CLINICAL AND PATHOLOGICAL EVALUATION OF RUPTURED ANTERIOR CRUCIATE LIGAMENT REPAIR IN THE CANINE SPECIES

by

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INTRODUCTION

Rupture of the anterior cruciate ligament in the canine has been a clinical problem for the small animal clinician for years. The clinician has been able to diagnose the condition by demonstrating the "drawer movement" in the affected stifle joint but the common problem has been treatment.

The early treatment consisted of joint immobilization with a splint to limit joint movement, thereby giving the ruptured ligament time to heal. The results were variable, and many times complete failure ensued.

The first surgical treatment was introduced into veterinary medicine by Paatsama (1952) when he published his work on the canine stifle joint. In this surgical method the fascia lata was used to construct a transplant ligament as Hey Groves (1917) had done previously in man.

Following the use of fascia lata to reconstruct a new ligament, many different types of materials have been substituted for the fascia lata but all of the techniques have been based upon the concept of ligament replacement. Hohn and Miller (1967) added a new procedure by using the tendon of the long digital extensor muscle to replace the ruptured ligament but this technique was still a ligament replacement operation.

A new concept in the surgical treatment was developed by Childers (1966) when he reported on a technique to correct the stifle joint instability by tightening the lateral patellar retinaculum. The joint instability was corrected with Lembert sutures placed in the soft tissues on the lateral side of the joint with no attempt to replace the ruptured ligament with body tissues or synthetic products.

The purpose of this investigation was to evaluate a modified Lembert suture technique for repair of the ruptured anterior cruciate ligament in the canine stifle joint. The evaluation was carried out by comparing this modified Lembert procedure to the established fascia lata transplant developed by Paatsama. Comparison was made by clinical, macroscopic and histopathological tissue studies.

LITERATURE REVIEW

Carlin (1926) was the first to report on symptoms of the ruptured anterior cruciate ligament in the canine in veterinary medical literature. He reported on two clinical cases that had been presented for clinical diagnosis. In both patients it was possible to displace the tibia in a cranial direction in relation to the femur. This same observation had been made previously by Carlin when he had experimentally cut the anterior cruciate ligament. This cranial movement of the tibia was described as the "anterior drawer movement." Following two weeks of rest with no improvement, the two patients were destroyed. Necropsy revealed a ruptured anterior cruciate ligament in both dogs.

A brief account was made by Brook (1932) on the clinical symptoms and diagnosis of ruptured anterior cruciate ligament in the dog. The diagnosis was based on radiographic examination and clinical signs. Schroeder and Schnelle (1936) reported that all injuries of the stifle joint were caused by direct violence such as being kicked, hit by a car or falling from the second story of a building. If an anterior drawer movement was demonstrated in such cases, it was considered pathognomonic of a ruptured anterior cruciate ligament. Most of the injuries involved the ligament first, but bone changes frequently followed as a result of abnormal movement within the joint.

The authors believed that ruptured anterior cruciate ligaments had been often overlooked.

Treatment was described using fixation with a Thomas splint for a 3- to 4-week period. Although it was assumed that an actual rupture of the cruciates would not repair completely with only splinting, it was thought that the splint would stabilize the limb sufficiently to restore adequate function.

Schroeder and Schnelle (1941) thought that rupture of the anterior cruciate ligament occurred especially in individuals with overextended stifle joints. The authors redescribed the treatment by fixation with a Thomas splint.

The first significant surgical contribution to treatment of the ruptured anterior cruciate ligament came when Paatsama (1952) published his work on the canine stifle joint. The object of this work was to give an account of the pathology, pathogenesis, diagnosis, therapy and prognosis of lesions of the ligaments of the stifle joint. Paatsama introduced Hey Groves' (1917, 1920) operative technique into veterinary surgery.

Hey Groves (1917) described a technique for repair of the ruptured anterior cruciate ligament in man in which fascia lata was used to replace the ruptured ligament. The strip of fascia lata was exposed on the lateral surface of the femur and was dissected from above the external condyle to about 2.5 cm below the tubercle of the tibia. The distal attachment of the strip was dissected free, leaving a portion of fascia lata approximately 8.5 cm in length and 2.5 cm in width attached proximally. Using the original area of attachment of the cruciate ligament as a starting point, a 6-mm drill was used to make a tunnel from within the joint proximally and laterally through the external condyle of the femur. A second hole was drilled distally and medially through the anterior intercondyloid fossa of the tibia. The fascia lata strip was then rolled into a cord and the free end was threaded through the femur and tibia and drawn tight. Where the fascial ligament emerged below the knee, it was turned proximally and sutured to the deep fascia and periosteum of the tibia. Following surgery the knee was placed in a splint for approximately 30 days.

Paatsama (1952) reported on the use of the Hey Groves technique in the canine. In this procedure the fascia lata was exposed on the lateral surface of the femur and a strip of fascia about 4 to 6 cm long and 1 cm wide was dissected free, except at the distal end. Fat and muscle tissue were removed from the fascia strip. The strip was temporarily positioned under the skin to protect it from drying.

The joint capsule was then entered on the lateral side of the patella and the patella was luxated to a position medial to the trochlear groove. The tunnels in the femur and tibia were drilled with a 4-mm bit. The femoral tunnel was drilled through the lateral condyle from a point above the femoral insertion of the lateral collateral ligament to the femoral insertion of the anterior cruciate ligament. The tibial tunnel was drilled proximally at an oblique angle from the medial border of the tibial tuberosity to the tibial insertion of the anterior cruciate ligament. The fascia transplant, still attached distally, was pulled through the femoral and tibial tunnels. The transplant was easier to pull through the tunnels if it was slightly twisted.

The fascia transplant was pulled taut so that no subluxation of the tibia could take place. The end of the fascia lata strip was sutured medially to the deep fascia of the tibia. The limb was stabilized in a Thomas splint for 15 days.

Nine experimental cases were reported in which the fascia lata strip transplantation was used. Eight of the 9 dogs were reported to have made a complete recovery during a 161-day observation period. Arthritic changes in the stifle joint of 8 experimental dogs were also reported. These arthritic changes occurred 50 days after the severance of the ligaments and were probably related to the laxity of the joints following the rupture of the cruciate ligament.

Paatsama in 1954 observed that pathological changes in the meniscus were present 50 days after the severance of the anterior cruciate ligament. Singleton (1957) reported that osteoarthritis had been most commonly found on the lips of the trochlear groove, the distal end of the patella and the posterior edge of the articulating surface of the tibia.

Gibbens (1957) adapted the use of skin as the transplant material for Paatsama's technique. He reported that the use of skin may prove to be better than fascia lata because of the greater strength afforded by the skin. The use of a whole skin transplant was described by Leighton in 1961. Results of 77 canine clinical cases were reported as 64 normal, 11 fair and 2 failures. The success was questioned by the author because the improvement may have been caused by a thickening of the joint capsule, forced rest from the pain of surgery and other inflammatory reactions of surgery rather than the actual replacement of the ligament.

Some surgeons have not used skin grafts within the stifle joint because of the possibility of introducing infection. However, in a study of 30 cases, Vaughan and Bowden (1964) found that the danger of such infection was negligible provided that usual measures of preoperative skin preparation were maintained. One dog of the 30 experienced a rupture of the replaced ligament.

Vaughan (1963) reported on 9 experimental cases in which 3 dogs were repaired with fascia lata, 3 with skin and 3 with nylon. Three months postoperatively the 3 skin grafts were intact as contrasted to only one satisfactory case in each of the other two groups. The final outcome of the skin graft ligaments in 6 goats was reported by Vaughan and Scott in 1966. The skin graft at 365 days had the appearance of tendon-type tissue which was composed of collagen.

Following the use of fascia lata and skin, other prosthetic materials were used to replace the ruptured ligament.

Johnson (1960) used braided nylon suture material anchored to the femur and tibia by vitallium screws. Butler (1964) used teflon mesh to replace the ruptured anterior cruciate ligament in the dog and found it to elicit little or no tissue reaction in the joint, unless infection occurred; then the teflon was rejected by the body and this foreign material acted as a reservoir of infection. Supramid threads were used by Zahm in 1966 to replace the ligament. Infection occurred in 4 of the 40 dogs studied over a 3-year period.

The use of the tendon of the musculus flexor digitalis longus to replace the ruptured ligament was reported in 1964 by Strande. The results in 6 dogs studied for 3 months were reported as satisfactory. A study of 41 dogs using tensor fascia lata, as Paatsama had reported in 1952, was published by Loeffler and Reuleaux in 1962.

Singleton (1963) departed slightly from the Paatsama technique and used teryleen braid in four strands threaded through the joint in the form of a figure of 8. This was done by drilling two converging tunnels through the lateral condyle of the femur and the medial tibial condyle. A double strand of teryleen braid was passed through the joint space to increase the strength of the material and to more efficiently stabilize the stifle joint. This method required a high degree of skill and accuracy in the drilling procedure and could result in failure with an inexperienced surgeon. Ormrod (1963) adopted a modified form of Singleton's method (1963) in which multistrand monofilament nylon was used. The prosthesis was passed through tunnels drilled in the femur and tibia, as described by Paatsama (1952), and the nylon ends were secured with small stainless-steel buttons.

Cameron et al. (1968) substituted plastic for the stainless-steel buttons used by Ormrod. In this technique strips of woven teflon were anchored by means of plastic buttons to replace the ruptured anterior cruciate ligament. In 9 experimental cases, 5 ligaments ruptured within an 8-month period.

Two of the most troublesome aspects of the Paatsama surgical procedure had been the proper placement of the holes in the femur and tibia and the threading of the prosthetic ligament through the femorotibial tunnel. A drill guide was developed by Brinker et al. (1965), as an aid in proper placement of the holes. Foster et al. (1963) and Rosenoff et al. (1966) developed modified intramedullary pins for placement of the prosthetic cruciate ligament.

O'Donoghue (1963) stated that the knee joint resisted invasion by any tissue not covered by synovial membrane with the single exception of the menisci, which are entirely fibrocartilage. Fascia lata, when passed through the knee joint, was particularly vulnerable because of its extreme avascularity and stringy character. Frequently after transplantation into the knee, the fascia lata would be resorbed. In 1966, O'Donoghue et al. reported that when the anterior cruciate ligament was completely severed, or when the overlying synovial membrane was torn, a hematoma could not form between the ligament ends because the blood was washed away by the joint fluid. It was therefore impossible for repair by organization of a hematoma to take place in the torn cruciate ligament. In some dogs the ligaments completely disappeared within a few weeks, because of loss of the major portion of the ligaments' blood supply. The exposed end of the cruciate ligament was apparently vulnerable to the absorptive action of the synovial fluid and was resorbed.

