Minimally invasive plate osteosynthesis accelerates early fracture healing in an ovine trauma model
+1Wullschleger, M; E; 2Steck, R; 3Webster, J; 4Wilson, K; 5Ito, K; 6Schuetz, M A
+Queensland University of Technology, Brisbane, Australia; 2The Prince Charles Hospital, Biological Research Facility, Brisbane, Australia
3Eindhoven University of Technology, Eindhoven, Netherlands
m.schuetz@qut.edu.au

Introduction: Over the last 10 years minimally invasive plate osteosynthesis (MIPO) has gained more and more popularity over the conventional open surgical approach (ORIF) for stabilizing certain long bone fractures, such as metaphyseal and diaphyseal fractures of the humerus, femur and tibia as well as in some cases fractures of the distal forearm and mid-shaft clavicle. Numerous clinical case collection studies [1, 2, 3] from different anatomical regions reported that the MIPO technique is a reliable method with good outcomes and therefore a reasonable alternative to the ORIF procedure. In addition to the obvious cosmetic advantage with smaller skin incisions, proponents of MIPO believe that this technique causes less surgical damage to the soft tissue envelope and therefore accelerates fracture healing. However, the MIPO technique has some significant drawbacks. It is a more demanding surgical technique with the risk of mal-reduction and mal-alignment. Furthermore, to control the reduction and correctly position the implant, imaging devices such as fluoroscopy are required and result in increased exposure to radiation.

To investigate the influence of surgical approach on soft tissue damage and fracture repair, a model suitably comparable with the clinical situation is required. A novel, standardized severe trauma model with severe circumferential soft tissue damage (Tscherne III) to the distal thigh and a multi-fragmentary distal femur fracture (AO C-type fracture) was recently developed by our group. The goal of this study was to use this model to compare fracture repair using the minimally invasive and open approaches.

Materials and Methods: 24 Merino wethers with a mean age of 5.4 ± 0.9 years (SD) and a mean weight of 39.1 ± 4.7 kg (SD) underwent severe trauma to the right distal thigh and femur including a fracture and bending of 180 degree to disrupt the peristomeum at the fracture site under general anaesthesia. After preliminary fracture reduction, an external fixator was applied temporarily. The soft tissue damage and recovery was monitored by intra-compartmental pressure measurements and serum blood tests for Creatin Kinase and Lactate Hydrogenase on a daily basis.

After 5 days healing, lateral plate fixation was performed, with random selection of either the minimally invasive (Figure 1) or conventional open approach and the external fixator removed. In all cases, the chosen implant was a 7-hole-4.5 mm Locking Compression Plate (LCP, stainless steel, Synthes, Switzerland) with two bi-cortical head locking screws in both (distal and proximal) main fragments (Figure 2). The sheep were held in a normal paddock and were able to move freely. Conventional radiographs were taken biweekly. The animals were sacrificed at 4 and 8 weeks (n = 6 each) after the plate fixation procedure.

Postmortem the femur was explanted, the implants removed and CT scans performed. Mechanical testing was performed using a biaxial testing machine (Instron) to determine the torsional rigidity and ultimate torque (strength). Data was tested for normality and parametric testing (ANOVA, p < 0.05) was used for statistical analysis.

Results: All but one sheep showed a complication free recovery with normal behavior and full weight bearing after 4 weeks. One animal developed a wound infection, which led to loosening of the proximal screws of the internal fixator and this sheep operated with MIPO technique in the 4-week group was excluded.

Soft tissue monitoring (Figure 3) showed significantly higher Creatin Kinase values in the sheep operated with the open surgical approach (1028.9 ± 827.0 U/L (SD), p < 0.05) compared to the minimally invasive technique (286.4 ± 259.7 U/L) following the second intervention.

At 4 weeks postop, the torsional rigidity of the fractured femur as a percentage of the intact contra-lateral limb was significantly higher (p = 0.05) in the MIPO group 30.1 ± 10.6% (SD) compared to the ORIF group 9.8 ± 12.4%. The ultimate torque results also showed a trend (p = 0.11, not significant) towards higher values in the MIPO group with 20.7 ± 11.0% versus 9.6 ± 9.8% for the ORIF group. After 8 weeks, the values of torsional rigidity (130.4 ± 61.9% vs. 100.4 ± 41.4%, p = 0.36) and ultimate torque (79.0 ± 23.6% vs. 64.4 ± 18.3%, p = 0.26) tended to be higher in the MIPO group, however these differences were not statistically significant.

Discussion: This study with a clinically relevant research question and an experimental model that is close to a clinical treatment scenario, shows an influence of the surgical approach during the early stage of fracture healing. The soft tissue damage caused by the second procedure with the open surgical approach is distinctly higher, shown by a postoperative peak in Creatin Kinase concentration (Figure 3). In addition, the surgical approach used in the open technique causes more devascularisation and direct damage to the fracture fragments. Several other factors further influence the outcome. Choosing the open approach, a larger cavity is created around the fracture site, which could lead to a larger fracture haematoma and ultimately callus formation. In contrast, the minimally invasive technique produces larger fracture gaps between the smaller fragments, which could potentially cause more inter-fragmentary ‘instability’ and thereby stimulate the callus formation. The two-stage fixation procedure includes a “wash-out” and subsequent re-formation of the fracture haematoma in the open approach, which could delay the process of fracture healing in the initial course, in contrast to the minimally invasive method.

In conclusion, the minimally invasive plate osteosynthesis shows an advanced fracture healing pattern in this clinically related experimental trauma and treatment model, compared to the conventional open fixation technique. However, this early advantage seems to diminish with increasing healing time.


Acknowledgements: Supported by a grant from the AO Research Fund of the AO Foundation.