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RESEARCH ARTICLE

Experimentally Induced Cranial Cruciate Ligament Ruptures with Repair of Caudal Tibial Muscle and Evaluation of Its Outcome in Dogs [1] [2]

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[1] *Preliminary results of this study were presented as a poster in 11th National Congress of Veterinary Surgery, 26-29 June 2008, Kusadasi, Aydin - Turkey*
[2] *All the results of this study were presented as a poster in 12th National Congress of Veterinary Surgery, 19-22 May 2010, Belek, Antalya - Turkey*

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Summary

This study examined the repair of experimentally induced cranial cruciate ligament (CrCL) ruptures with caudal tibial muscle (MTC). Clinical, necroscopical, histopathological and magnetic resonance imaging (MRI) evaluation of the dogs were made determine whether this tendon could be used as a new alternative in the repair of CrCL ruptures. The operation was carried out 10 dogs over 15 kg with different breeds, ages and sexes. Under anesthesia, CrCL was excised through lateral parapatellar approach. The medially located insertion of the MTC tendon was carefully cut to free up to the proximal end of the tibia. The tendon remained attached to the tibia with its origin was spined up to its freed end with polyglactin suture material. Then, an intraarticular tunnel in a manner openning to the right medial aspect of the proximal articular facet of the tibia (i.e. toward the insertion of the cruciate ligament to the tibia) was established with 4.5 mm drill. A second tunnel in lateral femoral condylus in the direction of the insertion to the CrCL was established. The tendon prepared before was passed through this tunnels and fixed in place with one or two screws. Each of the dogs was monitored during a year for performing clinical examinations. MRI was taken at the 3rd, 6th and 12th months of the study. Following euthanasia at the 12th month the reconstructed cranial cruciate ligaments of all dogs were histopathologically examined. Clinically all cases were observed to use their extremities normally at the 6th month. MRI demonstrated an impingement in the tunnel of one case, continuous band with low signal density at the intra-articular spaces of the cruciate ligament and the tunnels of the remaining cases and aslo the presence of grafts in the intra-articular spaces as well as the tunels of tibia and femur of all cases. According to these results, it was concluded that the use of caudal tibial muscle tendon can be appropriate for the reconstruction of cranial cruciate ligament rupture in dogs.

Keywords: *Cranial cruciate ligament, Ruptur, Caudal tibial muscle, Repair, Dog*

Köpeklerde Deneysel Olarak Oluşturulan Ön Çapraz Bağ Kopmalarının M. Tibialis Caudalis Kullanılarak Sağaltılması ve Sonuçlarının Değerlendirilmesi

Özet

Bu çalışmada köpeklerde deneysel olarak oluşturulan ön çapraz bağ (CrCL) kopmalarının m.tibialis caudalis (MTC) kullanılarak sağaltılması, sonuçlarının klinik, nekroskopik, histopatolojik ve manyetik resonans görüntüleme (MRI) olarak değerlendirilerek bu tendonun ön çapraz bağ kopmalarının sağaltımında yeni bir alternatif olup olamayacağının belirlenmesi amaçlanmıştır. Araştırmada genelde 15 kg'ın üzerinde olmak üzere farklı ağırlık, ırk, yaş ve cinsiyette 10 adet köpek kullanılmıştır. Anestezi altında lateral parapatellar ensizyonla ekleme ulaşıldıktan sonra CrCL kesilip uzaklaştırılmıştır. Medialde bulunan MTC tendosunun insersio noktası yapıştığı bölgeden dikkatlice ayrılarak tibianın proksimaline kadar serbest hale getirilmiştir. Origosu tibiaya bağlı kalacak şekilde serbest hale getirilmiş olan tendo tabandan uç kısma kadar polyglactin ile örülmüştür. Daha sonra 4,5 mm'lik bir matkap ucuyla tendo origosunun yanından tibianın proksimal eklem yüzeyinin medialine çıkacak şekilde (çapraz bağın tibiaya bağlı olan yönü doğrultusunda) eklem içine doğru bir tunel açılmıştır. Femurun lateral kondilusu içerisinden geçecek şekilde çapraz bağın yapışma yönünde ikinci bir tunel açılarak hazırlanmış tendo önce tibianın medialindeki, daha sonra femurun lateral kondilusundaki tunelden geçirilerek, femurun lateral yüzüne yerleştirilen bir veya iki adet vidaya tespit edilmiştir. Denekler bir yıl boyunca gözetim altında tutularak klinik muayeneleri yapılmış, 3.6.12. aylarda MR görüntüleri ve 12. ayda uyutularak nekroskopi sonrasında ise rekonstrukte edilen ön çapraz bağın histopatolojik muayenesi yapılmıştır. Klinik olarak olguların 6. aydan itibaren extremitelerini normal olarak kullanabildikleri, MR görüntülemede çalışma sonunda, yalnızca bir olguda gref sıkışması saptandığı diğer olgularda rekonstrukte çapraz bağın interkondiler aralıkta ve tunellerde düşük sinyal yoğunluklu devamlı bant olarak gözlendiği, tüm olgularda grefin eklem içinde, tibial ve femoral kanallarda mevcudiyeti tespit edilmiştir. Alınan sonuçlara bakılarak, köpeklerde ön çapraz bağ kopmalarının sağaltımında m.tibialis caudalis tendosunun kullanılmasının uygun olacağı kanısına varılmıştır.

