Presents:

ORTHOPEDIC DISORDERS & SURGERY

With:

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JANUARY 12, 2011

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INTRODUCTION
The extracapsular prosthetic ligament technique (EPLT) is the most common method of treating cranial cruciate ligament (CrCL) injuries in dogs and cats. While tibial plateau leveling osteotomy has become very popular for treatment of large dogs, EPLT remains a common method of treatment due to its lower cost and financial concerns of owners. The prosthetic ligament must be placed as isometrically as possible. Isometric positioning maintains similar tension on the ligament throughout the range of motion of the stifle, decreasing the chance of stretching or breaking the ligament, and allows more normal stifle movement.

ISOMETRIC SITES
A recent study by Hulse et al. assessed isometric positioning of a lateral extracapsular suture anchored to the lateral femoral condyle and the proximal tibia. The study evaluated 2 sites on the femur (F1, F2) and 3 sites on the tibia (T1, T2, T3). The most isometric position for a single lateral prosthetic extracapsular ligament is from the F2 site to the T3 site. If two prosthetic ligaments are to be placed, it is recommended that one ligament run from F2 to F3 and the other from F1 to T3. Proximal attachment is done around the femoropatellar ligament (F1 site) or near the origin of the lateral collateral ligament on the lateral femoral condyle (F2 site). The F2 site is located at the caudal extent of the condyle and at the same level as the distal pole of the lateral fabella of the gastrocnemius muscle. A bone anchor should be used when anchoring the ligament to the F2 site. A bone anchor can also be used at the F1 site or the suture may be anchored around the femorofabellar ligament. Distal attachment occurs at the proximal tibia using a bone tunnel, just caudal to the long digital extensor tendon. The hole for attachment should be positioned as proximal as possible in the tibia. Care should be taken to avoid drilling the hole too distal in the tibia because this location is not isometric.

METHODS OF ATTACHMENT OF PROSTHETIC LIGAMENT
The prosthetic ligament can be attached on the femoral side directly to the femur with a bone anchor or around the femorofabellar ligament. When securing the suture to the femorofabellar ligament it is important to direct the suture around the bulk of the ligament rather than around the actual fabella. The ligament is a broad tight ligament that runs form the cranial aspect of the lateral fabella to the caudal aspect of the lateral femoral condyle. The most common mistake is for the surgeon to pass the prosthetic ligament around the fabella and not the femorofabellar ligament. During stiffe range of motion, the prosthetic ligament may shift caudal to the fabella; if this occurs, the prosthetic ligament only encircles the muscle belly of the gastrocnemius muscle, which has little tensile strength.
Bone anchors provide a quick, reliable and cost-effective method of securing the suture prosthesis to bone. Many different styles of veterinary bone anchors are available. The advantage of using bone anchors is that they can be placed with minimal invasiveness and can be placed at the recommended isometric sites. Bone anchors have excellent pull out strength and are designed to reduce abrasion on the prosthetic ligament. At the present time, I recommend securing the prosthetic suture to a bone anchor on one end of the ligament only. The opposite end should be attached to a bone tunnel. A ligament placed tightly between two suture anchors has little ability to move or stretch during range of motion of the joint. If the ligament is not placed in an isometric position, the tensile strength of the suture could theoretically be exceeded leading to failure. Bone anchors are simple to place and have little instrumentation. An appropriate size hole is drilled into the bone and the anchor is inserted with a hand driver.

A bone tunnel can be used to attach the prosthetic ligament to the tibia. One or two holes are drilled through the proximal tibia at isometric locations and the suture prosthesis is passed through the hole or holes. If one hole is used, the suture is anchored to the medial aspect of the tibia using a suture button before passing the suture back through the bone tunnel and tying it to the complimentary end. If two holes are used, the suture is passed lateral to medial through the first hole, then medial to lateral through the second hole before tying to the complimentary end.

Excessive tension should not be placed on the suture when placing the knot. Excessive tensioning of the suture will increase the chance of suture failure and reduce the range of motion of the stifle due to over-constraint. The suture should be tensioned until cranial drawer motion is just eliminated. It is better to leave 1 or 2mm of cranial drawer rather than over-constrain the joint.

Recently a new ECLT technique has been described by Cook et al. for use in medium and large size dogs. The Tightrope technique uses a Tightrope implant (Arthrex Vet Systems) to place an extracapsular prosthetic ligament composed of 4 strands of fibertape from the F2 to T3 isometric sites. The ligament is placed through a femoral and tibial bone tunnel and is secured using 2 suture buttons. Clinical outcome appears favorable, although limitations are expected as patient size and the tibial plateau angle increases.

Meniscal Injury
The lateral meniscus is seldom damaged because of its mobility, however the medial meniscus is commonly damaged, in 20-80% of cases of cranial cruciate ligament rupture (Vasseur, 2003), due to its relatively immobile nature resulting from its firm attachment to the medial collateral ligament. Medial meniscal injury results from either crushing or tearing; the types of tears include radial, “bucket-handle”, and caudal peripheral detachment with folding.
Clinical Signs
Rupture of the cranial cruciate ligament results in stifle joint instability, which causes synovitis, osteoarthritis, osteophytosis and meniscal damage. Additionally, meniscal injury results in further instability and synovitis. Often, patients with chronic cranial cruciate ligament rupture will have returned to weight bearing. Acute onset lameness typically occurs at the time of meniscal injury.

In cases of acute rupture, stifle joint effusion, positive cranial drawer test, and pain with stifle manipulation are evident. In chronic cases, muscle atrophy, medial buttress formation (peri-articular fibrosis on the medial aspect of the joint), and crepitus with joint flexion and extension may be evident. Cranial drawer may be difficult to demonstrate due to the degree of peri-articular fibrosis. Sedation may allow cranial drawer to be elicited; in some cases, the tibial compression test may be more easily demonstrated.

Medial meniscal injury is seen in over 70% of cases of rupture of the cranial cruciate ligament in dogs (Flo, 1993). Meniscal injury can be detected on physical examination by the presence of a meniscal click that is a pop or soft tissue crepitus that occurs during stifle flexion. Folding tears of the medial meniscus can diminish the magnitude of cranial drawer since the folded horn of the meniscus can become wedged cranial to the femoral condyle. Meniscal injury not associated with rupture of the cranial cruciate ligament is rare in the dog, and if it occurs it is commonly associated with a traumatic overload of the joint, and more frequently involves the lateral meniscus than the medial meniscus.

