FULL ARTICLE

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Ex-vivo evaluation of a percutaneous thread technique to palmar/plantar annular desmotomy in horses

Avaliação ex-vivo de técnica de fio percutâneo para desmotomia anular palmar/plantar em equinos

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ABSTRACT

Palmar/plantar annular desmotomy (PAD) is a surgical procedure to mitigate pain, lameness, and other clinical manifestations of annular ligament syndrome. This study aimed to describe a minimally invasive technique for PAD and evaluate potential damage to adjacent structures in 15 cadaveric limbs from sound horses (forelimb = 6 and hindlimb = 9). A 6 USP polyglycolic acid thread was positioned around the palmar/plantar annular ligament (PAL) on both sides of the limbs through two incisions (proximal and distal to PAL) through the digital sheath and subcutaneous tissue. Kelly forceps, Gerlach or Obwegeser needles were used to thread placement. A back-and-forth motion allowed the thread to cut the ligament until it exited through the proximal skin incision, and the time was registered. The degree of PAL section and tissue injuries were evaluated. The section of the ligament was complete in all limbs. However, 30% (10/30) of the procedures produced iatrogenic injuries on adjacent structures regardless of the instrument used ($p > 0.1$). There was a higher frequency of lesions in the neurovascular bundle (NVB) on the medial side regardless of the limb ($p = 0.068$). The odds of injury in the NVB were correlated to side (lateral or medial ($p = 0.042$) and limb (hind or forelimb) ($p = 0.065$) by logistic regression. The Gerlach needle had a shorter execution time than the Kelly forceps ($p = 0.003$). The percutaneous approach to PAD in specimens was practical, quick, and easy to perform. However, this posed a potential chance of iatrogenic trauma to the surrounding tissue. Although they are all reasonable options, the Obwegeser needle was more efficient for applying the thread than the others.

Keywords: Lameness. Annular desmitis. Orthopedics. Digital sheath. Minimally invasive surgery.

RESUMO

A desmotomia do anular palmar/plantar (DAP) é um procedimento cirúrgico realizado com o intuito de mitigar a dor, claudicação e outras manifestações clínicas envolvidas na síndrome do ligamento anular palmar. O objetivo deste estudo foi descrever uma técnica minimamente invasiva para DAP e avaliar o potencial de trauma iatrogênico aos tecidos adjacentes em 15 mebros de cadáveres de equinos (torácicos = 6 e pélvicos = 9). Um fio de ácido poliglicólico USP 6 foi posicionado ao redor do ligamento anular palmar/plantar (LAP) em ambos as faces dos membros, através de duas incisões (proximal e distal ao ligamento): através da bainha digital e um túnel subcutâneo entre o LAP e a pele. Uma pinça Kelly, agulha de Gerlach ou de Obwegeser foram utilizadas para colocação do fio. Um movimento de serra foi realizado para seccionar o ligamento, até que o fio emergisse pela incisão proximal, sendo registrado o tempo. O grau de secção do LAP e as lesões nos tecidos moles foram avaliados. A secção LAP foi completada em todos os membros. Entretanto, 30% (10/30) dos procedimentos produziram lesões iatrogênicas em estruturas adjacentes independente do instrumento utilizado ($p > 0,1$). Houve tendência de maior frequência de lesões do feixe neurovascular (FNV) na face medial, independentemente do membro ($p = 0,068$). As chances de lesão no FNV foram correlacionadas com a face (lateral ou medial ($p = 0,042$) e membro (torácico ou pélvico) ($p = 0,065$) por regressão logística. A agulha de Gerlach teve um tempo de execução menor que a pinça Kelly ($p = 0,003$). A abordagem percutânea do DAP em cadáveres equinos foi eficaz, rápida e de fácil execução, porém com potencial chance de trauma iatrogênico aos tecidos moles adjacentes. A agulha de Obwegeser foi mais eficiente para aplicação do fio em relação as demais, entretanto todos os instrumentos foram opções razoáveis.

