Early Intervention and Management of Joint Disease

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Osteoarthritis is the most common cause of chronic pain in dogs with approximately one in five adult dogs having OA. OA (sometimes referred to as degenerative joint disease) is a slowly progressive degenerative disease involving the entire joint: articular cartilage, subchondral bone, synovial lining, joint fluid, ligaments, and muscles. Osteoarthritis is commonly classified as primary OA or secondary OA. Primary OA is associated with aging and chronic loading and wear of the articular surface. Secondary OA (the most common form seen in dogs) has many acquired and congenital etiologies including: ligamentous injury (CCL), abnormal joint conformation (elbow dysplasia), osteochondrosis (OCD shoulder). In general, OA can develop in any joint where abnormal stresses are imposed on a normal joint or alternatively where normal stresses are imposed on an abnormal joint. Although more senior dogs exhibit clinical signs of OA as compared to their younger counterparts, younger dogs may also exhibit signs of OA. Hip dysplasia is the most common cause of OA in younger dogs.

Innervation of joints includes nociceptors which are free nerve endings found in all joint tissue except articular cartilage. They are found in the subsynovial layer only two to four cell layers beneath the synoviocytes lining the joint cavity. Dogs with OA have an ongoing synovitis the severity of which varies depending upon activity and joint trauma. The synovitis is accompanied by the accumulation of increased levels of eicosinoids (prostaglandins, leukotreines) and pro-inflammatory cytokines (IL-1, TNF, NO) in joint fluid. Additionally, synovitis is accompanied by increased vascular flow in the subsynovial tissue. These two factors, increased inflammatory mediators in the joint fluid and increased blood flow in subsynovial tissue, increases the exposure of free nerve endings (nociceptors) to inflammatory mediators. The result is sensitization of free nerve endings, increased stimulation of free nerve endings, and transmission of pain to the CNS. Inflammatory mediators also up regulate the expression of harmful mediaors which play a role in catabolism of articular cartilage.

The chondrocyte is the cell in articular cartilage that produces the extracellular matrix. The matrix is composed of glycosaminoglycans (hyaluronan and proteoglycan) and collagens (mainly type II). The collagen forms a dense network that retains the proteoglycan. The proteoglycan is highly charged and attracts water into the tissue. Thus cartilage is 75% water. In normal cartilage there is a very slow turnover of collagens but the proteoglycan is constantly being renewed. The proteoglycans are aggregated into large molecules (“aggrecan”) with a protein core and many side chains of keratan sulphate and chondroitin sulphate. This core is in turn bound to hyaluronan chains with each chain containing many proteoglycan molecules. Aggrecan and water provide the compressive stiffness to the tissue whereas collagen provides the tensile strength. The morphological changes seen in OA
include: 1. cartilage loss, especially in areas of increased load, 2. subchondral bone remodelling (loss of bone initially followed by sclerosis), 3. marginal osteophytosis, 4. synovial inflammation, 5. synovial hyperplasia and fibrosis. The biochemical changes in the cartilage include: 1. loss of proteoglycan, 2. imbalance of degradative and synthetic activities of chondrocytes 3. disruption of the collagen network, 4. change in water content. These changes reduce the elasticity of the cartilage leading to fibrillation and fissuring of the cartilage with eventual loss of tissue. If this continues eburnation of subchondral bone may result. It is proposed that the cytokines responsible for stimulating cartilage degradation in OA are interleukins (IL-1 and IL-6) and tumor necrosis factor. Catabolic cytokines can stimulate the chondrocyte to produce and release degradative enzymes. The enzymes studied in most detail in this respect are the matrix metalloproteinases (MMPs) and the new family of endopeptidases known as aggrecanases (ADAM-TS-4 and -5). MMPs and aggrecanases can cleave the protein core of aggrecan and release the majority of the molecule from the matrix. Under normal circumstances the chondrocyte also produces a natural inhibitor of these enzymes known as tissue inhibitor of metalloproteinase (TIMP). TIMP production appears to be decreased in OA.

Osteoarthritis progresses slowly and has a gradual onset of clinical signs. Subsequently, the diagnosis of OA is often made in the later stages of the degenerative process after extensive bone and joint damage has occurred. Commonly the diagnosis of OA is made by radiographic changes characteristic of degenerative joint disease. However, by the time radiographic changes are apparent the condition has progressed considerably. Therefore, early intervention using alternative diagnostic modalities is essential for the well being of the animal. One recommendation is to establish an osteoarthritis pain assessment screening protocol. Behaviors consistent with OA in dogs include: limping, inactivity, difficulty rising, stopping on walks, difficulty posturing to eliminate. Managing the osteoarthritic dog or cat is multifactorial; an accurate diagnosis is essential for the management of secondary osteoarthritis since surgical intervention may be necessary to correct the underlying problem to achieve optimal outcome. In addition to appropriate surgical intervention, successful treatment of osteoarthritis is a compilation of strategies including client education, behavior modification (both client and pet), appropriate exercise activities, rest, weight control, disease modifying agents and anti-inflammatory medications. Of these, controlled exercise activity coupled with adequate rest and weight control will benefit your pet as much or more than any other modality.

Regular physical activity and rest play a key role in wellness. Episodic physical activity may also be preferable to continuous exercise by avoiding injury due to overuse. Episodic activity refers to those activities that occur for a reasonable time period multiple times throughout the day. Of considerable harm to the process of osteoarthritis is your pet having a sedentary life throughout the week only to exercise strenuously on the weekend. This lifestyle exacerbates the osteoarthritis and is very likely to result in serious injury. Treatment regimes should include regularly scheduled exercise and rest. Two types of exercise are important in osteoarthritis management. The first type,
therapeutic exercises, keeps joints working as well as possible. Therapeutic exercises are low impact and designed to maintain or increase joint range of motion, proprioceptive feedback, muscle tendon unit and periarticular tissue elasticity. Examples of therapeutic exercises are passive range of motion activity, massage, aquatic therapy, and stretching. The other type of exercise, aerobic conditioning exercises, improves strength and fitness, and controls weight. Examples are brisk walking, brisk walking or trotting through high grass, cavaletti training, and aquatic therapy. Weight and body condition are important in preventing osteoarthritis as. Heavy dogs are at increased risk of developing arthritis because their joints may be strained by excess weight. This is especially evident in weight-bearing joints such as the knees and hips, which often show the first signs of weight-related strain and injury. An investigation into the cause of cranial cruciate ligament injury and the development of secondary osteoarthritis showed a significant risk factor to be obesity. If your pet is overweight and you enforce a weight loss program, you will dramatically decrease the risk of your pet injuring its knee joint and developing osteoarthritis. Studies of dogs with hip osteoarthritis show that reaching target reduction weight increases a dogs’ ability to move in a more normal fashion as assessed by gait analysis and owner observations.

Pain control medication allows the OA dog and cat to engage in activity; this is turn helps control body weight and improve physical condition. The drugs of first choice for controlling arthritis in dogs are NSAIDs. NSAIDs function in part by inhibiting cyclooxygenase (COX) isoenzymes. COX-1 is the constitutive isoenzyme essential for the synthesis of homeostatic PGs in the GI tract, kidney, and platelets. COX-2 is for the most part induced and results in the production of PGs associated with pain and inflammation. However, COX-2 is also constitutively expressed and has a homeostatic role in canine brain, kidney, and vascular tissues. COX-3 is constitutively expressed and plays a role in brain tissue. Currently available NSAIDs approved for use in the dog in the U.S. include carprofen, deracoxib, meloxicam, and firocoxib. All inhibit COX-1 and COX-2 to varying degrees. The Coxib-class may exhibit less interference with the homeostatic functions of PGs associate with COX-1. Cats are very sensitive to NSAID treatment due to differences in metabolism of the drug. Side effects are more commonly seen with NSAID use in cats. Presently there is no approved NSAID for use to treat OA in cats. NSAIDs approved for treatment of pain and inflammation in cats include meloxicam and robenicoxib. These drugs are approved for up to 3 days only.

NSAIDS

Carprofen, a NSAID which is less ulcerogenic, was released by Pfizer Animal Health under their trade name Rimadyl™. Rimadyl relieves pain and clinical signs of osteoarthritis in dogs, while causing less gastrointestinal side effects. Plasma and serum concentrations of carprofen are consistent throughout the treatment period. Serum concentrations peak at 2 hours, while synovial concentrations peak between 3-6 hours. The synovial concentration of carprofen ranges between 1-10 mg/ml during
the treatment period in both normal and osteoarthritic joints. A significant reduction of PGE2 from chondrocytes occurs at all concentrations in this range. Recent studies have shown carprofen to have little effect on kidney and platelet function. Carprofen has been recently found to support cartilage metabolism and proteoglycan synthesis.