Treatment
The meniscus has a poor capacity to heal, due to a limited blood supply, which is isolated to its outer one-third. As a result, meniscal treatment in veterinary medicine is primarily centered on preserving the grossly normal, intact meniscus and removal of the damaged portion of the meniscus since they can cause lameness. The two most common types of medial meniscal injury seen in conjunction with cranial cruciate ligament rupture are injury confined to the inner, axial portion of the meniscus (bucket handle tear), and crushing and detachment of the caudal pole. In cases in which an inner axial tear is present, a partial medial meniscectomy can be performed (Figure 5). If the injury is isolated to the caudal pole of the meniscus, a caudal pole hemi-meniscectomy can be performed (Figure 6). In the rare event that the entire medial meniscus is damaged, a complete meniscectomy can be performed.

Prophylactic meniscal treatment
Latent meniscal injury is meniscal damage that is present at the initial surgery, but undetected by the surgeon at the time of joint exploration. A postliminary meniscal tear is one that occurs after the initial surgical procedure. Latent meniscal tears may be seen in 50% of dogs with cranial cruciate rupture. Postliminary meniscal injury has been reported in 17% of dogs with lateral suture stabilization, and 19% of dogs with a modified four-in-one over-the-top stabilization technique, at a median of 6 months following the initial stabilization procedure. Due to the relatively frequent occurrence of postliminary meniscal tears, several options to reduce this incidence have been suggested.

Some authors suggest that caudal pole hemi-meniscectomy should be routinely performed at the time of joint exploration if the medial meniscus is grossly normal. In this case, removal of the caudal pole of the medial meniscus precludes the possibility of postliminary damage to the caudal pole. Since most stifles have progressive osteoarthritis at the time of stabilization, hemi-meniscectomy seems to result in no worsening of lameness as compared to leaving the meniscus intact.

The TPLO procedure was reported to have a similar incidence of meniscal injury if a complete rupture of the cranial cruciate ligament was present, and the meniscus was normal and left intact. In order to minimize the frequency of postliminary meniscal tears, Dr. Slocum devised the meniscal release procedure. The meniscal release is the incision of the lateral attachment of the caudal horn of the medial meniscus, or an incision of the caudal horn of the medial meniscus. The purpose of the meniscal release is to allow the caudal horn of the medial meniscus to move away from the medial femoral condyle during cranial tibial translation, preventing meniscal impingement. In cases of TPLO with the meniscal release procedure, the
incidence of postliminary meniscal tears may be reduced to a rate as low as 1-2%. Although meniscal release appears to be effective in reducing the rate of postliminary meniscal tears, it has the adverse affect of diminishing the load transmission and stability functions of the meniscus (Pozzi A, et al, 2006). Thus, the efficacy of meniscal release at diminishing the rate of postliminary meniscal tears must be weighed against its adverse effects on meniscal function when considering its use on clinical cases.
How to Find and Treat that Elusive Meniscus  
Brian S. Beale DVM, Diplomate ACVS  
Gulf Coast Veterinary Specialists – Houston, TX

Anatomy

Cranial Cruciate Ligament
The cranial cruciate ligament (CnCL) originates in the intercondyloid fossa on the caudo-medial aspect of the lateral femoral condyle. It courses cranially, medially, and distally oriented in an outward spiral to insert at the cranial intercondyloid area of the tibia. The CnCL is composed of two parts, the craniomedial band and the larger caudo-lateral portion. These two portions blend together, and are made up of hundreds of separate strands, each with its own origin and insertion. Each strand is taut in different positions of stifle joint flexion, extension, and rotation. The cranio-medial band is taut in both flexion and extension, while the caudo-lateral portion is taut in extension and lax in flexion.

Caudal Cruciate Ligament
The caudal cruciate ligament (CdCL) originates in the intercondyloid fossa on the lateral aspect of the medial femoral condyle. It courses caudally and distally, oriented in a slight inward spiral to insert on the lateral aspect of the popliteal notch of the tibia. The caudal cruciate ligament is separated into two functional parts. The larger cranial portion is taut in flexion and lax in extension, while the caudal portion is taut in extension and lax in flexion. The caudal cruciate ligament prevents caudal translation of the tibia relative to the femur (caudal drawer motion), and helps limit internal rotation of the tibia by twisting together with the cranial cruciate ligament.

Collateral Ligaments and Menisci
The medial collateral ligament remains taut in both flexion and extension, while the lateral collateral ligament is taut in extension only. As the stifle is flexed, laxity in the lateral collateral ligament allows internal rotation of the tibia with caudal displacement of the lateral femoral condyle on the tibial plateau. The lateral meniscus accompanies the lateral femoral condyle in the cranial and caudal excursions, which occur in flexion and extension of the joint. The medial meniscus is limited in its mobility due to a firm attachment to the medial collateral ligament. Tibial rotation in conjunction with cranial and caudal displacement of the lateral femoral condyle on the tibial plateau is known as the “screw-home” mechanism. Since the stifle has primary motion in two planes, flexion and extension in the transverse plane, and internal and external rotation in the sagittal plane, the stifle is a complex hinge joint.

Figure 1: Normal anatomy of the canine stifle joint. (courtesy of Antonio Pozzi)
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Figure 2: Transverse and dorsal view of an inner axial (bucket handle) tear of the medial meniscus. (courtesy of Antonio Pozzi)

Figure 3: Transverse and dorsal view of a folding tear of the caudal horn of the medial meniscus. (courtesy of Antonio Pozzi)

Figure 4: Transverse and dorsal view of a radial tear of the caudal horn of the medial meniscus. (courtesy of Antonio Pozzi)
**Clinical Signs**

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In cases of acute rupture, stifle joint effusion, positive cranial drawer test, and pain with stifle manipulation are evident. In chronic cases, muscle atrophy, **medial buttress** formation (peri-articular fibrosis on the medial aspect of the joint), and crepitus with joint flexion and extension may be evident. Cranial drawer may be difficult to demonstrate due to the degree of peri-articular fibrosis. Sedation may allow cranial drawer to be elicited; in some cases, the tibial compression test may be more easily demonstrated.

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**Prophylactic meniscal treatment**

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impingement. In cases of TPLO with the meniscal release procedure, the incidence of postliminary meniscal tears may be reduced to a rate as low as 1-2%. Although meniscal release appears to be effective in reducing the rate of postliminary meniscal tears, it has the adverse affect of diminishing the load transmission and stability functions of the meniscus (Pozzi A, et al, 2006). Thus, the efficacy of meniscal release at diminishing the rate of postliminary meniscal tears must be weighed against its adverse effects on meniscal function when considering its use on clinical cases.

