ORIGINAL ARTICLE

Common calcaneal tendon repair in cats: outcomes and complications associated with different postoperative tarsocrural joint immobilisation methods

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Objectives: (1) To report surgical repair techniques for common calcaneal tendon injuries in cats; (2) to describe both short-term and long-term complications; (3) to investigate the long-term outcome following temporary postoperative immobilisation of the tarsocrural joint; and (4) to evaluate how all three objectives, as well as patient signalment and type of tendinous injury, compared to previously reported studies.

Materials and Methods: A multicentric, retrospective study reviewing cases from 11 referral veterinary centres. Data collected included patient demographics, common calcaneal tendon injuries characteristics, repair techniques employed and postoperative immobilisation methods. Based on the temporary tarsocrural joint immobilisation methods, the cases were divided into internal fixation group: calcaneotibial screws or plate and tibiometatarsal plate, and external immobilisation group: trans-articular external skeletal fixation or external coaptation. Complications were classified as minor, major or catastrophic. Long-term outcomes were assessed through clinical follow-up examination and owner-reported questionnaires.

Results: A total of 39 cases of common calcaneal tendon repair were analysed. The internal fixation and external immobilisation groups showed a complication rate of 13% and 54.2%, respectively. Catastrophic complications (5.2%) occurred only in the external immobilisation group. Long-term follow-up indicated that 82% of cases regained full or acceptable clinical function, with a higher rate of

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unacceptable outcomes observed in the external immobilisation group.

Clinical Significance: This study suggested that temporary internal fixation may be a more suitable method for postoperative immobilisation of the tarsocrural joint in cats compared with temporary external immobilisation, and it can be associated with lower complication rates.

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INTRODUCTION

The common calcaneal tendon (CCT), also known as the Achilles tendon, is composed of the tendons of the gastrocnemius muscle, the superficial digital flexor (SDFT) and the common tendon of the biceps femoris, semitendinosus and gracilis muscles (Hermanson & Evans, 1993). In cats, the CCT is completed laterally by a small tendon coming from the soleus muscle (Voss et al., 2009). Surgery is the generally accepted treatment of choice to effectively restore function. Several primary tenorrhaphy suture patterns have been described, including three-loop pulley, locking-loop, Krackow, continuous cruciate, vertical mattress, simple interrupted and Mason-Allen used alone or in combination (Carmichael & Marshall, 2018; Guerin et al., 1998; Moores et al., 2004; Renberg & Radlinsky, 2001; Wilson et al., 2014). Furthermore, augmentation techniques such as autologous grafts (Baltzer & Rist, 2009; Braden, 1976; Diserens & Venzin, 2015; Sangion et al., 2018), allografts (Tidwell et al., 2022) and synthetic implants (Morton et al., 2015; Vaughan, 1981) have been described. Temporary tarsocrural joint immobilisation combined with surgical repair of the CCT has been recommended to decrease the significant tensile forces imposed during tarsal joint extension throughout the healing process (Carmichael & Marshall, 2018; deHaan et al., 1995; Nielsen & Pluhar, 2006). Temporary immobilisation of this joint can be achieved using different techniques, including calcaneo-tibial screw (CTS), trans-articular external skeletal fixator (TA-ESF), calcaneo-tibial plate (CTP), tibio-metatarsal plate (TMP) and external coaptation (EC) (Boero Baroncelli et al., 2021; deHaan et al., 1995; Devereux et al., 2021; Guerin et al., 1998; Guthrie, 2024; Morshead & Leeds, 1984). Complications following common calcaneal tendon repair are reported to occur in up to 35% of dogs and between 33% and 41.5% of cats, and include failure of the primary tendon repair, skin infection, pressure sores and temporary stabilisation technique-related complications (implant failure, loosening, infection) (Beever et al., 2017; Boero Baroncelli et al., 2021; Cervi et al., 2010; Corr et al., 2010; Häußler et al., 2023a, 2023b; Nielsen & Pluhar, 2006; Norton et al., 2009; Reinke et al., 1993; Sivacolundhu et al., 2001). Most of those complications are commonly related to the method of immobilisation, rather than the tendon repair technique itself (Cervi et al., 2010; Häußler et al., 2023a; Nielsen & Pluhar, 2006).

The objectives of this multicentric study were (1) to report surgical repair techniques for common calcaneal tendon (CCT) injuries in cats; (2) to describe both short-term and long-term complications; (3) to investigate the long-term outcome following temporary postoperative immobilisation of the tarsocrural joint; and (4) to evaluate how the above three objectives, as well as patient signalment and type of tendinous injury, compared to previously reported studies.

