Stability of femoral neck osteosynthesis

Comparison of fixation methods in cadavers

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Fixation of vertical femoral neck osteotomies in 50 cadavers was performed with either von Bahr screws or a sliding hip compression screw. One specimen from each pair of femora was used for the osteotomy, the other serving as an intact control. At 0.05 r of torsion the load-deformation test showed that three von Bahr screws provided the strongest fixation, and this was confirmed by the the ultimate torsional moment test. Regardless of positioning, even two von Bahr screws were stronger than the sliding compression screw with or without an additional lag screw. The results indicate that the best torsional stability in femoral neck fractures can be obtained with three 5.5-mm screws.

We report torsional stability tests in 50 cadaveric femoral neck osteotomies fixed with three different von Bahr screw configurations and hip compression screws with or without an additional proximal lag screw.

Material and methods

Fifty pairs of macroscopically normal femora were harvested from fresh cadavers, stripped of soft tissue, and stored at minus 18 °C until testing (Sedlin and Hirsch 1966, Table 1). Prior to the experiments, the femora were thawed 8 hours at room temperature. In one femur of each pair, a vertical neck osteotomy was made; the other femur was used as an intact control. After an exact reduction, the osteotomies were fixed under direct vision with parallel placement of different types of screws. The following five techniques were used: von Bahr screws (shank diameter 5.5 mm, thread diameter 7.5 mm) in three different configurations: (a) one proximal and one distal screw, (b) like (a) but with the distal screw perforating the medial cortex of the neck, and (c) one screw proximal and two distal screws, and a Richards hip compression screw with or without an additional AO cancellous lag screw (shank diameter 4.5 mm, thread length 16 mm) proximally (Figure 1).

All the screws were inserted at a 140° angle in relation to the femoral shaft. All the screw holes were predrilled after making the osteotomy; the predrilling for the sliding screw was done to the subchondral bone of the femoral head. All the distal von Bahr screws had medial calcar support. The compression screw was attached to a 140° side plate with two holes. The compression screw was tightened just enough to obtain contact on the osteotomy surface, but impaction was avoided as recommended for elderly patients (Frandsen and Madsen 1983, Frandsen et al. 1984). The parallel lag screw was tightened according to the same principle. All the screws were driven into the subchondral bone of the femoral head, under direct vision, within 5 mm of its articular surface.

After the fixation of the osteotomy, the femoral head was cemented in a polyurethane block with its surface parallel to the osteotomy and the rotational axis passing through the center of the femoral neck. To avoid slipping under torsion, two Steinmann pins were inserted through the femoral head prior to the cementing of the control specimen. The polyurethane block fitted exactly into the rotational testing device on an Instron TTMM 5 ton Universal Materials Testing Machine. The specimens were mounted on the Instron machine with the femoral shaft fixed horizontally and the rotational axis passing through the center of the femoral neck. The torsional testing device ran with a

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Table 1. Characteristics of 50 cadaveric femora used in the experiments. Figures are mean *SD*

Type of fixation	Femora n	Female/ male	Age (yr)	Height (cm)	Weight (kg)
Two von Bahr screws (1 proximal, 1 distal)	10	9/1	72 *10*	163 *4*	58 *12*
Two von Bahr screws (1 proximal, 1 distal penetrating calcar medially)	10	8/2	82 *9*	162 *11*	57 *19*
Three von Bahr screws (1 proximal, 2 distal)	10	6/4	77 *16*	162 *13*	59 *9*
Hip compression screw with side plate	10	3/7	67 *10*	167 *7*	58 *8*
Hip compression screw with side plate and lag screw	10	6/4	72 *11*	163 *14*	62 *21*