Meloxicam was released by Boehringer Ingelheim in 2003. It is indicated for the control of pain and inflammation associated with OA in dogs. It is considered to have moderate COX-2 inhibition. It has also been approved for short term use in cats. It is available in a liquid form.

Deracoxib (Deramaxx) is a NSAID released by Elanco Animal Health approved for use in dogs for postoperative pain and inflammation. The recommended dose is 3-4 mg/kg, po, once daily for 7 days or 1-2 mg/kg, po, sid for chronic use. Like carprofen, deracoxib has a highly favorable Cox 1:Cox 2 ratio. The expected side effects are similar to other NSAIDS, primarily gastrointestinal disturbances.

Firocoxib (Previcox) is a NSAID released by Merial Animal Health approved for use in dogs for postoperative pain and inflammation. The recommended dose is 3-4 mg/kg, po, once daily for 7 days or 1-2 mg/kg, po, sid for chronic use. Like carprofen, deracoxib has a highly favorable Cox 1:Cox 2 ratio. The expected side effects are similar to other NSAIDS, primarily gastrointestinal disturbances.

Robenocoxib (Onsior) is a NSAID released by Elanco Animal Health approved for use in cats for postoperative pain and inflammation. The drug is available as a 6 mg tablet and as an injectable. The recommended dose is 1 mg/kg, po, sid for 3 days. Because of the limit of use of 3 days, this drug would need to be used as an extralabel use for treatment of OA in cats, but this is not recommended.

**CHONDROPROTECTANTS AND NUTRACEUTICALS**

Optimal recovery from musculoskeletal disorders requires attention to mechanical, environmental and biological factors. Characteristics associated with one factor often have an effect on another. For instance, proper attention to mechanical and environmental factors improves the biological environment of injured joints. Mechanical factors that play a role in enhancing recovery may include an appropriate level of physical activity, the use of special exercises to promote joint range of motion, and use of aids to protect or alleviate pain of a joint or limb. Environmental factors that affect rehabilitation include patient compliance, pet-owner compliance, weather conditions and the type of environment to which the pet is subjected. Biological factors affect the local environment of the joint. Examples include the quality and quantity of synovial fluid, presence of degradative enzymes within the synovial fluid and articular cartilage, condition of the extraarticular matrix of articular cartilage and the metabolic state of the chondrocytes. Nutraceuticals and chondroprotectants may play a beneficial role by providing favorable biological factors, thus enhancing joint health and the ability to recover from injury. Chondroprotective agents are purported to have three primary effects:
1. support or enhance the metabolism of the chondrocyte and synoviocyte (anabolic)
2. inhibit degradative enzymes within the synovial fluid and cartilage matrix (catabolic)
3. inhibit formation of thrombi in the small blood vessels supplying the joint. (antithrombotic)

Many different types of compounds have been purported to have chondroprotective effects or disease-modifying effects on the joint. These include glycosaminoglycans, amino sugars, structural proteins, enzymes, minerals, preparations of whole tissue and semi-synthetic compounds. These compounds are available in oral and injectable forms. Most oral chondroprotectants are classified as dietary supplements. Injectable chondroprotectants are drugs and these include glycosaminoglycan polysulfate ester, pentosan polysulphate and hyaluronic acid. Dasuquin is a popular supplement manufactured by Nutramax Laboratories containing glucosamine, chondroitin sulfate, manganese ascorbate and ASU. Several studies have shown a benefit of using this product in OA models of arthritis. In-vitro studies have shown an inhibition of inflammatory mediators and a stimulation of chondrocyte production of extracellular matrix constituents.

Omega-3 fatty acids have recently gained popularity for their potential use in pets with OA. These products are available naturally in fish and plant sources and commercially as nutraceutical supplements or as an ingredient in the diet. Omega-3 fatty acids are desaturated in the body to produce eicosapentaenoic acid, which is an analog of arachidonic acid. Prostaglandins, thromboxanes and leukotrienes are produced from both of these compounds through the action of cyclooxygenase and lipoxygenase. The products resulting from arachidonic acid metabolism are proinflammatory, proaggregatory and immunosuppressive as compared to the metabolic by-products of eicosapentaenoic acid which are less inflammatory, vasodilatory, antiaggregatory and not immunosuppressive. The use of omega-3 fatty acids are thought to benefit dogs and cats suffering from OA by decreasing inflammation and reducing the occurrence of microthrombi. The ideal ratio of N6:N3 fatty acids for canine diets is controversial, but a current recommendation is between 10:1 and 5:1. Antinol™ is a new fatty acid supplement released in the U.S. by Vetz Petz (and distributed by Merial) that uses fatty acids contained in the oil of the New Zealand green-lipped muscle that are extracted using a patented process. The product has been shown to improve weight bearing in arthritic dogs as evaluated by a force plate. Antinol most likely provides relief by providing anti-inflammatory activity in the joint. Recent studies have shown this product to be safe and efficacious in the dog and cat with no side effects. Antinol has also be shown to be safe and effective when given in combination with NSAID drugs. A common treatment regime to treat dogs with OA is daily administration with Antinol along with intermittent use of NSAID if clinical signs of OA increase. Antinol is often used as the sole source of treatment in OA in cats.
MPL in Small Breed Dogs and Cats: - Tricks to Success

