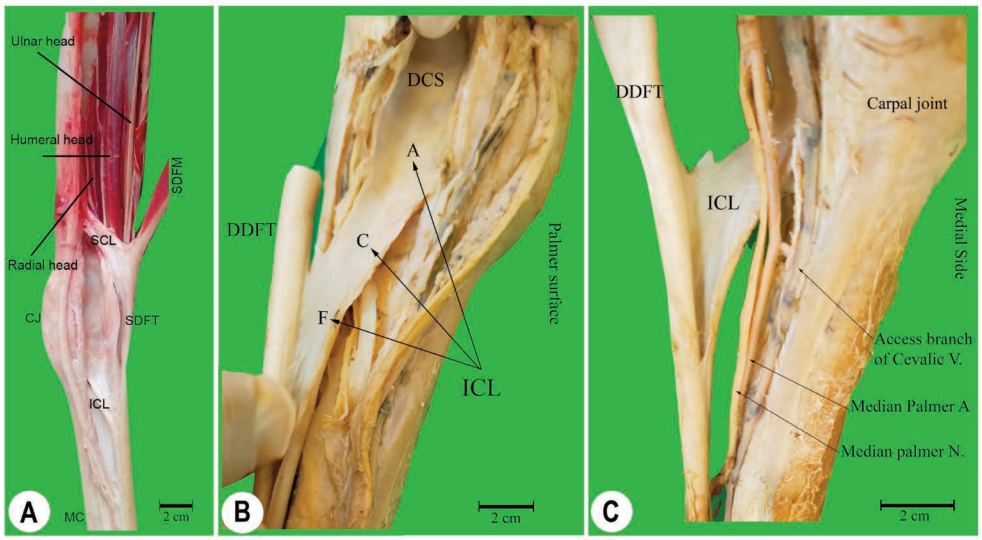

Fig. 6. The topography and main vessels and nerves associating ICL. (A & B) DDFT originates from the union of tendons of the three heads of DDFM, which appear deep to SDFM. The three parts of ICL; the attached part (A) originates from the dorsal carpal sheath (DCS) on the palmar aspect of the carpal joint, the connecting part (C), which connects between the radius and the corresponding DDFT, the fused part (F), which fuses with the DDFT. (B & C) The fused part starts to connect first from the lateral side of DDFT, and the free side of ICL wraps DDFT medially and remains free for a short distance. The free side connects more distally to the medial side of DDFT. (C) The median palmer artery, vein, and nerve are passing medial to ICL.

together with the SDFT through the carpal canal over the flexor aspect of the carpus, medial to the accessory carpal bone. Distal to the carpal joint, this tendon becomes rounded gradually and becomes in close relation with SDFT, however, there is no connection between them.

It is difficult to determine a line of demarcation between the fibers of the attached part of ICL and the palmar carpal ligaments (Fig. 6B). The connecting part is a discrete structure that is separated from the other structures on the palmar aspect of the bone with a prominent longitudinal striated pattern (Fig. 6B). The fused part starts to connect first from one side at the lateral border of DDFT, and the other free side of ICL wraps DDFT medially and remains free for a short distance (Fig.s 6B & C). ICL conforms to the dorsal, lateral and medial surfaces of DDFT. The free side connects more distally to the medial side of DDFT (Fig. 6C).

Topographically, ICL is bordered with the medial palmer artery, vein, and nerve medially, the interosseous muscle (proximal sesamoedean ligament) dorsally, the DDFT palmerly, and the distal ligament of the accessory carpal bone laterally (Fig. 6C).

Morphometric aspects of SCL and ICL in donkeys

Lengths of SCL and ICL in donkeys

The attached part of SCL to the caudo-medial aspect of the radial bone is thin and flat and its length is (2.57±0.17 cm). It runs obliquely and distally toward the axis of SDFT, where becomes thicker in the connecting part and its length is (2.74±0.13 cm). The fused part of the ligament, which fuses to the medial side of SDFT, gets smaller distally until its disappearance and length is (4.37 ± 0.264 cm); therefore, the entire length of SCL is (9.76±0.43 cm).