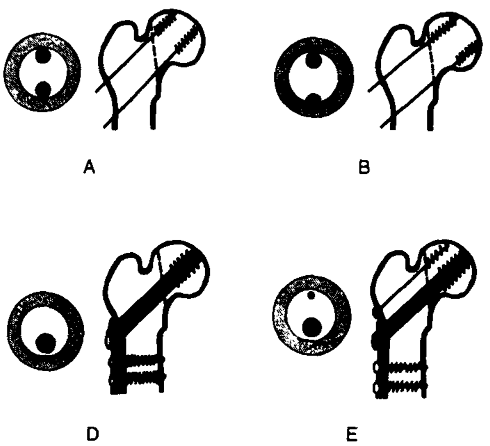

Figure 1. Different implants used in fixation of 50 femoral neck osteotomies.
A. Two von Bahr screws (5.5 mm).
B. Like A, but medial calcar penetrated.
C. Three von Bahr screws.
D. Richards' hip compression screw.
E. Like D, additional AO lag screw (4.5 mm).

speed of 0.26 r (15°/min), and the load-angular deformation was continuously recorded on a X-Y writer. The fixed osteotomies were tested to 0.52 r (30°) of torsion, and the control femora were tested to fracture. The following data were recorded for each specimen: torsional moment at 0.05 r (3°) and at maximal load, torque angle at maximal load, and the torsional stiffness. The ratio test/control femur was used as an expression of the relative strength of the osteosynthesis.

Analysis of variance (ANOVA) was used in the statistical analysis of all the indices tests/controls. Least Significance Difference Pairwise Comparison Test (LSD) was used when the ANOVA indicated significant differences between the groups. Residual analysis in the form of plotting of the residuals versus type of osteosynthesis was calculated for all the groups.

Results

At 0.05 r (3°) of rotation, the torsional moment indices showed that the construct with three von Bahr screws was the strongest and that the results with the other osteosynthesis methods varied insignificantly (Table 2). The torsional moment indices at maximal load confirmed that three von Bahr screws were stronger than all of the other osteosyntheses ($P < 0.05$), and that the two different configurations of two von Bahr screws were equal but stronger than the compression screw with or without an additional lag screw ($P < 0.05$; Table 3). The angular deformation indices at maximal load and the respective indices for torsional stiffness did not vary between the groups. Maximal torsional moment on the control femora correlated with the weight ($r = 0.55$, $P < 0.05$) and height ($r = 0.62$, $P <$

Table 2. Torsional moments at 0.05 rad and torsional stiffness of five osteosynthesis techniques. Figures are mean *SD*

Type of fixation	Femur pairs n	Torsional moment at 0.05 rad (Nm)			Torsional stiffness (Nm"/r)		
		Osteotomy	Control	Ratio	Osteotomy	Control	Ratio
Two von Bahr screws (1 cranially, 1 caudally)	10	9.9 *6.6*	32.4 *6.7*	0.32 *0.23*	7.5 *4.9*	26.4 *7.1*	0.30 *0.19*
Two von Bahr screws (1 cranially, 1 caudally penetrating calcar medially	10	8.0 *2.6*	27.5 *7.6*	0.31 *0.14*	7.7 *4.3*	23.9 *8.6*	0.36 *0.25*
Three von Bahr screws (1 cranially, 2 caudally)	10	16.0 *5.7*	36.3 *13.7*	0.49 *0.23**	14.0 *7.0*	31.3 *15.3*	0.51 *0.28*
Hip compression screw with side plate	10	9.7 *2.3*	38.2 *13.5*	0.28 *0.97*	9.3 *3.8*	32.6 *16.4*	0.34 *0.16*
Hip compression screw with side plate and lag screw	10	11.5 *5.6*	37.4 *9.7*	0.30 *0.14*	10.2 *6.5*	30.9 *9.7*	0.32 *0.20*

* Indicates significant difference from other groups ($P < 0.05$, LSD test).