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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. It 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 can not 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 stifle. 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 physes 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 dos 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 trochlear 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, 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.

**Patellar Sling Suture Technique**

The patellar sling suture is a simple procedure that provides lateral support to the patella in patients undergoing surgical stabilization of MPL. The sling is created using a suture anchor and heavy suture material. The author currently prefers the use of a Fastak anchor and #2 Fiberwire (Arthrex VetSystems, Naples, FL) in small dogs and cats or a Corkscrew anchor and #5 Fiberwire (Arthrex VetSystems, Naples, FL) in medium and large dogs. The suture anchor is inserted in routine fashion in the center of the lateral surface of the femoral condyle, perpendicular to the sagittal plane of the femur. The anchor can be directed slightly cranialateral to caudomedial to avoid inadvertent contact with the trochlear block created with the TBR. One arm of the suture is passed from lateral to medial through the insertion of the quadriceps tendon at the proximal pole of the patella. The suture can be passed using an 18-gauge needle and a nytinol wire passer. The needle is inserted from medial...
to lateral in the quadriceps tendon. The wire passer is inserted from lateral to medial through the lumen of the needle, exiting the hub of the needle medial to the patella. The needle is then removed by sliding it over the passing wire. The arm of the Fiberwire (FW) is threaded through the loop of the wire passer and the FW is pulled from lateral to medial through the quadriceps insertion by pulling the wire passer through the tissue. The FW is then passed from medial to lateral through the origin of the patellar tendon at the distal pole of the patella in similar fashion. The patellar sling suture encircles the patella, providing a secure method of fixation. The suture is tensioned, removing all the slack. It is important to emphasize proper tensioning of the suture. The goal is to tension the suture sufficiently to prevent any future medial displacement of the patella, but not to over-tension the suture, which could result in excessive lateral tension and subsequent lateral patellar luxation. The suture is secured by tying 2-3 routine square knots to the opposing arm of the suture. The patellar sling moves like a pendulum with the patella as the stifle moves through its normal range of motion.

The author emphasizes the need for strict aseptic technique when using FW for the patellar sling suture. A Dura Prep skin preparation and use of a Ioban drape (3M Products) are recommended to prevent contact of the braided suture material with the skin.

The advantages of the patellar sling compared to a derotational suture or lateral retinacular imbrication is the bone to bone attachment and the lack of elongation of the suture over time.
Tricks to managing patellar luxation in dogs and cats

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Fracture repair has become more simple due to a change in technology. Bone plate repair was traditionally an excellent means of fracture repair, but was not commonly used by general practitioners due to the expense and expertise required. Practitioners interested in repairing fractures most commonly used pins and wires or external fixators to repair fractures. These techniques certainly have merit and can be used successfully to treat a number of fractures in dogs and cats. Unfortunately, these techniques are also associated with frequent complications and postoperative morbidity. Locking plates were introduced in the past ten years and general practitioners have found that they offer an excellent option for repair of even the most complicated fracture.

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.

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 be 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.

**Direct Bone Healing**

Direct bone healing is expected when fracture fragments are anatomically reduced and rigidly stabilized (direct reduction). This requires a traditional surgical approach and application of an orthopedic implant. Direct bone healing is expected with little to no callus formation. Reconstruction of the bony column is achieved. The reconstructed bony column shares the weightbearing load with the implant, thus the implant has less stress on it and is less likely to fail. Direct bone healing is typically recommended with fairly simple fractures having 2 or 3 fragments. It is important to preserve blood supply to fracture fragments. If the fragments are stripped of blood supply in an effort to reduce the fracture, the fracture will heal more slowly and a higher incidence of infection and poor healing will be expected. If direct reduction of a highly comminuted fracture is attempted, blood supply will likely be disrupted leading to delayed fracture healing.

