SICOT Online Report E022
Accepted February 12th 2003

Experimental test of primary stability of the Wagner SL stem

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Abstract

We tested post-mortem the resistance against subsidence in vitro. Increasing axial load was applied through the femoral head by means of a compression device. One stem, which was firmly implanted into a remoulded cone proximal to the isthmus, sustained an axial load of 4.4 kN without subsidence. The second stem was implanted post-mortem distal to the isthmus in a femur with cortical defects requiring several cerclage wires to secure the partially fissured bone. It sustained only 0.8 kN before subsidence. Weight bearing after implantation of a revision stem must be adapted to the quality of the bone stock and the level of anchorage.

Introduction

The SL revision stem according to Wagner is a frequently used implant for bridging proximal femoral defects [1-3, 8]. The fixation should be performed preferably by fixation of the stem along the distal end over a length of 8-12 cm. This provides sufficient stability and a safe load transfer [1, 8]. A three-point locking along the antecurvation of the femur is less safe. The SL revision stem has shown a substantial number of stem subsidences. In our own study 6% of the stems had to be revised [1]. To prevent subsidence of the stem our patients are instructed to bear partially weight (15 kg) during the first six weeks and then to increase up to full weight bearing during the next six weeks. In order to determine the primary postoperative stability, two SL revision stems were studied in a post-mortem situation testing the resistance against subsidence in vitro.

Material and Method

Case 1: A 78 year old male patient died 7 days after a revision total hip arthroplasty. The indication for the revision arthroplasty (right side) was aseptic loosening after primary implantation of a cemented titanium stem. Due to a substantial loss of proximal femoral bone stock, a Wagner SL revision stem was implanted. After the application of a cerclage wire to secure the cortex, it was possible to ream a cone of 10 cm in length which allowed a high energy impaction of the stem (Wagner SL revision stem 225/19 mm) (Fig. 1).

Fig.1. (a) Preoperative radiograph of case 1 with osteolysis and loss of bone stock, (b) postoperative radiograph showing the SL stem.

Case 2: A 75 year old female patient died two days after the first step of a two stage revision arthroplasty (left side). The first operation included removal of the implant, securing the partially fissured cortex by cerclage-wires and implantation of a temporary custom-made cement spacer. As there was substantial loss of bone stock through the isthmus of the femur with several perforations of the cortex, it was planned to implant a Wagner SL revision stem in a second step after antibiotic treatment of a chronic infection associated with the implant (E. coli). After the explantation of the femur during autopsy the stem (Wagner SL revision 345/16 mm) was implanted post-mortem according to the original plan (Fig. 2).

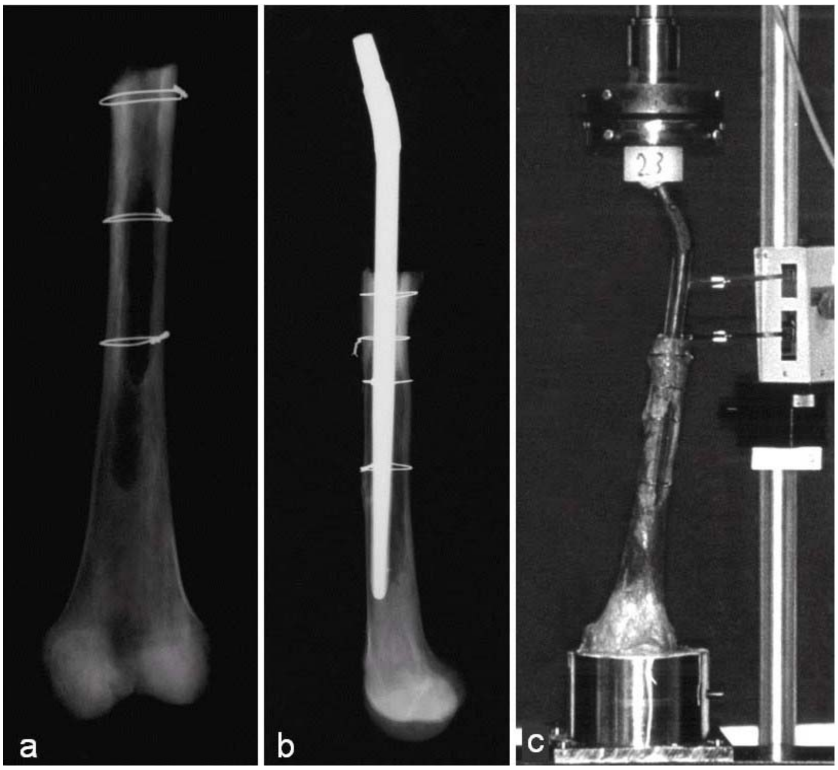

Fig.2. Case 2: (a) Radiograph of the femur after removal of the spacer showing large osseous defects in the middle third of the femoral shaft. (b) implantation of SL stem far distally to the isthmus of the femur. The femur (c) with SL stem mounted in the measuring device.

Biomechanical testing:

In case 1, the distal part of the femur was cut above the epiphysis and was cemented (Palacos) into a metal cup as far as the tip of the prosthesis whereas in case 2 the epiphysis itself was cemented into a metal cup (Fig. 2). In both cases the axis of the femoral diaphysis had a physiological valgus angle of 6° which resulted in a physiological load of the femur [9]. After fixation into the load measuring device, axial load was applied through the original head of the prosthesis. The load was increased by 0.02 kN / sec. The sensors which measured the distance were placed at the head of the prosthesis and the distal end of the femur in case 1. In case 2 the sensors were placed 3 cm apart at the femur and the prosthesis which allowed to measure the subsidence only. The measurement devices recorded a load and a distance graph. In case 1 four tests with increasing maximum force (up to 4.4 kN) and in case 2 one test with a maximum load of 1.125 kN were conducted.

Results

The maximum axial load applied in case 1 was 4.4 kN. Measurements were then stopped because no plastic deformation or subsidence was recordable. The graph showed initially an almost linear shortening due to elastic deformation (valgus position) of the stem and the prosthesis (Fig. 3).

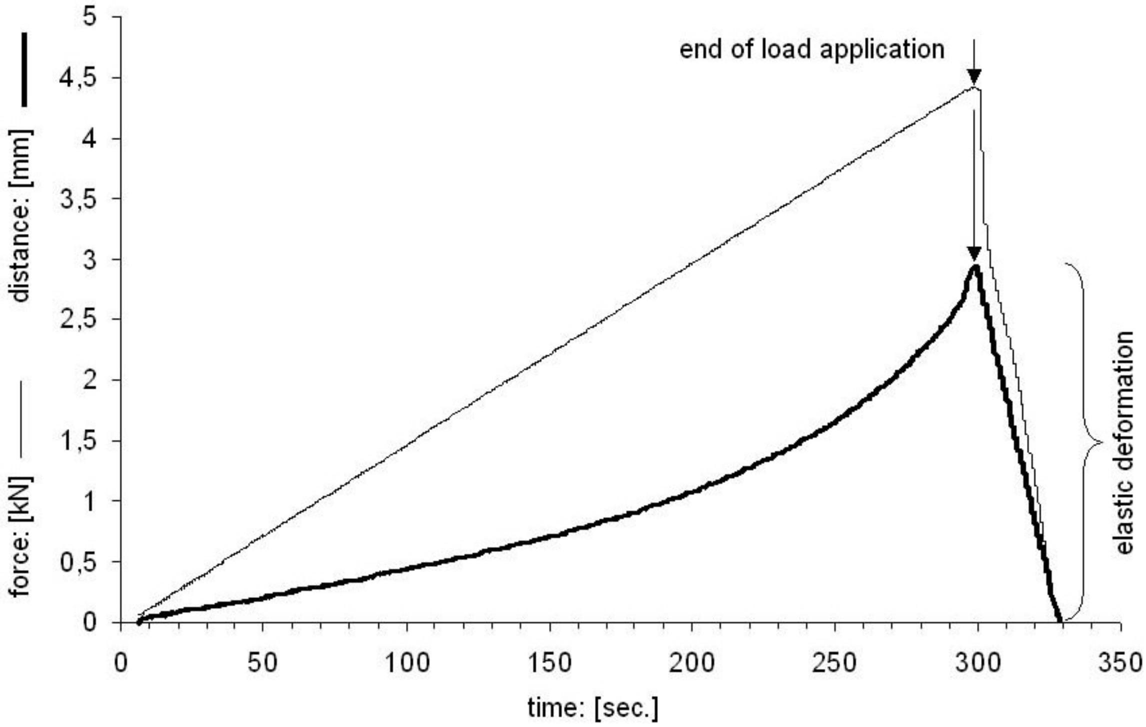

Fig. 3. The loading curve of case 1 is showing a linear increase of load application. The elastic deformation (distance) of the whole femoral shaft and prosthesis is showing an almost linear increase up to 1 kN.

It showed a further increase after the load passed beyond 2 kN due to an obvious bowing of the stem. After the load application was stopped the prosthesis and bone returned to the initial position. The graph showed only elastic deformity behaviour in all measurements and was stopped at 4.4 kN. No subsidence was detectable.

The maximum load applied in case 2 was 1.125 kN. There was no subsidence recordable up to 0.8 kN. From 0.8 to 1.125 kN the stem subsided 1.2 mm continuously. Above 1.125 kN the stem became unstable and measurements were stopped (Fig. 4).