Figure 5: Partial medial meniscectomy (courtesy of Antonio Pozzi)

![Partial Medial Meniscectomy](image)

Figure 6: Caudal pole, partial medial meniscectomy (courtesy of Antonio Pozzi)

![Caudal Pole Hemi-Meniscectomy](image)

References:
Elbow Dysplasia – Much More Common Than You Think
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INTRODUCTION
Elbow dysplasia is the most common cause of forelimb lameness in dogs. Elbow dysplasia includes an array of abnormalities including fragmented medial coronoid process (FCP), osteochondritis descicans (OCD), joint incongruity and ununited anconeal process (UAP). The severity of clinical signs, pathologic change and outcome vary greatly amongst patients. Early diagnosis and prompt treatment gives patients the best chance of avoiding debilitating osteoarthritis.

PATIENT WORK UP: Dogs affected by elbow dysplasia generally begin to show clinical signs prior to reaching two years of age. Clinical signs include intermittent or persistent lameness, elbow swelling, decreased range of motion and joint pain. Plain film radiography including cranio-caudal, medio-lateral, and flexed lateral views should enable the differentiation of ununited anconeal process (UAP), fragmented coronoid process (FCP), and osteochondrosis descicans (OCD). Additional oblique views have been advocated by some authors and may aid in the diagnosis of FCP. The value of computed tomography (CT) in the diagnosis of FCP has been well documented. We have found CT to be unnecessary in the diagnosis of FCP based on a high specificity of plain radiography; however, we perform CT on more confusing and milder arthroscopy patients in order to more accurately define the FCP lesion and assess for incongruity. Step lesions associated with short radius syndrome are clearly seen using CT. Although in the vast majority of cases the CT and arthroscopy findings concur, this has not been uniformly the case. In numerous cases, fragments have been demonstrated by CT that were not visible or palpable when directly visualized arthroscopically. This is most likely due to incomplete fragmentation of the coronoid. Other patients have been found to have small arthroscopic fragments that were not evident by CT. Nuclear scintigraphy (bone scan) has also been found to be helpful in diagnosing early or subtle FCP lesions.

UNUNITED ANCONEAL PROCESS: Ununited anconeal process (UAP) occurs most commonly in German shepherd dogs, but can be seen in many dog breeds. The anconeal process should fuse to the metaphyseal region of the proximal ulna at 4-5 months of age. If the process does not fuse, elbow stability is compromised and osteoarthritis ensues. Most patients having UAP have a short ulna relative to the length of the radius. The hypothesis is that as growth proceeds the anconeal process of affected dogs presses against the humeral trochlea. This creates a shear separating the anconeal process from the ulnar metaphysis. In cases of UAP the site of non-union will be clearly visible as an area of cartilage loss with exposed dense subchondral bone and possibly fibrocartilage. Cartilage erosion is also commonly seen in these patients. Surgical treatment is recommended. Arthroscopy allows assessment of the integrity of the anconeal fragment, the degree of fragment stability and the extent of osteoarthritis. The medial coronoid process should also be examined as many patients having UAP also have FCP. If the UAP fragment is of good integrity, it is a good candidate for reattachment using a lag screw.
A lag screw is placed into the ununited anconeal process (A). As the screw is tightened, the fragment is lagged back onto the ulna (black arrow).

A UAP fragments that are minimally displaced and partially attached may fare well with proximal dynamic ulnar osteotomy only. This procedure allows lengthening of the ulna as the radius grows and removes the shear stress of the anconeal process, allowing it to unite with the ulnar metaphysis. If the fragment is mobile and displaced, it should be reattached and stabilized using a lag screw and k-wire, combined with a proximal dynamic ulnar osteotomy. Arthroscopic guidance can be used to place the k-wire and lag screw. Arthroscopy can also be used to assess reduction and compression of the fragment as the lag screw is tightened. If OA of the fragment and trochlear notch is severe, fragment removal is suggested.

**OSTEOARTHRITIS:** The severity of osteoarthritis is best evaluated using an arthroscope. The arthroscope can be inserted into the joint using typical arthroscopic portals or through an arthrotomy incision to improve the surgeon’s view. Osteoarthritis can be treated arthroscopically using hand instruments or a motorized shaver. The goal of the treatment is debridement of necrotic cartilage, removal of sclerotic bone, neovascularization, and recruitment of pluripotential mesenchymal cells. Cartilage debridement is accomplished using a hand burr, hand curette or motorized shaver. The exposed subchondral bone can be treated using abrasion arthroplasty or micropick technique.

**Abrasion arthroplasty:** To perform abrasion arthroplasty, insert a hand burr or preferentially a power shaver burr through an instrument portal or arthrotomy. Either method will produce significant bone debris that can clog the egress portal and impede visualization, therefore it is important to monitor and maintain the flow of fluid through the joint during this procedure. Spin the burr to remove subchondral bone over the area of the lesion. Check for resulting bleeding frequently by stopping inflow of fluid and ensuring adequate outflow to decrease the pressure in the joint. When bleeding is observed diffusely from the lesion bed, lavage the joint to remove the remaining bone debris and close routinely. A hand curette can also be used for surface abrasion if the subchondral bone is not too sclerotic. Similar principles should be used as described above. The curette is also useful to contour the edge of the cartilage defect; an effort should be made to leave the edges of the articular cartilage perpendicular to the subchondral bone.

**Microfracture:** To perform microfracture, insert an appropriately angled micropick into the joint and press the tip against the subchondral bone surface. Have an assistant tap the pick handle once or twice. The pick should be held securely to avoid gouging the surface and adjacent healthy cartilage. Apply the micropick diffusely across the diseased area and check for resulting bleeding frequently by stopping inflow of fluid and ensuring adequate outflow. When bleeding is observed diffusely from the lesion bed, lavage the joint to remove the remaining bone debris and close routinely.

A motorized shaver is used for abrasion arthroplasty to remove necrotic cartilage and bone.

Grade 3 cartilage wear associated with chronic OA of the elbow.

Microfracture is used to treat the exposed subchondral bone after removal of necrotic cartilage.
**INCONGRUITY AND SHORT RADIUS SYNDROME:** Elbow dysplasia may be associated with a shortened radius relative to the length of the ulna. Incongruity of the joint surfaces occurs. This results in concentration of weightbearing forces on the medial aspect of the joint, leading to cartilage wear and fragmentation of the medial coronoid process and sclerosis and cartilage wear of the medial humeral condyle. The amount of shortening may be vary from severe to subtle. CT evaluation is likely the best way of documenting short radius syndrome incases of subtle shortening. When shortening of the radius becomes more marked, radiographic and arthroscopic examination can lead to a diagnosis. The goals of treatment include improved congruity of the elbow, removal of any loose intraarticular fragments and surface treatment of osteoarthritic cartilage. Improved congruity of the elbow is accomplished by dynamic ulnar partial ostectomy. A small portion of the ulna is excised, allowing improved humeroradial contact. The ulna is not rigidly stabilized in order to allow it to shift over time to the “best fit” position. Occasionally a small intramedullary pin is placed to give partial stability to decrease pain and prevent excessive caudal translation of the proximal ulna. This can be performed proximally, midshaft or distally. Morbidity is reduced the more distal the ostectomy is performed. It would seem that a more proximal ostectomy above the interosseous ligament would have a better chance of correction of incongruity, however anecdotal reports suggest distal osteotomy can also be effective. Some surgeons feel that distal osteotomy is best in immature dogs because they have a more flexible interosseous ligament. Mature dogs may require a higher ostectomy due to a more rigid interosseous attachment.