**Indirect Bone Healing**

Biological fracture management utilizes indirect fracture reduction to preserve the soft tissue envelope at the expense of anatomic reduction. This technique is typically used with comminuted fractures having 3 or more fragments. 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 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.

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 a 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.
Biomechanics for fracture fixation

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When fracture of the bone has happened, there is the process to restore continuity of the bone or “Bone healing”. Bone healing is a cascade of biological events leading to restoration of the continuity and mechanical properties of the bone. The healing process depends on mechanical and biological factors that are closely associated with bone blood supply. Any surgical procedure may alter the biological environment and any fracture fixation will alter the mechanical environment. Each type of fixation has influence on bone healing in term of mechanical stability and biological effect in term of application technique which disturb to the blood supply. These changes may have an effect to fracture healing so it is essential to understand the biomechanics of fracture fixation and can make appropriate decision for successful fracture management. The goals of fracture stabilization are to maintain the achieved reduction, restore stiffness at the fracture bone and minimize pain related to movement at the fracture site. The term we have to know is “Stability” that mean the degree of motion of fracture fragments. The goal of operative fixation is to provide adequate stability to keep the bone in proper alignment. The stability is divided into two groups so called; Absolute stability and Relative stability.

Absolute stability is complete absence of displacement and no motion between fracture surfaces, this type of stability will abolish the micromotion which is mechanical stimulus for repair by callus formation as a natural way of bone healing. The absolute stability can only be achieve by operative procedure to provide interfragmentary compression between fracture surface by anatomical reduction with full contact of fracture surface result in no motion of fracture surface. The indications for selecting absolute stability are intraarticular fracture, simple fracture of diaphysis or metaphysis of long bone, arthrodesis and correct nonunion of fracture. The procedures that can achieve absolute stability are Lag screw technique, compression plating, tension band wiring and compression by external fixator. The type of bone healing after absolute stability will be direct bone healing or primary bone healing which is direct bridging between bone ends without visible callus formation.

Relative stability is another type of stability that allows some micromotion between the fracture fragments in relation to each other when physiological load is applied across the fracture. Displacement is control by the optimal fixation that is not exceeding the strain of the bone cell when the load is applied. The relative stability can achieve by provide non-compressive fracture fixation that will allow micromotion between fracture end to induce forming callus at fracture site. However if the fixation is unstable with the excessive motion between fracture will result in implant failure and...
nonunion is inevitable. The indications for selecting relative stability are multifragmentary fracture of diaphyseal and metaphyseal area and non-articular fracture. The type of fixation that can achieve relative stability are external fixator, intramedullary nail and bridging plate. Indirect bone healing or secondary bone healing will happen in condition of relative stability that mean the bone healing by periosteal and endosteal callus formation between bone end. On follow up Xray there will be callus formation bridging between bone ends surrounding the fracture site. Both type of stability from operative treatment require correct mechanical principle as well as preservation of blood supply during application of implant. If we provide an excessive stability by complete devascularization of bone fragment the fracture will not united or in insufficient fixation that produce instability in order to preserve blood supply there will be nonunion. Stability and vascularity has to be balance in order to achieve successful fracture healing.

The goal of fracture management is to achieve full function with bone healing. There are three possible methods for the treatment of fractures. Some fractures can be treated conservatively such as non displaced fracture; some fractures must be treated by operative intervention; for example, displaced intra articular fractures. The last group is the fracture that may be treated with either method such as tibial shaft or humeral shaft fractures which need to discuss pros and cons with the patient. The internal fixation for treatment of fracture is justified only when there is a remarkable benefit to the patients. In order to have a successful outcome for the treatment of fractures, the surgeon has to realize the mechanism of the injury, make the correct diagnosis, classify bone and soft tissue condition in order to select the appropriate type of treatment. In case of operative treatment the surgeon has to outline the details of pre operative planning and perform the surgical procedure according to the plan.

Every traumatized limb should be carefully assessed for neurovascular injury and possible compartmental syndrome. Most of the fractures can be diagnosed by routine AP and lateral X-ray. It is necessary to have the X-ray which includes the whole length of bone to rule out the other lesions. In articular fractures the oblique X-ray may be added to see more details of the fractures. CT scan is helpful to determine the degree of the displaced articular surface or loose fragment in the joint. MRI is commonly used for the spine fractures to demonstrate the extent of neurological lesion caused by bony fragments. 3D reconstruction may be needed in complex intra articular fracture of calcaneus, acetabulum or maxillofacial.