Anahtar sözcükler: *Ön çapraz bağ, Kopma, M. tibialis caudalis, Sağaltım, Köpek*

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INTRODUCTION

Cranial cruciate ligament lesions are one of the most common reasons of the hind leg lameness in dogs due to its function in maintanining the cranio-caudal stability of the stifle joint [1-7].

The cranial cruciate ligament lesions are commonly induced by direct traumas. It may also occur as a result of sudden rotation of the stifle joint while in hyperflexion or hyperextension position. Ligament lesions may occur even after a minor trauma because of the degenerative changes in the structure of ligaments in the elderly dogs [2,8].

The stifle is a relatively instable joint due to its anatomical structure and has more axes and directions of motion than the other joints. During a motion, the degree of the forces acting on the stifle joint increase. In case of sudden forces, neuromuscular system cannot have enough time to initiate muscle contraction and thus prevents the lesions in different severity to occur in the CrCL [3,6,9].

Tibial compression test and anterior drawer motion are very important in the diagnosis of the CrCL ruptures and clinical evaluation of reconstructed CrCL [8,10,11]. Periarticular fibrosis and stabilization as a result of the muscle contractions may mislead the surgeon during these examinations. Therefore, radiography, arthroscopy, ultrasonography and MRI are recommended to support the diagnosis [8,12-14].

Failure to the repair of CrCL causes osteoarthrosis associated with chondral lesions and meniscus ruptures inflicted by subluxated and laxed stifle joint due to chronic cord failure. Treatment method should be decided following thorough case history, physical evaluation and proper imaging findings [9].

Magnetic resonance imaging with its high tissue contrast resolution and multiplanar view is the most accurate technique for interpreting CrCL lesions in both acute and chronic periods of the problem and also for evaluating the stability of CrCL reconstructed and the complications appearing in new ligaments and intra-articular tissues in due course [9,14]. T1 and T2 sequences are routinly used in MRI of the stifle joint but the former one provides particullarly precise data in revealing acute CrCL lesions. Since CrCL extends posterior-anterior and lateral-medial directions, it cannot be evaluated by a single MRI section only. In MRI, normal CrCL provides a dark image with low signal density whereas in case of rupture it renders a high density signal image [9,15].

Alleviating pain, increasing joint stability and eliminating or minimizing the risk of osteoarthrisis are achived with various reconstruction techniques of CrCL [1]. In recent years, beside intra-articular and extra-articular methods, anterior transposition of tuberositas tibia techniques has also been used for the ligament reconstruction [4,5,11,16-18]. Various autografts (patellar tendon, hamstring tendon, quadriceps tendon, fascia lata), allografts (achilles tendon, fascia lata, peroneus longus muscle, cranial tibial muscle tendon) and synthetic materials [19-25] are used intra-articularly while fascia lata, capitis fibularis transposition, circumfabellar suturing, lig.collaterale laterale and synthetic materials [8,10,26,27] are used extra-articularly to stabilize stifle joint.

In this study, it was aimed to determine whether the reconstruction of experimentally formed cranial cruciate ligament ruptures with m. tibialis caudalis could be a new alternative method in the treatment of CrCL ruptures, compared to the above noted methods with various complications, by evaluating its clinical, necroscopical, histopathological and radiographical (MRI) results and it is possible to lift avascular necrosis risk encountered in intra-articular methods allowing m. tibialis caudalis tendon to its insertion attached.

MATERIAL and METHODS

This study was carried out at the small animal clinic of Firat University. In study the operation was performed on randomly selected 10 vaccined and healthy dogs over 15 kg (15 to 30 kg) with different breeds, ages and sexes. All dogs were examined as required and vaccined. The animals used in the study was obtained from animal care shelter of Elazig Manucipiality. The study was conducted on approval by the Laboratory Animals Ethical Board of the Firat University (approval date: 20.06.2008 No: 27).