Our first hypothesis was that immobilisation with internal fixation techniques would result in a lower short-term complication rate compared with external immobilisation techniques. Our second hypothesis was that the overall long-term function after recovery would be comparable regardless of the immobilisation technique used, with most cats regaining full to acceptable function of the limb.

MATERIALS AND METHODS

Ethical approval for this retrospective multicentre study was obtained from an institutional Committee for Animal Research and Ethics (CARE).

Data collection

The medical records for cats that underwent surgical CCT repair at 11 referral centres were reviewed between 2008 and 2023. The collected data included the following: signalment, body weight (BW), body condition score (BCS), the onset of lameness, stance position, concurrent orthopaedic injuries, type and site of injury, the time between injury and surgery (acute: <48 hours, sub-acute: 2 to 21 days, chronic: >21 days) (Reinke et al., 1993), the techniques used for primary tendon repair and for temporary tarsocrural joint immobilisation. CCT injuries were further characterised as traumatic with or without presence of any wound and atraumatic when they occurred during normal activity or without any history of trauma (Häußler et al., 2023a). The wounds were classified as minor and major according to Kulendra et al. (2011). Suture material, size and pattern for the primary tendon repair were recorded and use of a calcaneal bone-tunnel was recorded if utilised. Use of temporary tarsocrural joint immobilisation methods and the duration of hospitalisation after surgery were also detailed. For the CTS cases, diameter and length of the screw, washer type (if used) and the screw/bone size ratio

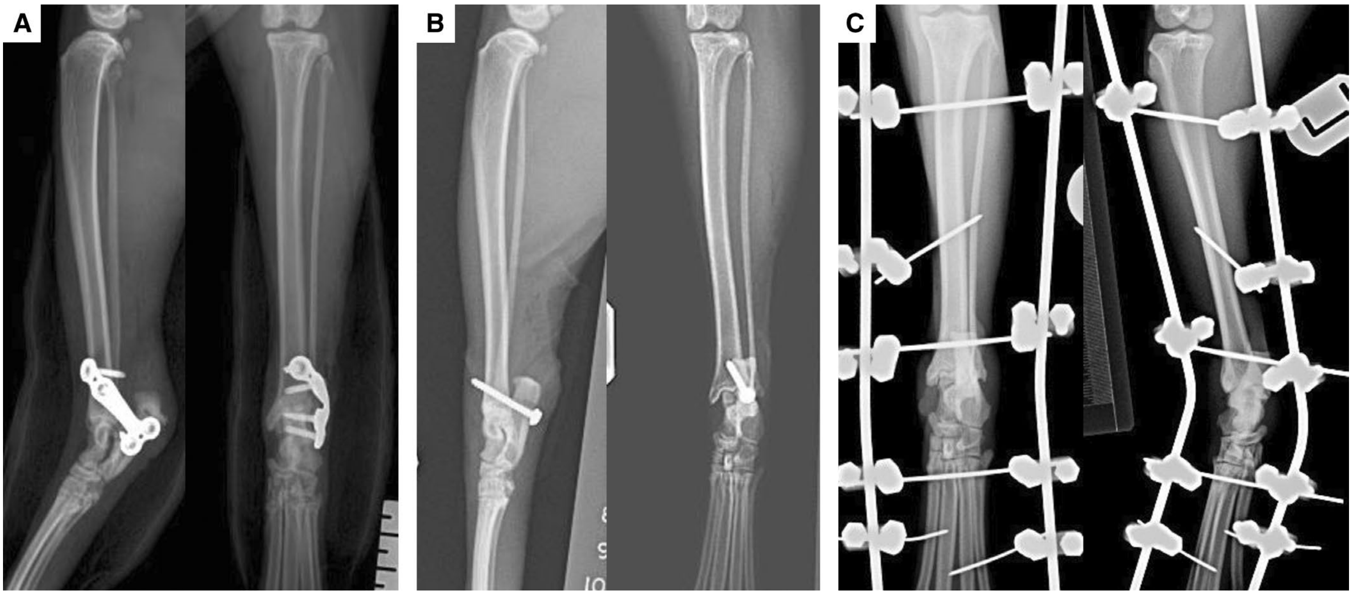

FIG 1. Lateral and craniocaudal radiographic views of different techniques of immobilization for common calcaneal tendon (CCT) repair in cats. (A) Calcaneotibial plate. (B) Calcaneotibial screw. (C) Modified type II external skeletal fixator.

measured on the medio-lateral radiographic view at point of screw insertion were recorded. For the TA-ESF cases, the ESF type and configuration were recorded. For the CTP and TMP cases, the type, size and location of the implant were recorded. For the EC cases, the type of coaptation (casting, splinting) was recorded.