Table 3. Ultimate torsional moments and torsional angles at ultimate load of five osteosynthesis techniques. Ratios test/control are indicated. Figures are mean *SD*

Type of fixation	Femur pairs n	Ultimate torsional moment (Nm)			Torsional angle at ultimate load (rad)		
		Osteotomy	Control	Ratio	Osteotomy	Control	Ratio
Two von Bahr screws (1 cranially, 1 caudally)	10	25.1 *10.2*	65.5 *19.9*	0.38 *0.11*	3.3 *1.4*	1.9 *7.4*	2.0 *1.1*
Two von Bahr screws (1 cranially, 1 caudally penetrating calcar medially	10	19.0 *6.4*	51.2 *22.4*	0.39 *0.11*	3.6 *1.6*	1.8 *7.7*	2.2 *1.4*
Three von Bahr screws (1 cranially, 2 caudally)	10	40.0 *11.1*	84.6 *20.6*	0.49 *0.16*	3.3 *2.1*	2.8 *1.8*	1.4 *1.1*
Hip compression screw with side plate	10	20.3 *6.0*	87.1 *23.8*	0.24 *0.50*	2.7 *1.6*	2.1 *7.7*	1.5 *9.5*
Hip compression screw with side plate and lag screw	10	17.3 *8.1*	84.4 *36.7*	0.20 *0.62*	2.3 *1.7*	2.0 *1.1*	1.3 *1.2*

0.05), but not with the age of the cadavers. The metal devices were removed from the specimens after testing. There was no indication of metal fatigue. All the specimens demonstrated that the main destruction of bone occurred in the loose trabecular bone in the trochanteric-cervical area. All the control femora fractured vertically in the neck at an ultimate rotational strength of 74.5 ±28.1 Nm (mean ±SD).

Discussion

Frankel (1959) found that after osteosynthesis of experimentally created femoral neck fractures, the bone absorbed 75 per cent of the load applied to the femoral head and the appliance absorbed the remaining 25 per cent. The variations in bone density from individual to individual could, for this reason, mask any advantage of one fixation method over the other. We found good correlation of intact bone strength with height and weight, but not with age. To avoid this problem, a paired comparison (Engesæter et al. 1984) or preloading with each femur as its own control (Swiontkowsky et al. 1987) has been used. Use of intact bone, as in the present study, simulates the clinical stress distribution best. In previous studies, we have shown that the bone density between right and left femora varies insignificantly (Husby et al. 1987).

When using hip compression screws with or without lag screws, we did not apply more compression over the osteotomy site than necessary for a good bone-to-bone contact; compression of osteoporotic bone may be harmful as shown both experimentally by Frandsen and Madsen 1983 and clinically by Linde et al. 1986. The reason is that compression increases to a certain limit, then the screw grip loosens, and the strength of the osteosynthesis subsequently decreases.

All the control fractures were vertical spiral fractures of the femoral neck. This is not surprising due to the concentration of shearing forces in this area in our torsional model. Interestingly, a quite similar fracture appears in the femoral neck when the femur is subjected to a vertical load either as a constant force (Alho et al. 1988) or in repeated cycles (Griffiths et al. 1971). The vertical shearing fracture in the femoral neck seems to be the common response to loading in this area.

Our study suggests that the compression screw is unreliable for femoral neck osteotomies when tested in rotation. Surprisingly, fixation was not improved when supplemented with a proximal cancellous screw. This may be because the distance between the sliding screw and the lag screw is less than between the von Bahr screw or because the diameter of the lag screw is too small to provide adequate holding power (Frandsen et al. 1984).

A number of authors have reported (van Audekercke et al. 1979, Engesæter et al. 1984, Swiontkowski et al. 1987, Husby et al. 1987) that the bending strength of the osteosynthesis in femoral neck fracture does not increase with the use of sliding screws even with a supplementary lag screw, or by using more than three screws (van Audekercke et al. 1979). However, increasing the number of screws from 2 to 3 and increasing the screw diameter, thus increasing the total amount of metal in the femoral head, may be deleterious to the femoral head vitality (Strømquist et al. 1983, Linde et al. 1986).

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