Palavras-chave: Claudicação. Desmite anular. Ortopedia. Bainha digital. Cirurgia minimamente invasiva.

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Introduction

The palmar/plantar annular ligament (PAL) is a digital sheath (DS) component that involves the superficial (SDFT) and deep digital flexor tendons (DDFT) in the metacarpal/metatarsal phalangeal joint region (Denoix, 1994). It is responsible for limiting movement and maintaining the anatomical position of these tendons and proximal sesamoid bones (König & Liebich, 2020). Together with the intersesamoid ligament, it balances the tension performed by the distal and extensor branches of the suspensory ligament of the fetlock on the abaxial surface of the proximal sesamoid bones. In addition, the metacarpal aspect of the PAL associated with other structures contributes to a reduction in the impact during the limb landing phase (Denoix, 1994).

Palmar annular ligament constriction may result from trauma and infection, with the primary cause being its inflammation and thickening, or, secondarily, it may be associated with the presence of injuries within the DS (Dik et al., 1995), inflammation of SDFT, or longitudinal ruptures of DDFT, which may also be affected by fibrosis and tenosynovitis (Eggleston et al., 2020). Thus, it prevents the normal sliding function of the tendons and causes later lameness, which may not be responsive to conservative treatments (Kümmerle et al., 2019). Its thickening has been associated with lameness in different conditions of DS and related structures (Wilderjans et al., 2003; Kaneps, 2007). All these affections have clinical manifestations of DS distention and PAL thickening in common. Therefore, they were called annular ligament syndrome (Schramme & Smith, 2011) or fetlock tunnel syndrome (van den Berg et al., 1995).

Palmar/plantar annular desmotomy (PAD) is indicated to alleviate pain from inflammation of DS structures, consequent edema, and relative PAL constriction due to reduced elasticity in cases of desmopathies (Gerring & Webbon, 1984; Verschooten & Picavet, 1986; Kaneps, 2007; Owen et al., 2008). Several techniques have been described, such as the open and closed transection through the lateral access (Kramer, 2006), the extrasynovial approach through the palmar sagittal line (Hawkins & Churchill, 1998), the tenoscopic approach, with several arthroscopic equipment (Nixon et al., 1993; Hawkins & Moulton, 2002; Lacitignola et al., 2018) or with a radiofrequency probe (McCoy & Goodrich, 2012) or even the use of hook knife to perform the procedure guided by ultrasound (Espinosa et al., 2017). In these cases, transection is performed with scissors, a scalpel, or another sharp instrument, which can inflict trauma on vessels and tendons. The open approach also has the disadvantage of increasing the risk of surgical wound dehiscence and synovial fistula formation (Hendrickson & Baird, 2013). In contrast, the use of tenoscopic examination reduces the risk of inadvertent trauma (Hawkins & Moulton, 2002), but with the disadvantage of requiring rigid endoscopy equipment, in addition to tenoscopic training.

Sherif (2017) proposed a new technique to perform medial patellar desmotomy for the treatment of cases of upward patellar fixation in cattle and donkeys by using a suture thread (1 USP) in a minimally invasive approach. De Gasperi et al. (2023) evaluated the feasibility of performing percutaneous desmotomy with surgical thread guided by ultrasound and obtained promising results. In this sense, the evaluation of a PAL percutaneous approach, without imaging resources, can be more practical and affordable if it does not cause damage to the soft tissues.

This study aimed to describe a percutaneous technique for desmotomy of PAL via a minimally invasive approach, using a conventional suture thread and three surgical instruments for suture thread application, and evaluate potential damage to adjacent structures. We hypothesize that the percutaneous approach using a suture thread efficiently performs PAD in equine specimens.

Materials and Methods

Both medial and lateral sides of 15 equine limbs were used in this study (six forelimbs and nine hindlimbs), which the animals were euthanized or died for reasons not related to the locomotor system and without macroscopic anatomical alterations. The limbs were collected immediately after death or euthanasia, sectioned at the carpus or tarsus level, and frozen at -20 °C until the study was carried out.