Based on the technique of immobilisation of the tarsocrural joint, the cases were divided into two groups: (1) internal fixation group (IFG), which included CTS, CTP and TMP cases, and (2) external immobilisation group (EIG) with TA-ESF and EC cases (Fig 1).

External coaptation and TA-ESF are biomechanically distinct techniques; however, due to the limited number of EC cases in this study, results for TA-ESF and EC were presented together under the EIG.

Intra- and postoperative complications and duration of temporary immobilisation were recorded. Postoperative complications were defined as minor (no surgical or medical treatment was required), major (further surgical or medical treatment was required) and catastrophic (complications resulting in permanent unacceptable function, death or euthanasia) (Cook et al., 2010).

Short-term complications were assessed by the attending veterinarian and were defined as those occurring while the implant remained in place, whereas long-term complications were assessed by a veterinarian after implant removal and were defined as those occurring after implant removal.

The subjective long-term clinical outcome assessed by a veterinarian was categorised as full, acceptable or unacceptable regarding the function of the operated limb, and additional information on long-term outcome was obtained from owners via a telephone questionnaire. The Feline Musculoskeletal Pain Index (North Carolina) (Benito et al., 2013) was used, with the addition of some questions regarding the ongoing administration of oral analgesia (if any), owner-observed lameness and owner-assessed quality of life and limb function (Appendix A). All data were reported using descriptive statistics, with the mean values reported for normally distributed data and the median values reported for non-normally distributed data for both the overall population and for each treatment group individually.

RESULTS

Medical records of 38 cats were reviewed. Thirty-seven cats sustained a unilateral CCT injury, and one cat had a bilateral CCT injury; therefore, 39 limbs with CCT injuries were included in this study. Breeds included Domestic Shorthair (35), Burmese (1), Maine Coon (1) and British Shorthair (1). The median age at presentation was 6.6 years [range: 0.6 to 15 years]. There were 18 males (1 entire and 17 castrated) and 20 spayed females. Median body weight was 4.66 kg [range: 2.8 to 8.2 kg] and median BCS was 6/9 [range: 3/9 to 9/9].

The CCT injuries were acute and traumatic in 31 of 39 limbs, and in 15 of 31 limbs were associated with wounds to the skin and associated tissues. Minor and major wounds were reported in 11 and in 4 of 15 limbs, respectively. Atraumatic CCT injuries were detected in 8 of 39 limbs. Plantigrade stance was the most common orthopaedic examination finding, present in 33 of 39 limbs. Concomitant orthopaedic injuries were reported in 3 of 39 limbs. These included a traumatic subluxation of the fourth and fifth digits on the same limb of the CCT injury in one cat, a traumatic third digit fracture on the same limb in one cat and tarsal instability associated with CCT injury in one cat. Based on surgical exploration, CCT rupture was complete in 16 of 39 limbs and partial in 18 of 39. For the cases with partial CCT rupture, all components but the SDFT were affected in 14 of 18, and only the gastrocnemius and only the SDFT were affected in 3/18 and 1/18, respectively. All the above data are summarised in Table 1.

It was unclear which components of the CCT were injured in three limbs and in two limbs this information was not recorded. In 21 of 39 limbs, the CCT rupture was at the level of the insertion site, in 9 of 39 limbs at the level of the tendon body and in 6 of 39 limbs it was at the level of the musculotendinous junction. In three limbs, this information was not recorded. The time between injury and surgery was <48 hours in 5 limbs, between 2 and 21 days in 29 limbs and >21 days in 5 limbs.

Table 1. Summarised study data including signalment, type of injury and components of the common calcaneal tendon affected in the reported cases

Signalment (38 cats)	
Sex	
Male entire	1
Male neutered	17
Female neutered	20
Breed	
DSH	35
Burmese	1
Maine Coon	1
British short haired	1
Age (years)	6.6 (0.6 to 15)
Body weight (kg)	4.66 (2.8 to 8.2)
Body condition score	6/9 (3/9 to 9/9)
CCT injury ($n=39$)	
Type of injury	
Acute/traumatic	31
Chronic/atraumatic	8
Components	
All components	16
Partial	18
Unclear	3
Not recorded	2

