Minimally Invasive Orthopedic Surgery: What is the evidence?
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Minimally Invasive Fracture Repair

Background

The quest for optimal fracture repair has a long history and will likely continue to evolve throughout the future. The foundations for modern fracture repair were first described in the early 19th century and most types of modern osteosynthesis were introduced into clinical practice during the years from 1886 to 1921 (the so-called “decisive era of operative fracture management”) (Miclau T, et al. 1997; Bartoníček J. 2010). In 1958, the Arbeitsgemeinschaft fur Osteosynthesefragen (AO) foundation was formed with the philosophy of open reduction and internal fixation (ORIF) to provide early weight bearing and rapid return to function and mobility (Müller ME, et al. 1997). AO promoted ORIF emphasizing anatomic reduction and rigid bone fragment stabilization via internal fixation and interfragmentary compression (Müller ME, et al. 1997). This was in an effort to avoid “fracture disease” or the complications associated with prolonged immobilization (Müller ME, et al. 1997). These ideas and techniques revolutionized fracture management and significantly improved clinical outcomes when compared to earlier methods of fracture management. However, the achievement of mechanical stability via anatomic reconstruction of the bone column came at a price. Even though preservation of the blood supply and gentle tissue handling were strongly emphasized by the AO foundation, the extensive approaches used to accomplish the goal of anatomic reconstruction resulted in iatrogenic trauma to the surrounding tissues, most notably to the fracture hematoma and periosteal blood supply. This approach to fracture management therefore brought about a newer set of complications, such as delayed and non-unions, implant failures, and an increased risk of infection (Gerber C, et al. 1990, Nikolaou VS, et al. 2008).

As this philosophy of fracture repair became more widely accepted and utilized, the problems that arose became more apparent. This led to a shift from striving for perfect anatomic reconstruction of the bone column to placing a greater emphasis on the preservation of the biologic fracture environment. This became the foundation for a new approach known as biological osteosynthesis. The concept of biological osteosynthesis refers to preservation of the vascularity of the bone and the fracture hematoma during surgical intervention to achieve improved fracture healing. Conservation of the biologic environment commonly involves gentle or no handling of the bone fragments, remote manipulation of bone fragments, restoration of limb alignment with no attempt at anatomic reduction, bridging plates or external fixator devices to bypass the fracture site, and the limited use of bone grafts. At this same time there was also a shift in the thought process about mechanical stability, from a traditional approach of restoring anatomy with rigid interfragmentary stability to restoration of alignment with achievement of construct stability. This involved several changes from the traditional plating techniques, such as the use of longer plates that bridged the fracture site and a decrease in the amount of hardware, such as limiting the number of screws in the plate and eliminating interfragmentary reduction screws and cerclage wire. Initially in the early 1980’s, the open but do not touch (OBDNT) approach was emphasized, however current techniques strive for completely closed or minimal exposures.

Several pivotal studies over the past 3 decades have shown that preservation of the fracture hematoma and vascular supply enhance fracture healing. When examining the role of the fracture hematoma, Grundnes et al. (Grundnes O, et al. 1993), reported that surgical removal of
the fracture hematoma at the time of fracture stabilization in an experimental rat femur fracture model resulted in impaired bone healing, along with significantly decreased biomechanical properties of the developing callus. Also, numerous growth factors have been identified in fracture hematomas, which are central regulators of cellular proliferation, differentiation, and matrix synthesis in the fracture healing process (Einhorn TA. 1998). Most recently multilineage mesenchymal progenitor cells have been isolated from human fracture hematomas, which have osteogentic, chondrogenic, and adipogenic potential, and likely play a vital role in bone healing (Oe K, et al. 2007).

It is well known that vascular supply to any injured tissue, including a fracture site, is essential for healing. In displaced femoral fractures the primary blood supply to the fracture site comes from the surrounding musculature that feed the perforating arteries, which ultimately supply the periosteaum (Rhinelander FW. 1968, Laing PG. 1952). Farounk O, et al. (Farouk O, et al. 1997, 1999) analyzed vascular damage to the femur using fresh human cadavers when either an ORIF or a MIPO technique was utilized. These studies showed that 100% of the MIPO specimens had intact perforating and nutrient arteries, suggesting preservation of periosteal and medullary perfusion, whereas only had 27.5% of the specimens in the ORIF had intact vasculature (Farouk O, et al. 1999).

Braumgaertel and colleagues (Baumgaertel F, et al. 1998), designed a sheep femur fracture model to compare anatomic (rigid) and biologic (bridging) fixation on bone healing. Bone healing was identified at 2-3 weeks after biologic fixation and after 6 weeks following rigid fixation. An increased breaking strength was also identified in the biologic group. Micro and macro angiographic assessment showed increased vasculature of the fragments in the bridging fixation, especially when biologic fixation was combined with a point contact plate. This study demonstrated the superiority of indirect bone healing in respect to radiologic appearance of healing, biomechanics, and microangiography (Baumgaertel F, et al. 1998).