After routine preparations for surgery, the dogs were placed on the table on lateral position and operation region up. General anesthesia was maintained with IM injections of 10-15 mg/kg ketamine HCl (50 mg/ml, Ketalar, Pfizer, Turkey) following IM injections of 1.5 ml/10 kg xylazine HCl (23.32 mg/ml, Rompun, Bayer, Turkey) premedication. CrCL was excised through lateral parapatellar approach. The parapatellar incision was extended down to the distal aspect of the tibia. The medially located insertion of the MCT tendon was carefully cut to free up to the proximal end of the tibia *(Fig. 1A)*. The tendon remained attached to the tibia with its origin was spined up to its freed end with polyglactin 910 (Vicryl, No: 2 Ethicon, Johnson&Johnson, USA) suture material. Then, an intra-articular tunnel in a manner openning to the right medial aspect of the proximal articular facet of the tibia (i.e. toward the insertion of the cruciate ligament to the tibia) was established with 4.5 mm drill. A second tunnel in lateral femoral condylus in the direction of the insertion to the CrCL was established *(Fig. 2 A,B)*. The tendon prepared before was passed through this tunnels and fixed with one or two screws in lateral aspect of the femur *(Fig. 3 A,B)*. After local administration of 1.000.000 IU crystalline penicilline (Kristapen, Deva, Turkey), the operation

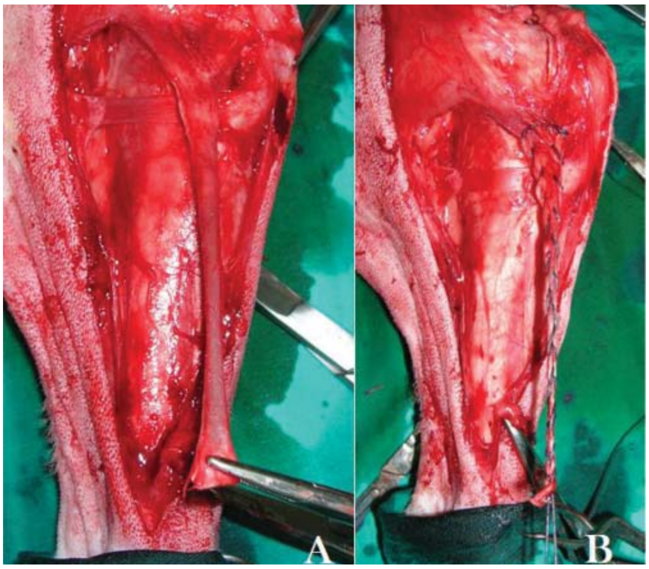

Fig 1. Appearance of carefully recovered freed MTC tendon from its insertion up to the proximal end **(A)**. The tendon sutured with polyglactin up to the end on a condition leaving its insertion attached to the tibia **(B)**

Şekil 1. MTC tendosunun insersio noktasının yapıştığı bölgeden dikkatlice ayrılarak tibianın proksimaline kadar serbest hale getirilmesi **(A)**. Tendo origosu tibiaya bağlı kalmak üzere polyglactin ile uç kısmına kadar dikilerek tespite hazır hale getirilmesi **(B)**

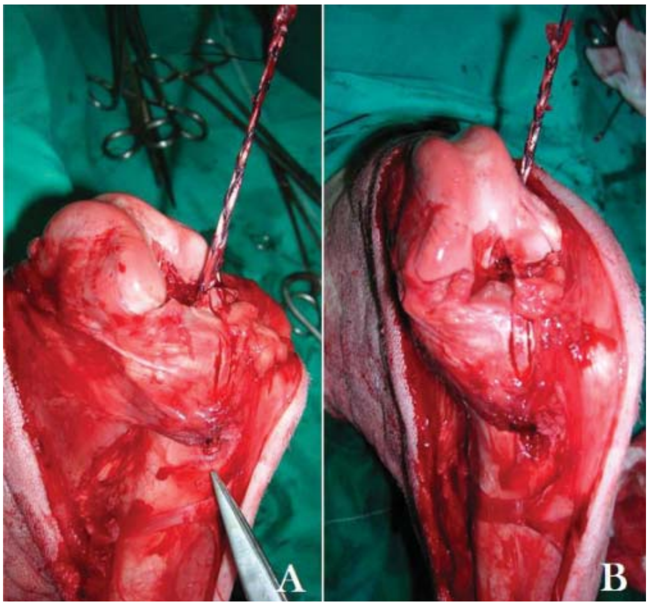

Fig 2. Passage of the prepared tendon first through the tunnel of medial of the tibia (**A**) and then lateral condylus of the femur (**B**)

Şekil 2. Hazırlanmış tendonun önce tibianın medialindeki (**A**) daha sonra femurun lateral kondilusundaki tunelden geçirilmesi **(B)**

region was closed with usual manners. The operated leg was supported with polyvinyl chloride (PVC) bandage up to the stifle joint. Reptopen S (0.5 ml/5 kg IM, DIF, Turkey) and Novo-cyan (5 cc IM DIF, Turkey) were prescribed postoperatively for the all dogs at the days 6 and 10, respectively. On the 12th day after the operation, the bandages and the sutures were removed. Then the subjects were allowed to walk freely in the boxes.

