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Strength of femoral neck fracture fixation

Comparison of six techniques in cadavers

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A neck osteotomy parallel to the femoral shaft was made on 36 cadaveric femora using the contralateral intact femur as a control. The osteotomies were fixed using a Thornton nail, two von Bahr screws, three Gouffon screws, three Knowles pins, a Haukebø compression screw, or an AO compression screw. The femora were then tested for bending strength using the load ratio test/control at 2- and 5-mm displacement as an expression of the relative strength of the osteosynthesis. There was no difference between the von Bahr, Haukebø, and the AO screws. These implants gave stronger fixation than the Thornton nail, Gouffon screws, and Knowles pins. The Thornton nail was stronger than three Gouffon screws or Knowles pins. The relatively stronger compression hip screws were thus not superior to two optimally placed 5-mm screws.

The best way to stabilize a fracture of the femoral neck is still debatable. Several strong implants based on the sliding screw principle have recently been introduced (Frandsen 1979, Nordkild and Sonne-Holm 1984, Svenningsen et al. 1985). However, factors other than implant strength should not be neglected, notably the strength of bone and the exactness of reduction (Frandsen 1979). We have compared the strength of compression hip screw systems with that of simple nailing and multiple pinning.

Material and methods

Thirty-six pairs of macroscopically normal cadaveric femora (60–87 years, 18 females, 18 males) were used, six pairs in each group. A neck osteotomy parallel to the femoral shaft was made on one femur of each pair (Figure 1). The six osteotomies in each group were fixed using different implants (Figure 2). All the implants were inserted in a 140° angle to the shaft of the femur. Standard techniques were used following the instructions of the producer. The Thornton nails rested on the calcar femorale. One von Bahr screw rested on the medial calcar; the other screw had a proximal position. The Gouffon and Knowles pins had two screws distally resting on the calcar and one proximal screw. The Haukebø compression screw was placed rather centrally, and had a supplementary lag screw proximally.

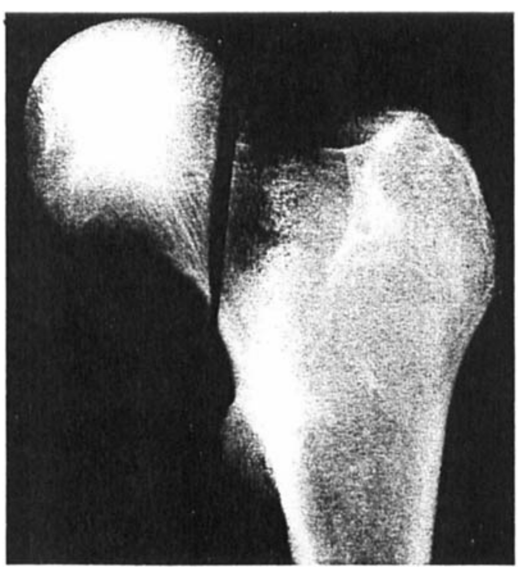

Figure 1. A neck osteotomy parallel to the femoral shaft was made on one femur of each pair.

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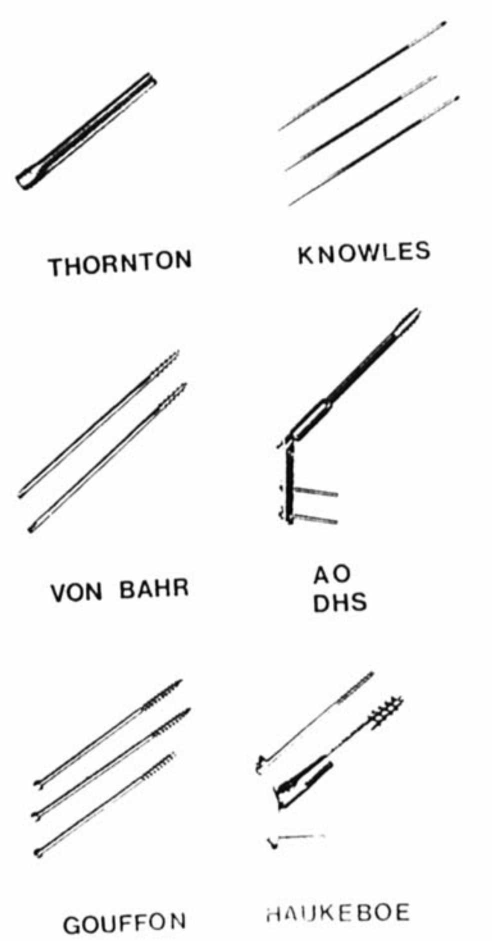

Figure 2. Different types of metal implant used in the fixation of femoral neck osteotomies.

Figure 3. Thirty-four of 36 control femora had vertical subcapital fractures. Bone biopsies were taken after the fracture occurred.

The AO screws were also placed rather centrally in the femoral neck. All the pins/screws were parallel to each other.

Between the different stages in the experiments, the bones were kept in a freezer at −18°C. (Sedlin and Hirsch 1966). After 8–10 hours at room temperature, the femora were tested in an Instron machine (TTMM 5 ton, Universal Material Testing Machine), mounted with the condyles resting on the horizontal plane. The angle between the femoral shaft and the bending load was 15–20 degrees. The vertical load was applied on the top of the femoral head with a speed of 5 mm/min. Thus, the force applied mimicked the longitudinal static forces in vivo. Except for the interfragmentary compression on the osteotomies exerted by sliding screws, no compression was applied perpendicular to the osteotomies. The measured loads at 2- and 5-mm deformation at the osteotomy side were compared with the corresponding values on the control side and with the strength at fracture of the control femur. The ratios between loads recorded on the two sides were used as an expression of the relative strength of the osteosyntheses. The fractures produced on the control side were vertical fractures in the very lateral part of the neck (Figure 3), except for one fracture of the femoral shaft (female, 87 years) and one subtrochanteric fracture (male, 71 years). The loads at fracture on the control side varied from 2.75 to 9.61 Newtons.