Inferior check ligament arises from the palmar carpal ligament, which lies on the dorsal surface of the carpal sheath. It

measures (after dissecting it out the limb) reached approximately (1.17±0.06 cm). The connecting part runs distally for a short distance (1.45±0.1 cm) nearly parallel to DDFT. It joins the dorsal surface of DDFT in the proximal fourth of the metacarpal bone. We could trace the fused part through the CS whose length was (6.99±0.42 cm); therefore, the entire calculated length of ICL is (9.62±0.64 cm).

Cross-section area (CSA) of SCL and ICL in donkeys

The shape of SCL cross-section is thin and flat at its attached part to the radial bone (Fig. 7). Its thickness increases distally, where its CSA and CI measure (5.23±0.66 and 0.17±0.08 mm, respectively) at its start and (18.18±3.32 and 0.49±0.18 mm, respectively) just before the connecting part. The shape of the CS becomes triangular/oval in the connecting part, where its CSA and CI measure (40.26±2.33 and 0.54±0.087 mm, respectively). Just before fusion with SDFT, its CS becomes more elongated, where its CSA and CI measure (42.48±1.53 and 0.50±0.16 mm, respectively). The fused part becomes triangular distally, where its CSA and CI measure (14.4±1.8 and 0.55±0.16 mm, respectively). After its fusion with the tendon, the CSA and CI decrease gradually and reach (12.7±1.83 mm and 0.45±0.07 mm, respectively) just before its end.

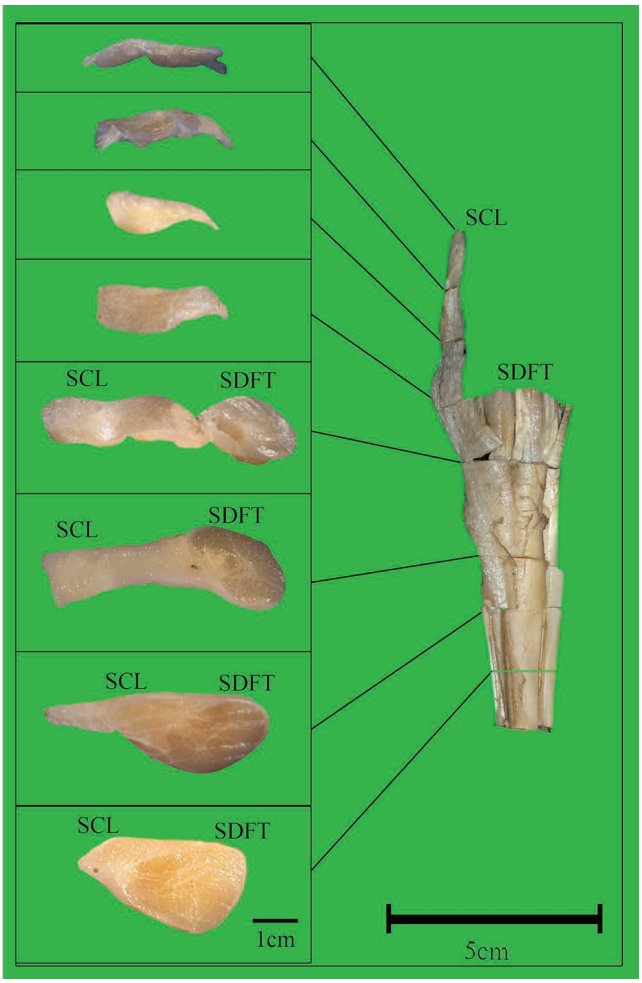

Fig. 7. The profile of SCL cross-section at different levels along its length. The right pane shows the different chosen levels of the CS and the left pane shows the different CS. The first upper two sections are taken from the attached part. The following two sections are taken from the connecting part. The lower four sections are taken from the fused part.