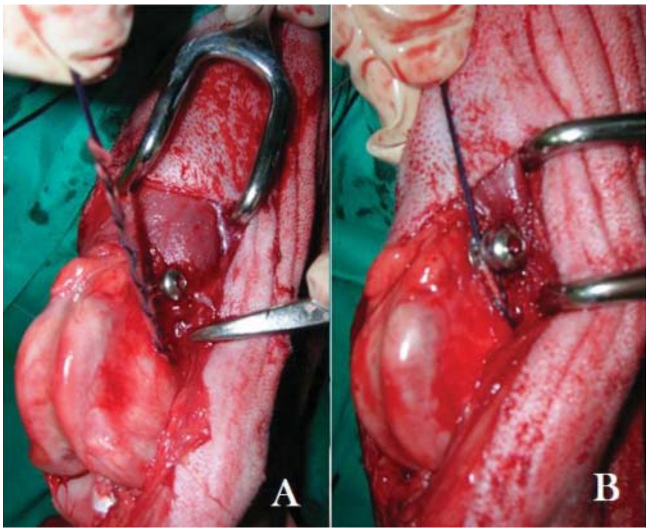

Fig 3. Fixation of prepared tendon to the lateral aspect of the femur with a screw **(A,B)**

Şekil 3. Hazırlanmış tendonun femurun lateral yüzüne yerleştirilen vidaya tespit edilmesi **(A,B)**

During 12 months follow-up period clinical examinations including inspection of posture and walk, presence of local pain and swelling findings with palpation of the knee joint, anterior drawer motion of the joints and tibial compression tests were performed. In addition MRI were taken at the 3rd, 6th and 12th months. In the 12th month the dogs were euthanized and the materials used intra-articularly in place of the ligament were examined necroscopically and histopathologically.

MRI (Siemens Maestro Class, 1.5 Tesla, Germany) was taken under general anesthesia dorsal recumbency position and applying extremite coili to the leg. Imaging was obtained at sagittal, dorsal (T1, T2, gradient and proton weighted, 1.3 mm sectioned) and transversal (T2 weighted, 2 mm sectioned) positions. Persistence of the reconstructed ligament, which gave a low density image in sagittal, dorsal and transversal sequences, in lateral femoral condylus, intercondylar notch and the tunnel in tibia was evaluated.

The graft and inner joint were examined grossly after exposuring the stifle joint of the euthanized cases. To examine the tibial and femoral tunnels, femur and tibia were excised from the diaphyse and retained in 10% formalin solution. Persistence of the graft in tibial and femoral tunnels was observed in sagittal sections and transversal sections of 5 cases each.

For histopathological examinations, normal ligament from the right knee and the graft used in place of the ligament of the left knee and normal MTC on the right tibia were taken and fixed in 10% neutral formalin solution. Five µ thick sections cut from the paraffin blocks were stained with Hematoxylin-Eosin and examined with light microscope (X 200, X 400).

RESULTS

Clinical Findings: No infection but muscular atrophy was observed in all cases following removal of bandage at the 12th day of the surgery. Postoperative muscular atrophy reduced gradually in the first 3 months and disappeared completely in the sixth month. The dogs always held their operated limbs up in the first postoperative days and started to step intermittantly 20 days later and could use their extremities normally with no response to tibial compression test and forward drawer motion.

MRI Findings: In sagittal and dorsal MRI taken at the 3rd, 6th and 12th months and at T1, T2, gradient and proton sequences, the reconstructed ligament in intercondylar space and the tunnels was recorded as a low density continuous band *(Fig. 4 A,B)*. Low density images of the graft in the tibial and femoral tunnels were taken in transversal T2 weighted sequence in all months. In a case, an increase in intra-articular synovial fluid and edema in the reconstructed ligament were seen in T2 weighted transversal MRI *(Fig. 5A)* at the 3rd month but the same case presented no edema at the 12th month *(Fig. 5B)*. In another case, impingement was determined in the dorsal gradient weighted sequence *(Fig. 6A)*. In all cases, the metal screws used for the immobilization of the reconstructed ligament caused artifacts *(Fig. 4 A,B)*. The complications like cyclops lesion and cystic degenerations were not observed in the reconstructed ligament.