**OSTEOCHONDRITIS DISSECANS:** Osteochondritis dissecans (OCD) affects the medial humeral condyle. OCD lesions are more difficult to view than FCP lesions. OCD can occur in combination with FCP. The OCD lesion may extend relatively far caudally and medially along the medial humeral condyle. Osteochondrosis dessicans will usually appear on the humeral trochlea as a thickened flap of cartilage overlying a relatively deep (1-2 mm) subchondral bone defect. This is in contrast to subchondral bone exposure found with osteoarthritis, which is more polished and follows the regular contours of the joint surface. Osteoarthritic lesions of varying degree may also accompany the OCD on either the adjacent humeral trochlea or on the opposing ulnar surface. Treatment includes OCD flap removal and abrasion arthroplasty or microfracture of the subchondral bone. Recent advances have made it possible to replace the damages area of the medial humeral condyle with an osteochondral graft obtained from the patient’s stifle joint.

**FRAGMENTED MEDIAL CORONOID PROCESS:** Changes associated with FCP are extremely varied. The area of fragmentation is most commonly on the cranialateral aspect of the medial coronoid adjacent to the radial head. The bone of fragments will most often be dead and yellow in appearance in contrast to the well-vascularized red colored bone of the remainder of the joint. Fully migrated fragments may have revascularized from attachments to the synovium. Additional changes associated with FCP will include varying degrees of osteoarthritic lesions on the remainder of the coronoid, trochlear notch and humeral trochlea. Changes seen in the radial head may include rounding off of the cranial and medial borders.
Canine Elbow Dysplasia (ED) is a commonly reported thoracic limb disorder. ED signifies an abnormal development of the elbow joint coupled with characteristic pathological changes of the medial compartment. Pathologic changes are associated with the coronoid process and humeral condyle. Pathology of the medial coronoid is typified by subchondral bone micro-cracks and fragmentation as well as cartilage erosion secondary to incongruence as seen in Fig 1. Many hypotheses have been formulated about the etiopathogenesis of the pathologic changes including radio-ulnar incongruence. The prevailing belief is that radio-ulnar incongruence is secondary to improper growth of the radius/ulna during maturation. The result is mal-alignment of the articular surfaces where the medial coronoid is subject to high mechanical loads and microfracture or fragmentation. There is no question that mal-alignment and incongruence occurs. However, fragmentation and incongruence secondary to radius/ulna growth abnormality would best explain abnormalities found in younger patients or mature patients with chronic recurring clinical problems. On the other hand, abnormal growth and incongruence may not explain medial coronoid pathology seen cases which exhibit lameness but no other abnormal physical or radiographic findings. Arthroscopy confirms fragmentation of the medial coronoid adjacent to the radial head without the presence of visible cartilage erosion. In these cases, fragmentation/microfracture of the medial coronoid may be secondary to mechanical overload associated with contraction of the biceps brachii/brachialis muscle complex. The histologic and ultrastructural appearance of FCP is consistent with mechanical failure and subsequent unsuccessful fibrous repair.

The biceps/brachialis muscles constitute a large muscular complex. The anatomic origin and insertion of the biceps and brachialis muscles are such that the muscular complex exerts considerable force on the medial compartment of the elbow. The force exerted by the biceps is continuous since it is a pennate muscle with central tendon. More importantly, because the insertion of the biceps/brachialis complex is at the ulnar tuberosity, a large polar (rotational) moment is exerted at the cranial segment of the medial coronoid. The magnitude of the polar moment is a product of the moment arm (distance from the ulnar tuberosity to the tip of the coronoid) multiplied by the force created by the biceps/brachialis muscular complex. The polar moment rotates and compresses the craniofemoral segment of the medial coronoid against the radial head. The compressive force is medial to lateral transverse to the long axis of the coronoid. A compressive force generates internal shear stress at an oblique angle to the applied compressive force. In this situation, maximal internal shear stress would be oblique to the long axis of the coronoid. Under the right circumstances, the polar moment and resultant compressive force produced by the biceps/brachialis complex may produce sufficient internal shear stress to exceed the material strength of the cancellous bone in the craniofemoral segment of the medial coronoid. The result would be microfracture/fragmentation adjacent to the radial head at an oblique angle to the long axis of the medial coronoid. Interestingly, microfracture/fragmentation of the coronoid seen clinically is in the craniofemoral segment of the medial coronoid adjacent to the radial head. This location corresponds to the plane of maximal shear stress generated by the compressive force exerted by the polar moment produced by contracture of the biceps/brachialis complex.
The fragment and underlying necrotic bone should be removed arthroscopically or through a minimally-invasive arthrotomy. The underlying subchondral bone can be treated with abrasion arthroplasty or microfracture to encourage fibrocartilaginous repair (see above under osteoarthritis). Some patients may also benefit from sliding humeral osteotomy or biceps tendon release as a means of reducing pressure on the medial aspect of the joint.

References are available upon request.
Patella luxation is a problem in all breeds and sizes of dogs, but the condition is most common in small breed dogs. Commonly affected breeds include the Yorkshire Terrier, Maltese, Toy Poodle, Miniature Poodle, Pomeranian, Pekingese and Chihuahua. Medial patellar luxation predominates in both small and large breeds, although past literature suggests lateral luxation is much more common in large breeds. Patellar luxation occurs less frequently in cats and medial luxation is most common. Patellar luxation is generally graded from 1-4 based on increasing severity. Grade 1 patellar luxations are generally not repaired, but surgical repair is recommended for grades 2-4, depending on the age and clinical presentation of the patient. Treatment of medial patella luxation may be conservative (small breeds only) or surgical. The decision as to which method is applicable for a patient is dependent upon the clinical history, physical findings and the age of the patient. An older patient in which patella luxation is noted as an incidental finding on physical examination and in which the client reports nonclinical lameness does not warrant surgical intervention. Rather, the client should be informed as to the clinical signs associated with patella luxation. Surgery is advised in the young adult patient even though no clinical problem is apparent since intermittent luxation may prematurely wear the articular cartilage of the patella. Surgery is indicated in any aged patient exhibiting lameness and is strongly advised in a patient with active growth plates since skeletal deformity may worsen rapidly. However surgical techniques used in actively growing animals should be those that will not adversely affect skeletal growth. Surgical options include trochleoplasty, trochlear wedge recession, trochlear block recession, tibial tuberosity transposition, tibial tuberosity transposition, rectus femoris transposition, retinacular imbrication, derotational suture, retinacular releasing incision and corrective osteotomy in cases of femoral or tibial deformity. In severe cases that do not respond to the above treatments, patellectomy and stifle arthrodesis are a possibility; these techniques are fortunately rarely needed (these techniques will not be presented).