Strande (1966) and Dueland (1966) both reported on the use of the Jones (1963) technique for repair of the ruptured anterior cruciate ligament. In this procedure the central one-third of the patellar ligament was used along with a full-length strip of the superficial one-half of the central third of the patella and a full thickness strip of the quadriceps tendon to replace the ruptured ligament. The strip was left attached to the tibial tubercle and threaded into a predrilled tunnel in the femur. The tunnel was drilled from the medial side of the lateral condyle out to the lateral side of the lateral condyle. As the new ligament was pulled through the tunnel, the patellar portion of the ligament became wedged in the tunnel and gave additional strength.

Lam (1968) presented a modification to Jones's technique. He stated that the weakest point in the Jones ligament was at the junction between the patella and the patellar ligament. Lam constructed the new ligament by the removal of a continuous strip of quadriceps tendon, patella with the attached quadriceps expansion, and patellar tendon. This ligament was approximately 8 to 10 mm wide and was removed from the medial side of the extensor apparatus rather than from its central portion. Six human patients have undergone this modified procedure with good results.

Hohn and Miller (1967) reported on the use of transplantation of the long digital extensor tendon for correction of anterior cruciate ligament rupture in the dog. The tendon of the long digital extensor muscle was isolated after subperiosteal elevation of the tibialis anterior muscle from the sulcus muscularis. A trough was cut in the tibial crest, and the long digital extensor tendon was transplanted into it and fixed in place with heavy wire sutures. In this position, the tendon functioned as a ligament between the femur and the tibia. Its direction was almost parallel to that of the normal anterior cruciate ligament. A disadvantage of the technique was that the femoral attachment of the tendon was occasionally absent, making completion of the procedure impossible. Roush et al. (1970) evaluated 100 cases of ruptured anterior cruciate ligaments in the dog treated with the transplantation of the long digital extensor tendon. Results from 6 months to 3 years postoperatively revealed little or no lameness in 89 of the cases and frequent or continuous lameness in 11.

In 1966, Childers reported on a Lembert suture technique for cruciate ligament repair. This method was accidentally found while performing the Paatsama technique. After the transplanted fascia lata strip had been anchored, an attempt was made to reduce the anterior drawer movement by suturing the joint capsule. He subsequently attempted correction by suturing the joint fascia to strengthen and stabilize the joint. About 10 Lembert sutures were placed 5 mm apart on the lateral side of the joint. The areolar subcutaneous tissue was removed and the sutures were placed in the underlying fascia, thus making an inverted longitudinal fold in the joint capsule. Chromic catgut suture material was used, and as much tension as possible was placed on the sutured fascia. If anterior drawer movement was still present, an additional row of Lembert sutures was placed over the original one. The joint capsule was incised only when a torn meniscus was suspected. A total of 9 cases was reported as being repaired successfully.

Blair in 1942 described a procedure using 2 strips of fascia lata on the medial and lateral sides of the knee joint in man. The fascial strips were sutured in an "X" pattern to the muscles on the medial and lateral sides of the joint. The joint capsule was not entered. Good results were seen in 10 clinical cases over a 10-year period. The success of this procedure may have been from stabilization received by fibrous connective tissue changes near the joint capsule.

A modified suture technique has been described by Pearson (1969). The modification required the use of 2 layers of Lembert sutures on the lateral side of the joint and one layer of sutures on the medial side. Heat-sterilized synthetic[1] suture material was used.

To replace the cruciate ligament with synthetic materials or body tissues, it was essential to know the breaking strength of the normal ligaments. Fifty-two stifle joints of 26 dogs were tested for the breaking strength of normal cruciate ligaments by Bhola _et al_. (1969). The breaking load of the normal anterior cruciate ligament was almost four times the body weight.

In 1969, Gupta and Brinker reported unsatisfactory results when the anterior cruciate ligament was replaced with braided dacron coated with silicone rubber in 10 dogs. The breaking strength of the prosthesis was given as 14.0 kg. Prostheses in 7 dogs ruptured within a 4-month period. Braided dacron coated with silicone rubber proved to be an unsatisfactory prosthetic material.

The etiology of anterior cruciate ligament rupture has been difficult to explain. Approximately one-third of the 106 clinical cases studied by Singleton (1969) occurred at 6 to 7 years of age with a sharp rise at 7 years. Degenerative changes may take place within the ligamentous tissue prior to rupture.

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[1]Vetafil Bengen, Bengen and Co., Hannover, West Germany.

Most of the clinical cases that have been reported in veterinary medical literature have been in the canine species. McManus and Nimmons (1966) stated that the condition has seldom been reported in the feline species.

MATERIALS AND METHODS

Experimental Animals

Twenty-six dogs of mixed breeds were used as experimental subjects. The dogs were selected without regard to age or sex. Their weights ranged from 4 to 30 kg and the age span was from 6 months to 6 years. All dogs obtained for this study were given a complete physical examination to make sure they were in good health and to determine if any existing stifle joint abnormalities were present. Each dog was vaccinated for canine distemper and infectious canine hepatitis. Each animal was treated for internal parasites when indicated.

All animals were kenneled for 2 weeks before being entered into the study to allow them to adjust to their new environment and to make certain they were in good health. All dogs were housed in steel cages and were exercised for about 30 minutes twice daily. The cages were cleaned at least twice daily and were chemically disinfected once daily. A good grade of commercial dry dog food was fed ad lib.

The 26 dogs were divided into 3 groups. Group 1 was observed for 90 postoperative days, group 2 for 180 days and group 3 for 365 days. Following these observation periods, euthanasia was performed with an overdose of pentobarbital sodium, and necropsies were performed. Complete macroscopic tissue evaluations were made and recorded on each stifle joint. Representative tissue samples were collected from each stifle joint followed by a complete gross examination of all tissues in the body. The tissue specimens were placed in 10 percent buffered formalin for 48 to 72 hours. The bone specimens were then decalcified in a 10 percent solution of (Ethylenedinitrilo) tetraacetic acid disodium salt[1] for a 14- to 21-day period. Tissues were embedded in paraffin and cut sections were stained with hematoxylin and eosin.

Anesthesia and Presurgical Preparations

All animals were given 0.04 mg/kg body weight of atropine sulfate administered subcutaneously. Anesthesia was induced by intravenous injection of 5 percent thiamylal sodium[2] at a rate not exceeding 18 mg/kg of body weight. An endotracheal catheter was introduced into the trachea and surgical anesthesia was maintained with Methoxyflurane[3] in a closed circle system.

Both hind limbs were clipped on all sides from the coxofemoral joint distally to the hock joint. The surgical field was scrubbed a minimum of 3 times with a hexachlorophene surgical soap[4] and rinsed with tap water. An alcohol rinse

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[1] (Ethylenedinitrilo) tetraacetic acid disodium salt, Matheson, Coleman and Bell, Manufacturing Chemists, Norwood, Ohio.

[2] Surital, Park-Davis and Company, Detroit, Michigan.

[3] Metofane, Pitman-Moore, Indianapolis, Indiana.

[4] Phisohex, Winthrop Laboratories, New York, New York.

was applied followed by at least 2 applications of a 1:3,000 phenylmercuric nitrate solution[1].

Routine aseptic preparations were completed by the surgeon while the surgical patient was placed in a dorsal recumbent position with both hind limbs extending over the end of the surgery table. The hind limbs were covered with sterile orthopedic stockinette and then placed through a small aperture in a sterile cloth drape (Figure 1).

Surgical Technique

One rear limb was selected at random and the stifle joint was exposed with a lateral parapatellar incision. The anterior cruciate ligament was exposed and a 5-mm section removed. A fascia lata strip was formed and passed through the predrilled tunnels in the femur and tibia as described by Paatsama (1952). The joint capsule was closed with a heat-sterilized, medium-weight synthetic suture material[2]. The deep and superficial subcutaneous fascial layers were each closed with continuous 000 chromic catgut sutures. The skin was sutured with simple mattress sutures using the same synthetic suture material.

The modified Lembert suture technique as described by Pearson (1969) was used on the opposite stifle joint. An

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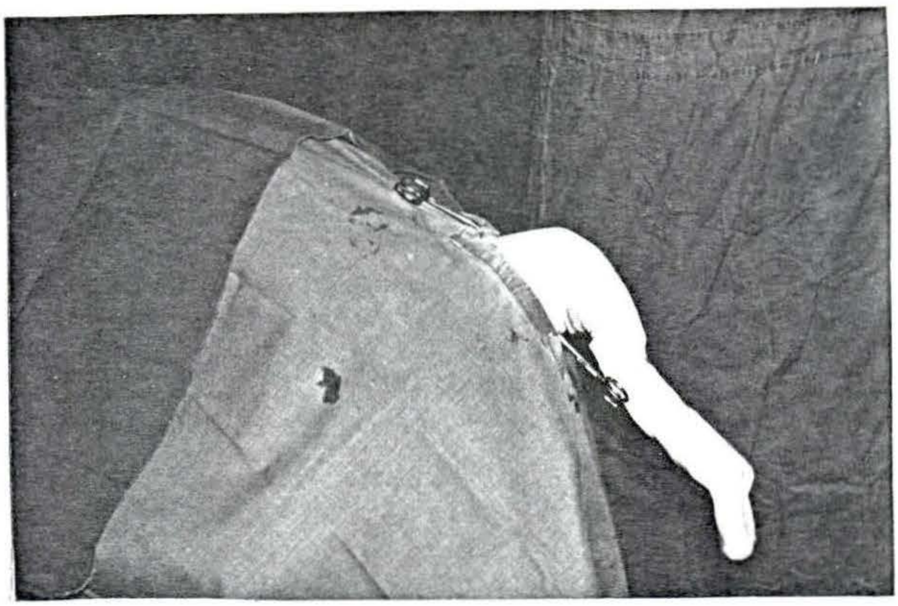
[1]Phe-mer-nite Preoperative, 1:3,000, S. E. Massengill Company, Bristol, Tennessee.

[2]Vetafil Bengen, Bengen and Company, Hannover, West Germany.

Figure 1. The surgical patient prepared for aseptic surgery in the dorsal recumbent position with both hind limbs extending over the end of the surgery table



anterior lateral skin incision was made over the stifle joint which extended from 2 to 4 cm above the patella to slightly distal to the tibial tuberosity (Figure 2). The incision was continued through the superficial subcutaneous fascia. The deep subcutaneous fascia was dissected free from the anterior portion of the straight patellar ligament and patella with a curved blunt scissors (Figure 3).

The joint surface was exposed by making a 1.5- to 2.0-cm incision with a #15 blade on the lateral side of the straight patellar ligament just proximal to the tibial tuberosity (Figure 4). A curved blunt scissors was used to extend this incision proximally, keeping 2 to 3 mm lateral to the patella, and continuing to a point about 2 cm above the patella (Figure 5). The patella and straight patellar ligament were reflected over the medial condyle of the femur and the exposed anterior cruciate ligament was observed (Figure 6). A 5-mm section was removed from the anterior cruciate ligament and the stifle joint was examined for lesions.