The limbs were thawed for 12 h at room temperature before carrying out the study. This was followed by cleaning

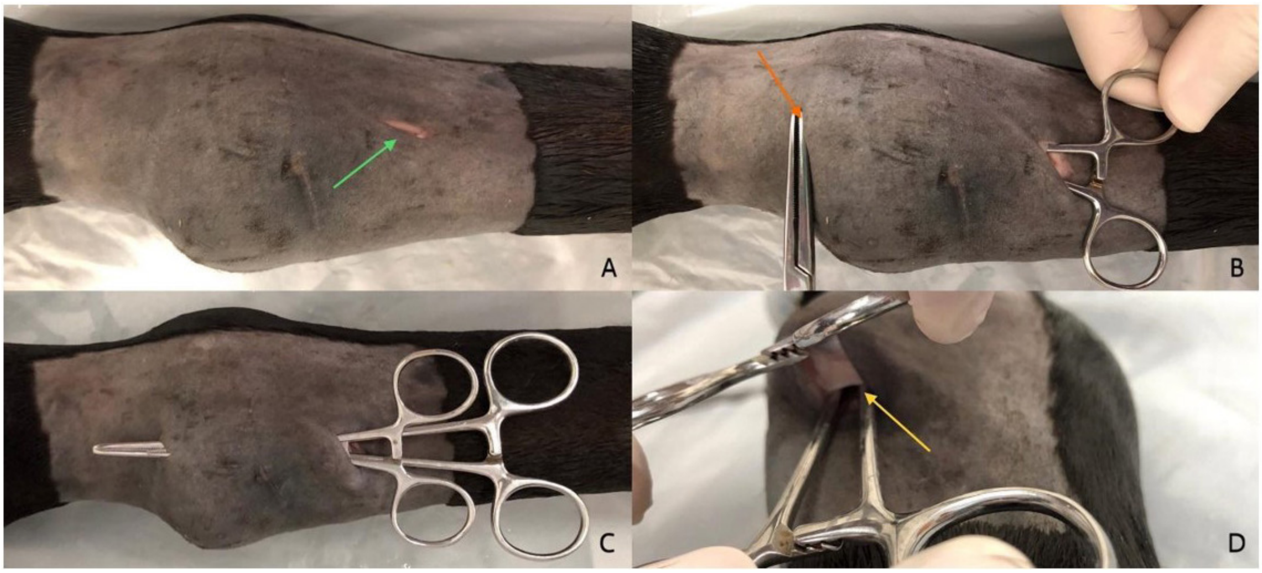

Figure 1 – The sequence of percutaneous approach to palmar annular desmotomy at the medial side of a hindlimb, with the Kelly hemostatic forceps. (A) Incision proximal to a palmar annular ligament (PAL), close to the apex of the sesamoid bone (green arrow); (B) After placing the forceps on the digital sheath, the incision site is distal to PAL (orange arrow); (C) Positioning of two Kelly hemostatic forceps after subcutaneous divulsion, indicating portal formation; (D) Formed portal indicating PAL between the Kelly forceps (yellow arrow). Distal is on the left.

and clipping both lateral and medial sides of the fetlock, from the distal third of the metacarpal or metatarsal region to the middle of the pastern. Each limb underwent two randomized procedures (lateral and medial), obtaining an equal number of sides for each group. Initially, an incision of two centimeters proximal to PAL, at the level of apex of the sesamoid bone and right abaxial to neurovascular bundle (NVB) was performed on the lateral or medial side (Figure 1A) of the limb, advancing to DS, between SDFT and DDFT. Three instruments were used to pass a surgical thread (6 USP multifilament polyglycolic acid) around the PAL for its section: Kelly traumatic hemostatic forceps (GKelly), Gerlach needle (GGerlach), or Obwegeser needle (GObwegeser) (Figure 2).

