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Stability of fixation in femoral neck fractures

Comparison of four fixation devices in vivo and in cadavers

On human cadaveric femora, internal fixation of cervical osteotomies was performed with four different devices. With the use of a lever, a static force was applied through the acetabulum to the osteotomy site. Motion at the osteotomy site was measured by two strain gauges. The compression force necessary to inhibit motion at the osteotomy site during the fixation procedure was measured. This force was lower with a hook pin than with the other devices.

During surgery in 12 patients with displaced femoral neck fractures, the forces holding the fracture surfaces together were measured with a dynamometer. The force at which widening of the fracture gap was observed by fluoroscopy was recorded. In seven fractures, the mean compression force was 110 (60–170) N. The remaining five fractures did not open up when pressures of up to 200 N were applied. These forces were always greater than the hook pin forces measured in the cadaver experiments, but often less than the forces obtained with the other devices.

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Introduction

The cause of necrosis after fracture of the femoral neck is a lack of blood supply to the femoral head. When the femoral neck fractures, the transosseous blood vessels are disrupted. This means that the circulation, at least initially, depends on the retinacular vessels, because the ligamentum teres provides only in rare cases adequate circulation for supply of the whole femoral head (Sevitt & Thompson 1965). In this situation, it is clearly important to prevent additional vascular damage. Such damage may occur because of fracture separation or rotation of the femoral head when the fixation device is introduced (Calandruccio & Andersen 1980, Strömqvist et al. 1984a).

In cervical hip fracture the incidence of femoral head necrosis is associated with the type of fixation device (Linton 1944, Barnes et al. 1976, Frandsen & Andersen 1981, Svenningsen et al. 1984, Strömqvist et al. 1984a). With technetium scans obtained 1 to 2 weeks postoperatively, Strömqvist et al. (1983) found that the femoral head isotope uptake was greater after pinning than after nailing, although tracer techniques showed that the preoperative femoral head circulation was the same.

Whereas all fixation methods, to some degree, may cause motion at the fracture site during the osteosynthesis procedure and thus may influence the blood supply to the femoral head, some will do so more than others.

The purpose of our study was to use four different methods of internal fixation and to measure the minimal compression force required to inhibit motion at the fracture site.

Materials and methods

Cadaver study. Fresh human autopsy specimens of the acetabulum and proximal femur were taken from 15 adults. The specimens had no evidence of bony abnormality or arthrosis in the hip joint. They were kept frozen until the testing was performed. A subcapital osteotomy was made perpendicular to the femoral neck following removal of a part of the capsule. A v-shaped clamp was used to fix the femoral shaft to a board (Figure 1). The board itself was rigidly clamped vertically in a heavy duty bench vice. The femur was orientated with its medial surface facing the board. The head and neck of the femur protruded over the top of the board towards the back of the apparatus. The hemi-pelvis was orientated in the correct anatomic plane and held in place by a lever. Static forces of different magnitudes could be applied by the lever through the acetabulum and hence on to the osteotomy site. Motion at the osteotomy site was measured by two highly compliant displacement gauges. These were constructed by welding needles on to spring steel hemicircles. were bonded to the steel. The displacement gauges were applied across the osteotomy, one at right angle and the other obliquely. The strain gauge elements were connected to a constant current bridge, and the variations in the electrical signal caused by displacement of the femoral head during internal fixation were amplified,

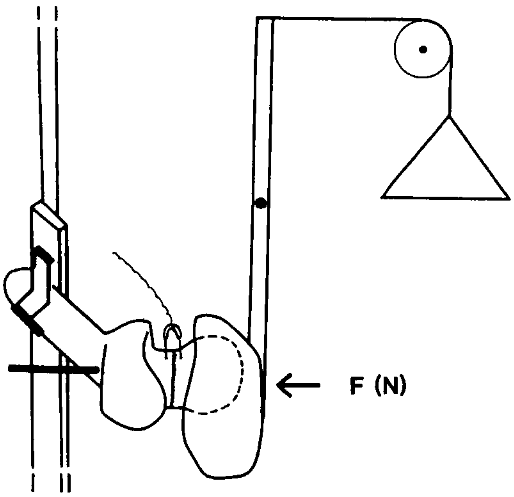

Figure 1. The fixation of the femoral neck, the application of force across the osteotomy by a lever and the placement of the strain gauge. The force at which displacement of not more than 0.1 mm occurred at the osteotomy site was measured.

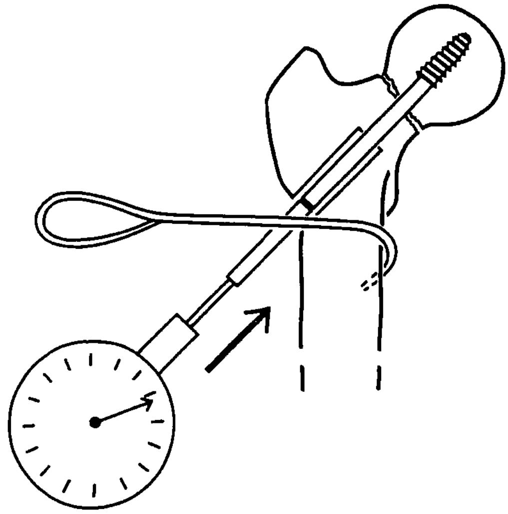

Figure 2. The measurement of compression forces across the fracture site during surgery in 12 patients with displaced femoral neck fracture.

filtered, and recorded on an oscilloscope. The signal was calibrated so that displacements of 0.1 mm and above could be detected.