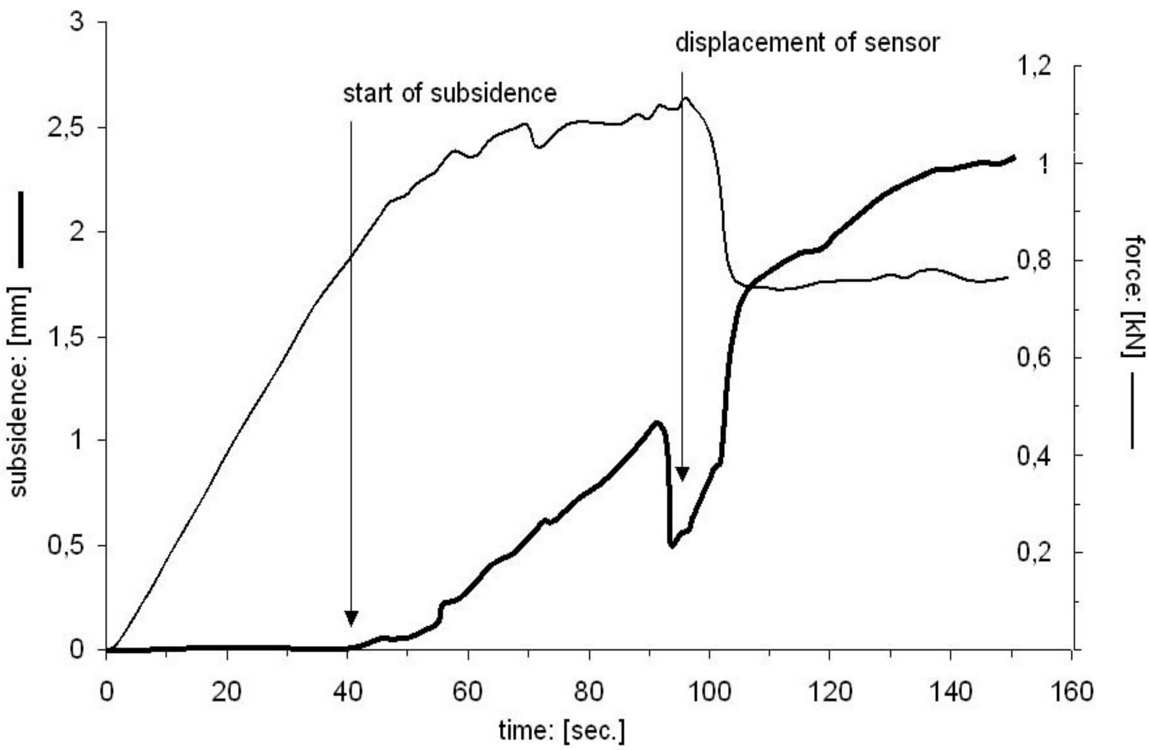

Fig. 4. The loading curve of case 2 is showing a linear increase of load application up to 0.8kN. Thereafter the stem started to subside

Discussion

The subsidence of the Wagner SL revision stem leading to revision has been described several times [1, 4, 5]. A subsidence of less than 1 cm in the first 3 months as well as the surgical approach did not influence the further outcome [3]. However, if there was a subsidence of more than 1 cm, there was a 50% chance that prostheses had to undergo revision [3]. The primary stability of the two cases which were investigated differed considerably according to the quality of bone stock and fixation of the implant and therefore it is important to adapt the postoperative weight bearing.

Rashmir et al. [6] showed that the force required to implant the femoral stem correlated with the force required for stem subsidence. The morphology of the stem also correlated with the subsidence rate of stems. Femora with a stovepipe morphology were six times more likely to show subsidence than implants in femora with normal appearance and 72 times more than implants in champagne- fluted femora. This supports our results that a well moulded cone-like shape of the femur requiring a strong force for implantation provides high primary stability of the implant as in case 1. However when a fixation of the prosthesis distal to the isthmus of the femur is necessary, it is possible to ream a cone of only 3 to 5 cm length. Large bone stock defects or thin corticalis in the diaphysis require additional cerclage-wires which provide a much less stable implantation as shown in case 2.

In vivo measurements of joint reaction forces acting on a total hip arthroplasty during normal gait (0.9 m/sec) showed forces around 1200 N corresponding to 1.8 fold body weight in both heel strike and push off phases [7]. A faster cadence of walking (1.3 m/sec) further increased the joint reacting forces up to 1800 N. Even the forces during the swing phase reached almost 50% of the forces during the stance phase [7]. According to these results the primary stability of case 1 would have been sufficient to resist forces occurring during normal gait, whereas in case 2 a partial weight bearing postoperatively would have been appropriate.

It remains unclear whether a high primary stability remains the same during the first postoperative year or whether bone remodelling leads to a weakening of the primary fixation of the stem during this period. However, our results indicate that a partial weight bearing of 15 kg is very likely to be tolerated as it is far below the maximum strength measured here.

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