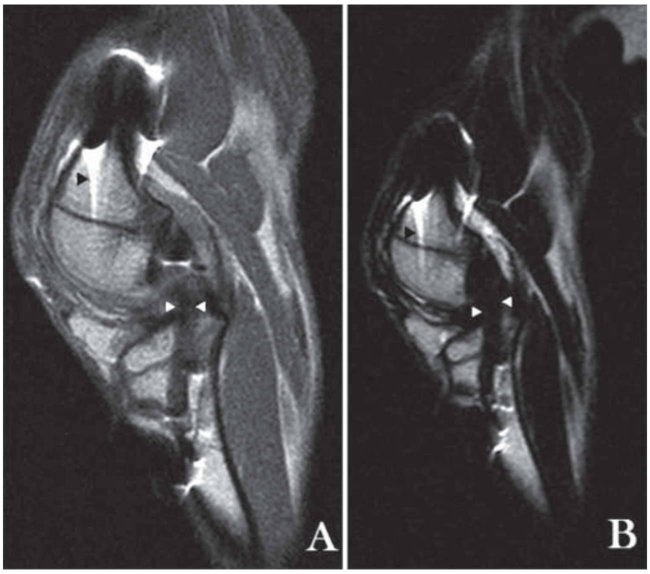

Fig 4. Appearances of reconstructed ligament at interchondylar notch with sagittal T1 MRI at the 6th month (white arrow) and artifact of metal screw (black arrow head) **(A)**. Appearance of low density signal continuing band and artifact of metal screw (black arrow head) of the same case on sagittal T2 MRI **(B)**

Şekil 4. Altıncı ayda sagital T1 ağırlıklı MR görüntülemede rekonstrükte bağın interkondiler çentikte görünümü (beyaz ok başı) ve metal vida artifaktları (siyah ok başı) **(A)**, Aynı olgunun T2 ağırlıklı sagital MR görüntülenmesinde düşük yoğunluklu sinyal veren devamlı bandın görünümü (beyaz ok başı) ve metal vida artifaktları (siyah ok başı) **(B)**

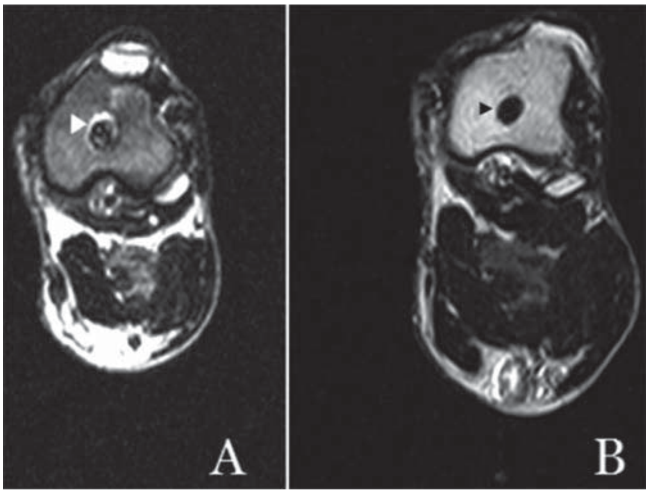

Fig 5. A view of the reconstructed band edema (white arrow head) in the tibial tunnel by transversal T2 MRI in a case at the 3rd month **(A)**. A view of low density signal produced reconstructed CrCL (black arrow head) of the same case at the 12th month on transversal T2 MRI **(B)**

Şekil 5. Üçüncü ayını dolduran olgumuzun birinde T2 transversal MR görüntülenmesinde tibiadaki tunelde rekonstrükte bağın ödemi (Beyaz ok başı) **(A)**. Aynı olgunun 12. aydaki T2 transversal MR görüntülemede tibiadaki tunelde düşük yoğunluklu sinyal veren rekonstrükte bağın görüntüsü (Siyah ok başı) **(B)**

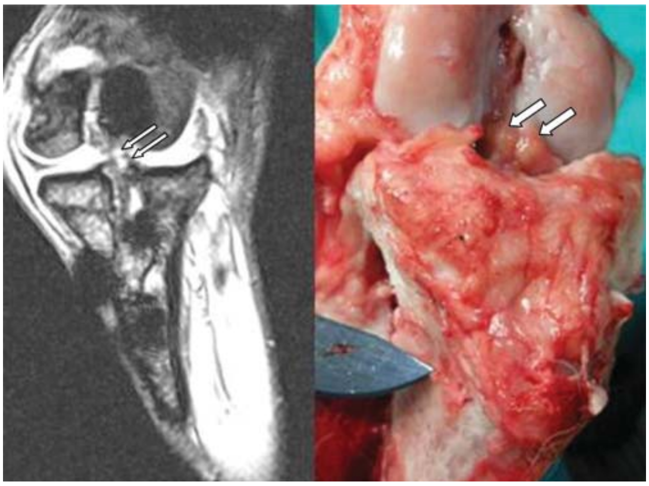

Fig 6. Appearance of high density produced impingement **(A)** (arrows) on dorsal gradient MRI at the 12th month. The appearance of impingement detected by necropsy of the same case **(B)** (arrows)

Şekil 6. Onikinci ayda dorsal gradient ağırlıklı MR görüntülemede yüksek yoğunluklu sinyal veren gref sıkışmasının görünümü **(A)** (oklar). Aynı olgunun nekroskopik incelenmesinde saptanan gref sıkışmasının görünümü **(B)** (oklar)

Necroscopic Findings: Synovial fluid, meniscuses and joint surfaces were normal in all case except one in which partial inferior meniscus resection was performed. It was seen that grafts fitted in the tunnels tightly, vascularization increased and tunnel entrances and screws were surrounded by a fibrous tissue. In all cases, graft was detected in the joint, femoral and tibial tunnels *(Fig. 7 A,B, Fig. 8 A,B)*. Graft impingement seen on MRI of a case in the 12th month was also necroscopically proved *(Fig. 6 B)*.

