Telemetric monitoring of bone healing in femoral nonunions treated by an internal fixator

INTRODUCTION:
Monitoring of bone healing is typically performed by the evaluation of subsequent radiographic images. Especially, in nonunions, due to projection problems, it may be difficult to define healing properly. Applying modern micro electronics, e.g., built into mobile telephones or digital cameras, a system for monitoring bone healing on an internal fixator was developed. As for every new approach in medicine, the main question posed, was what clinically relevant information can be drawn from its application. The purpose of the performed prospective study was to analyse the information gained during the treatment of femoral nonunions.

METHODS:
Telemetric measurement modules, consisting of a strain gauge bridge and a 12mm by 12mm electronic circuit were mounted on a titanium internal fixator (200mm x 20mm x 6.5mm, Litos GmbH Hamburg, Germany). A developed external reader system was connected to a notebook/PC (Fig.1). Consecutive cases of femoral nonunions were treated by application of the instrumented internal fixator. After the removal of the existing implant, the nonunion was revised, and the femoral canal restored. The internal fixator was mounted laterally and a cancellous bone graft from the anterior iliac crest was performed in all cases. Four bicortical locked screws were used on each side of the nonunion gap. An antibiotic chain was inserted along the plate for prophylactic reasons. Routine radiographs in two planes were taken postoperatively and in intervals of 4 weeks. 12 weeks postoperatively, a computed tomography scan was performed.

Telemetric measurements were performed every 2 or 4 weeks. External loads were applied via a force transducer in a foot plate in standing position. A measurement consisted of a 3 cycles of increasing and decreasing external loads with a sample rate of 5 per second. Linear regression lines between externally applied load and measured fixator loads were evaluated. The slope of the regression line was used as the parameter for the elasticity of the osteosynthesis. To determine the course of healing, the elasticity values of the different instants were divided by the maximum value obtained during the early - healing process, intradividually. For comparison of computed tomography results with the measurement values, a staging of the computed tomography results was performed.

RESULTS:
27 patients received the instrumented implant, 24 males and 3 females. The median age was 43 yrs. with a minimum of 19 yrs. and a maximum of 66 yrs. 19 patients had an atrophic nonunion, 5 an oligotrophic nonunion and 3 a hypertrophic nonunion. Up to 5 operations had been performed before. The time from trauma to implantation of the intelligent implant was determined between 5 and 69 month with a median of 12 months. The previously used implant was, in most of the cases, a reamed femoral nail (11), in the other cases a retrograd nail (5), a gamma-nail (4), a reamed nail (3), a locked plate (3) or a Dynamic Compression Plate (1). 14 nonunions were located in the mid femoral shaft. However, all segments were represented. All nonunions healed. The time until clinical healing was wide, ranging from 13 to 37 weeks, with a median of 21 weeks. In the median, the elasticity decreased to 50% after 7 weeks, 30% were reached after 12 weeks and 10% after 19 weeks (Fig.2). In 5 patients, telemetric measurements showed an initial increase in elasticity. The comparison between the telemetric mechanical measurements and the computed tomography imaging showed, that a beginning osseous bridging in the nonunion gap opposite to the plate was related to elasticity values below 30%. The measured values were significantly different between the healing stages determined on the computed tomography scans (Kruskal-Wallis test p=0.0065). A level of 10% was reached by all patients during their final healing course, in the median after 19 weeks. This point in time closely resembles that of clinical healing after 21 weeks.

DISCUSSION:
Assessment of bone healing still is a difficult problem. There is a lack of consensus with regard to the definition of fracture healing [1]. Besides clinical examination, predominantly radiographic criteria are used. In nonunions, it is often impossible to judge nonunion healing by radiographs, CT scanning is required [2]. Moreover, radiographic examinations are difficult to correlate with mechanical stability. In this study, telemetric measurements proved to be a practical tool for bone healing monitoring in non unions. Considering the low prices of electronic circuits, it could be used routinely in the future.

SIGNIFICANCE:
A new technical system, which could solve problems to monitor bone healing when using internal implants, was shown to be clinically practicable.

REFERENCES: