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Trochanteric fracture-implant motion during healing – A radiostereometry (RSA) study

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ABSTRACT

Cut-out complication remains a major unsolved problem in the treatment of trochanteric hip fractures. A better understanding of the three-dimensional fracture-implant motions is needed to enable further development of clinical strategies and countermeasures. The aim of this clinical study was to characterise and quantify three-dimensional motions between the implant and the bone and between the lag screw and nail of the Gamma nail.

Radiostereometry Analysis (RSA) analysis was applied in 20 patients with trochanteric hip fractures treated with an intramedullary nail. The following three-dimensional motions were measured postoperatively, at 1 week, 3, 6 and 12 months: translations of the tip of the lag screw in the femoral head, motions of the lag screw in the nail, femoral head motions relative to the nail and nail movements in the femoral shaft.

Cranial migration of the tip of the lag screw dominated over the other two translation components in the femoral head. In all fractures the lag screw slid laterally in the nail and the femoral head moved both laterally and inferiorly towards the nail. All femoral heads translated posteriorly relative to the nail, and rotations occurred in both directions with median values close to zero. The nail tended to retrovert in the femoral shaft.

Adverse fracture-implant motions were detected in stable trochanteric hip fractures treated with intramedullary nails with high resolution. Therefore, RSA method can be used to evaluate new implant designs and clinical strategies, which aim to reduce cut-out complications. Future RSA studies should aim at more unstable fractures as these are more likely to fail with cut-out.

Background

The modern operative treatment of trochanteric hip fractures was conceived in the late 1930′s [1]. Since then numerous extramedullary and more recently intramedullary implants have been designed with the aim of improving outcomes. Despite the many incremental improvements, cephalic screw or blade cut-out remains a relatively common complication necessitating revision surgery in the most fragile of orthopaedic patients. The risk factors for the cut-out complication i.e. the perforation of the implant (a screw, pin or blade) through the femoral head, have been identified [2,3]. The consensus is that both reduction of the fracture and postioning of the implant play critical roles in this event, and that the implant selection seems to be less important [4].

The cut-out complication remains an unsolved problem and its absolute numbers are likely to increase as the elderly population increases in numbers [5]. Nowadays, it is widely accepted that the nature of the cut-out event is multidirectional with significant rotational and translational displacements. These motions are a direct consequence of the large and dynamic three-dimensional hip forces and moments that act on the proximal femur even in ordinary walking [6]. The multidirectional character was observed by a number of authors in both biomechanical and clinical studies [7–10]. However laboratory testing and retrospective studies on plain radiographs have obvious methodological limitations. Therefore there is still a need for further clinical research into the cut-out mechanism and to understand the interplay between the three dimensional movements of the bone-implant system in patients during the period between surgery and final healing of the fracture. Accordingly, the authors considered the application of Radiosterometric Analysis (RSA) that could enable accurate and precise delineation of the screw and nail implant motions relative to the femoral head. The interplay between head fragment, screw

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and nail motions during healing will give us the first detailed insights into how the screw moves within cancellous bone after it's initial placement. In a previous baseline experimental study [11], we evaluated the accuracy and precision of RSA in a trochanteric hip fracture model fixed with an intramedullary nail. This study demonstrated that the three-dimensional bone and implant motions in trochanteric fractures can be obtained with both high accuracy and precision. This sets the scene for the present study in which the three-dimensional relative motions of the head of the femur to the screw and the screw to the nail are measured in a patient series to gain insights into the nature of implant stability during the healing period. The aim of the present clinical study was to characterise and quantify the three-dimensional motions of the tip of the screw relative to the femoral head, as well as motions of the screw relative to the nail. It is hoped that this study will be a step toward RSA becoming a standard method for testing of new devices for trochanteric fracture fixation where implant migration is used as a predictor for failure [12].

Approval by the local ethics committee was obtained on the 1st June 2009, registration number 100-09.

Methods

The prospective cohort study was performed at the Sahlgrenska University Hospital in Mölndal, Sweden. 30 patients (median age 82.5 years, 22 females) with pertrochanteric fractures (AO/ASIF 31 A2.1) considered as stable were enrolled in the study. The reason for only including stable fractures was to adapt the RSA method in trochanteric fractures treated with intramedullary implants and to study a uniform group as far as fracture type is concerned. Further inclusion criteria were: a signed informed consent prior to the surgery, ability to walk with or without ambulatory aids and intact mental status. Subsequently, patients were treated with short Gamma nails (Stryker GmbH, Schönkirchen, Germany). All operations were performed under spinal anaesthesia by five orthopaedic surgeons trained in marking the fracture fragments with tantalum beads. The operative procedures were performed on a traction table, guided with the use of the image intensifier. After fracture reduction and insertion of the Gamma nail, the lag screw guide wire was placed in the femoral head aiming for the central–central position as seen on both the antero-posterior and lateral views. Once the lag screw canal was drilled, all the instruments and the nail were removed from the femur while ensuring that the fracture reduction was not lost. Using a specially designed insertion device (UmRSA Biomedical, Umeå, Sweden), six to nine tantalum beads, 1 mm in diameter, were pressed into the trabecular bone of the femoral head though the prepared lag screw canal. In eight patients, three to six beads were placed in the femoral shaft, lateral to the fracture line, through the opening in the lateral cortex and through the opening at the top of the greater trochanter. The nail was then reinserted and the lag screw placed in the femoral head within 1 cm from the subchondral bone and locked dynamically by the set-screw, subsequently, the nail was distally locked. The nail and the lag screw were previously marked by the manufacturer with four tantalum beads each (Fig. 1).

All patients underwent their first RSA examination within 24 h postoperatively, prior to any weight bearing or sitting up in bed. After this first assessement, the patients were allowed unrestricted full weight bearing. The subsequent four follow-up RSA examinations were scheduled at 1 week, 3, 6 and 12 months postoperatively. All RSA examinations were performed with the patient in the suppine position, and all the assessements were done by the same x-ray technician using the same protocoll at each time point as follows:

The radiostereometric examinations were performed with use of two simultaneously exposing (within 0.3 s) roentgen tubes angulated at about 40 ° to each other. All examinations were done using an Adora radiographic system (NRT-Nordisk Røntgen Teknik A/S, Hasselager, Denmark) and exposed at 133 kV and 5 mAs, with the use of an uniplanar RSA calibration cage (cage 77, UmRSA Biomedical, Umeå, Sweden). Digital screens (Canon CXDI-50RF, 5.9 pixels, 4096 grayscales, 12-bit) were placed underneath the hip. The three-dimensional position of each marker and the relative movement of the marked fracture and implant components were calculated using specially designed software (UmRSA Biomedical, Umeå, Sweden). In summary, the RSA method enables the accurate and precise determination of position of all RSA the marker beads relative to one another, to be derived from the stereo pairs of X-ray pictures obtained at each time point.

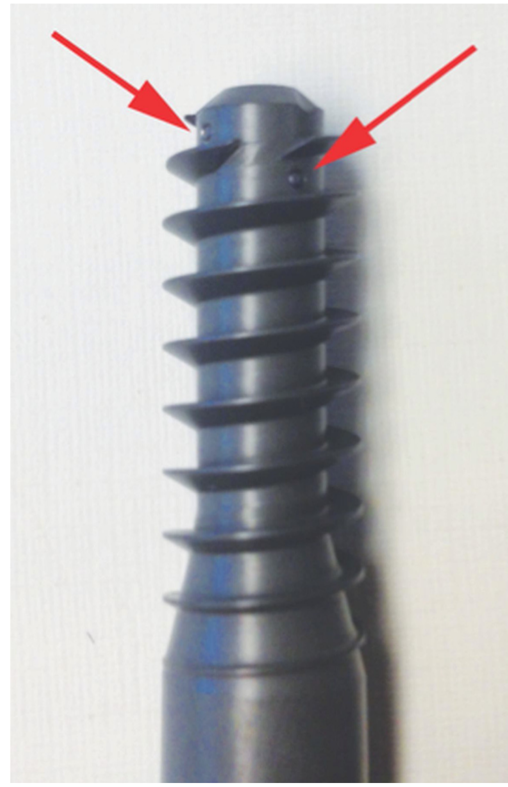

Fig. 1. Lag screw marked with 2 tantalum beads at its proximal end.

The condition number calculated at each RSA examination is a measure of marker distribution which influences the resolution of the measurements. High condition numbers indicate poor marker distribution, while low condition numbers indicate adequte marker distribution. In this study, the accepted median condition number for markers in the femoral head were 50 (range 29–84, n = 20) and for the femoral shaft 78 (range 44–151, n = 8). The corresponding condition numbers for the intramedullary nail (n = 19) and lag screw (n = 20) were 116 (115–120) and 182, range (176–209), respectively. In patient number 4 one bead in the distal tip of the nail was not visible at 6 months follow-up and the condition number increased to 221, thus, this patient was excluded from the evaluations of movements including the nail. The accepted mean error of rigid body fitting was less than 0.35 mm.

The following movements were analysed (Fig. 2):

1. Translations of the proximal tip of the lag screw in the femoral head. They were analysed as the average translations in the femoral head of the two tantalum markers placed in the proximal tip of the lag screw (point motion). The analysis was made along the anatomical axes.