After gathering the information about the patient and the personality of the fractures, the surgeon has to answer the following questions. Is the surgery has to be done as an emergency, urgency or as the elective procedure? What is the condition of the soft tissue and other associated injury? What is the position of the patient and the appropriate surgical approach? Which type of the stability of the fixation is suitable for the fracture? What kind of implants should be used to obtain the desired sta-
bility with minimal disturbance to the viability of bone and soft tissue? Which method of reduction is required in respect to the accuracy of reduction and axial alignment of the extremity? Do you need any additional equipment or instrument to facilitate the surgical procedure? The answers to these questions are a part of the whole pre operative planning to help the surgeons to think ahead about the possible problems. It will also reduce the operative time and the complication because everyone in the team follows the steps according to the plan.

Successful operative reduction and internal fixation necessitates a thorough understanding of all phases of the procedure, the approach, and the mechanics of the fracture. This goal is easier to achieve when the operation is planned beforehand. The steps of planning are as follows: the sound side of the fractured extremity is traced. The fractures are traced and reduced within the contours of the sound side tracing or around the axes of the appropriate joint. A transparent sheet with the outline of the appropriate implant is then place over the out line of the reduced fracture, which is then also traced onto its proper location. This tracing represents the desired end result. Lastly, one works backward through the steps which allowed the tracing of the desired end result. This becomes the surgical tactic for the given case.

In summary every fracture requires proper classification and understands of the morphology and location fracture. The surgeon has to select either non operative or operative treatment according to the diagnosis and indication. In case of operative treatment proper pre operative planning is required to obtain the good outcome. In addition as a learning surgeon to review every post operative procedure and ask yourself is there any mistake that it should be avoid and what can I improve in the next case. What I did wrong and how to prevent not to happen again. Post operative x-ray is the valuable education materials to analyses quality of the operation for further improvement. Surgeon develops skill by performing procedure follow the surgical technique and at the same time adapts the tactics from the experience and mistake to make sure that every case has the reproducible result. No any surgeon never has complication but it is important to learn not to repeat it again.

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Fracture reduction What, Why and How

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What is the fracture reduction?

Fracture reduction is the act of restoring the correct relation and position of fracture fragments, including the process of reconstruction of impacted cancellous bone and articular fragments in articular fracture. We can divide the purpose of reduction into two groups.

1. Anatomical reduction that mean perfect restoration of bone morphology.
2. Anatomical alignment that mean to restoration of anatomical relationships of proximal and distal main fragments in term of Length, Axis and rotation.

Why do we need reduction?

The purpose of fracture reduction is to restore proper alignment of the bone, to provide properly bone healing by bringing the fracture close to each other to reduce pain and morbidity of patients, to prevent neurological deficit in displaced spine fracture and avoid long term complication such as malunion or nonunion.

How to do reduction?

The decision, which aiming of reduction method should be used, depends on the location and morphology of fracture;

• In articular fractures with displacement or depression of articular surface require anatomical reduction to avoid step or gapping which lead to joint incongruity, instability and traumatic arthritis.

• Meta- and diaphyseal fractures usually need anatomical alignment to achieve correct length, axis and rotation is sufficient and is not recommended to do anatomical reduction of every fragment particularly in multifragmentary fracture that will result in destruction of blood supply to the bone.

There are two techniques for reduction of fracture:

• Direct reduction where every fragment is restored under direct vision. This technique requires exposure to bone fragment and use instrument to hold reduction in place. Direct reduction is indicted in displaced articular fracture, simple diaphyseal fracture such as oblique, spiral and transverse fracture. After reduction the fracture will be maintain by different technique of absolute stability depend on morphology of fracture. In general direct reduction is associated with absolute stability and bone healing by primary bone healing. The disadvantage of...
direct reduction is direct exposure to the fracture site with detachment of soft tissue while reduction and applying instruments. The damage to vascularity and biology of the bone can be minimized by limited soft tissue stripping of the bone. Some instruments such as point reduction forceps, Cerclage wire, small Hohman retractor is recommended to reduce and/or hold reduction before definitive fixation of the fracture.

