Introduction:
Internal fixator systems, incorporating a locked screw plate interface, are increasingly applied in extremity fractures with limited opportunities to achieve stable fixation. Favourable clinical results are achieved. In 3 biomechanical studies, the mode of stability enhancement was investigated from various points of view.

Material and Methods:
1. Simulation with plastic models
Internal fixator systems were mounted on fracture models made of fiberglass tubes (Young’s-Modulus 12 GPa) simulating cortical bone and polyurethane foam (Young’s-Modulus 0.5 GPa) simulating cancellous bone or osteoporotic cortical bone. Screw plate interface was either locked or non locked using equal plates. In a material testing machine increasing statical loads were applied and maximum strength of the osteosynthesis determined. Model arrangements simulated a limited plate-bone contact diaphyseal osteosynthesis, a diaphyseal osteosynthesis in osteoporotic bone, short meta/epiphyseal cancellous bone fragments with screws parallel to the fracture gap (distal tibial osteosynthesis) and a triangular arrangement of 3 screws (tibial head, femoral condyle osteosynthesis). Each arrangement was built and tested 3 times.

2. Static tests on cadaveric tibia shafts
On cadaveric tibiae osteotomised to simulate a transverse defect fracture, 6 hole plate internal fixators were mounted with varying screw arrangements: 3 locked bicortical versus 3 unlocked bicortical screws (on either side of the fracture), as well as 3 locked monocortical screws and 2 locked bicortical screws combined with a corresponding reduction in plate length. Increasing statical axial and torsional loads were applied and maximum strength as well as the mode of failure of the osteosyntheses determined. Each arrangement was built and tested 5 times.

3. Dynamic tests on cadaveric tibial heads
Dynamic tests in an MTS testing machine were performed on cadaveric preparations of a tibial head internal fixator osteosynthesis with 3 subarticular screws. Screw plate interface was either locked or non locked. Cyclic loads with a frequency of 5 Hz and force increasing from 50N in steps of 50N after each 2000 cycles were applied. The tibial heads were loaded axially (perpendicular to the articular surface) by a femoral component of knee surface replacement. The force at which the load deformation curve left the linear range was determined (failure load). Each arrangement was built and tested 5 times.

Results
1. Simulation with plastic models
In diaphyseal osteosyntheses simulating healthy bone there was an effect of locked screws under torsion (failure occurred at 16.8 (median, range 15.7-17.9) Nm with locked and at 5.1 (4.4-5.9) Nm with non locked screws, which is a factor of 3.3). Under axial load a definitive effect was found when osteoporotic bone was simulated (260 (250-270) N with locked,120 (80-160) N with non locked screws, factor 2.2). When axial load and a cortical bone with a Young’s modulus of healthy cortical bone was assumed the effect was small (780 (640-920) N with locked screws,700 (640-760) N with non locked screws, factor 1.1).

2. Static tests on cadaveric tibia shafts

Discussion
Instead of pressing plates on bone to achieve stability as in conventional plate osteosynthesis, the locked screw plate interface results in an angularly stable frame structure, similar to an external fixator. The performed studies indicate that this results in a reduction of maximum stressess in the implant-bone interface. The stability of the osteosynthesis is enhanced.

With locked screw plate interface, a monocortical arrangement seems possible. By this the advantage of the angular stability is diminished, however.

Plate bone contact is principally not necessary with angularly stable implants. So, biological (perfusion saving) “bridging” osteosynthesis as well as minimally invasive approaches are simplified with internal fixators.

The mode of failure was significantly different between the arrangements. Under axial as well as under torsional load a fracture through the screw holes of the cortex below the plate was observed in non-locked and locked monocortical screw fixation, while the locked bicortical (3 or 2 screws) mountings failed by plastic deformation of the plate with screw bone interface still remaining stable (p<0,05).

A dependence on the bone quality was found. One preparation was osteoporotic (100mg HA/cm² vs. 171mg + 10 mg HA/ cm² of the others). Here, torsional strength was 11Nm and 19Nm in non locked and locked monocortical osteosynthesis respectively, but 29Nm and 28Nm in locked bicortical ones, 3 or 2 screws, respectively. The values in the locked arrangements were equal, even for shorter plates with only 2 bicortical screws, between osteoporotic and good bone quality (30+2 Nm with 2 locked bicortical, 28+3Nm with 3 locked bicortical screws, 24Nm with 3 locked monocortical, 25+2Nm with 3 non-locked bicortical screws).

3. Dynamic tests on cadaveric tibial head
For the dynamically loaded tibial head osteosynthesis a significant enhancement in stability was found with the locked internal fixator (p<0,05). The non-locked arrangement failed at 350N (median, range 200N-450N) and the locked arrangement at 600 N (median, range 550N-700N). As in the other experiments, the difference in stability increased with decreasing bone strength. The mode of failure observed was not an abrupt fracture but a stepwise settling of the screws through the cancellous bone with loosening of the implant.

Plate bone contact is principally not necessary with angularly stable implants. So, biological (perfusion saving) “bridging” osteosynthesis as well as minimally invasive approaches are simplified with internal fixators.