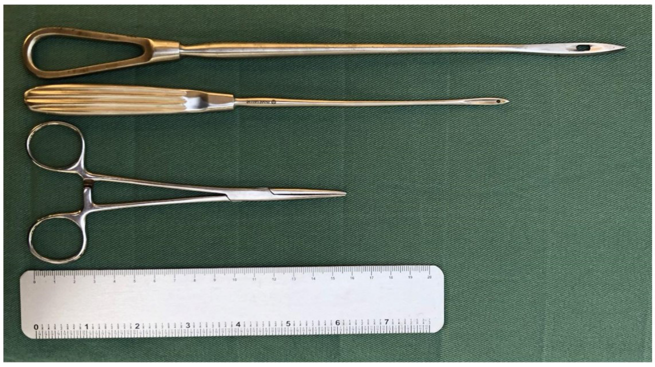

Figure 2 – Instruments used to pass a surgical thread around the palmar annular ligament: Gerlach needle (35 cm) above, Obwegeser needle (24 cm) in the center, and Kelly traumatic hemostatic forceps (14 cm) below.

The instruments progressed distally through DS, and a second incision was made to the distal limit of PAL (Figure 1B). The defined accesses allowed a blunt divulsion of the subcutaneous tissue between skin and PAL (Figures 1C, D), communicating the two incisions. After that, the instrument was passed between the incisions, from proximal to distal, through the DS, and the thread was hooked so that one end could be retracted to the proximal incision. Afterward, the instrument was passed again through the subcutaneous tunnel, and the other end of the thread was hooked and retracted, leaving it looped around the PAL with both ends exiting the same proximal incision (Figure 3).

A back-and-forth motion was performed with the thread tensioned until the loop emerged from the proximal incision, thus ending the procedure. Immediately after the procedure, the limb was dissected to confirm the complete transection of the ligament (Figure 4) and identify possible iatrogenic injuries to the adjacent tissues, all of which were documented.

The frequencies (%) of total or partial PAL transections and the identification of the absence or presence of injuries to the NVB, the superficial and deep digital flexor tendons (SDFT and DDFT, respectively), and the cartilage of the proximal sesamoid bones (CSB) were recorded. Procedure duration was also recorded from palpation to completion of desmotomy. A photographic recording was performed. The same surgeon performed all procedures, and the study follows the SUPER checklist recommendations (Zhang et al., 2023).

Figure 3 – Positioning of the thread using the Kelly hemostatic traumatic forceps (A) in the distal portion of the palmar annular ligament and Gerlach needle (B) to perform the palmar/plantar annular desmotomy. Positioning of the Obwegeser needle through the digital sheath to the distal portion of the palmar annular ligament (C). Distal is at the bottom.

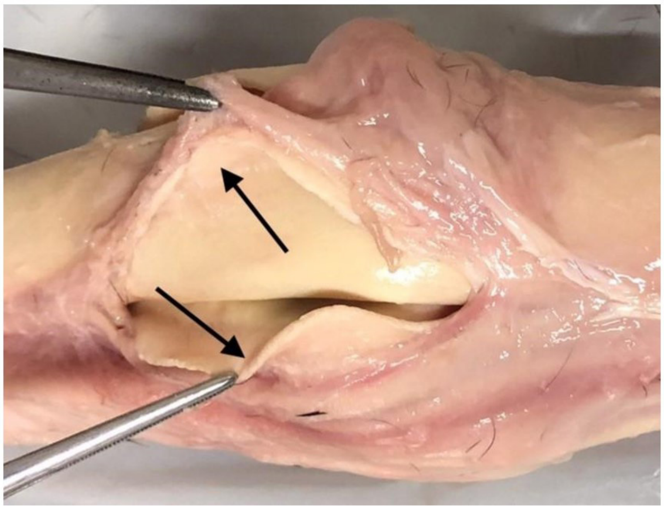

Figure 4 – Complete palmar annular ligament transection (black arrows) evidenced after dissection of the fetlock region.