Analysis of variance (ANOVA) was used in the statistics, which included all the ratios test/control. The reasoning behind this method was the possibility to sort out the variational differences between the single femoral heads from the operation methods used. In this way it was possible to study the variational differences and resulting means between the nailing procedures used.

Table 1. Loads and load ratios test:control at 2- and 5-mm displacement. Figures are mean kN (SD)

Osteosynthesis	F/M	2-mm deformation			5-mm deformation		
		Osteotomy	Control	Ratio	Osteotomy	Control	Ratio
Thornton nail	3/3	0.40 (0.24)	1.14 (0.30)	0.37 (0.23)	0.70 (0.50)	2.73 (0.80)	0.26 (0.2)
von Bahr screws	3/3	0.57 (0.18)	1.01 (0.29)	0.59 (0.17)	0.91 (0.30)	2.61 (0.94)	0.36 (0.1)
Gouffon screws	1/5	0.34 (0.18)	1.60 (0.46)	0.22 (0.80)	0.71 (0.48)	3.86 (1.19)	0.18 (0.9)
Knowles pins	3/3	0.34 (0.20)	1.72 (0.35)	1.19 (0.10)	0.46 (0.28)	3.98 (0.61)	0.11 (0.7)
Haukebø screw	4/2	0.54 (0.34)	1.51 (0.52)	0.42 (0.32)	0.92 (0.52)	3.45 (1.02)	0.30 (0.2)
AO screw	4/2	0.59 (0.27)	1.39 (0.31)	0.42 (0.17)	1.10 (4.0)	3.08 (0.76)	0.34 (0.1)

Results

The load ratios at 2- and 5-mm displacement showed that 2 von Bahr screws, the Haukebø screw, and the AO device were superior to the other impants ($P < 0.001$, Table 1). The Thornton nail was superior to the Knowles and Gouffon pins ($P < 0.001$).

The loads needed to deform all the 36 osteosyntheses by 2 and 5 mm were pooled and compared with the corresponding values and the maximal strength of the respective control femur (Figure 4). Independent of the various osteosynthesis implants, the strength of the control femur was positively associated with the stability of the osteosynthesis as measured at 2- and 5-mm deflection of osteotomy compared with that of intact femur or maximal strength of intact femur ($P < 0.005$, chi-square test).

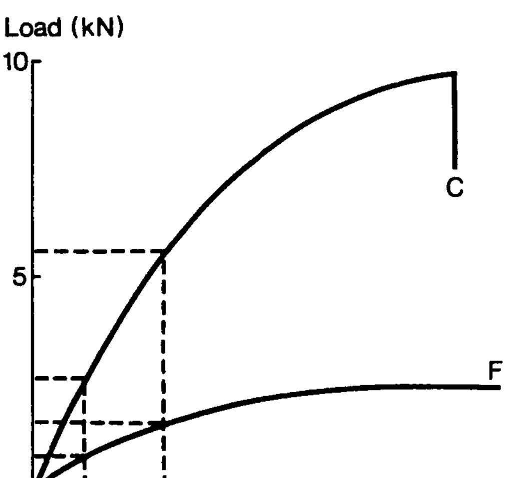

Figure 4. Typical load-deformation curves for a fixed femoral osteotomy and its control femur. Loads at 2- and 5-mm displacement are marked by slotted lines.

Discussion

The mechanical properties of internally fixed femoral fractures depend not only on the strength of the implant, but also on the type of fracture and the bone itself (Dalén et al. 1976, Frandsen 1979, Frankel 1959, Frankel 1960). We recorded the loads at 2 and 5 mm of deformation, assuming that a deformation more than 5 mm is unacceptable. Our finding that the strength of osteosynthesis in the femoral necks was not increased by hip compression screws with side plates compared with two von Bahr screws with a wing diameter of 7 mm confirms previous observations (Engesæter et al. 1984, Frandsen 1979, Mackechnie-Jarvis 1983, van Audekercke et al. 1979). We also found that the von Bahr screws gave stronger fixation than the Thornton nail, Gouffon Screws, or Knowles pins.

Using cadaveric upper femora, Engesæter et al. (1984) found no difference between von Bahr screws and the Zimmer compression hip screw provided with a lag screw proximally; the osteotomy was made perpendicular to the femoral neck and the implant inserted at an angle of 130°. We used an osteotomy parallel to the femoral shaft, which is most unfavorable for the implant. Others have found no difference between multiple pinning and a hip compression screw (Mackechnie-Jarvis 1983, van Audekercke et al. 1979). In the latter study, the triflange nail was inferior to the multiple pinning/sliding screw. Further, Frandsen and Madsen (1983) showed experimentally that axial compression of a hip screw may be harmful in osteoporotic femoral necks because the compression increases to a certain point, then the screw grip loosens and the strength of the osteosynthesis subsequently decreases.

In addition to the strength of the implant, the structure of the bone seems to be important. We found that the strength values of all the osteosyntheses compiled were associated with the maximal strength of the control bone. This indicates that, in addition to the rigidity of the implant, bone fragility also affects the stability of the femoral neck osteosynthesis. Osteosynthesis with a hip compression screw is a relatively large surgical trauma (Frandsen and Madsen 1983). In addition, from a mechanical point of view, two screws in the femoral neck may give a stronger rotational stability than one central screw.

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