CCT Common calcaneal tendon, DSH Domestic short haired

Common calcaneal tendon repair

Primary tenorrhaphy was performed with a three-loop pulley suture in 16 of 39 limbs, with a locking loop suture in 9 of 39 and by a combination of both in 3 of 39. Other techniques used were modified Kessler suture pattern in two limbs, central gastrocnemius turnover aponeurosis flap technique in two limbs, braided ultra-high molecular weight polyethylene (UHMWPE) synthetic ligament (Novaten 2000, Novetech Surgery, Monaco) in one limb and modified Kessler suture in combination with epitendinous sutures and mini Tight-rope® with a loop suture pattern (Arthrex Vet Systems, Naples, FL, USA) in one limb. In this latter case, in contrast to the original description (Schulz et al., 2019), the repair was reinforced by a modified Kessler suture and autogenous leukoreduced platelet-rich plasma was not applied. Postoperative immobilisation consisted of a univalve cast in the limb treated with the UHMWPE synthetic ligament and in the limb where a modified Kessler suture combined with epitendinous sutures and a mini TightRope® with a loop suture pattern construct was used, whereas a TA-ESF was applied in the remaining limbs managed with other primary tenorrhaphy techniques. In five limbs, the type of tenorrhaphy was not recorded. Primary tenorrhaphy was performed using the following suture: polypropylene in 11 limbs, nylon in 7 limbs, polydioxanone in 6 limbs and polyglycolic acid in 2 limbs. In two limbs, a combination of polypropylene and polydioxanone was employed. The suture material used was not recorded in 11 limbs. The size of suture material employed was 3.0 metric in 16 limbs, 2.0 metric in 8 limbs, 3.5 metric in 3 limbs and 1.5 metric in 1 limb. The size of the suture material was not recorded in 12 limbs. A bone tunnel was created in the calcaneus in 20 of 39 limbs.

Internal fixation group (IFG)

Fifteen limbs were included in the internal fixation group: CTS (11 limbs), CTP (3 limbs) and TMP (1 limb).

For the CTS technique, a cortical screw of 2.4 mm or 2.7 mm diameter was used in seven limbs and four limbs, respectively. Additionally, flat washers were used in four limbs. Screw length was recorded in only three of 11 limbs, measuring 20, 22 and 25 mm. The median screw-to-bone ratio was on average 0.36 [range: 0.29 to 0.48] for the 2.7 mm screw and 0.32 [range: 0.26 to 0.43] for the 2.4 mm screw.

In the three limbs where a CTP was used, the implants were applied laterally in three limbs and dorsally in one limb. A 1.9 to 2.5 mm L and a T plate (Fixin, Intrauma, Italy) were used in three limbs and they were applied to the calcaneus and the distal tibia. A 2.0 mm hybrid carpal arthrodesis plate (Veterinary Instrumentation, United Kingdom) was used in one limb, and it was applied to the dorsum of the tarsus and third metatarsal bone. In the IFG, the mean duration time of temporary joint immobilisation was 47 ± 7 days for the limbs treated with CTS and 55 ± 17 days for the limbs treated with CTP and TMP. The mean duration of hospitalisation in the IFG group was 2.2 ± 2 days.

External immobilisation group (EIG)

In this group, 24 limbs were included: TA-ESF and EC were used in 22 and 2 limbs, respectively. A modified type II TA-ESF was used in 6 of 22 limbs, a type II ESF type was used in 5 limbs and a type I ESF was used in 6 limbs. A hybrid type I–II was used in two limbs, and a free frame acrylic external fixation was used in one limb. The median number of pins or half-pins per bone segment was 2.5 [range: 1 to 5 pins/bone fragment]. In two limbs, the information about the type and configuration was not recorded. For the EC cases, two limbs had a univalve splint bandage.

In the EIG, the mean duration time of temporary joint immobilisation of the TA-ESF and external coaptation was 42 ± 12 days (44 ± 11 and 28 ± 20 days, respectively). The mean duration of hospitalisation was 4.5 ± 6 days (Fig 1).

Complications

The overall complication rate, regardless of the joint immobilisation technique used, was 38.5% (15/39) comprised of seven minor, six major and two catastrophic complications. Complications in the

Table 2. Summarised study data including type of tarsocrural joint immobilisation and associated complications

	Short-term complications			Long-term complications		
	Minor	Major	Catastrophic	Minor	Major	Catastrophic
EIG						
TA-ESF ($n=22$)	Skin irritation and/or Pin tract drainage ($n=6$)	Wounds over the calcaneus ($n=1$) Pin loosening ($n=1$)			Wounds over the calcaneus ($n=1$) Implant failure ($n=1$)	Osteomyelitis ($n=1$) Failure of tendon healing ($n=1$)
EC ($n=2$)				Skin sores ($n=1$)		
IFG						
CTS ($n=11$)					Tendon repair failure ($n=1$)	
CTP ($n=3$)						
TMP ($n=1$)	Limb swelling ($n=1$)					

CTP Calcaneo-tibial plate, CTS Calcaneo-tibial screw, EC External coaptation, EIG External immobilisation group, IFG Internal fixation group, TA-ESF Trans-articular external skeletal fixator, TMP Tibio-metatarsal plate