The presence of lesions to NVB, SDFT, DDFT, and CSB was described in frequencies (%) and analyzed by the Chi-square test according to the group, limb, or side of the limb. Logistic regression was performed to analyze the effect of predictor factors on the chance of iatrogenic injuries occurring in adjacent structures during the procedure. The frequencies of injuries inflicted on NVB and SDFT were considered dependent variables. DDFT and CSB were not analyzed by logistic regression because they presented no injuries. The group (instrumental used: Gerlach, Obwegeser, and Kelly), limb (fore or hindlimb), and side of the limb (lateral or medial) were considered predictor factors. The variance inflation factor (VIF) assessed the collinearity of predictors. The likelihood ratio was used to verify the significance of predictors on the outcome. Nagelkerke's pseudo-R^2 was used to evaluate the predictors regarding the association with the odds of occurrence of injuries.

The procedure duration was initially converted to decimals. The data normality was evaluated by the Shapiro-Wilk test, the homogeneity of variances by the Levene test, and the comparison between groups by the Welch ANOVA test followed by the Games-Howell post hoc test. All analyses were performed using the Jamovi software (version 2.2.5). Values of $p < 0.05$ were considered significant, and $p < 0.10$ were considered as a tendency.

Results

Complete transection of the PAL was achieved in all procedures (100%, 30/30), and in 70% of cases (21/40), no iatrogenic trauma occurred. Of these, 80% in GKelly (8/10), 60% in GGerlach (6/10), and 70% in GObwegeser (7/10). The frequency of lesions to NVB (Figure 5A) was similar between groups ($p = 0.329$) and between limbs ($p = 0.165$), but with a trend to occur on the medial side ($p = 0.068$) regardless of the limb (Table 1). The frequencies of injuries to SDFT (Figure 5B) were similar among the group ($p > 0.99$), sides ($p > 0.99$), and limbs ($p = 0.449$) (Table 1). No lesions were observed in DDFT, CSB, or manica flexoria.

Multivariate logistic regression showed the significance of the side of the limb (likelihood ratio $p = 0.042$) and a trend as a function of the limb (likelihood ratio $p = 0.065$) on the odds of injury in NVB. However, the odds ratio for both was not significant ($p > 0.99$) (Table 2). The analyzed predictor factors did not contribute to an increase in the chances of SDFT injury occurrence ($p > 0.10$) (Table 3).

Nagelkerke's pseudo-R^2 for NVB injury was 0.651 and 0.031 for a lesion in SDFT. That is, the effect of the analyzed predictors on the identified iatrogenic lesions was 65.1% in NVB and 3.1% in SDFT. The variance inflation factor (VIF) was 1 (range of 1–1.02), demonstrating no collinearity between the model's predictors.

The average time to perform the techniques ranged from 09'49"±03'13" (05'43" – 14'30") for GKelly, 05'02"±01'04" (03'54"-12'40") for GGerlach, and 06'49"±02'25" (03'17"-06'45") for GObwegeser. The average time to perform the techniques ranged from 09'49"±03'13" (05'43"-14'30") for GKelly, 05'02"±01'04" (03'54"-12'40") for GGerlach, and 06'49"±02'25" (03'17" - 06'45") for GObwegeser. The Kelly