**Clinical Outcomes**

An early retrospective clinical evaluation in humans, examined the evolution of femoral plating techniques over 3 decades (Rozbruch RS, et al. 1998). In the 1970’s and 1980’s, anatomic reduction with compression plating was the fixation primarily used, whereas in the 90’s there was a shift to more biologic repairs. Over this time period there was a significant increase in the length of the plate used with significantly less plate/screw density and a decrease in the number of cases having primary bone grafting. The numbers of malunions and non-unions decreased, with significant decreases in the time to clinical union and the need for revision surgeries. A significant increase in the number of successful outcomes (boney union without deformities) was also identified over this time period. This study portrays a general improvement of fracture healing over 3 decades with increasing significance being placed on maintenance of the biologic environment (Rozbruch RS, et al. 1998).

Two early retrospective canine studies in the 1980’s and 1990’s, attempted to compare ORIF and minimally invasive fracture repair techniques. The first examined dogs with a closed reduction and external skeletal fixation compared to ORIF. In this study, although the radiographic time to healing was not significantly different between the groups the dogs treated with ORIF had significantly more complications (Dudley M, et al. 1997). The other study examined ORIF to bridging plate fixation (OBDNT) and found that the bridging plate had significantly shorter operating times and faster radiographic evidence of bone healing (Johnson AL, et al. 1998). These were the initial veterinary studies, which first identified some of the differences between open anatomic reduction and biologic fixation.
Some of the most compelling clinical data in dogs using minimally invasive osteosynthesis (MIO) is the work by Déjardin and Guiot (Guiot LP, et al. 2011), on the evaluation of minimally invasive plate osteosynthesis (MIPO) in tibial fractures. This prospective study revealed a decrease in healing times (36/45 days) and complication rates (2.8%) (Guiot LP, et al. 2011) when compared to the reported historical literature on ORIF tibial fracture healing time (87 days) and complication rates (18%) (Dudley M, et al. 1997). Similarly, in a smaller case series of dogs and cats using the MIPO technique for tibial fractures, the time to fracture healing was also shorter when compared to the historical literature (4-5 weeks) (Schmokel HG, et al. 20017). However, a retrospective comparison of 22 tibial fractures repaired with MIPO and matched ORIF cases, failed to show statistical significant differences in healing time and complications (Broncelli BA, et al. 2012). In this study, all dogs except one dog in the ORIF had a radiographically healed fracture at 60 days and at 30 days 5 of the MIPO cases were healed as compared to 2 dogs in the ORIF group. No complications were reported in the MIPO group where as one major complication was reported in the ORIF group (Broncelli BA, et al. 2012).

Other direct clinical comparisons of MIO and ORIF in veterinary patients examined the use of the interlocking nail. This retrospective study only had 20 cases (11 MIO and 9 ORIF), and even though no significant difference was observed in the complication rate, the time to healing was significantly shorter in the MIO group (6 weeks) as compared to ORIF (8 weeks) (Horstman CL, et al. 2004). Lastly, when evaluating healing of radius and ulna fractures in dogs with MIPO as compared to ORIF, one retrospective study did not find any differences in healing time and complications (Pozzi A, et al. 2013), whereas a prospective comparison found a significant decrease in healing time for the MIPO group (30 days) compared to ORIF (64 days), and abundant vascularization in the MIPO fracture sites (Pozzi A, et al. 2012).


The most common outcome measure in most of the clinical comparisons described above is time to clinical union. Time to fracture healing of weeks to a month may at first not appear to be clinically relevant in our veterinary patients, however the time to clinical union likely represents a way of evaluation of our ultimate goal of improving rates of fracture healing and decreasing complication rates.

Arthroscopy

In human medicine, arthroscopy has become an indispensable tool and the benefits of arthroscopy over open arthrotomy include less post-operative pain, early return to activity, smaller incisions with improved cosmesis, improved visualization of the anatomic structures, less synovial and periarticular scarring, shorter hospital stays, and improved long term functional outcome. Some human studies have even indicated a better overall (long term) outcome with the use of arthroscopic treatment when compared to arthrotomy (Buess E, et al. 2005). (Pozzi A, et al. 2008) These variables are thought to be similar in our veterinary patients, although little to no studies have been performed to evaluate them. The one variable that has been examined is visualization, and arthroscopy was shown to be superior in visualization and diagnostic accuracy of meniscal injures in cadaveric canine stifle joints with the use of arthroscopy (Pozzi A, et al. 2008).