IFG were reported in only 2 of 15 limbs (13%): one limb developed a minor short-term complication (limb swelling at 3 weeks postoperatively) after temporary TMP, and one limb had a major complication (tendon repair failure) 8 weeks after CTS removal. In the EIG, overall complications were reported in 13 of 24 limbs (54.2%). Short-term complications occurred in eight limbs, while an additional five limbs experienced long-term complications. Minor complications were observed in six limbs (25%), major complications in five limbs (20.8%) and catastrophic complications in two limbs (8.4%). Minor complications included self-limiting skin sores from a univalve cast in one limb, and skin irritation or pin tract drainage in five limbs treated with TA-ESF. Major complications comprised wounds over the calcaneus, implant failure, infection and pin loosening. Catastrophic complications involved osteomyelitis secondary to pin tract infection and failure of tendon healing, which was ultimately addressed by amputation of the affected limb.

Long-term outcome

Clinical follow-up available from the clinical records showed a return to full function in 18 of 39 limbs, acceptable function in 14 of 39 limbs and unacceptable function in 4 of 39 limbs. These follow-up assessments were conducted at a mean of 295 days postoperatively [range: 7 to 1800]. In three limbs, the clinical outcome was not reported. Unacceptable function was reported only in the EIG (TA-ESF subgroup).

Modified Feline Musculoskeletal Pain Index (FMPI) was completed by telephone for 10 cats: four managed with internal fixation and six managed with external immobilisation. In the remaining cases, follow-up could not be obtained due to the owners declining the telephonic calls.

The median time for questionnaire follow-up was 28 months [range 2 to 96 months]. The median FMPI score was 3/72 [range 0 to 24/72] (a higher score indicates a greater degree of pain and functional impairment). Quality of life was described as excellent ($n=8$) and good ($n=2$). No patients required long-term analgesia, and the questionnaire indicated that the overall limb function was excellent ($n=6$), very good ($n=2$), good ($n=1$) and fair ($n=1$). The data described above are presented in Tables 2 and 3.

Table 3. Summarised long-term outcome study data

	Long-term outcome			
	Full function	Acceptable	Unacceptable	Not recorded
EIG				
TA-ESF ($n=22$)	9	6	4	3
EC ($n=2$)	2			
IFG				
CTS ($n=11$)	4	7		
CTP ($n=3$)	3			
TMP ($n=1$)		1		

CTP Calcaneo-tibial plate, CTS Calcaneo-tibial screw, EC External coaptation, EIG External immobilisation group, IFG Internal fixation group, TA-ESF Trans-articular external skeletal fixator, TMP Tarsometatarsal plate

DISCUSSION

The present multicentre retrospective study is based on 39 cases of CCT injury in cats over a period of 15 years. Despite contributions from several referral centres over a relatively long period of time, the limited number of cases suggests that this is an infrequently encountered pathology.

The mechanism of disruption of the CCT remains incompletely understood (Cervi et al., 2010; Häußler et al., 2023b) and despite factors such as sex, age and body weight being suggested as predisposing factors, findings across studies remain inconsistent (Cervi et al., 2010; Häußler et al., 2023b). Notably, Cervi et al. (2010) and Häußler et al. (2023a, 2023b) found that geriatric female cats were predisposed to atraumatic CCT insertion avulsion and although not reaching statistical significance, Häußler et al. (2023a, 2023b) reported that obesity may be a contributing factor to atraumatic CCT injuries.

The population of cats in our series, sex distribution was balanced (male 47% and female 53%), with a median age of 6.6 years, median body weight of 4.66 kg and median BCS of 6/9 consistent with the feline population reported in previous studies. By incorporating the BSC to achieve a more comprehensive assessment of the cats' overall body condition, we further categorised the cats in our study as overweight rather than obese.

In contrast to previous studies (Cervi et al., 2010; Häußler et al., 2023b), we reported a relatively high incidence of acute and traumatic CCT injuries (79.5%). Defining CCT injuries as atraumatic proved challenging, particularly when relying solely on historical reporting by cat owners of the occurrence of injury during routine activity or without witnessed or documented trauma. Since histological examination of the affected tendons was not performed in any of our cases, it is difficult to fully elucidate this aspect (Klatte-Schulz et al., 2018). In contrast with Cervi et al. (2010) and Häußler et al. (2023a, 2023b), our case series reported here revealed an almost equal distribution between partial (46%) and complete (41%) CCT injury. However, the most frequent anatomical location of injury in our cases, as well as in other canine studies (Corr et al., 2010; Reinke et al., 1993), was at the tendinous insertion on the calcaneus (53%). This consistent involvement of the tendinous insertion, regardless of whether the rupture was partial or complete, or of traumatic or atraumatic origin, suggests that this site represents an inherent point of weakness of the CCT in dogs and cats.