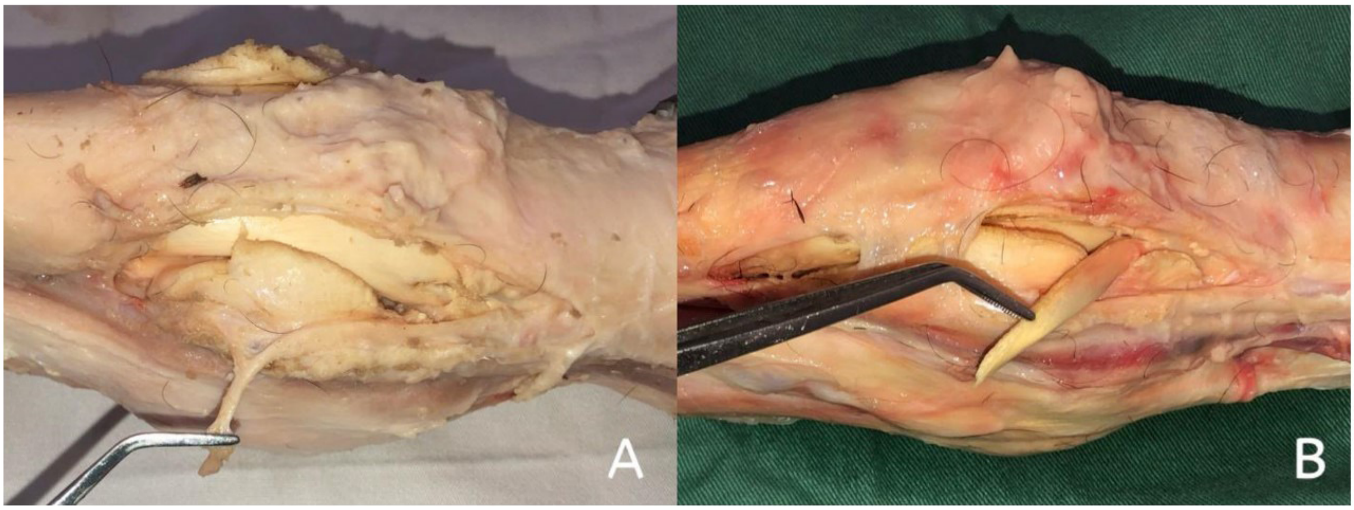

Figure 5 – Transection of the palmar digital nerve (indicated with the forceps) (A). Partial avulsion of the lateral portion of the superficial digital flexor tendon (indicated with the forceps) (B). Distal is on the right.

Table 1 – Frequencies (%) of injuries to structures as a function of (i) the group regardless of the limb and its side, (ii) the side of the limb regardless of the group and the limb, and (iii) the limb regardless of the group and the side of the percutaneous approach to PAD

Variable	––– Lesion –––			
	NVP	***SDFT***	***DDFT***	***CSB***
Group:				
Kelly	0% (0/10)	20% (2/10)	0% (0/10)	0% (0/10)
Gerlach	20% (2/10)	20% (2/10)	0% (0/10)	0% (0/10)
Obwegeser	10% (1/10)	20% (2/10)	0% (0/10)	0% (0/10)
*P-value**	0.329	1	1	1
Side:				
Lateral	0% (0/15)	20% (3/15)	0% (0/15)	0% (0/15)
Medial	20% (3/15)	20% (3/15)	0% (0/15)	0% (0/15)
*P-value**	0.068	1	1	1
Limb:				
Forelimb	0% (0/12)	25% (3/12)	0% (0/12)	0% (0/12)
Hindlimb	16,7% (3/18)	16.7% (3/18)	0% (0/18)	0% (0/18)
*P-value**	0.165	0.449	1	1

Abbreviations: CSB: cartilage of the sesamoid bone, DDFT: deep digital flexor tendon, NVP: neurovascular plexus, SDFT: superficial digital flexor tendon. *By the Chi-square test.

Table 2 – Result of logistic regression analysis of the effect of predictors on neurovascular bundle injury

Predictor	––– Model coefficients –––					*Likelihood ratio**
	Estimation	***SE***	***OR***	***CI (95%)***	***P-value***	
Intercept	-0.935	1.066	0.393	0.05 - 3.17	0.381	-
Group:						0.958
Kelly-Obwegeser	-0.002	1.130	0.998	0.11 - 9.14	0.999	
Gerlach-Obwegeser	-0.151	1.148	0.860	0.09 - 8.15	0.895	
Gerlach-Kelly	-0.149	1.148	0.861	0.09 - 8.17	0.897	
Side:						0.958
Medial-Lateral	0.048	0.925	1.050	0.17 - 6.43	0.958	
Limb:						0.444
Hindlimb-Forelimb	-0.726	0.947	0.484	0.08 - 3.10	0.443	

Note: The estimate represents the log odds of "NVP injury = Present vs. Absent." Abbreviations: CI (95%): 95% confidence interval of odds ratio, OR: odds ratio. SE: standard error of the estimate. *P-value by the Chi-square test.