Clinical Findings
Pet owners typically report a skipping lameness in affected pets. Typically the pet uses the affected leg normally between skipping episodes. Some owners do not recognize any lameness or gait abnormality in affected patients. Patellar luxation frequently occurs bilaterally, but may one stifle may be more severely affected than the other. Owners often report a slow progression in severity of clinical lameness. The lameness may appear to resolve in some patients over time, but this may be due to the progression of patellar luxation from grade 2 to grade 3. The skipping gait may disappear because the patella is no longer displacing into and out of the trochlear groove. If the patella remains in a luxated position, the patient may not exhibit obvious lameness, but may have a bowlegged gait. Lameness that acutely worsens in patients with patellar luxation may be associated with a concomitant tear of the cranial cruciate ligament. Cranial cruciate ligament injury occurs in approximately 25% of patients with patellar luxation.

Patellar luxation is generally graded from 1-4 based on increasing severity. Grade 1 luxation is not associated with clinical lameness. The patella can be displaced out of the trochlear groove by applying digital pressure, but spontaneous luxation does not occur. Grade 2 luxation typically presents with an intermittent non-weightbearing lameness, the typical “skipping-gait”. Digital displacement of the patella is possible during examination, but the patella moves back into the trochlear groove when pressure is released or when the stifle is extended. Grade 3 luxation may present with intermittent non-weightbearing lameness or persistent weightbearing lameness. Many of these patients do not have an obvious lameness, but rather display a bowlegged posture when walking. The patella is typically luxated at the time of examination, but can be replaced into the trochlear groove with digital pressure. The patella usually quickly luxates again once pressure is released or the stifle is moved through a range of motion. Grade 4 luxation presents as a persistent weightbearing lameness or bowlegged gait. The patella is fixed in a luxated position and cannot be reduced with digital pressure, even in the anesthetized patient.
Radiographic Findings

Patients having medial patellar luxation should be evaluated with appropriately positioned orthogonal survey radiographic views of the stifte. Orthogonal views of the entire femur and tibia should also be evaluated if limb deformity is present in small breed dogs and in all medium and large breed dogs with patellar luxation. The patient should be assessed for patella position, distension of the joint capsule, presence of tibial translation, tibial tuberosity position, axial alignment of the femur and tibia, torsional alignment of the femur and tibia, and osteoarthritis. CT imaging is recommended, if available, to more accurately assess hind limb alignment.

Radiographic changes vary from no obvious change to severe limb deformity and marked patellar displacement depending on the grade of luxation, age at onset of patellar luxation and duration of the condition. Minimal radiographic changes are seen in adult patients with uncomplicated grade 1 or 2 medial patellar luxation. Some patients have no abnormal radiographic changes. Radiographic changes that may be seen include patellar displacement, tibial tuberosity displacement, and rarely mild osteoarthritis and mild joint effusion. Grade 3 and grade 4 patellar luxations are more likely to have radiographic patellar displacement, tibial tuberosity displacement, joint effusion and osteoarthritis. These patients are also more commonly affected with axial or torsional abnormalities of the femur or tibia. Patients with severe medial patellar luxation and abnormal limb alignment usually have distal femoral varus, proximal tibial valgus, internal femoral torsion or internal tibial torsion. Radiographic assessment of the depth of the trochlear groove is usually best evaluated by palpation or gross observation, but severely shallow trochlear grooves can be seen radiographically.

Radiographic changes are most severe in puppies where the onset of patellar luxation occurs at an early age when the physis is undergoing rapid growth. Medial luxation of the patella in these dogs causes compression on one side of the distal femoral and proximal tibial physis and compression on the opposite side. As a consequence, the medial aspect of the femoral physis has retarded growth and the lateral aspect has accelerated growth resulting in distal femoral varus. The lateral aspect of the tibial physis has retarded growth and the medial aspect has accelerated growth resulting in proximal tibial valgus. Torsional deformity of the femur and tibia can also occur simultaneously. Correction of the deformity is usually based on comparison of the degree of angulation and torsion found on radiographic examination of the affected patient in comparison to normal reference values. The surgeon should be cautious when interpreting the measured angle of axial deformity as torsional deformity can artificially raise or lower the actual amount of axial malalignment. A CT scan is likely to give the most accurate measurement of axial and torsional deformity.

Patients with medial patellar luxation should also be evaluated for the potential for concomitant cranial cruciate injury. Typical radiographic changes include joint distension and cranial tibial displacement. Osteoarthritic changes are more likely with cranial cruciate ligament injury. If cranial cruciate ligament injury is suspected, measurement of the slope of the tibial plateau may be helpful when deciding on a surgical plan.
Complications associated with medial patellar luxation (MPL) repair can be categorized as intraoperative or postoperative. Complications are fairly common, but fortunately many are easy to resolve or prevent. Most complications can be avoided by better preoperative planning, meticulous surgical technique and appropriate postoperative care.

Decision-Making for Patellar Luxation Repair

Many surgical options are available when considering repair of the luxating patella. It is important to consider the underlying problems associated with the particular luxation when choosing a surgical plan. Factors to consider include, depth of the trochlear groove, alignment of the quadriceps mechanism (quadriceps, patella, patellar tendon), and the presence of excessive laxity or tension of the joint capsule and retinacular tissues medially and laterally. The surgical options chosen should alleviate the underlying factor contributing to the luxation. For example, if a dog has good alignment of the quadriceps mechanism, but a shallow trochlear groove - the surgical plan should include a technique to deepen the femoral trochlea, but not a tibial tuberosity transposition.

Methods to Deepen the Trochlea

Three methods are commonly used to deepen a shallow trochlear groove. These methods are described below. A head-to-head comparison as not been performed to document superior efficacy of one technique compared to the others. Usually trochleoplasty is reserved for toy-breed dogs and cats. Trochlear wedge recession and trochlear block recession are preferred for small, medium and large breed dogs, but also can be performed effectively in toy-breed dogs and cats with a slight increase in technical difficulty.