- **Indirect reduction** where the reduction of fracture is done without directly exposed and seen. The reduction is accomplished by using instruments or implants introduced away from fracture area. Indirect reduction is indicated when anatomical reduction is not the aim such as in non-articular fractures, multifragmentary fracture of diaphyseal or metaphyseal bone and when absolute stability is not possible or at risk. After obtaining satisfactory alignment by indirect reduction the fracture is maintained with relative stability and bone healing by secondary bone healing. The advantage of indirect reduction is to avoid direct exposure of fracture site which reduce damage of soft tissue and blood supply around fracture area, decrease incidence of nonunion, refracture and infection. Primary bone graft is not recommended and early healing by callus formation as a rule. The disadvantages of indirect reduction are difficulty to achieve reduction that may lead to malalignment. For indirect reduction requires more careful planning and intraoperative image intensifier to verify reduction. In addition the surgeon has to understand the intraoperative assessment of anatomical limb axis and alignment to avoid malalignment. Indirect reduction is technique to manipulate bone fragments indirectly by applying corrective force at a distance from the fracture. There are different techniques and instrument using distraction or ligamentotaxis without exposing the fracture site. Some methods to achieve reduction such as manual traction, distractor or intraoperative external fixator as a reduction tool fracture table, and precontour or anatomical plate. Keep in mind that goal of operative fracture treatment is stable fixation with the least possible disturbance of the soft tissue.

Every trauma case the surgeon has to realize the mechanism of the injury, make the correct diagnosis, and classify bone and soft tissue condition in order to select the appropriate type of treatment. The traumatized limb should be carefully assessed for neurovascular injury and possible compartmental syndrome. Most of the fractures can be diagnosed by routine AP and lateral X-ray. It is necessary to have the X-ray which includes the whole length of bone to rule out the other lesions. If the patient is unconscious, the lateral cervical spine and pelvic X-ray should be taken to rule out the injury. In articular fractures the oblique X-ray may be added to see more details of the fractures. CT scan is helpful to determine the degree of the displaced articular surface or loose fragment in the joint. 3D reconstruction may be needed in complex intra articular fracture of calcaneus, acetabulum or maxillofacial.
After gathering the information about the patient and the personality of the fractures, the surgeon has to answer the following questions. Is the surgery has to be done as an emergency, urgency or as the elective procedure? What is the position of the patient and the appropriate surgical approach? Which type of the stability of the fixation is suitable for the fracture? What kind of implants should be used to obtain the desired stability with less disturbance to the viability of bone and soft tissue? Which method of reduction is required in respect to the accuracy of reduction and axial alignment of the extremity? Do you need any additional equipment or instrument to facilitate the surgical procedure? The answers to these questions are decision making process and pre operative planning to help the surgeons to think ahead about the possible problems.

References
Complication of Osteosynthesis “10 rules to remember”

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Internal fixation is an area of surgical procedure intended to facilitate osseous union. Primary goal is to promote and achieve bone healing in a functional position to gain the full function of the injured limb not only the bony union. This process requires a traumatic surgical technique and appropriate reduction incorporate by fixation device with correct biomechanical principle. Internal fixation is a process requiring careful surgical intervention although some complications may occur but most of them are preventable. We can divide the complications of internal fixation into two groups: 1.) Implant complication 2.) Latrogenic complication.

1. Implant complication

A foreign material for fixation has several potential complications such as 1.) Allergic reaction from patients who has hypersensitivity to stainless steel (most common is allergic to nickel component). Patients who has allergic reaction to implant will has cutaneous skin lesion such as eczema, vasculitis or urticaria and will persist until implant is removed. The surgeon should keep in mind and ask the patients for history of allergic reaction. 2.) Implant migration that mostly occur in smooth K-wire especially when use it near to the high motion area. The migration can be prevent by bending the end of wire, prevent thermal necrosis during drilling and early removal.

2. Latrogenic complications

Each internal fixation device available has inherent disadvantages and risks. However, the primary complications of internal fixation such as; infection, neurovascular injury, non-union, delayed union and implant failure are often secondary to poor surgical technique or judgement from surgeon. The surgeon must understand the risk and his competency for any surgical procedure before performing surgery to the patients.

Infection is the main causes of morbidity and mortality in any type of surgery. The predisposing factors are patients’ factors such as underlying disease diabetes mellitus, malnutrition, poor immune system, history of corticosteroid or immunosuppressive use. The surgeons’ factors mainly from inappropriate surgical sterile technique, poor soft tissue handling with excessive stripping of soft tissue and blood loss. The operating room should have adequate space with good ventilation system. All personnel in operating room should have good hygiene, strict discipline for sterile technique. In general the infection rate of the operating theatre for the clean case should not exceeding 2 %. When there is infection the management steps are early diagnosis with adequate debridement, provide enough stability and give proper antibiotic.
Neurovascular injury is preventable complication when happen will cause different degree of morbidity to patients. Prolong tourniquet time, direct injury from inappropriate surgical exposure or entrap by instrument are cause of injury. The good surgical exposure, well understand anatomical landmark and carefully use of instrument can prevent this complication.