Previous studies have shown that, as long as the method of postoperative immobilisation used is properly applied to facilitate tendon healing, the primary repair is unlikely to fail, irrespective of the type or pattern of suture employed for tendon repair (Cervi et al., 2010; Häußler et al., 2023b). Despite the application of an appropriately selected and executed tarsocrural immobilisation method, the surgical technique employed for primary tendinous repair remains a critical determinant of outcome. Achieving precise apposition of the tendinous ends is essential, as even minimal gap formation can lead to healing with biomechanically inferior fibrous tissue, thereby creating a weak point that predisposes the tendon to future repair failure. Tendon healing relies on fibroblast proliferation and collagen matrix deposition (Montgomery & Flitch, 2003), and gaps exceeding 3 mm significantly reduce tendon strength and promote scar tissue accumulation (Gelberman et al., 1999). Consequently, the integrity of the repair during the early postoperative period, supported by suture and immobilisation, is fundamental to prevent re-rupture and ensure optimal functional recovery (Berg & Egger, 1986; Dueland & Quentin, 1980).

In our series, primary tendon repair failure was reported in two cases and considering the retrospective design of the study, it remains uncertain whether adequate apposition of the tendinous wound was achieved, which may, in turn, have contributed to the failure of the repair. One was an obese cat with a BCS of 9/9 with a chronic and atraumatic partial rupture of the gastrocnemius only at the insertion site, treated with a CTS. Tendon repair failure was noted 8 weeks after the CTS was removed, and it was treated with a pantarsal arthrodesis. Following pantarsal arthrodesis, at the 12-week follow-up, limb function was categorised as acceptable, though only fair. It is noteworthy that this case was the only one with long-term complications in our series. In this particular cat, obesity may have played an important role in the repair failure, both through mechanical factors (increased body weight producing greater forces that had to be counteracted by the repaired tendon compared with a cat of normal body condition) and through a possible underlying tendon pathology associated with obesity (chronic low-grade inflammation), which could have contributed to the atraumatic rupture initially observed or to the subsequent complication due to impaired healing. The second case involved a chronic complete rupture at the insertion site accompanied by minor wounds. The CCT rupture was repaired with a locking loop suture and postoperative immobilisation and a modified type II TA-ESF. Tendon repair failure occurred and was associated with an infected wound over the calcaneus. This resulted in unacceptable limb function, ultimately leading to limb amputation.

The importance of postoperative joint stabilisation following CCT primary repair to allow appropriate tendon healing has been extensively reported, with recommended immobilisation periods ranging between 6 and 10 weeks (Berg & Egger, 1986; Braden, 1976; Carmichael & Marshall, 2018; Dueland & Quentin, 1980; Gelberman et al., 1999; Hirsch, 1974; Maffulli & Kader, 2002; Montgomery & Flitch, 2003; Nielsen & Pluhar, 2006). In the study reported here, the mean immobilisation period for all limbs was 45 days, with a longer period in the internal fixation group (49 ± 10 days) than in the external immobilisation group (42 ± 12 days).

Complications associated with CCT repair are more frequently attributed to the method of immobilisation rather than the tendon repair technique itself (Cervi et al., 2010; Häußler et al., 2023b; Nielsen & Pluhar, 2006). Recent studies in the feline population have reported overall complication rates ranging from 28.6% to 41.3% (Cervi et al., 2010; Häußler et al., 2023b). In our cases series, the overall complication rate was 38.5%, including 18% minor, 15.3% major and 5.2% catastrophic complications. Detailed information on the management of the complications was not recorded, as this was beyond the scope of the present study.

Within the IFG, the overall complication rate was 13% (2/11), with one limb (6%) treated with a CTP experiencing a minor complication (self-limiting swelling) and one limb (6%) treated with a CTS sustaining a major complication (failure of tendon repair after screw removal). Complication rates associated with the placement of CTS have been reported in 16% of cases (6/38) in a canine series, including screw bending, breakage and loosening (Beever et al., 2017). Similarly, in cats treated with a CTS, Häußler et al. (2023b) reported a 23% (5/21) incidence of minor short-term complications and a 14% (3/21) rate of major short-term complications (including CCT rupture after screw removal, calcaneal fracture, calcaneal tuber apophysiolysis). Our results compare favourably with previous reports (Corr et al., 2010; Häußler et al., 2023b), demonstrating a lower complication rate in our IFG.