The patella was returned to its normal position in the femoral trochlear groove and the joint capsule was closed with small Lembert sutures of synthetic suture material (Figure 7). The stifle joint was then stabilized by 3 layers of Lembert sutures, placing 2 layers on the lateral side of the stifle joint and 1 layer on the medial side. The suture material was a heat-sterilized, medium-weight synthetic suture.

Figure 2. Skin incision on the anterior lateral surface of the stifle joint

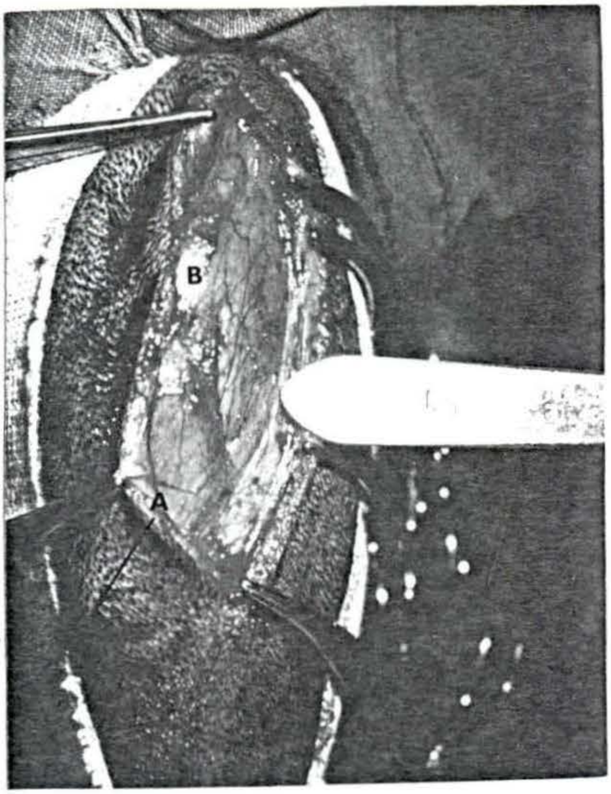
A. Area of tibial tuberosity

B. Area of patella

Figure 3. Dissection of deep subcutaneous fascia from the anterior portion of the straight patellar ligament and patella

A. Area of tibial tuberosity

B. Area of patella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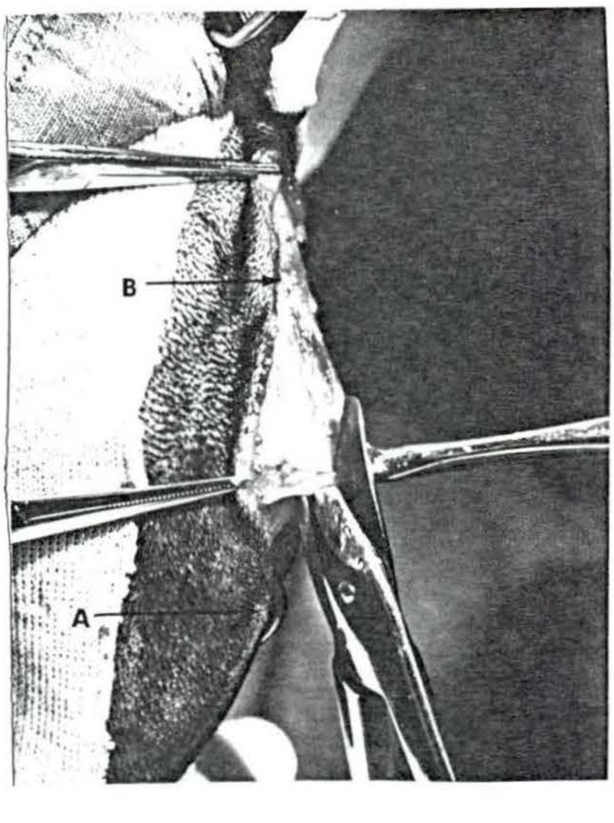
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Figure 4. Incision with a #15 blade on the lateral side of the straight patellar ligament proximal to the tibial tuberosity

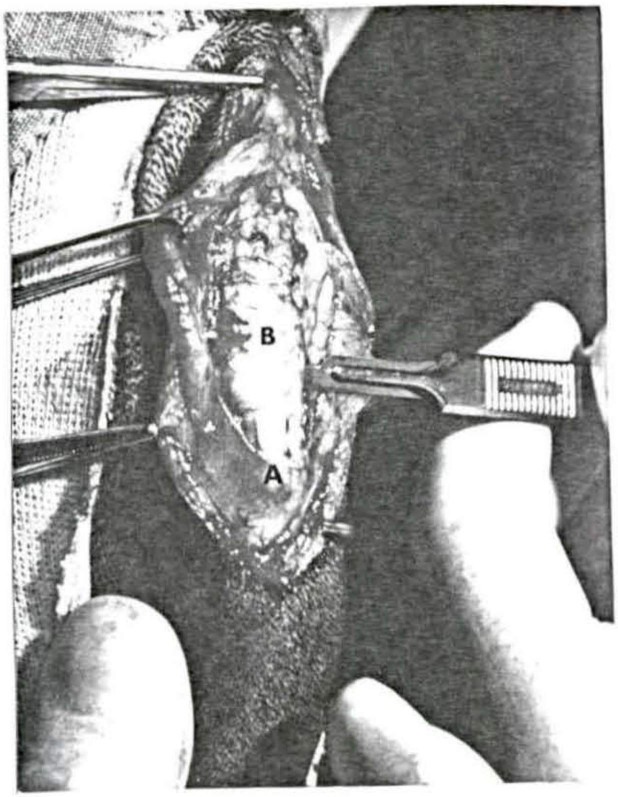
A. Area of tibial tuberosity

B. Area of patella

Figure 5. Extension of incision proximally keeping 2 to 3 mm lateral to the patella

A. Area of tibial tuberosity

B. Area of patella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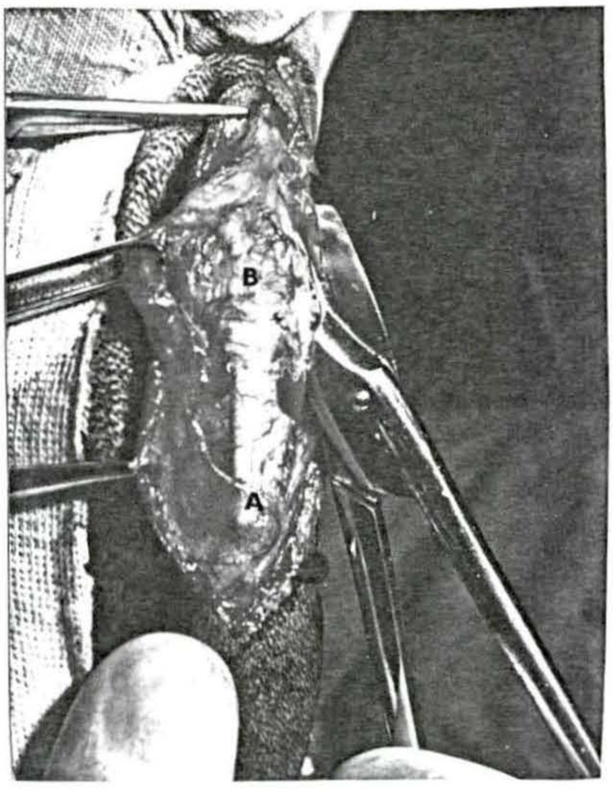
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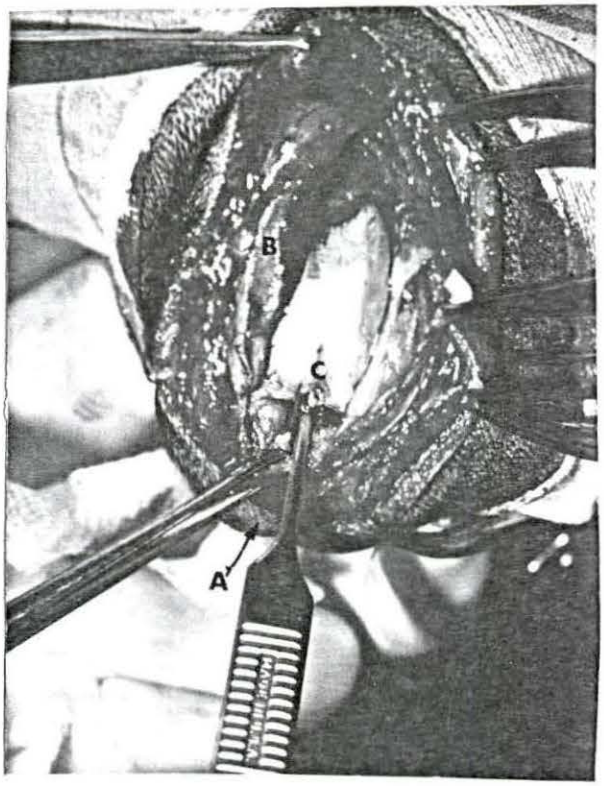
Figure 6. Exposure of the condyle area of the femur with the patella reflected medially

A. Area of tibial tuberosity

B. Area of patella

C. Area of anterior cruciate ligament

Figure 7. Closure of joint capsule with synthetic suture material using small Lembert sutures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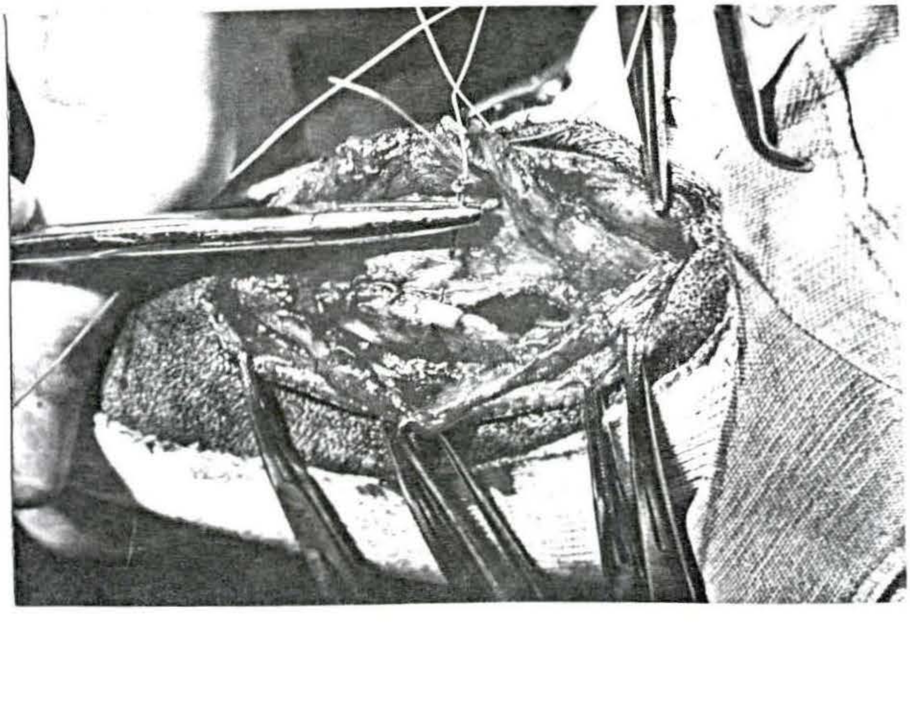

The first suture layer was started on the lateral side of the stifle joint 1.5 to 2.0 cm above the patella, and extended to just above the tibial tuberosity. Each Lembert suture was 0.5 to 1.0 cm apart and placed so that the first bite of the suture was one-third of the distance from the anterior to the posterior borders of the stifle joint (near the convergence of the fascia lata and the biceps femoris muscle), and the second bite of the suture was placed on a line just lateral to the edge of the patella and the straight patellar ligament (Figure 8). The first layer contained from 10 to 15 Lembert sutures which were held in place with a spring-type needle holder until the first layer was completely placed (Figure 9). Then the limb was held in extension and each suture was tied to draw the tissues taut (Figure 10). A second layer of Lembert sutures was placed on the lateral side of the stifle joint in the same manner as the first layer, but only contained 4 to 6 sutures. These reinforcing sutures were concentrated in the area between the patella and the tibial crest.

