Orthopaedic surgeons have long attempted to obtain the maximal stability of their osteosynthesis repair while preserving the soft tissue environment of the fracture site. While this philosophy has proven clinically successful for decades, of late, these traditional approaches have begun to be critically evaluated. Starting in the mid 80’s, a better understanding of the crucial importance of gentle manipulation of soft tissues progressively led surgeons to increasingly rely on indirect reduction techniques during diaphyseal fracture repair. The acceptance of these new techniques resulted in a slow paradigm shift, which became the foundation of a new concept known as “biological osteosynthesis”. Adoption of biological osteosynthesis principles progressively expanded from treatment of diaphyseal fractures to include articular and periarticular fractures today. Successful implementation of minimally invasive osteosynthesis (MIO) techniques is however considered more challenging and less forgiving for non-diaphyseal fractures and requires continued strict adherence to previously well-established principles. These include 1) restoration of alignment in all planes, 2) anatomical reduction (articular fractures), 3) interfragmentary compression (articular fractures) and 4) restoration of the limb mechanical (functional) axis. Considering the devastating effect of infection on joint function, needless to say that scrupulous adherence to aseptic surgical techniques is an absolute must.

The main purpose of MIO for articular fractures is to decrease iatrogenic (surgical) articular cartilage trauma and periarticular fibrosis, both of which potentially lead to poor functional recovery due to OA progression and limited ROM. The neophyte surgeon must keep in mind however that more damage can be created by excessive external/indirect attempts at closed reduction than by sharp, precise open surgical techniques. In that regard, it is essential to recognize which cases are amenable to MIO and which ones are not. The latter include non-reducible and chronic or severely displaced fractures. Yet another integral part of MIO for articular fractures consists of implantation of a comprehensive post-operative rehabilitation regimen, even more so than with diaphyseal fractures. There is no point in reducing a femoral condylar fracture through stab incisions if inadequate fixation requires long term postoperative immobilization to protect the repair.

Compared to shaft fractures, most MIO of peri- and articular fractures heavily rely on advanced pre- and intraoperative imaging techniques. In that regard, 3-D reconstructed (and animated) representation of the joint of interest often proves invaluable during pre-operative planning (Figure 1). We routinely use such imaging techniques to assist with mental visualization of the fragments throughout surgery. Reconstruction software are currently available for both PC (e.g. Voxar 3-D) or Apple (e.g. Osirix – free download) computer operating systems. Similarly, intra-operative imaging is next to indispensable in most cases, particularly for fracture of proximal joints, growth plates, femoral neck as well as sacroiliac luxation/fracture. The use of intra-operative fluoroscopy (C-Arm) along with a radiolucent surgical table is necessary to ascertain proper reduction, as well as adequate implant selection and position. Alternatively, arthroscopic evaluation of fracture reduction as pioneered by Tomlinson can be performed in selected cases such as supraglenoid fractures. Effective use of intra-operative fluoroscopy requires proper patient positioning. In particular, the surgeon must ascertain that, prior to draping, unobstructed visualization of the region of interest is achievable in two orthogonal planes (articular and physeal fractures) or at least in the lateral plane (sacroiliac luxation fractures). Unhindered maneuverability of the C-Arm considerably
facilitates visualization of the bone fragment during reduction as well as appropriate implant fixation. For fractures of the forelimb, the anesthesia station should be positioned at the rear end of the patient (Figure 2 – Left). Based on fracture location, the animal is placed in lateral (distal joints / physes / SI) or dorsal (proximal joints / physes) recumbency. In the former case, the limb should extend away from the surgical table while in the latter case, the chest is elevated so that the entire shoulder can be imaged without superimposition of thoracic structures (Figure 2 – Left). Regardless of patient position, the use of restrictive devices is recommended to prevent accidental fall from the table during surgery. For SI luxation/fracture treatment the use of 2 C-arms may prove helpful (Figure 2 – Right).

Figure 1 – Illustration of the potential advantages of CT scan images compared to plain radiographs. The 3-D reconstructed images can be manipulated in any direction to help the surgeon visualize fragment displacement.