The shape of ICL cross-section is thin and flat at its attached part to the dorsal carpal sheath (Fig. 8). It increases distally and becomes more elongated, where its CSA and CI measure (33.76±0.98 and 0.45±0.04 mm, respectively). The shape of the CS becomes more elongated in the connecting part, where its CSA and CI measure (40.36±1.7 and 0.44±0.12 mm, respectively). The fused part has a C-shape in the CS because it wraps DDFT dorsally, medially, and laterally. Its CSA and CI measure (40.79±4.24 and 0.29±0.02 mm, respectively) in the fused part. CSA and CI decrease gradually distally and reaches (28.39±1.08 and 0.37±0.21 mm, respectively) just before its end. Finally, the ligament becomes thinner and its fibers blend with the tissue of the DDFT in a manner like the dualism symbol of Yin and Yang.

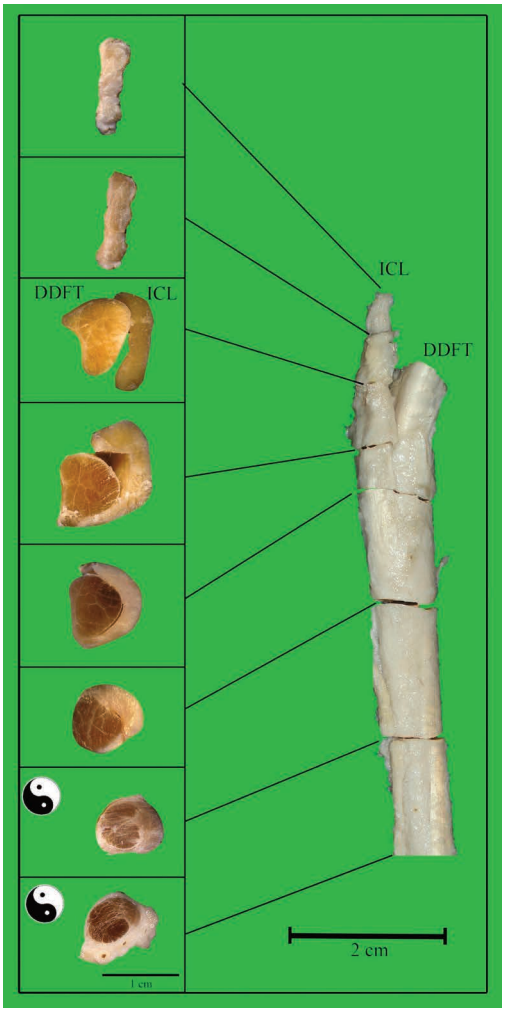

Fig. 8. The profile of SCL cross-section at different levels along its length. The right pane shows the different chosen levels of the CS and the left pane shows the different CS. The first upper section is taken from the attached part. The following two sections are taken from the connecting part. The lower five sections are taken from the fused part. Note the fusion of one side first. The last two CS of the fused part blend with DDFT in a manner giving it the shape of the dualism symbol of Yin and Yang.

Surgical exposure for desmotomy of SCL and ICL in donkeys

The desmotomy of SCL and ICL were successfully performed in thoracic limbs of donkeys without intra- or postoperative complications. There were no recorded deaths between donkeys. The anesthetic protocol used for surgical interventions was satisfactory with smooth onset and recovery in all donkeys.

