Internal fixation of equine fractures has advanced over the last few decades primarily because of the improving expertise of practicing surgeons and correct application of implants according to proven mechanical principles. The unfortunate reality of fracture repair in horses, however, is that failures still occur commonly because of infection, delayed union and implant failure. Delayed union in species other than the horse is a lesser issue because the consequences of severe lameness and overload of the contralateral limb are less and the expectations for return to function are usually lower. In horses, we still generally recognize that immediate comfort (i.e. stability) is an important element of successful fracture repair and that delayed union is a major complication because of implant failure and contralateral limb problems. Equine surgeons have naturally tended towards aggressive open fracture repairs in order to minimize mechanical “errors” that might reduce stability.

A large proportion of fractures in horses occur in the distal extremities where soft tissue coverage is poor. Aggressive open exposures and application of plates/screws/IM nails etc. all adversely affect local vascularity. Open surgical reduction usually disrupts the fracture hematoma, medullary elements and periosteal integrity. The natural evolution of surgical technique is to make procedures less invasive. Less invasive approaches may diminish the risk of infection and ameliorate postoperative pain. Less aggressive soft tissue and skin disruption should cause less scarring, fewer cosmetic blemishes and generally interfere less with the healing processes. The disadvantages of less invasive techniques include the necessity for accessory imaging modalities such as endoscopy and fluoroscopy. There is also little doubt that it is easier to make errors when using less invasive techniques. Most importantly, in horses we are usually seeking to assure that the horse can bear full weight comfortably on the limb immediately following internal fixation. This has traditionally demanded that we attain meticulous cortical reconstructions of long bones so that the bone and the implants share the load. Newer locking implants appear to be considerably more stable and may allow less meticulous cortical reconstructions. The locking compression plate has allowed us to try much less invasive techniques. Finally, although the technology is not yet widely available, intraoperative computed tomography further expands our ability to repair more difficult and complex fractures with minimally invasive approaches.

Case Selection:
There are certainly many orthopaedic cases that we (currently) have no chance of repairing with any technique other than completely open reduction and internal fixation. As surgeons develop more confidence with endoscopic and fluoroscopic imaging, however, less aggressive dissections and exposures become more appealing. It was not that long ago when it was considered essential to perform an arthrotomy when repairing carpal slab fractures and MC3/MT3 condylar fractures but currently arthroscopic reduction is accepted common practice. As we gain experience, selected long bone fractures and arthrodeses may also be done more commonly using less invasive techniques.[1] The fundamental approach for displaced articular fractures involves manipulation of the fracture fragments under arthroscopic observation and positioning of implants with digital or fluoroscopic imaging. My preference is to place the glide hole and insert sleeve for the lag screw before attempting to reduce the fracture.
condylar fractures, carpal slab fractures and mid-body sesamoid fractures are common injuries typically repaired using this basic approach. The philosophical approach to try less invasive repairs has pushed us to attempt more challenging cases.

Medial condylar fractures:

Fractures propagating proximally from the medial condyle are very different from those arising in the lateral condyle. Medial fractures, unlike their lateral counterpart, rarely course towards the near cortex. Instead, the fractures split the bone vertically only to radiographically disappear in the diaphysis or they spiral more definably up the limb.

Either configuration has a high risk of catastrophic failure. Catastrophic dehiscence of these fractures is especially probable when the affected cannon bone is in a hindlimb.

There are many options for treating these injuries including lag screw fixation of the visible portion of the fracture only, open application of a combination of lag screws and plate. Special anesthetic recovery systems such as a pool system are invaluable but fractures can occur up to a few weeks after lag screw fixation. Plate fixation has therefore become a more standard treatment. Because these fractures are not displaced, a minimally invasive approach can be used to place the plate. The horse is placed with the affected limb uppermost. First, two cortical screws are placed in lag fashion across the condyle using routine technique as described above. The screws are placed from lateral to medial even though the smaller portion of the fracture is medial. This is not a mechanical problem because the bone is very dense in this region and the medial fragment is large enough to provide adequate strength. The "normal" direction of screws is reversed because the plate is placed lateral. Lateral placement is strongly recommended because the plates are removed with the horse standing. A 2 cm incision is made between through the skin on the proximal cannon bone. We use a (previously used) broad DCP with a sharpened end attached to a handle to make a subcutaneous tunnel for the plate. After the subQ tunnel is made, a roughly contoured 10 or 12 hole broad limited contact dynamic compression plate (LC-DCP) or locking compression plate (LCP) is slid down into it. Unless there is an economic limitation of the owner, I prefer the LCP. The locking plate is biomechanically much better suited to being positioned in an extraperiosteal location. The mechanical function of a traditional plate demands considerable friction between the plate and the bone but the function of a locking plate is maintained even if there is no contact, let alone friction, between the plate and the bone. The LCP also has tapered ends to facilitate minimally invasive placement and a holding device screwed into the terminal locking screw hole is inserted after the plate is passed into the tunnel, the “fit” of the plate is assessed palpably and with fluoroscopy. The plate is contoured as needed and replaced. The holes in the plate can be easily palpated distally. Stab incisions are made over holes and screws inserted routinely. I generally use 4.5 mm cortical screws for this procedure. If you are using an LCP, the all cortical screws should be placed before you insert the locking screws. After two screws are inserted, a plate of the same length is placed on the surface of the skin and incision made through that plate’s holes. The remaining screws are inserted. The distal one or two screws in the plate may be placed in lag fashion if the fracture plane is radiographically visible at that level. Fluoroscopy is used to check implant positioning. One or two skin sutures are used for each stab.