Trochleoplasty – Trochleoplasty is a traditional technique that involves removal of articular cartilage and subchondral bone from the trochlear sulcus, thereby deepening the sulcus. Fibrocartilage repair is generally seen. This technique is considered less desirable to cartilage-sparing techniques described below, although it is sometimes used in toy breeds very successfully. Trochleoplasty is technically easy to perform. A deepened groove can be quickly formed using appropriate sized rongeurs. Attention should be paid to ensuring adequate depth of the groove proximally.

Trochlear Wedge Recession – Trochlear wedge recession provides a means of adequately deepening the trochlear sulcus, while preserving most of the articular cartilage. This technique is described elsewhere, but basically involves removal of a v-shaped wedge of bone and cartilage from the trochlear sulcus, removal of underlying bone, followed by replacement of the original wedge in a recessed position. This is an excellent technique, but technically more demanding than trochleoplasty. The technique is performed using a fine-tooth hand saw-blade. Care should be taken when beginning the saw cut, not to excoriate the adjacent cartilage due to slippage. The cut is initiated perpendicular to the cartilage surface adjacent to the peak of the trochlear ridge. Once the saw blade has engaged the subchondral bone, the blade is gradually redirected in the proper direction, parallel to the v-shaped trochlear groove. A cut is made from the lateral and medial ridge, meeting deep to the central sulcus of the groove. The wedge is removed and carefully stored to avoid accidental discard. The groove is further deepened by removing a block of bone from one side of the groove by making a parallel cut with the handsaw. A modification of this technique is to broaden and deepen the proximal aspect of the new, deepened groove by performing a partial trochleoplasty in the proximal aspect of the groove only, as described above using rongeurs. A portion of bone can also be removed from the underside of the
trocchlear wedge to further deepen the groove. The wedge is replaced and the adequate depth of the groove is documented. Fixation of the wedge is usually not needed due to pressure applied from the patella lying above and the congruency between the groove and wedge geometry.

**Trochlear Block Recession** – Trochlear block recession is similar to trochlear wedge recession except that a block-shaped wedge is removed from the trochlear sulcus rather than a v-shaped wedge. This technique allows a deeper sulcus proximally, which may provide better biomechanical stability of the patella when the stifle is in an extended position. This is an excellent technique, but technically more demanding than trochleoplasty. The technique is performed using a fine-tooth hand saw-blade, a small osteotome and mallet. Care should be taken when beginning the saw cut, not to excoriate the adjacent cartilage due to slippage. The cut is initiated perpendicular to the cartilage surface adjacent to the peak of the trochlear ridge. Once the saw blade has engaged the subchondral bone, the blade is gradually redirected in the proper direction, perpendicular to the long axis of the bone. A cut is made from the lateral and medial ridge and each cut is carried to an adequate depth deep to the central sulcus of the groove. The block of cartilage and bone is removed gently using an osteotome and mallet. The osteotome is positioned just proximal to the intercondylar notch beginning at the depth of the trochlear cuts. The osteotome is directed towards the proximal extent to the trochlear groove. Gentle raps with the mallet will advance the osteotome, dislodging the trochlear block. The trochlear block is removed and carefully stored to avoid accidental discard. The groove is further deepened by removing a complimentary block of bone from the deep portion of the groove by making a parallel cut with the osteotome or by deepening with a rongeur. A portion of bone can also be removed from the underside of the trochlear block to further deepen the groove. The block is replaced and the adequate depth of the groove is documented. Fixation of the block is not needed due to pressure applied from the patella lying above and the congruency between the groove and block geometry.
Alignment of the Quadriceps Mechanism

Tibial Tuberosity Transposition – Tibial tuberosity transposition is an excellent method of improving alignment of the patellar mechanism in patients having an abaxially displaced tibial tuberosity. If the tuberosity is displaced medially, luxation occurs medially; therefore, the tuberosity must be transposed laterally and secured. Lateral luxations require medial tibial tuberosity transposition. An osteotomy is performed as previously described; the tuberosity is transposed then secured with a single or multiple k-wires. An attempt is made when performing the osteotomy to leave the distal cortical bone intact to act as a tension band against the pull of the quadriceps mechanism. If the tuberosity is freed completely, it is prudent to secure the transposed bone with either a pin and tension band or a lag screw. The tuberosity should be transposed to a position that restores axial alignment to the quadriceps mechanism.

Rectus Femoris Transposition – This is a technique described by Dr. Barclay Slocum for use in bow-legged dogs having medial patellar luxation. This technique is done in combination with a medial releasing incision. A trochlear deepening technique should also be performed as needed. The rectus femoris is transected from its pelvic origin with a small piece of attached bone, and then laterally transposed by tunneling under the vastus lateralis and reattaching it to the cervical tubercle or third trochanter of the proximal femur with wire or heavy suture. This realigns the quadriceps mechanism, restoring a straight-line pull.

Corrective Osteotomy of the Femur—Varus deformity of the distal femur is a contributing factor to medial patellar luxation particularly in large breed dogs. Accurate radiographic assessment of the distal femur is needed to measure angulation. If the distal femur has a varus deviation of greater than 10° a varus corrective osteotomy may be needed. A closing wedge osteotomy using a bone plate is commonly used for this procedure.

Corrective Osteotomy of the Tibia—Valgus deformity of the proximal tibia may require corrective osteotomy using a closing wedge osteotomy. This typically is only needed in dogs having severe medial patellar luxation when they were puppies. Unequal pressure on the growth plate leads to incongruent growth and angulation of the proximal tibia.

Retinacular Imbrication

Lateral imbrication is usually performed with correction of a medial patellar luxation as a means of creating lateral restraint. The stretching of the lateral joint capsule and retinaculum occurs chronically with longstanding patellar luxation. Occasionally a traumatic luxation may result in rupture of these tissues; imbrication is also a good technique for repair in this case. Imbrication is usually performed using heavy, absorbable, monofilament suture placed in a vest-over-pants- or horizontal mattress pattern. Care must be taken not to tighten the retinaculum excessively (especially if a retinacular releasing incision has been performed on the opposite side), because it is possible to create an iatrogenic luxation in the opposite direction. An alternative method of supplying lateral restraint is placement of a lateral derotational suture from the lateral fabella to a bone tunnel in the tibial tuberosity.