Surgical exposure for desmotomy of SCL

A 7-8 cm cutaneous medial incision caudal to the distal part of the radius, 4–5 cm distal to the chestnut provided adequate surgical access for exploration of SCL. There were subcutaneous blood vessels, which required careful dissection

and ligation before transection. The presence of the main cephalic vein in the theater of the operation represented a great risk that required careful dissection and retraction caudally away from the incision site of the antebrachial fascia. Moreover, the antebrachial fascia is penetrated by a branch of the main cephalic vein that had to be first transected between double ligations before opening of the antebrachial fascia. After the incision of the antebrachial fascia, SCL was identified 6–7 cm distal to the chestnut. Care should be taken while lifting and transecting of SCL to avoid severing of the underneath blood vessels (the nutrient artery of the SDFT). Superior check ligament was recognized with its attachment to the caudomedial surface of the radius. However, the identification of SCL for desmotomy required well-trained surgeons. Wounds healed by the primary intention without recorded complications in all donkeys.

Surgical exposure for desmotomy of ICL

The lateral approach over DDFT with a linear incision at the proximal third of the metacarpus provided adequate surgical access to ICL. After the incision of the paratenon, DDFT had to be first identified and isolated from the SDFT. Inferior check ligament was recognized inserting in DDFT between the proximal and the second fourth of the metacarpus. The elevation and transecting of ICL was performed successfully in all donkeys. Wounds healed by the primary intention without any recorded complications in all donkeys.

Modified techniques for desmotomy of SCL and ICL in donkeys

Modified technique for desmotomy of SCL

It was easier, less time consuming, and less invasive to tissues to use the modified technique for SCL desmotomy. Once the attachment of SCL to the caudo-medial border of the radius had been recognized, it was reliable to introduce the tenotome and transected SCL in situ. The attachment landmark of SCL to the radius was efficiently recognized through the hard texture of the attachment rather than tissue texture above and distal to it during conducting the down pressure with the tenotome caudal to the radius and 6-7 cm distal to the chestnut according to the earlier anatomical and morphometric features of SCL. The desmotomy of SCL by the modified technique was tolerated by all donkeys.

Modified technique for desmotomy of ICL

The modified technique of ICL desmotomy was tolerated by all donkeys without recorded complications. It was reliable to fix the polypropylene cover on the cutting bud of the ligament with four interrupted sutures.

Discussion

This study explored the anatomical and morphometric features of SCL and ICL in donkeys. Also, the study reported reliable landmarks for the surgical approach and desmotomy of SCL and ICL in donkeys, which were somewhat different from that of horses. Moreover, the study developed modifications in desmotomy techniques of SCL and ICL, which could enhance outcomes and reduce adverse effects of these techniques in donkeys.

The desmotomy of SCL and ICL is routinely used for correction of more severe flexural deformities of limbs or when the failure of other methods of treatment or do not respond to conservative therapy (Carlier *et al*., 2016; O'Grady, 2012; Getman, 2011; Ghurashi *et al*., 2014; Tamilmahan and Prabhakar, 2018). Transection of SCL has been conducted where hyperextension of the carpus or fetlock joint was required (Shoemaker *et al*., 1991; Hawkins and Ross, 1995; Alexander *et al*., 2001; David *et al*., 2011).

Like horses, SCL of donkeys originates from the caudomedial surface of the radius at its distal half (Denoix, 1994; Nazem and Sajjadian, 2017). The length of its attached part measures (2.57 ± 0.17 cm), which indicates how strong it attached to the radius to prevent the over stretching of SDFT during maximal extension of the carpal joint (Denoix, 1994; Nagy and Dyson, 2011).

There was an attachment between SCL and the tendon sheath of the FCRM on the medial border of the radius as in horses (Jann *et al*., 1986; Denoix, 1994). Furthermore, this study recorded an attachment between the attached part of SCL and the radial head of DDFM laterally, which has not been reported before in horses.

SCL in the donkeys is bordered by the flexor retinaculum medially. Similar findings have been reported in horses (Barone, 1989; David *et al*., 2011). The fibers of SCL are inserted and fused to the craniomedial aspect of SDFT (the fused part of the SCL) (Nazem and Sajjadian, 2017).

The desmotomy of SCL was performed at the beginning of the connecting part (Bramlage, 1986; Ross, 1997) because it was difficult to dissect SCL out the bone in the living animal. Describing the ligaments as divided into the attached, connecting, and fused parts provides the veterinarians and surgeons with a detailed description of SCL and ICL along their lengths.