Specific cautions with this technique include the need to avoid the contralateral splint bone with bits and screws, the difficulty in accurately measuring the depth of holes and the need to check carefully that each screw is fully inserted into the plate.
The plate is removed about 3 months following implantation. The horse should be walking at least 30 minutes twice daily for a month prior to removal. Sedation with detomidine is usually adequate. Local anesthesia with direct infiltration over the implant or by means of a regional nerve block is done and a short incision made over the proximal 2 cm of the plate. The most proximal screw is partially removed. A matching plate is placed on the skin and stab incisions made through its holes. Each screw is backed out above the skin edge. A battery-powered drill with the screwdriver attachment is quieter and easier to use in a standing horse. After the screws are all counted, they are removed. (It is a very bad idea to try to remove the plate if one of the screws is still in it!) The plate is pried up at its proximal end, grasped with vise grips and extracted proximally. Hand walk 60 days, paddock turnout for another month then return to training.

A-DP view of medial condylar fracture

B-Lateral lag screw and 12-hole broad DCP repair of medial fracture

C-Standing removal of bone plate. Each screw is backed out and the plate is slid out of a proximal incision.
Arthrodesis:

Minimally invasive approaches can also be used for metacarpophalangeal and proximal interphalangeal arthrodesis. The major disadvantage is the difficulty in removing a large percentage of articular cartilage. It is very feasible to accurately place a plate and transarticular screws through stab incisions. The cartilage is destroyed with a 5.5 mm bit directed under fluoroscopic control in multiple planes. With the limb in varus stress, a drill placed through a lateral stab incision can be directed in several paths. The dorsopalmar(plantar) drilling also can be done in multiple planes through 1 or 2 small incisions and flexion/extension of the joint. In the fetlock, more accurate cartilage destruction, especially of the sesamoids can be done arthroscopically but it still is not as complete as an open approach. My current opinion is that minimally invasive technique for arthrodesis of the pastern and the fetlock has the advantages of less soft tissue disruption and incisional complications but it should be reserved for cases with moderately severe existing osteoarthritis. My impression is that the fusion occurs more slowly.

MCP Arthrodesis:

Although we are attempting newer techniques, minimally invasive arthrodesis of the fetlock at this time is considered only in horses with an intact suspensory apparatus and severe osteoarthritis. Cartilage removal is ideally done with a combination of arthroscopic debridement with a motorized burr and fluoroscopically guided drilling across the metacarpophalangeal joint space with a large drill bit. The drilling is done in various planes through stab incisions in an effort to avoid leaving large areas of undestroyed cartilage. After the cartilage is extensively destroyed as possible, a 12 hole broad DCP plate is placed on the midline over the skin such that 4 holes are over dorsal P1. A 3cm incision is then made proximal to the upper end of the plate. The plate passer is used to create a tunnel through the joint and down over the dorsal surface of P1. If necessary, a mallet is used to drive the passer (or an appropriate sized osteotome) over the dorsal rim of P1. Care is taken to stay deep to the extensor tendon over the entire length.

The transarticular (MC3 to sesamoid) screws are then placed being very careful to place them abaxially enough to avoid the midline plate. The fetlock is placed in slight palmar flexion and 5.5 mm glide holes directed through stab incisions over the dorsal metacarpus towards the center of each sesamoid. Routine lag screw technique is used to compress the sesamoid bones to the palmar metacarpus. The plate is contoured appropriately (about 10-15 degrees) in the large bending press then slid down into position. A nail set and mallet may be used to drive the plate distally. The skin will be tented dorsally because of the angle of the plate. The final position of the plate is checked fluoroscopically. The four distal screws (5.5 mm) are placed through stab incisions and fully tightened. It is imperative that the longitudinal axis of the plate is checked before drilling the second screw hole; the proximal part of the plate MUST line up on the dorsal metacarpus. The plate is then manually pulled against the dorsal metacarpus and the plate tension device applied. The tension device is maximally tightened to compress the joint surface. Two or 3 screws are then placed through the proximal portion of the plate, the tension device is removed and the remainder of the holes filled with screws. Fluoroscopy is used throughout. Finally, two transarticular screws are drilled from P1 into MC3, avoiding the plate, its screws and the MCP-sesamoid screws. Only skin sutures are placed and a half-limb cast is applied.