In our study, we also report the use of a temporary CTP and TMP in four limbs. The plate was applied laterally in three limbs and dorsally in one limb. Boero Baroncelli et al. (2021) reported a temporary tarsocrural immobilisation technique with L and T conical coupling locking implants in eight dogs, which yielded a successful outcome. Complications, including osteomyelitis or screw pull out, were observed in two cases from their series. None of the limbs treated with CTP in our study developed either of these postoperative complications. Limb swelling was reported in one limb involving the use of a dorsal plate. A limited approach, as described by Guthrie (2024) might reduce postoperative swelling.

It is worth mentioning that one cat treated with CTP involved a bilateral traumatic CCT rupture, and plates were used in both tarsi. This cat reached full functional recovery with a decreased range of motion and experienced no complications. In this mode of operation, the biomechanical strength of a locking implant with four screws is unknown in comparison with a single calcaneo-tibial cortical screw, and further biomechanical studies comparing these constructs are warranted to investigate this.

In the EIG, the overall complication rate was 54% (13/24) with 25% classified as minor, 20% as major and 8% as catastrophic, with all of them occurring in limbs that received a TA-ESF. The most frequent minor complications, observed in 25% of the limbs, were pin tract drainage and skin irritation. Catastrophic complications were reported exclusively in the EIG.

In cats, the anatomical site in which ESF is used is a contributing factor in the development of complications, with the tarsus associated with a complication rate of 35% (Beever et al., 2017). Furthermore, the number of pins per bone segment used may impact clinical outcomes. In our study, the average number of full/half pins used per bone segment was 2.5. Kulendra et al. (2011) recommend placement of a minimum of three pins proximally and distally to the talocrural joint to reduce the incidence of implant-related complications. A lower number of ESF pins in our limbs may have been associated with complications in some of our cases, but other causes, such as pin insertion technique, drilling speed, pin size and owner compliance with the provided postoperative aftercare instructions, may have additionally contributed to the reported complications. The relatively elevated complication rate associated with the TA-ESF in our study is consistent with findings from other studies (Cervi et al., 2010; Häußler et al., 2023a; Nielsen & Pluhar, 2006). To date, no single immobilisation method has been proven superior in terms of complication rate, duration of immobilisation, recovery time or functional outcome (Carmichael & Marshall, 2018; deHaan et al., 1995; Guerin et al., 1998; King & Jerram, 2003; Nielsen & Pluhar, 2006: Norton et al., 2009; Maffulli & Ajis, 2008; Morshead & Leeds, 1984; Sivacolundhu et al., 2001). However, the higher overall complication rate observed with the TA-ESF compared to the calcaneo-tibial plate or screw used here suggests that internal fixation may be a more appropriate method for immobilising the tarsocrural joint in cats. Nevertheless, it is important to note that the removal of the external skeletal fixation is typically less complex and invasive than internal fixation, particularly when the latter requires explantation.

The prognosis following surgical repair of CCT injuries in dogs is generally considered good to excellent (King & Jerram, 2003; Nielsen & Pluhar, 2006; Voss et al., 2009). In our cohort, long-term clinical follow-up was available for only 18 of 39 limbs. Among these, 14 limbs exhibited acceptable limb function, while four limbs were deemed to have unacceptable function. The limbs with unacceptable function were exclusively observed in the EIG.

There are several limitations to our study mainly related to its retrospective nature with data reliant on the accuracy of medical records. Given that this was a multicentric study, several surgeons performed the surgical procedures, introducing variability in surgical expertise, treatment selection criteria and preferences over the immobilisation technique used. Additionally, the long-term outcomes were assessed through a questionnaire in a limited number of cases, dependent entirely on the owners' subjective perceptions of lameness and overall mobility performance, which may have introduced bias. The use of kinetic gait analysis could have mitigated observer bias; however, its implementation is technically challenging in feline patients, and such equipment is not readily available in all veterinary centres, limiting its widespread application. Finally, the population size was too small for *statistical analysis* to evaluate the impact of the tarsocrural joint immobilisation method on the outcome and complications.

In conclusion, this retrospective multicentric study on surgical repair of the CCT in cats outlined different repair techniques and immobilisation methods used in clinical practice. While our results suggested that internal immobilisation with internal fixation techniques resulted in a lower rate of postoperative complications compared to external immobilisation techniques, caution should be exercised when making definitive conclusions beyond what was presented in the data. Based on our results, our initial hypotheses were supported to a degree by the descriptive results presented.

Further studies with larger sample sizes and more rigorous analyses are necessary to confirm these findings and provide more certain guidance for the treatment of CCT injury in cats.