Inferior check ligament arises in donkeys from the palmar carpal ligaments, which is attached at the dorsal surface of the carpal sheath as in horses (Getty, 1975; Muylle *et al*., 2010). It is inserted on the dorsal surface of DDFT between the proximal and the second fourth of the metacarpus; dislike the previous description in horses, where it inserted at the mid-metacarpal region (Getty, 1975; Muylle *et al*., 2010).

The length of ICL in donkeys (9.62 ± 0.64 cm) is shorter than in horses (13.7 ± 0.4 cm) (Zarucco *et al*., 2004, Muylle *et al*., 2010). This means that the connecting part of ICL in donkeys is much shorter than that of horses, which add to the challenge facing the surgeons dealing with donkeys.

Concerning the vasculature of the lower forearm, the current investigation reported similar findings to that of the horses (Auer, 2006). The most critical vessel had to be considered on conducting SCL desmotomy is the cephalic vein, which superficially passes near the radius at its caudo-medial border, and its accessory branch penetrates the antebrachial fascia. Topographically, after cutting FCRM and retracting its ends away, the median artery and nerves could be seen passing together with SDFT and DDFT through the carpal canal. Before entering the carpal canal, a palmar branch of the median artery, a nutrient artery, passes proximally and more deeply and pierces SCL between the attached and connecting parts of SCL. A similar description has been reported for horses, where SCL is fed proximally by a large nutrient artery connected to a palmar branch of the median artery and is drained by a branch of the cephalic vein medially (Southwood *et al*., 1998; David *et al*., 2011). Concerning the vasculature of the higher manus, where ICL is located, the median palmer artery, vein, and nerve are found at the medial aspect of the manus region, which makes ICL desmotomy so serious to be performed medially (Auer, 2006; Tnibar, 2010).

Measurement of the CSA is the most valid and accurate technique for the detection of the tendon or ligament injury and is a satisfactory method to evaluate the healthy status of the flexor tendons and ligaments of the metacarpal region in equines (Dehghan *et al*., 2007; Maoudifard, 2008; Reis and Baccarin, 2010; Nerurkar, 2010). The shape of the cross-section of SCL in donkeys was thin and flat at its attached part to the

radial bone. The shape of the CS became a triangular/oval in the connecting part as its thickness increases gradually distally. Just before fusion with SDFT, its CS became more elongated. The fused part becomes thicker and triangular distally. After its fusion with the tendon, the CSA and CI decrease gradually. According to the available literature, it is the first time to be described in donkeys.

In donkeys, normal CS shape of ICL is thin and flat at its attached part to the dorsal carpal sheath. It increases distally and becomes more elongated. The shape of the CS becomes more elongated in the connecting part. A similar description has been reported in horses by magnetic resonance, where the CSA of ICL was elongated in shape, and increased gradually until it reaches DDFT (Nagy and Dyson, 2011).

The CS of the fused part has C-shape in donkeys because it wraps DDFT dorsally, medially, and laterally, while in horses it is L-shape wrapping DDFT in the proximal 7 cm of the metacarpal region (Nagy and Dyson, 2011). The CSA of the fused part decreases gradually distally. Finally, the ligament becomes thinner and its fibers blend with the tissue of DDFT in a manner like the Chinese dualism symbol of Yin and Yang, which has not been reported in horses.

In this study, no complications were recorded with the desmotomy of SCL, as the identification of SCL was practiced on cadaveric limbs to confirm complete desmotomy of SCL before performing the procedure in donkeys. However, some studies reported complications with the medial SCL desmotomy (Jennings, 1984; Bramlage, 1986; Ross, 1997), including transection of structures other than the SCL, incomplete desmotomy, hemorrhage that led to prolonged hospitalization and increased cost (Cote *et al*., 1994; Hogan and Bramlage, 1995; Southwood *et al*., 1999; Ross, 2003; David *et al*., 2011).