Retinacular Releasing Incision

A medial releasing incision is performed if fibrous hyperplasia has occurred medially following prolonged or severe medial patellar luxation. An incision is made through the retinacular tissues in a medial parapatellar location. The incision should extend proximally beside the medial edge of the quadriceps tendon. Placement of the incision in this location will release the insertion of the sartorius muscle, decreasing pull on the patella. The incision occasionally has to be carried deeper to include the joint capsule if marked joint capsular fibrosis has occurred creating excessive medial restraint. The incision is left open and not sutured. Arthroscopic medial releasing incisions can be performed. This technique is quick, easy to perform and has low morbidity. Long-term follow-up is presently unavailable. In addition, the clinical indications with this technique are presently unknown.
Comminuted fractures can be especially challenging due to the complexity of the fracture fragments and concomitant soft tissue injury. Careful consideration should be given to decision-making prior to onset of fracture repair. Factors that should be considered include mechanical, biological and postoperative compliance. Complex fractures that are treated with a mechanically sound repair often leave the surgeon pondering what could have possibly gone wrong when a “perfect” repair fails. Often times, the answer lies in the neglect of the biological or postoperative compliance factors. Neurologic function should always be assessed because complex fractures are often associated with high-energy trauma that also can injure the brachial plexus or peripheral nerves of the forelimb. This lecture will focus on presentation of clinical cases involving complex fractures of the forelimb and hindlimb, with an emphasis on the decision-making process. A variety of fracture repair techniques will be discussed including interlocking nails, plate-rod construct and linear external fixators.

Minimally-invasive surgical approaches reduce pain and minimize trauma to the soft tissues. Biological factors important for fracture healing are preserved, enhancing the body's ability for indirect bone healing. The technique can be used with all fracture types, but is particularly useful for stabilization of comminuted fractures. This type of bone healing is also referred to as secondary bone healing, spontaneous bone healing and callus healing. Stabilization of fractures using the principles of biologic fracture management is performed with the same type of implant systems used with traditional fracture repair, including externally and internally applied devices.

Fracture Management
Comminuted fractures of the extremities can be challenging. It is always a race between a fracture healing and an implant failing. Steps can be taken to tip the scale in the direction of early fracture healing. These steps include:

1. minimally invasive surgical approach
2. preservation of soft tissue attachments to bone fragments
3. use of cancellous bone grafts
4. rigid method of fracture stabilization
5. early return to function

It is always important to obtain an accurate history prior to stabilizing fractures. A complete physical exam and appropriate diagnostic tests should performed. Pathologic fractures are more likely to be seen in the geriatric dog and cat and should be identified preoperatively to ensure proper client education and communication.

Indirect Bone Healing
Biological fracture management utilizes indirect fracture reduction to preserve the soft tissue envelope at the expense of anatomic reduction. Indirect bone healing occurs as a result. Indirect bone healing consists of three elements: 1) the formation of granulation tissue at the fracture site 2) fracture gap widening due to resorption of bone ends 3) new bone formation involving formation of a bone callus. Less disruption of the vascular supply to bone fragments is achieved through minimal handling of the fragments, promoting early callus formation. Indirect bone healing is first associated with the formation of fibrous connective tissue and cartilage callus between the fragments. Indirect bone healing occurs due to instability at the fracture site and is partially regulated by fragment gap strain. Interfragmentary strain is a ratio of change in the gap width to the total width prior to physiological loading. A study of the “interfragmentary strain hypothesis” using ovine osteotomy models demonstrated that the initial stages of indirect bone healing occur earlier and more extensively between gaps with lower shear strain. Management of a non-reducible diaphyseal fracture with an implant system that does not utilize anatomical reconstruction and creation of subsequent small fracture gaps avoids high interfragmentary strain, favoring bone healing.
Implant Systems
External and internal implant systems can be used to achieve bone healing using biological fracture management. Examples of external devices when used in an appropriate manner include casts, splints, linear external fixators and circular fixators. Internal devices commonly used for this application include the plate-rod system, interlocking nail and bone plates. Other implant systems can also be used for biologic fracture management as long as the soft tissue envelope is preserved at the fracture site. Whatever implant system is used, its application must be possible with minimal or no handling of the comminuted fracture fragments.

External Fixator
External fixators provide rigid stabilization and can be used with minimally-invasive technique. Many fractures of the radius and tibia can be reduced closed and stabilized with an external fixator. The main disadvantage is the potential for complications with premature pin loosening and the added care needed in the postoperative period. The use of external fixators for fracture repair is not optimal if the patient or owner is likely to have poor compliance in the postoperative period. External fixators frames can be applied in one of 3 configurations- linear, circular or as a hybrid of linear and circular.

Plate-rod construct
The plate rod system has been found to be an ideal implant system for biological fracture management. Management of a non-reducible diaphyseal fracture with a combination of an IM Steinmann pin and bone plate can be applied without anatomical reconstruction and thus, avoids the development of small fracture gaps with high interfragmentary strain. The addition of the IM pin to the plate also significantly increases the construct stiffness and estimated number of cycles to fatigue failure when compared to a plate only construct. An IM pin serves to replace any transcortical defect in the bone column and acts in concert with the eccentrically positioned plate to resist bending. Mathematical analysis of the plate-rod construct in the canine femur demonstrated that the pin and plate act most like a dual-beam structure, assuming slight motion of the pin in the canal. Addition of an IM pin to a bone plate has been shown by Hulse et al. to decrease strain on the plate two-fold and subsequently increase the fatigue life of the plate-rod construct ten-fold compared to that of the plate alone. In the canine femur, plate strain is reduced by approximately 19%, 44%, and 61% with the addition of an IM pin occupying 30%, 40% and 50% of the marrow cavity, respectively. Stiffness of plate-rod repairs may be as much as 40% and 78% greater when the pin occupies 40% and 50% of the marrow cavity, respectively.

Locking Plates
Locking plates have become very popular for minimally-invasive fracture repair. Many locking plate systems are available including the Synthes, FIXIN, SOP and ALPS. Locking plates have the ability to lock the screw into the hole of the plate. The mechanism for locking varies amongst manufactures. The Italian design FIXIN locking plate system has a conical locking mechanism while the Synthes system has a threaded locking mechanism. The FIXIN plate hole is tapered to match the conical nature of the head of the screw. This type of fitting is similar to the Morse taper of the head and neck fitting of the Total Hip Replacement implant. The stability of this design is extremely secure. The Synthes locking plate has threaded holes in the hole of the plate. Corresponding threads in the head of the screw engage the threads of the hole, locking the screw to the plate. The ability to lock the screw to the plate increases pull-out strength of the screw and construct stability. Traditional plates do not have threaded holes. Screws placed in ordinary plates apply pressure to the plate, pressing it onto the bone surface. The friction between the plate and the bone provides the stability to the bone-implant construct. In contrast, the locking plate achieves stability through the concept of a fixed-angle construct. The locking plate is not pressed firmly against the bone as the screws are tightened. The locking screws and plate function more like an external fixator. Locking plates are essential “internal fixators”. The plate functions as a connecting bar and the screw functions as a threaded fixator pin. The

The FIXIN locking plate uses a conical head to lock into a matching conical hole in the plate creating fixed-angle stabilization.
A tapered or threaded head of the locking screw engages the hole of the plate, similar to the clamp of an external fixator. The Synthes locking plate also has combi-holes which allow use of traditional or locking screws when desired. Traditional screws should be placed prior to locking screw when using locking plates.