Table 3 – Result of logistic regression analysis of the effect of predictors on injury in superficial digital flexor tendon

Predictor	––– Model coefficients –––					Likelihood ratio*
	Estimation	*SE*	*OR*	*CI (95%)*	*P-value*	
Intercept	-41.35	9373.18	1.10^{-18}	0.00 - inf	0.996	-
Group:						0.142
Kelly-Obwegeser	-18.88	7616.72	6.34^{-9}	0.00 - inf	0.998	
Gerlach-Obwegeser	1.79	1.68	6.00	0.22 - 163	0.287	
Gerlach-Kelly	20.7	7617	9.46^{8}	0.00 - inf	0.998	
Side:						0.042
Medial-Lateral	20.07	6178.33	5.19^{8}	0.00 - inf	0.997	
Limb:						0.065
Hindlimb-Forelimb	20.19	7048.75	5.85^{8}	0.00 - inf	0.998	

Note: The estimate represents the log odds of "SDFT injury = Present vs. Absent." Abbreviations: CI (95%): 95% confidence interval of odds ratio, OR: odds ratio. SE: standard error of the estimate. *P-value by the Chi-square test.

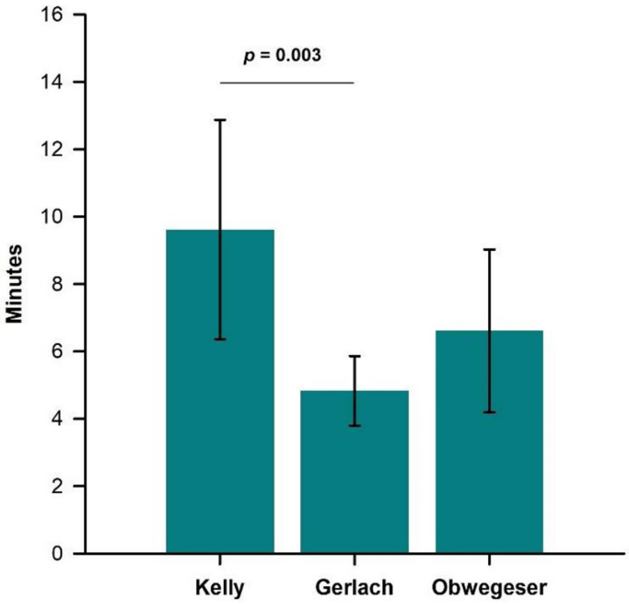

Figure 6 – Duration (minutes) of percutaneous approach to palmar annular ligament desmotomy using different instruments. P-value by the Games-Howell test.

group executed the techniques longer than the Gerlach group (p = 0.03) (Figure 6).

Discussion

This ex vivo study describes a minimally invasive surgical technique for PAD, comparing three instruments for passing the suture thread that performs the ligament section. In general, the technique was efficient in the division of PAL, with quick and straightforward performance. However, a significant potential for iatrogenic trauma was identified, suggesting attention from the surgeon and refinement of the technique.

Minimally invasive surgical techniques allow efficiency similar to open procedures, limit the size of skin incisions, reduce postoperative pain and morbidity, and allow the faster return of the animal to function (Martens et al., 2019). The complete PAL transection in all specimens indicates the effectiveness of the technique described in this study compared to those already mentioned in the literature. Espinosa et al. (2017) reported that 11/12 procedures showed complete transection with the ultrasound-guided technique, while McCoy & Goodrich (2012) reported that only 4/12 ligaments were completely sectioned in those using a radiofrequency probe for tenoscopic-guided desmotomy.