The third layer of Lembert sutures was placed on the medial side of the stifle joint. This layer consisted of 4 to 6 Lembert sutures which were concentrated in the area between the patella and the tibial crest. One bite of the Lembert suture was one-third of the distance from the anterior to the posterior borders of the stifle joint (near the area of the caudal portion of the sartorius muscle) and the second bite of the suture was placed just medial to the edge of the patella

Figure 8. Placement of first layer of Lembert sutures on the lateral side of the stifle joint

A. Area of tibial tuberosity

B. Area of patella

C. Area of convergence of fascia lata and biceps femoris muscle

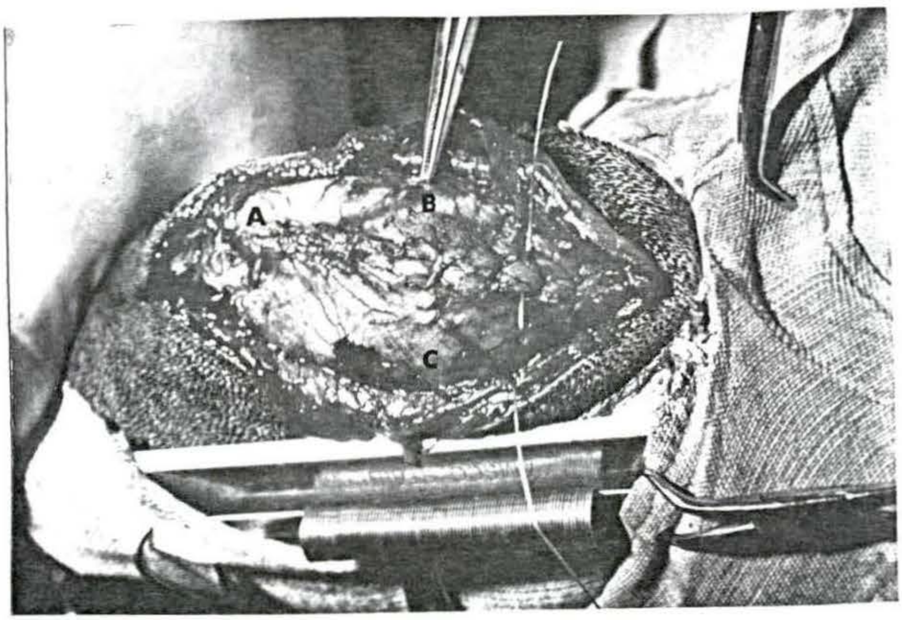
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Figure 9. Completed first layer of Lembert sutures held in place with a spring-type needle holder

A. Area of tibial tuberosity

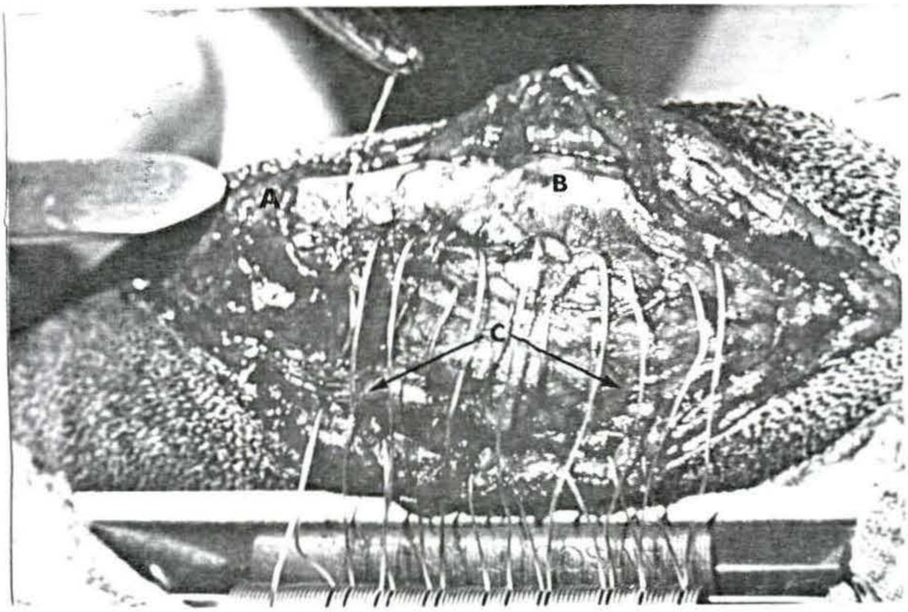
B. Area of patella

C. Area of convergence of fascia lata and biceps femoris muscle

Figure 10. Tied Lembert sutures of the first layer with the lateral joint tissues drawn taut

A. Area of tibial tuberosity

B. Area of patella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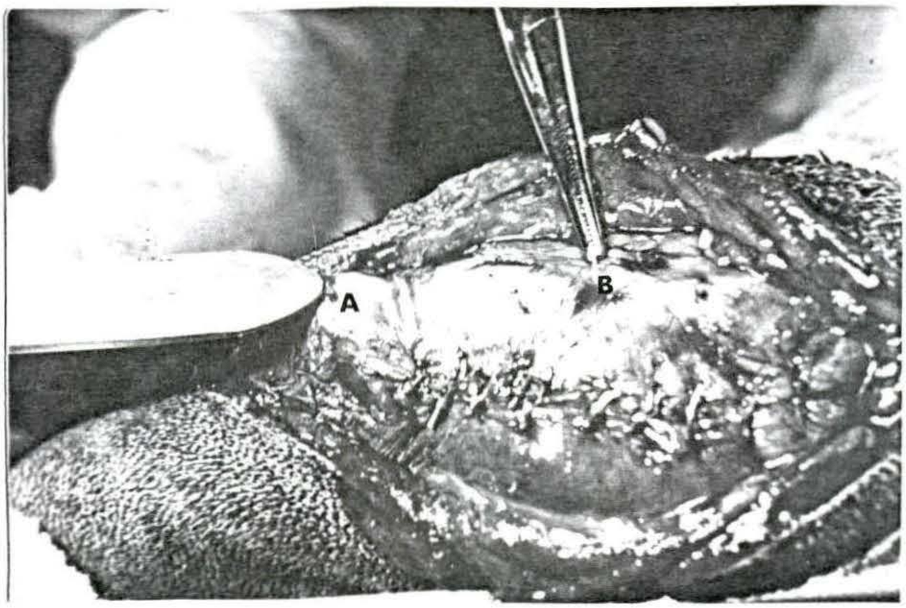
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and the straight patellar ligament (Figure 11). After all medial sutures were placed, each was tied so the tissues became taut.

The stifle joint was examined for drawer movement following the placement of all 3 layers of sutures. The deep and superficial subcutaneous fascia were closed with continuous 000 chromic catgut sutures (Figure 12). The skin was closed with simple mattress sutures using synthetic suture material.

The stifle joints were not bandaged or splinted following surgery. Penicillin-dihydrostreptomycin injections were given twice daily for at least 3 days following surgery.

Figure 11. Placement of the third layer of Lembert sutures on the medial side of the stifle joint

A. Area of tibial tuberosity

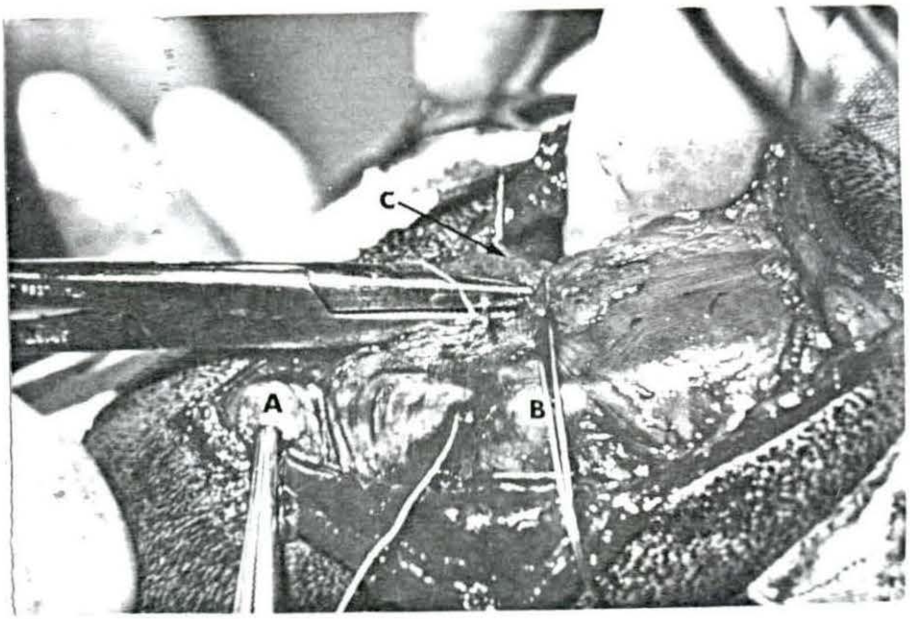
B. Area of patella

C. Area of caudal portion of sartorius muscle

Figure 12. Continuous catgut suture placed in the deep subcutaneous fascia

A. Area of tibial tuberosity

B. Area of patella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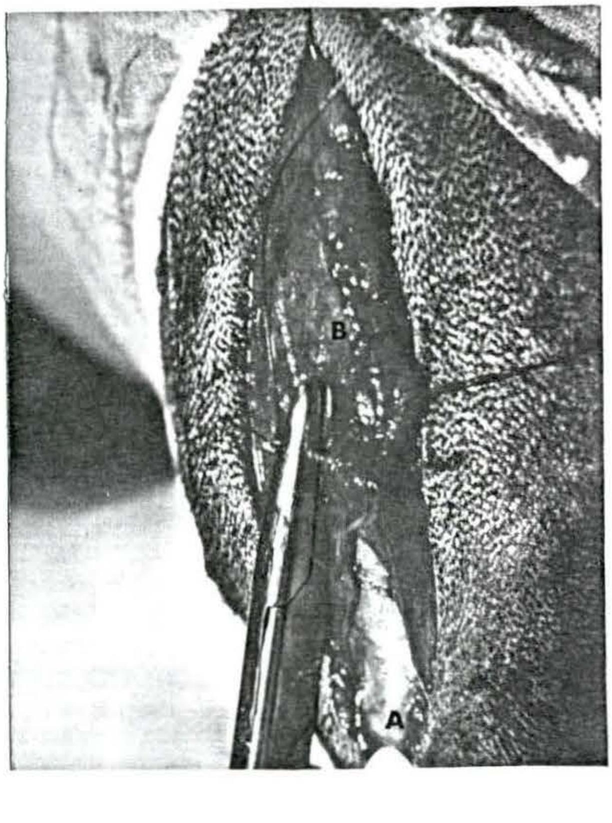
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RESULTS

Group 1: 90-Day Observation Period

In group 1 the anterior cruciate ligament was experimentally severed in 18 stifle joints of 9 dogs. The severed ligaments were repaired in each animal by using the Lembert suture technique in one stifle joint and the Paatsama fascia lata transplant in the other stifle joint.