Superior check ligament desmotomy laterally seemed to be difficult due to the distance between the incision and SCL, this procedure has been performed in horses by using the tenoscopic approach through the carpal sheath to avoid injury risk of blood vessels that found medially (Southwood *et al*., 1999; David *et al*., 2011). The intrathecal bleeding in electrosurgical tenoscopic desmotomy of SCL has been advocated to coagulate using electrocautery instruments (Nixon, 2002; Desjardins *et al*., 2004; Mcllwraith *et al*., 2005; David *et al*., 2011).

The surgical landmarks for the surgical approach of SCL in donkeys were different from that in the horse. The incision for SCL desmotomy in donkey was conducted below the chestnut by about three fingers (3.02±1.99 cm), while in horse the chestnut was at the center of the incision medially (Jennings, 1984; Jann *et al*., 1986; Auer, 2006). This may be attributed to the difference in height between the donkeys and horses. Therefore, based on this study the practitioner cannot rely on the landmarks of the horse for SCL desmotomy in donkeys. This was in accordance with Stanek (2020), who has reported that horses (Equus caballus) and donkeys (*Equus asinus*) belong to different species.

The main cephalic vein was a major intraoperative concern, which required careful dissection and retraction caudally before opening the antebrachial fascia. The cephalic vein branch that penetrates the antebrachial fascia had to be first transected between double ligations before opening of the antebrachial fascia (Bramlage, 1986; Ross, 1997; Auer, 2006).

On the medial approach in the horses, care should be taken to avoid transecting the large proximal perforating vessel, the nutrient artery for SDFT as transection of this vessel could cause ischemic injury to SDFT (Jann *et al*., 1986; Bramlge and Hogan, 1996; Southwood *et al*., 1999). In contrast, SCL desmotomy was far away from that artery in donkeys as this artery pierced more in the attached part of SCL and desmotomy of SCL was performed more on the beginning of the connecting part.

It has been proposed that SCL likely heals after transection (Hogan and Bramlage, 1995; Ross, 1997). Therefore, the desmotomy of SCL by the modified technique using polypropylene mesh might prevent healing or adhesion of the transected ligament to the surrounding structures. Also, conducting the modified technique using the tenotome was reliable for identification and transecting of SCL in situ. Moreover, it turned SCL desmotomy technique easier, safer, timesaving and less invasive to tissue.

The lateral approach for ICL desmotomy in donkey was somewhat similar to that recorded in horses (Mcllwraith and Turner, 1982; Soennichsen, 1982; Auer, 2006). Here, in this study, ICL was performed laterally because most ICL positioned laterally (Auer, 2006; Roger and Smith, 2008; Tnibar, 2010) and to avoid the major vasculature, which is significantly larger on the medial side (Jennings, 1984; Auer, 2006; Tnibar, 2010). Potential complications have been recorded following ICL desmotomy, include incisional swelling, incision dehiscence, postoperative scarring, and infection, which can have serious consequences, such as carpal tenosynovitis or infectious desmitis (Mcllwraith and Fessler, 1978; Wagner *et al*., 1985; Wagner, 1990; Tnibar, 2010). In this study using polypropylene cover on the cutting bud of the ligament with four interrupted sutures in the modified technique of ICL desmotomy might prevent healing of the cutting end of ICL or adhesion with other structures.

Conclusion

The anatomical and morphometric features of SCL and ICL, as well as surgical exploration and desmotomy of SCL and ICL were described in detail in donkeys. The study provided the surgical landmarks and techniques for SCL and ICL desmotomy that were different from that described in literature for horses. Moreover, the study developed modifications in the desmotomy techniques of SCL and ICL, which could enhance outcomes and reduce adverse effects of these techniques in donkeys.

Conflict of interest

The authors declare that they have no conflict of interest

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