De Gasperi et al. (2023) evaluated the performance of percutaneous desmotomy using the Touhy needle to apply the surgical thread guided by ultrasound. In addition, they performed a hydrodissection of the subcutaneous portion of the access. These authors were successful in complete transection in 80% of the procedures (17/21), with iatrogenic injuries occurring in 19% of the cases (4/21), but none of them occurred in the NVB. In addition, the average time to perform the procedure was 16 min. Confronting the results of our study, we obtained a shorter procedure time, with a higher frequency of complete ligament transection, but with more iatrogenic injuries. This suggests that performing the technique proposed in this study guided by ultrasound could be beneficial in avoiding injury to the surrounding tissue. The closed technique proposed by Kramer (2006) has often been used for its simplicity and efficiency and does not require sophisticated equipment. However, a slightly larger dissection may be required, and incomplete ligament transection may occur more frequently than reported in this study.

Overall, the Obwegeser and Gerlach needles were easier to pass through DS and the divulsion of the subcutaneous tissue, which could be performed in just one movement until it progressed towards the distal incision. On the other hand, the Kelly forceps presented higher resistance in subcutaneous sliding and difficulty in the presentation in the distal incision due to their higher thickness and blunt tip. The exact location of the distal incision is also facilitated by the first two instruments, which have a sharp tip, allowing better targeting with less effort.

Injuries inflicted on NVB were observed at the proximal incision level, and the palmar/plantar digital vein or artery was affected in none of them. Attention must be paid to the remaining structures to be sectioned at the end of the saw movement, thus preventing NVB from being mistakenly injured. The literature has shown the formation of a painful neuroma, DDFT rupture, distal interphalangeal dislocation, lack of sensation in the foot, and the fracture of the navicular bone as possible complications of sectioning the palmar/plantar digital nerve (Jackman et al., 1993; Maher et al., 2008; Eggleston et al., 2020).

As desmotomy is performed on only one side of the limb, the contralateral innervation will be preserved, and the complications associated with neurectomy will be minimized if an inadvertent section of the digital nerve occurs. The direction of the instruments in the distal portion of PAL may have contributed to the occurrence of SDFT lesions due to the smaller space of DS at this point. The instruments must be conducted to the abaxial portion of the limb, deviating from SDFT but avoiding meeting NVB. Therefore, we emphasize the importance of palpating structures and training using cadavers to become familiar with the technique before patient use.

The Gerlach needle was faster than the anatomical Kelly forceps due to its shape, sharper tip, and ease of gripping the thread. However, these characteristics may be the cause of a higher incidence of trauma or inadvertent perforations. However, the frequency of lesions to NVB was similar to Kelly forceps, which is blunter. The time with the Obwegeser needle was similar to that with the Gerlach needle, but it had other advantages: it is shorter, which facilitates manipulation, primarily if a standing approach is performed; and the tip has a less sharp profile than the Gerlach, which reduces potential trauma. It allows us to suggest using the Obwegeser needle as the best option among the evaluated instruments. However, all instruments are suitable options for performing PAD.

Although standard PAD techniques have described only the lateral approach (Nixon et al., 1993; Hawkins & Churchill, 1998; McCoy & Goodrich, 2012; Espinosa et al., 2017), the medial side was added to the study as an alternative to cases in which continuity solutions or any other problem prevent the approach from the lateral side of the fetlock. However, a possible higher chance of trauma in NVB must be considered.

The limitations of the study include (i) the number of specimens, which could increase the significance of the evaluated parameters if increased to better correlate the injuries inflicted on NVB and SDFT to the analyzed predictor factors, and (ii) non-evaluation in clinical cases to verify the performance and difficulties that the use of the technique may present given alterations such as thickening and adhesions of the ligament and DS distensions. Further studies are required to determine safety and efficiency in clinical cases.

Conclusion

The percutaneous approach to PAD in equine specimens was effective, quick, and easy to perform, although with a potential chance of iatrogenic trauma to the surrounding tissue. The Obwegeser needle was more efficient for applying the thread, but the other instruments are reasonable options. Using the instruments evaluated in this study, a percutaneous approach to PAD may be less costly, especially in cases not associated with severe tenosynovitis and in a standing approach.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethics Statement

The Ethics Committee approved the study for the Use of Animals at the School of Veterinary Medicine and Animal Science at the University of São Paulo, protocol number 9186170521.

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