There was some degree of lameness related to 5 of the 18 joints at the time of euthanasia. Occasional lameness was seen in all 5 of the affected joints with 3 from the Paatsama group and 2 from the Lembert group (Table 1).

Lameness in each experimental case was classified according to the weight-bearing status of each limb. The categories were: normal ambulation, occasional lameness, frequent lameness and continuous lameness. Lameness, if present, was found to persist from the day of surgery in all experimental animals.

The amount of drawer movement was determined by the degree of anterior movement of the tibia when the femur was held stationary. Movements were recorded as slight (1/16 to 1/8 inch), moderate (1/4 to 3/8 inch) and severe (1/2 inch or more). In this group the drawer movement varied from slight to moderate.

Macroscopic lesions

Wound healing of the surgical incisions was complete and free of ulcerations in all dogs except 5L (Table 1). The

Table 1. Summary of observations and findings in 9 dogs during the 90-day post-operative period

No.[a]	Operation[b]	Transplanted ligament	Clinical lameness	Drawer movement	Macroscopic lesions	Microscopic lesions	
						Pannus	Chondropathy
1L	P	intact	none	slight	moderate	moderate	slight
1R	S	---	none	slight	slight	slight	slight
2L	S	---	none	moderate	slight	moderate	none
2R	P	intact	none	moderate	slight	moderate	none
3L	P	intact	none	moderate	moderate	severe	none
3R	S	---	none	moderate	none	none	none
4L	S	---	occasional	slight	none	none	moderate
4R	P	ruptured	occasional	moderate	none	none	moderate
5L	S	---	none	moderate	slight (suture granuloma)	none	none
5R	P	intact	occasional	moderate	moderate	moderate	severe

[a]L indicates left stifle joint; R indicates right stifle joint.

[b]P indicates Paatsama's technique; S indicates Lembert suture technique.

Table 1. (Continued)

No.[a]	Operation[b]	Transplanted ligament	Clinical lameness	Drawer movement	Macroscopic lesions	Microscopic lesions	
						Pannus	Chondropathy
6L	S	---	occasional	moderate	slight	slight	moderate
6R	P	intact	occasional	moderate	severe	moderate	none
7L	S	---	none	moderate	none	none	none
7R	P	ruptured	none	moderate	none	moderate	moderate
8L	P	intact	none	moderate	none	moderate	none
8R	S	---	none	moderate	none	moderate	moderate
9L	S	---	none	slight	none	none	slight
9R	P	intact	none	slight	none	none	none

appearance of a chronic granulomatous reaction of 3 to 5 mm was observed grossly in 2 areas around the synthetic suture material in joint 5L. Bacteriological cultures on blood agar of the reactive areas were negative.

Two of the 9 transplanted fascia lata ligaments had ruptured (Table 1). Osteophyte formations were present in 9 of the 18 joints. Evaluation of gross arthropathies were recorded as none, slight (exostosis or erosion of one femoral condyle, Figure 13), moderate (exostosis or erosion of both femoral condyles, Figure 14) and severe (exostosis of both femoral condyles with soft tissue lesions, Figure 15).

Five of the 9 joints repaired by the Paatsama technique contained gross lesions of slight to severe. Four of the 9 joints repaired by the Lembert suture technique had gross lesions varying from slight to moderate (Table 1).

Microscopic lesions

Microscopic evaluation of each joint included the examination of the articular cartilage, bone and associated soft tissues. In all cases the histopathological lesions seen in the bone (exostosis) and soft tissues (chronic granulomatous reaction around the synthetic suture material, Figure 16) confirmed the gross observations.

The histopathological lesions observed in the articular cartilage were not apparent on gross observation. The articular cartilage lesions were recorded as pannus (granulation

Figure 13. Articular cartilage of stifle joint 30R with "slight" arthropathy

A. Lateral femoral condyle with exostosis

B. Intact transplanted fascia lata ligament

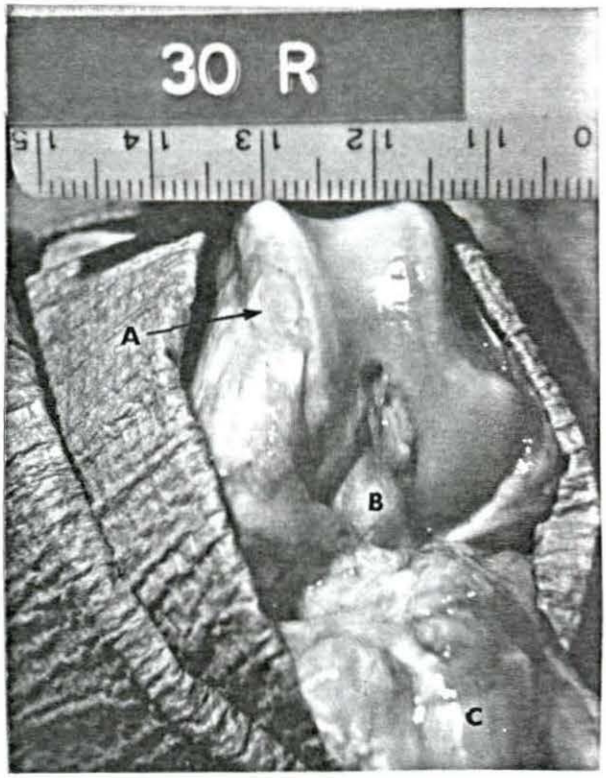
C. Normal patella

Figure 14. Articular cartilage of stifle joint 26R with "moderate" arthropathy

A. Lateral femoral condyle with exostosis

B. Medial femoral condyle with exostosis

C. Normal patella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B
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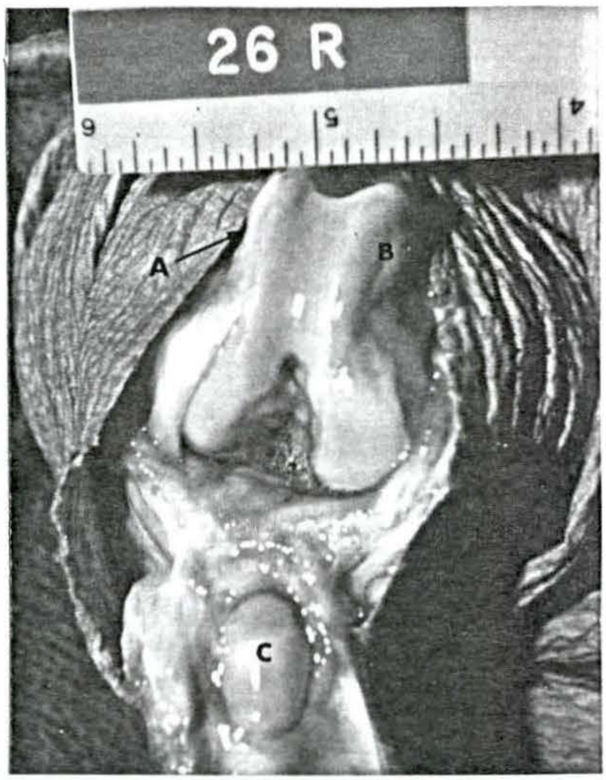

26 R
A
B
C

Figure 15. Articular cartilage of stifle joint 26L with "severe" arthropathy

A. Lateral femoral condyle with exostosis

B. Medial femoral condyle with exostosis and erosion

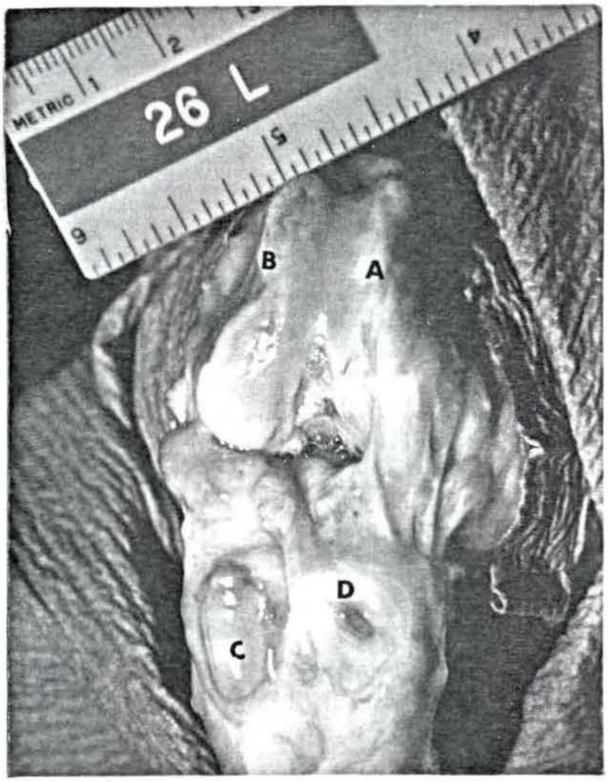
C. Normal patella

D. Chronic granulomatous reaction around synthetic suture material

Figure 16. Chronic granulomatous reaction around synthetic suture material in stifle joint 5L. Hematoxylin and eosin stain photographed with partially polarized light. X 56

A. Cross section of synthetic suture material

B. Tissue reaction (macrophages, plasma cells and fibrous connective tissue) to suture material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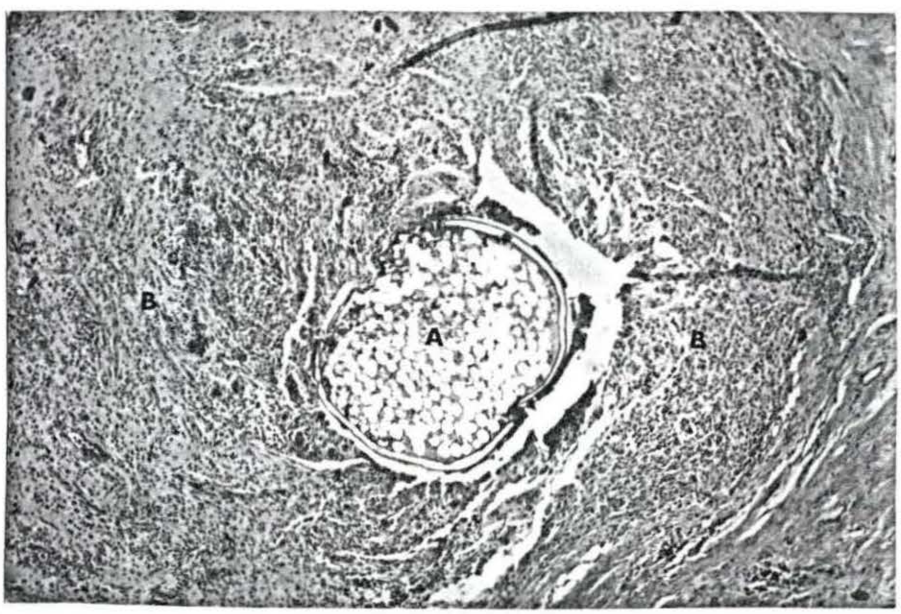
B
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B

tissue that had spread across the articular cartilage) and chondropathy (disease of cartilage).