Author contributions

C. Rizkallal: Conceptualization (equal); data curation (equal); writing – original draft (lead); writing – review and editing (equal). **A. J. Currie:** Data curation (equal); writing – review and editing (equal). **R. Meeson:** Data curation (equal); writing – review and editing (equal). **K. Compagnone:** Data curation (equal); writing – review and editing (equal). **R. Alvarez:** Data curation (equal); writing – review and editing (equal). **I. Kalmukov:** Data curation (equal); writing – review and editing (equal). **G. Pisani:** Data curation (equal); writing – review and editing (equal). **F. Cinti:** Data curation (equal); writing – review and editing (equal). **M. Owen:** Data curation (equal); writing – review and editing (equal). **F. Bird:** Data curation (equal); writing – review and editing (equal). **L. Vezzoni:** Data curation (equal); writing – review and editing (equal). **L. A. Piras:** Data curation (equal); writing – review and editing (equal). **W. Marshall:** Data curation (equal); writing – review and editing (equal). **B. Dean:** Data curation (equal); writing – review and editing (equal). **A. Bourbos:** Data curation (equal); writing – review and editing (equal). **R. Vallefuoco:** Conceptualization (equal); writing – review and editing (equal); data curation (equal).

Conflict of interest

None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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APPENDIX A

FELINE MUSCULOSKELETAL PAIN INDEX

CASE NUMBER:

How is your cat's mobility in general?

- Very good
- Good
- Fair
- Poor
- Very poor

How does your cat move?

- No stiffness or limping
- Mild stiffness or limping

- Moderate stiffness or limping
- Severe stiffness or limping
- Extreme stiffness or limping

What is your cat's ability to run?
- Normal
- Not quite normal
- Moderately worse than normal
- Barely or with great effort
- Not at all

How easily does your cat jump UP?
- Easily and with no hesitation
- With mild difficulty and/or hesitation
- With moderate difficulty and/or hesitation
- With severe difficulty and/or hesitation
- With extreme difficulty and/or hesitation

How easily does your cat jump DOWN?
- Easily and with no hesitation
- With mild difficulty and/or hesitation
- With moderate difficulty and/or hesitation
- With severe difficulty and/or hesitation
- With extreme difficulty and/or hesitation

How well does your cat jump UP stairs?
- Easily and with no hesitation
- With mild difficulty and/or hesitation
- With moderate difficulty and/or hesitation
- With severe difficulty and/or hesitation
- With extreme difficulty and/or hesitation

How well does your cat go DOWN stairs?
- Easily and with no hesitation
- With mild difficulty and/or hesitation
- With moderate difficulty and/or hesitation
- With severe difficulty and/or hesitation
- With extreme difficulty and/or hesitation

How does your cat interact with you and human family members?
- Eagerly
- Willingly
- Reluctantly
- Rarely
- Never

How does your cat play and/or interact with other pets?
- Eagerly
- Willingly
- Reluctantly
- Rarely
- Never
- Not applicable

How easily does your cat get up from a resting position?
- Easily
- With mild difficulty and/or stiffness
- With moderate difficulty and/or stiffness
- With severe difficulty and/or stiffness
- With extreme difficulty and/or stiffness

How does your cat like being touched and/or held?
- Loves it
- Accepts it willingly
- Accepts it reluctantly
- Rarely accepts it
- Not at all

What is your cat's ability to groom him/herself?
- Normal
- Not quite normal
- Moderately worse than normal
- Barely, or with great effort
- Does not groom

How well does your cat jump UP to a meter height?
- Easily reaches jump
- Struggles but always makes the jump
- Struggles and occasionally misses the jump
- Struggles and generally misses the jump
- Always misses or is not possible

What is your cat's ability to stretch?
- Normal
- Not quite normal
- Moderately worse than normal
- Barely or with great effort
- Does not stretch

What is your cat's overall quality of life?
- Excellent
- Good
- Fair
- Poor
- Very poor

How has your cat's happiness changed after procedure?
- Much happier
- Slightly happier
- No change
- Slightly more unhappy
- Much more unhappy

Does your cat move stiffly or limp?
- Yes
- No

Does your cat prefer several small jumps to one big jump UP?
- Yes
- No

Does your cat hit his/her back legs on the object when jumping UP?

- Yes
- No

Does your cat reach towards the ground before jumping DOWN to shorten the distance?

- Yes
- No

How much pain did your cat experience after procedure?

- None
- Mild
- Moderate
- Severe
- Extreme

Any medication was given?

- Yes, which one:____
- No

Frequency or analgesic used:

- Short-term treatment
- Long-term treatment
- Never
- Other:____

What was the effect of analgesia on your cat lameness:

- No longer able to see lameness
- Mild reduction in lameness

What do you think about your cat's limb function overall?

- Excellent
- Very good
- Good
- Fair
- Poor

Any other comments? (Optional)

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____

____