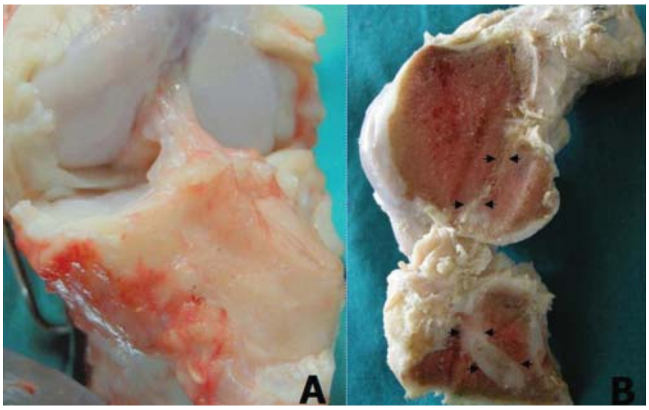

Fig 7. Views of the graft **(A)** used in place of the CrCL and the graft in the femoral and tibial tunnels **(B)** on sagittal section at the 12th month (arrows)

Şekil 7. Onikinci ayda çapraz bağ yerine kullanılan grefin görünümü **(A)**, Sagital keside femoral ve tibial tunellerde grefin (oklar) görünümü **(B)**

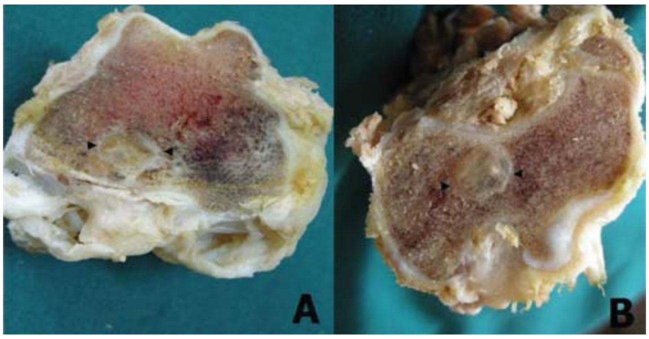

Fig 8. Appearance of the graft in the tunnel on the transversal sections of the femur **(A)** and tibia **(B)** (black arrow heads)

Şekil 8. Femur **(A)** ve tibianın **(B)** transversal kesitlerinde grefin tuneldeki görünümü (siyah ok başları)

Histopathological Findings: In histopathological examination of the graft used in place of the CrCL it was determined that vascularization increased, collagen fibers were oriented parallel to each other similar to and resembled gradually the CrCL *(Fig. 9 A,B,C , Fig. 10)*. Some calcifications were observed in the case with impingement *(Fig. 11)*.

DISCUSSION

Cranial cruciate ligament ruptures in dogs have been reported to occur commonly due to traffic accidents, high jump, sudden hyperextension or hyperflexion [2,8,28]. Various methods have been used in the reconstruction of the CrCL ruptures [2,4,8,10,11,25,26]. These methods are divided into two groups: intra-articular and extra-articular. Although extra-articular methods were generally performed on the small breed dogs [8,10] it has been reported [11] that this can be successfully performed on the giant and over 15 kg breed dogs.

It was reported that in extra-articular method, the stabilization of the stifle with suturing periarticular tissues could restrict the internal rotation of tibia, increase weight bear compression on the joint and impair the kinematic of the joint [8,16]. However, in intra-articular methods, while the movement of the joint is maintained at great extent its main disadvantage was reported to be graft necrosis [8,23].

The intra-articular method used in the present study was considered as a most suitable and closer method as the physiological structure. The results obtained were quite satisfactory.

During reconstruction in humans, it has been reported that interior meniscus should be protected and the stability of knees with deficient cranial cruciate ligament is maintained by interior meniscus [9,29]. Reconstructed ligament edema detected in a case at the 3rd month with MRI is thought to be due to the resection of the interior meniscus.

Artrofibrosis (cyclops lesion) may develop as a result of reconstruction in acute period and condral lesions and meniscus ruptures occur in late period [9,15]. Here, reconstruction was performed immediately after cutting the CrCL. Cyclops lesion was not encountered in MRI of our cases at their early periods.