Pannus was recorded as slight (Figure 17), moderate and severe (Figure 18). The chondropathies were recorded as slight (Figure 19), moderate and severe (Figure 20).

Pannus was observed in 11 of the 18 joints, with 7 from the Paatsama technique and 4 from the Lembert suture technique. Chondropathies were observed in 10 of the 18 joints, 5 from each group.

Group 2: 180-Day Observation Period

In group 2 the anterior cruciate ligament was experimentally severed in 22 stifle joints of 11 dogs. The severed ligaments were repaired in each animal by using the Lembert suture technique in one stifle joint and the Paatsama fascia lata transplant in the other stifle joint. There was some degree of lameness related to 4 of the 22 joints at the time of euthanasia. There was evidence of occasional lameness referable to one joint repaired with Paatsama's technique and 2 joints repaired with the Lembert suture technique. One joint repaired by the suture technique caused frequent lameness (Table 2). In this group the drawer movement varied from slight to severe.

Macroscopic lesions

Wound healing of the surgical incisions was complete and free from ulcerations in all dogs except 26L. Chronic

Figure 17. Articular cartilage of stifle joint 2R with "slight" pannus. Hematoxylin and eosin stain. X 56

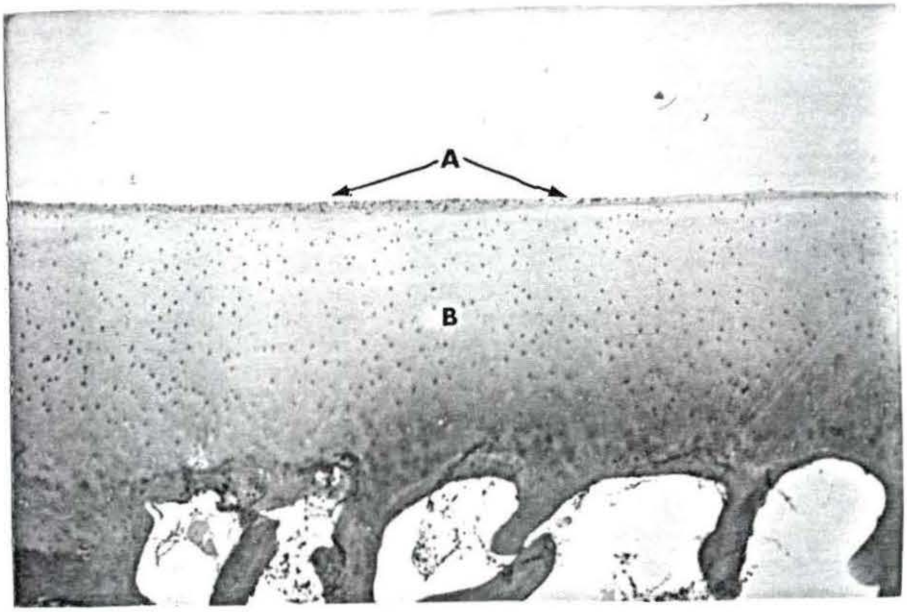
A. Area of pannus formation

B. Articular cartilage

Figure 18. Articular cartilage of stifle joint 3L with "severe" pannus. Hematoxylin and eosin stain. X 56

A. Area of pannus formation

B. Articular cartilage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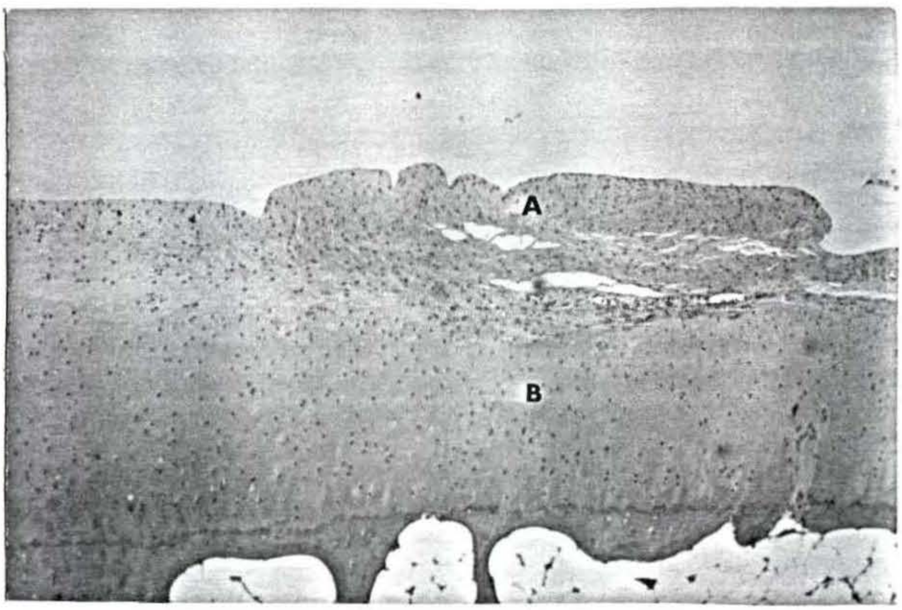
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Figure 19. Articular cartilage of stifle joint 20R with "slight" chondropathy. Hematoxylin and eosin stain. X 56

A. Degenerative lesion in articular cartilage

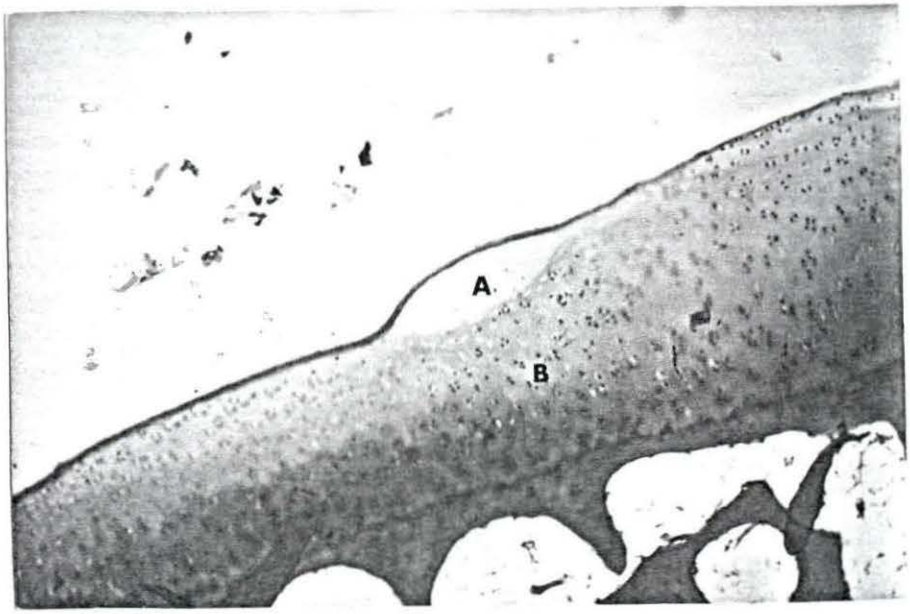
B. Articular cartilage

Figure 20. Articular cartilage of stifle joint 5R with "severe" chondropathy. Hematoxylin and eosin stain. X 56

A. Fissures in the articular cartilage

B. Articular cartilage

C. Cartilage debris from extensive erosion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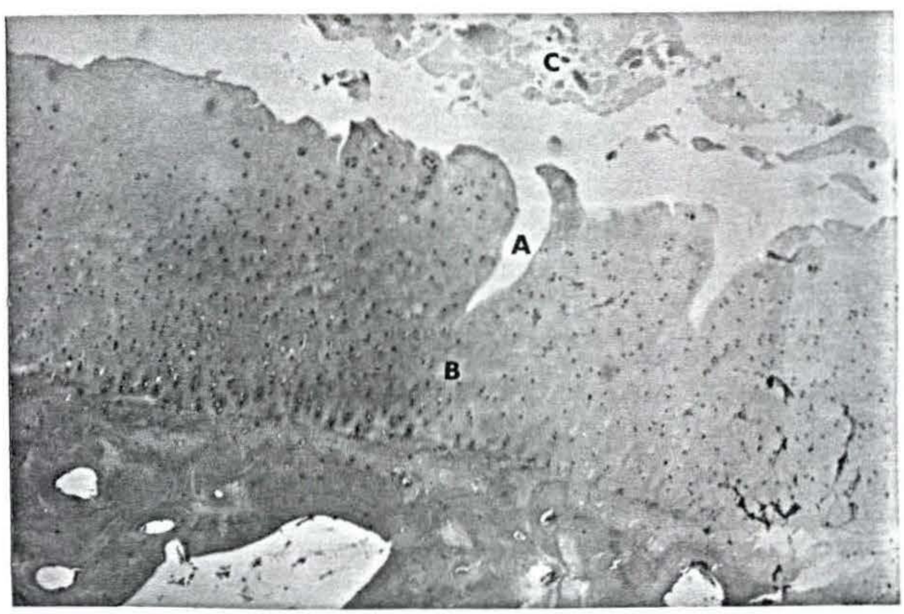
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Table 2. Summary of observations and findings in 11 dogs during the 180-day post-operative period

No.[a]	Operation[b]	Transplanted ligament	Clinical lameness	Drawer movement	Macroscopic lesions	Microscopic lesions	
						Pannus	Chondropathy
20L	P	intact	none	moderate	slight	none	none
20R	S	---	none	slight	moderate	none	slight
21L	S	---	none	moderate	none	none	none
21R	P	intact	none	slight	slight	none	none
22L	S	---	none	moderate	slight	none	none
22R	P	intact	none	moderate	moderate	slight	none
23L	P	intact	none	moderate	none	none	none
23R	S	---	none	moderate	none	none	none
24L	S	---	frequent	moderate	slight	none	moderate
24R	P	partly ruptured	none	moderate	slight	slight	none
25L	S	---	none	slight	moderate	none	none
25R	P	ruptured	none	slight	slight	none	none

[a] L indicates left stifle joint; R indicates right stifle joint.