Locking plates are ideal for minimally-invasive fracture repair for several reasons. Blood supply to the bone is preserved because the plate is not pressed tightly against the bone. The plate does not require perfect anatomic contouring because the displacement of the plate will not occur as the screw is tightened into the hole of the plate. Accurate contouring is difficult with a minimally-invasive approach due to the minimal exposure to the shaft of the bone. Lastly, locking screws give fixed angle support to the non-reduced fracture, increasing stability and less chance of collapse and instability at the fracture gap.

**Interlocking nail**

The Deuland interlocking nail system presently available in the U.S. (Innovative Animal Products, Inc., Rochester, MN) is a modified Steinmann pin modified by drilling one or two holes proximally and distally in the pin, which allows the placement of transverse bolts or screws through the bone and nail. The nail, bolts and screws can be applied in closed or open fashion due to the incorporation of a specific guide system that attaches to the nail. The equipment needed to place the nail includes a hand chuck, extension device, aiming device, drill sleeve, drill guide, tap guide, drill bit, tap, depth gauge, and screwdriver. Cost of the system is reasonable and each nail is approximately half the cost of a comparative bone plate. The nails are available in diameters of 4.0, 4.7, 6, 8 and 10 mm and varying lengths and hole configurations. The 4.0 and 4.7 mm nails use 2.0 mm screws or bolts. The 6 mm nail is available in two models and will accommodate either 2.7 or 3.5 mm screws or bolts. The 8 mm nail is also available in two models and will accommodate either 3.5 or 4.5 mm screws or bolts. The 10 mm nail uses 4.5 mm screws or bolts. The solid cross locking bolts have a larger diameter compared to a similar diameter screw, thus are less likely to break. Bolts also provide superior mechanical behavior compared to screws.

The interlocking nail is placed along the mechanical axis of the bone. The interlocking nail neutralizes bending, rotational and axial compressive forces due to incorporation of transfixation bolts or screws which pass through the pin and lock into the bone. This is in contrast to a single intramedullary Steinmann pin which is only effective in neutralization of bending forces. The interlocking nail has a similar bending strength compared to bone plates, but is slightly weaker in neutralization of torsional forces. The screws also prevent pin migration, a common complication seen with Steinmann pins.

When using an interlocking nail, the largest diameter nail should be selected that can be accommodated by the medullary cavity at the fracture site. In most large dogs, an 8 mm nail and either 3.5 or 4.5 mm screws or bolts can be used in the femur and humerus. In medium-sized dogs, the 6 mm nail and either 2.7 or 3.5 mm screws or bolts are typically used. In small dogs and cats, the 4.7 mm nail and 2.0 mm screws are typically used. The tibia of medium and large - sized dogs will usually accommodate a 6 mm nail, but some large dogs will accept an 8 mm nail. Small dogs and some cats will accept a 4.0 mm nail for repair of tibial fractures.

Dejardin et. al. have developed a novel interlocking nail that provides an angle stable locking mechanism. The advantage of angle stable locking is the
elimination of torsional and bending slack, resulting in reduced interfragmentary motion. This interlocking nail system provided comparable mechanical performance to a plate system. Dejardin’s nail is currently unavailable, but release of the nail is expected in the near future.

**Surgical Approach**

Closed reduction and stabilization is the optimal method of treatment when possible. Unfortunately, this method is rarely possible in the senior patient due to the severity of fractures seen, long time until bony union, and the tendency for patients to develop bandage sores. Open surgical approaches can be either traditional or minimally invasive. The minimally invasive approach has also been described as an “open but don’t touch” approach. The acronym, OBDT, is used to describe this technique. The advantages to using an OBDT technique is preservation of vascular supply to the fracture site and thus quicker healing, shorter intraoperative time, less postoperative pain and early return to function. Methods of stabilization that work well with an OBDT approach include the interlocking nail, plate-rod hybrid and external fixation. The key feature of a minimally-invasive approach is the preservation of the soft tissue envelope at the fracture site. Small comminuted fragments will become quickly incorporated into the bony callus if left with a vascular pedicle. Anatomic reduction of small fragments is difficult if vascular supply to the fragment is to remain uncompromised.

**Bone Grafts**

Numerous sites for harvest of cancellous bone graft have been described in the dog, but the most practical are the greater tubercle of the humerus, wing of the ilium and the medial, proximal tibia. The humerus provides the greatest amount of cancellous bone, but the ilium and tibia provide sufficient amounts for most applications. All of these sites are readily accessible, have easily recognizable landmarks, have little soft tissue covering, and provide relatively large amounts of cancellous bone. The greater trochanter can also be used if other sites are not available; however, the yield of cancellous bone is markedly less. Occasionally multiple sites are required to harvest sufficient quantities of bone to fill large bone defects or during arthrodesis.

Minimal instrumentation is required for harvest of cancellous bone graft. Basic surgical instruments are used to approach the site selected for harvest. A hole is drilled through the near cortex using either a drill bit, trephine or trocar-pointed pin. A curette is used to scoop the graft out of the metaphyseal cancellous bone. The cancellous bone should be scooped out in large clumps if possible. Use a curette that can be comfortably manipulated in the medullary cavity; I prefer to use a relatively large curette as this speeds harvest and reduces trauma to the graft. Closure is performed routinely in 2-3 layers. Recently, a technique was described using an acetabular reamer to harvest large amounts of corticocancellous bone graft from the lateral surface of the wing of the ilium.

The graft collected should be handled gently. It is desirable to collect the graft immediately prior to usage. This increases the osteogenic properties of the graft. As graft is harvested, it should be placed on blood-soaked gauze until transfer to the recipient site. Extreme care should be taken to store the graft properly; do not accidentally discard the graft due to misidentification of the gauze as being used. The graft should be atraumatically packed into the recipient site. Lavage of the site should be avoided after the graft is placed.
Plate-rod repair of a comminuted femur fracture

Minimally-invasive surgical approach maintains blood supply to comminuted fragments encouraging early healing

Minimally-invasive technique useful for application of a plate-rod construct

Plate-rod repair of a comminuted femur fracture

Gross specimen of an application of a plate-rod construct

Comminuted fractures can be managed biologically using an interlocking nail, shortening surgical time and speeding bone union
References:
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