Figure 2 – Patient positioning is critical when performing MIO with intra-operative fluoroscopy. The C-arm should be freely movable around the region of interest in order to provide good quality images in 2 orthogonal planes (left). The use of 2 C-arms (right) may be useful in the treatment of SIL in large dogs.

Similar principles apply for the treatment of hind limb fractures. Pelvic elevation with the animal on the edge of the table is particularly useful for visualization of capital and femoral neck fractures. One of the limiting factors of MIO is exposure to harmful radiation. Proper protection should include 1) full frontal lead shielding that includes the thyroid region for all individuals present in the OR, 2) lead glasses (surgeon/assistants), 3) attenuation surgical gloves (surgeon), 4) understanding of the risks of back-scatter radiation and 5) knowledge of the spatial scatter of the equipment used. In addition, regular evaluation, and if necessary recalibration, of the C-Arm is highly recommended. Finally, monitoring of the radiation level to which the surgeon and associated personnel are exposed must be performed through the use of waist, thyroid and finger dosimeters.

Yet another challenge of MIO is the limited availability of effective and specific techniques and/or devices for fracture reduction. Indirect reduction techniques may include limb traction (hanging leg technique) for the radius ulna and tibia, or use of traction tables as described by Rovesti. Such tables however are not yet readily available and may represent a substantial investment. Alternatively the surgeon may use ligamentotaxis techniques to
achieve fragment apposition. An example of the use of such a technique is for the reduction of distal femoral physeal fractures. With the knee bent at 90°, the tibia is first pulled forward (cranial drawer motion) to bring the distal femoral epiphysis into a cranial position. Subsequent extension of the tibia creates a fulcrum point at the level of the fracture and, thanks to the intact collateral and cruciate ligaments, helps reduce the fracture. Similarly, manipulation of the radius ulna can be used to reduce humeral condylar fractures. Application of manual pressure direct on the fragments is ill advised as it may create local soft tissue trauma, disrupt the blood supply to the fracture as well as the fracture hematoma. Rather, pointed AO reduction forceps, K-wires or Steinman pins judiciously implanted in the bone fragments may be used to facilitate remote reduction. Care should be taken not to weaken small fragments and not to interfere with the placement of implants used for fixation. In cases of sacroiliac luxation/fractures, effective manipulation of the affected hemipelvis can be consistently achieved using a Kern bone holding forceps over the wing of the ilium (pushing), the ischium (pulling) or both. Alternatively, in small dogs and cats, K-wires or Steinman pins may be used in the same locations. Other fracture-specific reduction techniques include the use of radiolucent reduction clamps developed decades ago for the treatment of humeral condylar fractures (Figure 3). Likewise, over the past few years, effective, specific minimally invasive reduction instruments have been developed in human orthopedics. While some are also suited for veterinary use, the cost of such instruments currently limits their utilization.

Figure 3 – Left: Craniocaudal preop radiograph of a Salter-Harris IV of the distal humeral condyles in a 14 week old female golden retriever. The fracture was externally reduced then temporally stabilized using a radiolucent condylar clamp (center left). Anatomical reduction was ascertained via intraop fluoroscopy (center right). Fixation was achieved by percutaneously inserting a temporary transcondylar K-wire from the medial epicondyle. Once proper K-wire position was verified, it was removed and replaced by a position trans-condylar screw inserted through a stab skin incision from the lateral epicondyle. Craniocaudal postop radiograph showing anatomical alignment and fracture reduction. Final stabilization was achieved using a transcondylar position bone screw and an anti-rotational K-wire inserted in the lateral humeral epicondyar branch (right).

While clinically rewarding, MIO techniques are technically more challenging when used for non diaphyseal fractures. Because the fracture site cannot be visually controlled, a clear appreciation of the 3-dimensional bone geometry, as well as spatial limb alignment, is indispensable. Restoration of limb segment length and alignment in both frontal and sagittal planes, as well as in rotation, are indeed crucial to functional recovery. To achieve this, the surgeon’s reliance on intra-operative fluoroscopy becomes even more critical than it is in the treatment of diaphyseal fractures. Finally, one must keep in mind that while striking a balance between biological and mechanical constraints is the basic principle governing biological synthesis, minimally invasive techniques are not applicable in all cases and are not meant as a substitute to more traditional fixation techniques with visual control of the fracture site and limb alignment.