[b] P indicates Paatsama's technique; S indicates Lembert suture technique.

Table 2. (Continued)

No.[a]	Operation[b]	Transplanted ligament	Clinical lameness	Drawer movement	Macroscopic lesions	Microscopic lesions: Pannus	Microscopic lesions: Chondropathy
26L	P	ruptured	none	slight	severe (suture granuloma)	none	moderate
26R	S	---	occasional	moderate	moderate	none	moderate
27L	S	---	none	slight	none	none	none
27R	P	ruptured	none	slight	none	slight	none
28L	P	ruptured	none	slight	none	none	none
28R	S	---	none	slight	slight	none	none
29L	P	partly ruptured	occasional	severe	none	none	slight
29R	S	---	occasional	severe	slight	none	none
30L	S	---	none	slight	none	none	none
30R	P	intact	none	moderate	slight	none	none

granulomatous reactions were observed grossly around the synthetic suture material in 3 areas of 2 to 4 mm in diameter in the soft tissue on the lateral side of joint 26L. Bacteriological cultures on blood agar of the reactive areas were negative.

Four of the 11 transplanted fascia lata ligaments had ruptured completely and 2 were partly ruptured. Osteophyte formations were present in 14 of the 22 joints.

Seven of the 11 joints repaired by the Lembert suture technique developed gross lesions of slight to severe. Seven of the 11 joints that underwent the Paatsama technique developed lesions of slight to severe (Table 2).

Microscopic lesions

Pannus was observed in 3 of the 22 joints, all 3 being in the Paatsama group. Chondropathies were observed in 5 of the 22 joints, 2 from the Paatsama group and 3 from the Lembert group (Table 2).

Group 3: 365-Day Observation Period

In group 3 the anterior cruciate ligament was experimentally severed in 12 stifle joints of 6 dogs. The severed ligaments were repaired in each animal by using the Lembert suture technique in one stifle joint and the Paatsama fascia lata transplant in the other stifle joint.

There was some degree of lameness referable to 5 of the 12 joints at the time of euthanasia. There was occasional lameness referable to 2 of the 6 joints repaired by the Lembert suture technique. Occasional, frequent and continuous lameness, respectively, were referable to 3 of the 6 joints repaired by the Paatsama technique (Table 3). In this group the drawer movement varied from slight to severe.

Macroscopic lesions

Wound healing of the surgical incisions was complete in all dogs with no evidence of ulceration. Most joints contained the intact subcutaneous chromic catgut suture with no gross evidence of granulomatous reaction (Figure 21). The synthetic suture material used in both groups was nonreactive on gross examination.

One of the 6 transplanted fascia lata ligaments was completely ruptured and a second ligament was partly ruptured. Osteophyte formations were present in 9 of the 12 joints.

There were gross lesions of slight to moderate in 4 of the 6 joints repaired by the Lembert suture technique. Five of the 6 Paatsama-repaired joints had gross lesions of slight to moderate (Table 3).

Microscopic lesions

Pannus was observed in 4 of the 12 stifle joints. Pannus was detected in 3 of the Paatsama group and one of the Lembert group. Chondropathies were observed in 2 of the 12 joints with both observations from the Paatsama group.

Table 3. Summary of observations and findings in 6 dogs during the 365-day post-operative period

No.[a]	Operation[b]	Transplanted ligament	Clinical lameness	Drawer movement	Macroscopic lesions	Microscopic lesions	
						Pannus	Chondropathy
101L	S	---	none	slight	slight	none	none
101R	P	intact	none	slight	slight	severe	none
102L	S	---	none	slight	moderate	none	none
102R	P	intact	none	slight	slight	none	severe
103L	S	---	occasional	moderate	none	none	none
103R	P	ruptured	frequent	moderate	none	moderate	moderate
104L	P	intact	occasional	moderate	none	none	none
104R	S	---	occasional	moderate	none	slight	none
105L	P	intact	none	slight	none	none	none
105R	S	---	none	slight	none	none	none
106L	P	ruptured	continuous	severe	moderate	moderate	none
106R	S	---	none	moderate	moderate	none	none

[a]L indicates left stifle joint; R indicates right stifle joint.

[b]P indicates Paatsama's technique; S indicates Lembert suture technique.

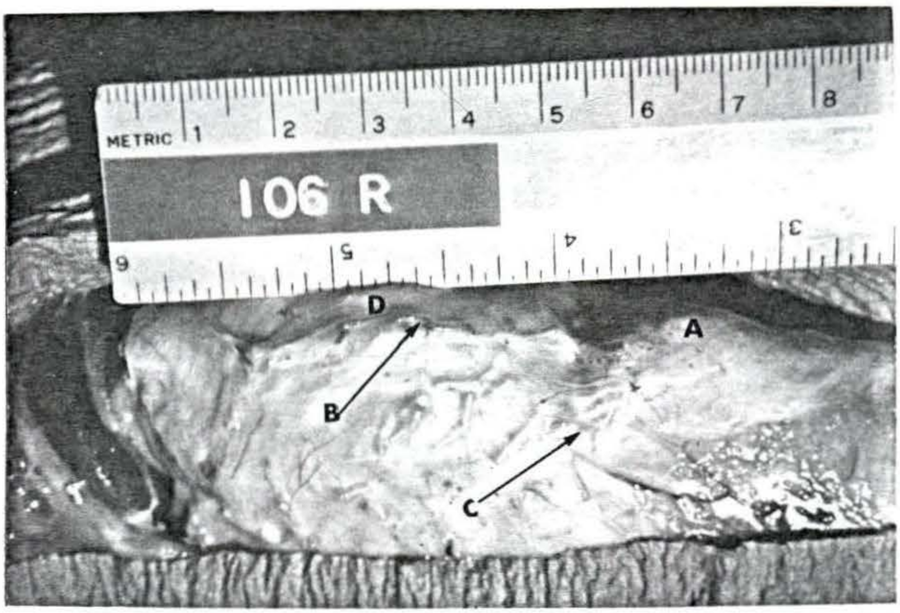
Figure 21. Lateral surface of stifle joint 106R with no macroscopic lesions in the soft tissue

A. Area of tibial tuberosity

B. Area of catgut sutures

C. Area of synthetic suture material

D. Area of patella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DISCUSSION

This investigation, in which 26 dogs were used, was done to compare the results of the established Paatsama technique to the Lembert suture technique for repair of the ruptured anterior cruciate ligament in the dog. A review of the literature revealed that prior to 1952 the only treatment for a ruptured cruciate ligament was the use of the Thomas splint.

After Paatsama (1952) published his work on the canine stifle joint, veterinary surgeons used his fascia lata transplant technique for repair of the ruptured anterior cruciate ligament. The results of Paatsama's technique were usually satisfactory, but the transplanted ligament occasionally ruptured and sometimes resulted in an unstable joint. Many investigators substituted synthetic materials and other body tissues in an effort to find a better replacement than fascia lata. Results of all these procedures to re-establish joint function by replacement of the ruptured anterior cruciate ligament were variable.

A new surgical approach was presented by Childers (1966) when he reported on the use of Lembert sutures to stabilize joint movement. This technique relied on the connective tissue changes in the joint capsule and fascia to stabilize the joint as contrasted to other procedures that depended on ligament replacement.

Three advantages were possible with the Lembert suture technique. First, the procedure could be done without entering the joint. A closed technique could be used, provided the injury was acute and joint pathology was not found during the physical and/or radiographic examination. The second advantage of the suture technique was that it did not require the use of specialized orthopedic equipment. The third advantage was the elimination of the drilling procedure in the femur and tibia necessary in the Paatsama technique.

This study was designed to compare the two procedures on clinical results, macroscopic lesions and microscopic lesions. The clinical results varied from group to group but were comparable. A total of 52 stifle joints had surgical correction of experimentally produced ruptured anterior cruciate ligaments, with 14 limbs having some degree of disfunction as evidenced by lameness at the time of euthanasia. Of the 14 clinically lame joints, 7 were in the Lembert group and 7 from the Paatsama group. Clinical results of the two techniques were similar.

The Paatsama technique was used on 26 joints and the transplanted fascia lata ligament was found partly or completely ruptured in 10 stifle joints. In the 10 joints with ruptured transplanted ligaments, only 4 had some degree of lameness at the time of euthanasia. The success may have resulted from a thickening of the joint capsule, forced rest from the pain of surgery and other inflammatory reactions as suggested by Leighton, rather than the actual replacement of the ligament. Results of this investigation would support the observations previously made by Leighton (1961).

Although all 52 joints had some degree of drawer movement, only 29 joints had macroscopic lesions at the time of necropsy. Normal ambulation was observed in 38 of the 52 joints with gross lesions detected in 21 of these 38 joints. One animal had occasional lameness in both stifle joints but did not have macroscopic lesions. No relationship was found between the extent of joint pathology and the weight-bearing status of the limb. This work agreed with that previously done by Vaughan (1963).

Osteophyte formations were observed in 14 of the 26 joints repaired with the Lembert suture technique and 15 of the 26 joints repaired by the Paatsama technique. The osteophyte formations observed were located on the medial and lateral edges of the medial and lateral femoral condyles respectively. No direct relationship was found between osteophyte formations and joint stability.

Minimal chronic granulomatous tissue reactions were observed grossly around the synthetic suture material in 2 (one joint was involved from each group) of the 52 joints. On macroscopic examination these 2 lesions were free of exudate, and bacteriological cultures on blood agar were negative.

The macroscopic lesions of osteophyte formation and chronic granulomatous reactions were confirmed in all experimental cases by the histopathological study of the tissues. The evaluation of exostosis was best determined by gross observations as the extent of the lesions could not be fully evaluated by the study of several microscopic tissue sections taken from each stifle joint.

The histopathological lesions found in the articular cartilage were not apparent on gross evaluation. The cartilage lesions were recorded as pannus (granulation tissue that had spread across the articular cartilage) and chondropathy (disease of cartilage).

Pannus formation was detected in 18 of the 52 joints, with 11 of these from the 90-day observation group. Pannus formation may be part of the initial inflammatory reaction and may reflect the degree of insult to the articular surface. Of the 18 affected joints, 13 were in the Paatsama group and 5 from the Lembert group.

Since both techniques required an open stifle joint approach to sever the anterior cruciate ligaments, some of the reactions seen in both groups may have resulted from the initial joint invasion. The higher number of joints involved in the Paatsama group, however, may have been a direct result of the bone drillings. A surgical procedure which would not require bone drilling would probably reduce the pannus formation.