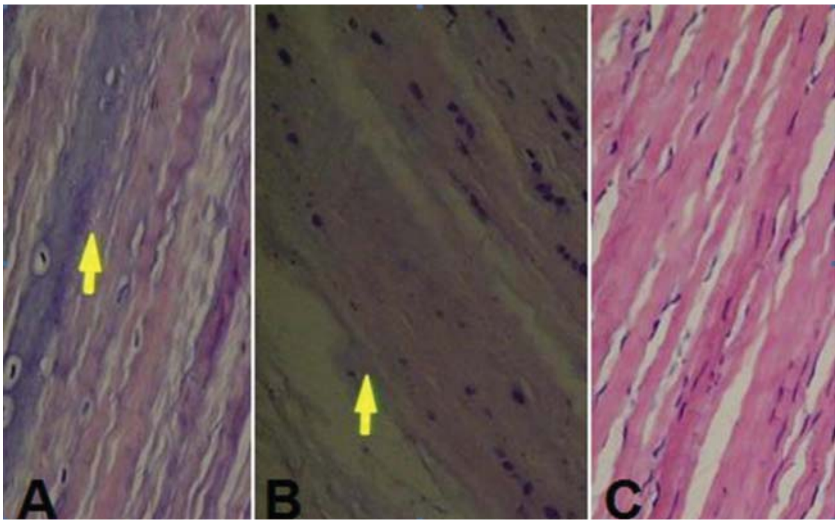

Fig 9. A- Appearance of collagen fibrils in the normal CrCL (yellow arrow). **B-** The graft, collagen fibrils initiated and gradually resemble to CrCL. **C-** View of m. tibialis, (H.E. X400)

Şekil 9. A- Normal ön çapraz bağ, kollagen lifin görünümü (sarı ok). **B-** Gref, kollagen lifler oluşmaya başlamış gittikçe ön çapraz bağa benzemekte, **C-** M. tibialis caudalisin görünümü, (H.E. X400)

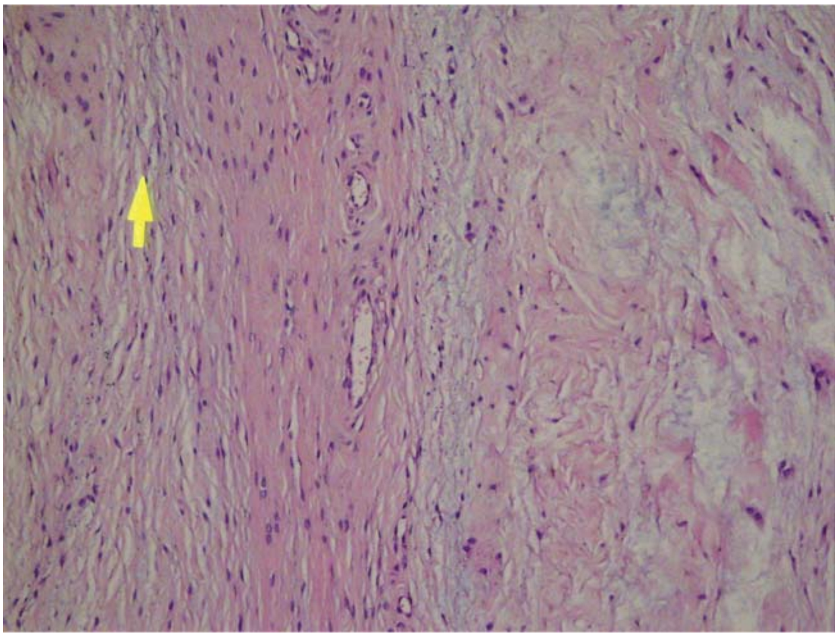

Fig 10. Appearance of collagen fibrils in the graft (H.E.X200)

Şekil 10. Gref, kollagen liflerin görünümü (H.E.X200)