Delay union, nonunion and implant failure after internal fixation are not failure of implant but it is failure of surgeon to choose and apply it. The main causes of failure are surgeon who does not understand the principle of biomechanics and does not achieve proper stability, perform inadequate reduction and use incorrect implant for fixation, poor soft tissue handling and poor surgical technique that destroy biology and blood supply.

Despite the complication after internal fixation that cause morbidity and some case may lead to mortality. Most of these complications are preventable. There are several etiologies that cause complications which can be summarize into 10 rules that the surgeons have to remember.

• **Rule no.1** The necessity to provide mechanical stabilization of fractures is accompanied by the need to preserve the surrounding biology and vascularity.
• **Rule no.2** Optimal fracture healing requires a balanced interplay of the biological (vascularity) and optimal mechanical (stability) environments.
• **Rule no.3** Bone has a special response to mechanical stimuli. Parameters, such as the strain of the repair tissue, have been identified as important factors influencing bone healing.
• **Rule no.4** Healing can be achieved by carefully planning the correct osteosynthesis with regard to the degree of stability needed for early initiation of repair.
• **Rule no.5** Choice of the implant used, configuration of the fixation elements, and functional load with optimal stability of each type of implant are the key mechanical parameters for result.
• **Rule no.6** Modern fracture management has evolved by taking advantage of the fact that control of bone healing lies in the surgeon’s hands aided by proper image and pre-op planning.
• **Rule no.7** A key biological factor is the timing of surgery. Correct timing is needed to preserve the soft and hard tissues and with it the blood supply to bone.
• **Rule no.8** In treatment of articular fracture, anatomical reduction of articular fracture, the correctly placed plate to provide support and sufficient stability to allow early motion are the keys to success.
• **Rule no.9** To operate on fractures requires a full understanding of surgical approach, patho anatomy of fracture, reduction and fixation technique. Last but not least what is the level of your competency?
• **Rule no.10** Each post operative x-ray of osteosynthesis should be critically analyses to evaluate for the possible pitfall and further improvement to have reproducible outcome.
In order to reduce the complication the proper pre operative planning in very case and perform the surgical procedure according to the plan. The well planned surgery will reduce the operating time and the surgeon can anticipate the possible problem that may happen during surgery. All the proper instruments and implants are checked before the operation.

The treatment of the complication case is even more difficult and requires extensive analysis. What are the causes of failure and how the fixation has to be revise? Do we need a better investigation to analyze the fracture? Is there associated with infection and why it fails? Please keep in mind that the patient has already suffer for the failure of the first operation that can be vary from some months or years that he could not work or have a good function. The preoperative planning with the following answers: shall we use the same incision or different, how do we remove the implant, shall we use the implant as the reference for the insertion of new implant, do we use the same type of implant or change to new type. Do you require special type of implants or instrument? Is bone graft necessary? Finally are you competent to perform this operation and guarantee the success. Do you need to consult or refer this case?

When evaluating the complication of osteosynthesis particularly on implant failure it can be divided into the following causes i.e. wrong timing, wrong approach, wrong principle, wrong implant, wrong technique. The difficulty in the revision of failed internal fixation case are numerous. The scar and soft tissue contracture around the previous incision. There is no well define anatomical landmark of the bone around the fracture zone. Multiple loosening holes create by screw and disuse osteoporosis compromise the good purchasing of new screw fixation. More bleeding and more stripping of surrounding soft tissue to expose the fracture area. The operative time is longer and the chance of infection is higher. The more difficult and complex surgery require meticulous analysis and pre operative planning in more detail to reassure for the successful outcome.

As surgeons you are fully responsible for the success and failure of surgical intervention that have done to the patient. You should always treated the patient with the right indication and the best available technique same as you want to be treated. Prevention of complication is always better than correction. However when there is complication you have to analyze how it happened and not to repeat the same mistake. It is mandatory that all trauma surgeons have to follow the AO principle of operative treatment of fracture, to be educate and well train to avoid the complication which cause disability and suffering for the patients.

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