Chondropathies were observed in 16 of the 52 joints examined histopathologically. Nine of the 16 observations were seen in the 90-day observation group. The appearance of the articular cartilage lesions would suggest that the reaction was a reflexion of the initial inflammatory response.

Of the 16 affected joints, 8 were contained within each group. The equal distribution between the 2 groups indicates that the cartilage change may not be entirely caused by the drillings necessary for the Paatsama procedure. The invasion of the joint and the resulting joint stability following surgery were both involved in the degree of articular change that resulted.

From the above experimental findings, the extent of microscopic change could probably be reduced if the ruptured anterior cruciate ligament was repaired by a closed technique rather than an open approach. The results of this study would support the use of the modified Lembert suture technique for repair of the ruptured anterior cruciate ligament.

It is seldom possible to reproduce an experimental condition exactly as it occurs under natural conditions. The violent force that is necessary to cause rupture of the anterior cruciate ligament must also to some extent damage other joint structures, such as the collateral ligaments, joint capsule and menisci. The lameness that ensues is perhaps the result of a combination of all these factors.

Additional information could be gathered on the closed-joint Lembert suture procedure if an experimental technique could be derived to produce a ruptured anterior cruciate ligament without entering the joint capsule.

SUMMARY AND CONCLUSIONS

1. The purpose of this study was to evaluate a modified Lembert suture technique for repair of the ruptured anterior cruciate ligament in the canine stifle joint.

2. The evaluation was made by comparing the results of the modified Lembert suture technique to the established fascia lata transplant developed by Paatsama. Comparison was made by clinical, macroscopic and histopathological tissue studies.

3. Twenty-six dogs of mixed breeds were divided into 3 groups and observed for 90, 180 and 365 postoperative days respectively. Each animal underwent bilateral surgical repair of the experimentally severed anterior cruciate ligaments. One stifle joint was repaired with the Paatsama fascia lata transplant while the opposite stifle joint was repaired with the modified Lembert suture technique.

4. Lameness in each experimental case was classified according to weight-bearing status of each limb. The categories were: normal ambulation, occasional lameness, frequent lameness and continuous lameness. Some degree of disfunction, as evidenced by lameness, was observed at the time of euthanasia in 14 of the 52 stifle joints that underwent surgical repair. Of the 14 clinically lame joints, 7 were in the Lembert group and 7 from the Paatsama group. Lameness, if present, was found to persist from the day of surgery in all experimental animals.

5. The Paatsama technique was used on 26 joints, and the transplanted fascia lata ligament was found partly or completely ruptured in 10 joints. In the 10 joints with ruptured transplanted ligaments, only 4 had some degree of disfunction as evidenced by lameness at the time of euthanasia. The success may have resulted from a thickening of the joint capsule, forced rest from the pain of surgery and other inflammatory reactions of surgery rather than the actual replacement of the ligament.

6. Evaluations of gross arthropathies were recorded as none, slight (exostosis or erosion of one femoral condyle), moderate (exostosis or erosion of both femoral condyles) and severe (exostosis of both femoral condyles with soft tissue lesions). Osteophyte formations were observed in 14 of the 26 joints repaired with the Lembert suture technique and 15 of the 26 joints repaired by the Paatsama technique. No direct relationship was found between osteophyte formations and joint stability. Minimal chronic granulomatous tissue reactions were observed grossly around the synthetic suture material in 2 (one joint was involved from each surgical technique) of the 52 joints.

7. The histopathological lesions seen in the articular cartilage were not observed by gross examination. The cartilage lesions were recorded as pannus (granulation tissue that had spread across the articular cartilage) and chondropathy (disease of cartilage).

8. Pannus formation was found in 18 of the 52 joints with 11 of these from the 90-day observation group. In the 18 affected joints, 13 were in the Paatsama group and 5 in the Lembert group. The higher number of joints involved in the Paatsama group may have been a direct result of the bone drillings.

9. Chondropathies were observed in 16 of the 52 joints histopathologically. From the 16 involved joints, 8 were in each group. The equal distribution between the 2 groups indicates that the cartilage change may not be entirely caused by the drillings necessary for the Paatsama procedure. The invasion of the joint and the resulting joint stability following surgery were both involved in the degree of articular change that resulted.

10. The results of this study support the use of the modified Lembert suture technique for repair of the ruptured anterior cruciate ligament in the canine stifle joint.

BIBLIOGRAPHY

Bhola, N. G., Brinker, W. O. and Subramanian, K. N. 1969. Breaking strength of cruciate ligaments in the dog. Journal of the American Veterinary Medical Association 155: 1586-1588.

Blair, H. C. 1942. A simple operation for stabilization of the knee joint. Surgery, Gynecology and Obstetrics 74: 855-859.

Brinker, W. O., Brown, R., and Keller, W. F. 1965. A drill guide for use in repair of a ruptured anterior (lateral) cruciate ligament in the dog. Veterinary Medicine and Small Animal Clinician 60: 709-712.

Brook, G. B. 1932. Rupture of the anterior cruciate ligament in the dog. Veterinary Record 12: 240-242.

Butler, H. C. 1964. Teflon as a prosthetic ligament in repair of ruptured anterior cruciate ligaments. American Journal of Veterinary Research 25: 55-59.

Cameron, T., Sevy, C., Carren, D., Cooper, L., and McKeown, D. 1968. An aid in the repair of the anterior cruciate ligament. Veterinary Medicine and Small Animal Clinician 63: 337-340.

Carlin, I. 1926. Ruptur des Ligamentum cruciatum anterius in Kniegelenk beim Hund. Archiv Für Wissenschaftliche und Parktische Tierheilkunde 54: 420-422.

Childers, H. E. 1966. New methods for cruciate ligament repair. Modern Veterinary Practice 47: 59-60.

Dueland, R. 1966. A recent technique for reconstruction of the anterior cruciate ligament. Animal Hospital 2: 1-5.

Foster, W. J., Imhoff, R. K. and Cordell, J. T. 1963. "Closed-joint" repair of anterior cruciate ligament repair in the dog. Journal of the American Veterinary Medical Association 143: 281-283.

Gibbens, R. 1957. Patellectomy and a variation of Paatsama's operation on the anterior cruciate ligament of a dog. Journal of the American Veterinary Medical Association 131: 557-558.

Gupta, B. N. and Brinker, W. O. 1969. Anterior cruciate ligament prosthesis in the dog. Journal of the American Veterinary Medical Association 154: 1057-1061.

Hey Groves, E. W. 1917. Operation for repair of the crucial ligaments. Lancet 4914: 674-675.

Hey Groves, E. W. 1920. The crucial ligaments of the knee joint: their function, rupture, and the operative treatment of the same. British Journal of Surgery 7: 505-515.

Hohn, B. R. and Miller, J. M. 1967. Surgical correction of rupture of the anterior cruciate ligament in the dog. Journal of the American Veterinary Medical Association 150: 1133-1141.

Johnson, F. L. 1960. Prosthetic anterior cruciate ligament. Journal of the American Veterinary Medical Association 137: 646-647.

Jones, K. G. 1963. Reconstruction of the anterior cruciate ligament. Journal of Bone and Joint Surgery 45-A: 925-931.

Lam, S. J. 1968. Reconstruction of the anterior cruciate ligament using the Jones procedure and its Guy's hospital modification. Journal of Bone and Joint Surgery 50-A: 1213-1224.

Leighton, R. L. 1961. Repair of ruptured anterior cruciate ligament with whole thickness skin. Small Animal Clinician 1: 246-259.

Loeffler, V. K. and Reuleaux, I. R. 1962. Zur chirurgie der ruptur des ligamentum decussatum laterale. Deutsche Tierärztliche Wochenschrift 69: 69-72.

McManus, J. L. and Nimmons, G. B. 1966. Ruptured anterior cruciate ligament in a cat. Canadian Veterinary Journal 7: 264.

O'Donoghue, D. H. 1963. A method for replacement of the anterior cruciate ligament of the knee. Journal of Bone and Joint Surgery 45-A: 905-924.

O'Donoghue, D. H., Rockwood, C. A., Frank, G. R., Jack, S. C., and Kenyon, R. 1966. Repair of the anterior cruciate ligament in dogs. Journal of Bone and Joint Surgery 48-A: 503-519.

Ormrod, A. N. 1963. Re-stabilization of the femoro-tibial joint in the dog following rupture of the anterior cruciate ligament. Veterinary Record 75: 375-377.

Paatsama, S. 1952. Ligament injuries in the canine stifle joint. Helsinki, Finland, Kauppakirjapaino, O. Y.

Paatsama, S. 1954. The structure and histopathology of the canine meniscus. American Journal of Veterinary Research 15: 495-499.

Pearson, P. T. 1969. The canine stifle joint. American Animal Hospital Association Proceedings 1969: 397-404.

Rosenoff, H. L., Antelyes, J., and Buonavita, F. P. 1966. A modified intramedullary pin for placement of a prosthetic cruciate ligament. Journal of the American Veterinary Medical Association 149: 523-524.

Roush, J. C., Hohn, R. B., and DeAngelis, M. 1970. Evaluation of transplantation of the long digital extensor tendon for correction of anterior cruciate ligament rupture in dogs. Journal of the American Veterinary Medical Association 156: 309-312.

Schroeder, E. F. and Schnelle, G. B. 1936. Stifle injuries. North American Veterinarian 17: 43-53.

Schroeder, E. F. and Schnelle, G. B. 1941. Veterinary radiography, the stifle joint. North American Veterinarian 22: 353-360.

Singleton, W. B. 1957. The diagnosis and surgical treatment of some abnormal stifle conditions in the dog. Veterinary Record 69: 1387-1394.

Singleton, W. B. 1963. Stifle joint surgery in the dog. Canadian Veterinary Journal 4: 142-150.

Singleton, W. B. 1969. Observations based upon the surgical repair of 106 cases of anterior cruciate ligament rupture. Journal of Small Animal Practice 10: 269-278.

Strande, A. 1964. A study of the replacement of the anterior cruciate ligament in the dog by the tendon of flexor digitalis pedis longus. Nordisk Veteriner Medicin 10: 820-827.

Strande, A. 1966. Replacement of the anterior cruciate ligament in the dog. Journal of Small Animal Practice 7: 351-359.

Vaughan, L. C. 1963. A study of the replacement of the anterior cruciate ligament in the dog by fascia, skin, and nylon. Veterinary Record 75: 537-541.

Vaughan, L. C. and Bowden, N. L. 1964. The use of skin for the replacement of the anterior cruciate ligament in the dog: a review of thirty cases. Journal of Small Animal Practice 5: 167-171.

Vaughan, L. C. and Scott, M. A. 1966. An experimental study of the fate of autografts of whole-thickness skin used to replace the anterior cruciate ligament. Veterinary Record 79: 412-416.

Zahm, V. H. 1966. Die operative behandlung des Kreuzbandrisses beim hund mit synthetischem material. Berliner und Munchener Tierärztliche Wochenschrift 79: 1-4.

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