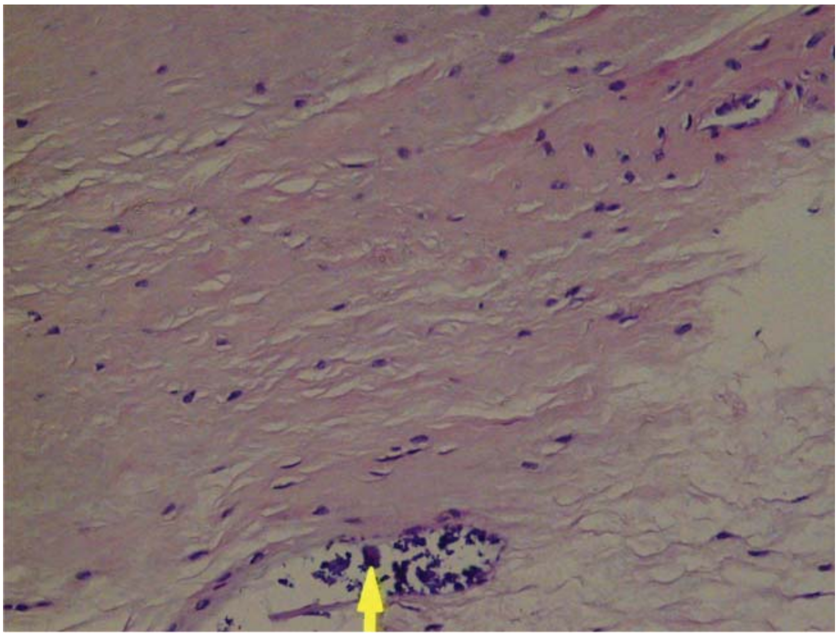

Fig 11. Few isolated calcification foci in the impingement detected case

Şekil 11. Gref sıkışması saptanan olguda tek tük gözlenen kalsifikasyon (H.E. X 400)

The previous studies also reported that synthetic grafts caused negative results such as disease transportation by allografts, graft reactions and high costs [9,23,25]. Another study demonstrated that avascular graft began to be enclosed by vascular synovial membrane in the post-operative 4th week and highly vascularized synovial membrane formed in the postoperative 6th week [30]. Therefore, autografts are preferred for their easy intra-articular adaptation and successful results in graft ligamentization [9,23]. MTC tendon was used as autograft in our cases expecting earlier ligamentization due to better tropism for do not separate of its origin, easy application and fixation. An explicit vascularization was seen in grafts in all cases in necroscopical and histopathological examinations done in the 12th month.

The most intraoperative complication was argued to be insufficient graft length taken in intra-articular methods [9,23]. No problem was encountered related to the graft lengt in our study.

Fixation of autograft in femoral and tibial tunnels is believed to determine the success rate of CrCL re-construction [14,15,23,29]. In our cases, as the ligaments had strongly attachment to the place their fixation with one or two screws in lateral aspect of the femur was not so difficult once graft was managed to pass through tibial and femoral tunnels. However, the screws formed artifact on MRI, which is thought to be overcome by using absorbable screws.

On MRI T1 and T2 sequences are used in evaluating

CrCL lesions and T2 sequence is particullarly accurate in determining acute CrCL lesion and imaging reconstructed CrCL [9,15]. The integrity of CrCL cannot be evaluated only by one image since it extends from anterior to posterior and from lateral to medial [9,31]. When T1 and T2 sequences were compared in this study, T2 sequence was found to provide better imaging of reconstructed CrCL. In sagittal sequences 1.3 mm and in transversal sequences 2 mm array images were obtained and the integrity of reconstructed CrCL and the surrounding tissues were evaluated.

It is noted that tibial and femoral tunnels should be established in a way that ligament is centralized and in an angle that does not cause graft to tear. Otherwise, graft impingement may occur in the tunnel. Impingement demonstrates focal increased signal on T1 and T2 weighted sequences in the distal two thirds of the graft [9,14,15]. In this study, tibial tunnel was performed just from medial tuberositas tibia, near tendon origin to the tibial connection of CrCL. Femoral tunnel was extended in the adhesion direction of the ligament through lateral femoral condylus, and prepared tendon was passed from external to internal through the femoral tunnel. The graft was fixed on the lateral surface of femur by one or two screws after giving normal anatomic position and applying necessary tension. Thus, isometric graft position was maintained and only in one case graft impingement was not detected on MRI taken in the 12th month.

It was reported that anterior arthrofibrosis (cyclops lesion) possible caused by cranial ligament remnant in tibia, metaplasia of infrapatellar fat pad, intercondylar fibrosis or the graft itself. Cyclops lesion could be observed as low signal density focal nodular lesion at the cranial of intercondylar notch in T1 sequences. It was also emphasized that cyctic degeneration was a late observed complication in tibial tunnel and gave a fluid signal in T2 sequences [14,15]. In the present study, neither cyclops lesion nor cyctic degeneration were seen.

For graft fixations of the reconstruction of CrCL, various materials such as cortical and cancellous screws, periosteal flap, graftgrap, non absorbable suture materials, endobuttons, bioabsorbable, biodegredable and titanium screws, bioabsorbable buttons, bioabsorbable and titanium transfixation implants are used [15,22,32-35]. In this study, MTC tendon was sutured by polyglactine, then passed through the tunnel in lateral condylus of femur and attached in place by one or two cortical screws. Except the artifacts formed by the screws in MRI, no disadvantages related to the screws was notted during the follow-up period.

As a result, according to clinical, MRI, necroscopic and histopathologic findings, it was concluded that MTC tendon could be used in the reconstruction of CrCL and can bring in veterinary practice later experimented in the clinic cases.

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