It is worth noting that I have some doubts that this technique is worth its difficulties for two reasons. First is that it does not save much time because the manipulations can be difficult and closure of an open approach is not that difficult. The second reason I prefer an open
approach is that I believe MCP arthrodeses are all best done with a true tension band (preferably a cable).

**PIP Joint**

In my opinion, minimally invasive pastern arthrodesis is best reserved for the horse with advanced osteoarthritis, especially if the goal of the surgery is to achieve an athlete. The current technique of transarticular abaxial screws with a dorsal midline plate is an extremely stable fixation. If the joint is opened to remove all of the cartilage, the rapidity of healing and minimal bony proliferation you can achieve with an open exposure is probably worthwhile in terms of athletic function. If there is already extensive cartilage loss and extensive bony proliferation, opening the joint is more difficult and affords a smaller advantage. Minimally invasive PIP arthrodesis in suitable cases can be done by simply drilling across the joint space through a lateral stab incision with a 5.5 mm bit. Two proximal-dorsal to distal-palmar/plantar transarticular 5.5 mm screws are placed and tightened *before* the plate is applied. The concept is that the transarticular screws compress the palmar/plantar joint as much as possible then the loaded plate compresses the joint dorsally. Think of the plate as trying to bend the transarticular screws. (It won’t.) A 3 hole narrow locking pastern arthrodesis plate (or any narrow plate can work) is positioned in a subtendinous tunnel on the dorsal midline. With a three hole LCP, the surgeon must be sure to check the orientation of the holes and insert the plate such that compression can be applied with a cortical screw in the middle hole. The distal locked 5.0 mm screw in proximal P2 is inserted and partially tightened, i.e. enough that the threads of the screw are definitely in the threaded portion of the plate. It is important to physically hold the plate against the bone while the screw is being inserted because the screw will NOT lag the plate to the bone. The second screw should be a 5.5 mm cortical screw and inserted with the drill guide in a load position. This screw is lightly tightened then the locking screw in P2 is maximally tightened. The 5.5 cortex screw is then fully tightened to compress the dorsal aspect of the joint and pull the plate against the bone. Finally, the proximal hole in the plate is filled with another 5.0 mm locking screw. Only skin sutures are placed and a half-limb cast should be applied. That cast is typically changed at two weeks and the second cast left on for another 4-6 weeks if the horse wears it comfortably.

**Minimally invasive long bone fracture repair (other than medial condylar fractures):**

Minimally invasive techniques for anything other than non-displaced medial condylar fractures are clearly still in their infancy. In humans, minimally invasive techniques for total joint arthroplasty and femoral fractures have both gradually become more popular but both have required significant investment in new implants and technology. In many minimally invasive orthopaedic systems, the instrumentation is highly specialized and very expensive. In horses, our minimally invasive efforts are still constrained by economic considerations. For example, in humans there are specially equipped operating suites integrating computed tomographic information with computer-controlled stereotaxis. This allows remarkably accurate insertion of implants in difficult locations like the pelvis without open exposures. Computer assisted surgery has been used in equine surgery but it seems unlikely to become standard practice any time in the near future. On the other hand, preoperative and intraoperative computed tomography without directed computer assistance is more likely to become available to more equine surgeons.
The strength and stability of locking plates has allowed us to try minimally invasive long bone repair of some seriously comminuted fractures in the distal limb of foals and smaller large animals (llamas, alpacas etc.). It is still premature to claim that a majority of foal metacarpal and metatarsal fractures might be treated this way but the complications with aggressive open exposures in such fractures is high enough that further efforts seem warranted. The metacarpus/metatarsus is particularly well suited to minimally invasive plate placement because of the minimum overlying soft tissue and relatively straight bone. If the periosteal sleeve and its contained comminuted fragments and fracture hematoma are undisturbed by two extraperiosteal bone plates, it seems highly probable that the normal progression of fracture healing will be unimpaired. Because meticulous reconstruction is not always feasible with a minimally invasive approach, load sharing by accurately realigned cortices may be impossible. This therefore demands a more rigid implant system like the locking plate. The technique requires ancillary imaging such as fluoroscopy or intraoperative digital radiography. The most challenging aspect of minimally invasive double plating is the difficulty in maintaining orientation of the implants and fragment alignment but small details such as being unable to easily see the surface of the plate can be problematic. When using a locking plate, it is essential that the drill guide and the screw both be threaded precisely into the plate in order to achieve the mechanical advantage of the implant. It is surprisingly easy to incompletely thread the head of the screw into the plate when placing these plates via a minimally invasive approach.

Dorsopalmar and Lateromedial views of metacarpophalangeal (A,B) and proximal interphalangeal (C,D) arthrodesis performed through stab incisions.