Four devices for fixation of femoral neck fractures were tested: 1) the hook pin (Hansson 1982); 2) the Gouffon pin (Howmedica, Inc.); 3) the four-flanged nail (Rydell 1964); and 4) the Richards sliding hip screw.

All the fixation devices were placed according to the manufacturers' operation manuals. If the procedure required impaction of the nail during insertion, the impact force was reproduced by a hammer pivoting about its distal end through an arc of 90°.

The same specimen was used with two to three different methods in random order. In eight of the specimens, four various fixation procedures were performed, the last being one of the preceding methods (Table 1). The previous fixation device was extracted before each of the subsequent procedures. Radiographs were used to ensure that the nail, pin, or screw did not enter a previously made track in the femoral head. It was also determined that the tracks were sufficiently separated and that the fixation device was adequately placed into the head every time. We defined this as the tip of the implant being about 5 mm from the articular surface.

During the internal fixation the compression forces applied by the lever were accordingly increased and decreased to find the minimal force at which displacement of not more than 0.1 mm occurred during the entire internal fixation procedure for each specimen. The force measured was the force necessary to prevent

Table 1. The compression force applied across the osteotomy necessary to inhibit movement of the femoral head during different methods of internal fixation

Specimen number	Force (N)			
	A n=14	B n=13	C n=13	D n=13
1	35	100	120	–
	40			
2	40	130	120	–
		110		
3	50	85	170	–
4	55	100	100	–
5	40	80	160	–
			160	
6	40	75	–	175
				170
7	35	70	–	175
				195
8	50	150	–	225
				195
9	65	140	–	235
				295
10	55	100	–	215
				200
11	60	–	180	–
			120	
12	60	–	90	–
			100	
13	50	–	160	280
14	–	130	130	200
15	–	60	100	220
Mean	48	102	132	214
(SD)	(10)	(28)	(31)	(38)
p	<0,001	<0,05	<0,001	

A Hansson hook pin
B Gouffon screw
C Rydell four-flanged nail
D Richards sliding screw

motion at the osteotomy site during the internal fixation and not the holding power of the completed internal fixation. This is an indirect measure of the distracting and/or rotational forces at the osteotomy site during internal fixation.

In vivo study. Ten women and two men, aged 82 (75–90) years, with displaced femoral neck fractures were operated on in a standard fashion. At the time of internal fixation, the leg traction was removed and internal fixation was performed using a sliding hip screw and side plates with one or two screws. A sterilized dynamometer was used to apply a pressure on the barrel guide of the lag screw. Counterforce was provided with a hook around the femoral shaft (Figure 2). The force required to make a visible widening of the fracture gap on fluoroscopy was recorded as the compression force across the fracture surfaces.

Statistics. The different compression forces were compared using the Mann Whitney test.

Results

Cadaver study

The compression forces applied across the osteotomy necessary to prevent motion were less for the hook pin than for the sliding hip screw, the four-flanged nail, and the Gouffon pin (Table 1). Both the Gouffon pin and the four-flanged nail had lower values than the sliding hip screw. The Gouffon pin had a lower value than the four-flanged nail.

The devices differed, not only in the forces produced, but also how they tended to displace the osteotomy. The four-flanged nail had a tendency to cause distraction of the osteotomy during punching and when the nail and the hook were inserted. Both the Gouffon pin and the Richards sliding screw caused rotation of the femoral head.

All the fixation devices had the tendency to displace the osteotomy site when they reached the subchondral bone. The sliding screw produced most motion, notably when it reached the bottom of the drill hole.

In vivo study

In 7 cases the mean compression force across the surfaces of the femoral neck fracture was 110 (60–170) N. In the remaining 5 cases the fracture did not open up when a maximum pressure of up to 200 N was applied.

Discussion

If a femoral neck fracture is firmly locked by a tight capsule as the femur is internally rotated, there will probably be little risk of displacing the fracture during the internal fixation (Flynn 1974). However, Drake & Meyers (1984) found a torn capsule in 2 out of 12 patients with a femoral neck fracture. Nagy et al. (1975) reported a 14 per cent incidence of capsular tear in the same situation. Our experiments simulated these cases, which have the worst stability and prognosis.

In the clinical situation, two hook pins and at least three Gouffon pins are inserted in a fracture. Because we tested only one hook pin or Gouffon pin, our results are only relevant to the first pin. When the following pin is inserted, the fracture is already stabilized.

The osteotomy is obviously not completely representative of a fracture, which is much more uneven, and often multifragmental. The osteotomy surfaces probably had a lower friction coefficient than irregular fracture surfaces, and the compression force necessary to inhibit rotation was therefore probably greater in our experiments than in the clinical situation.

The results obtained with the Gouffon pin and especially the sliding screw may therefore be somewhat misleading. This could explain the reports of good clinical results with the sliding screw plate (Nordkild & Sonne-Holm 1984, Frandsen et al. 1984a).

Clawson (1964) has described rotation of the femoral head while inserting the sliding screw despite the use of a second guide pin. Rau et al. (1982) observed that the femoral head rotated during insertion of the screw and actually bent two guide pins placed across the fracture and through the joint. It is interesting to note that their patients were comparatively young, with a mean age of 62 years, and therefore probably had less osteoporotic femoral heads yielding a greater resistance to the screw insertion. However, with the use of two extra Knowles pins, Ort & LaMont (1984) could avoid femoral head rotation during sliding screw osteosynthesis.

The in vivo experiments were performed to determine the clinical relevance of our cadaver experiments. With our method, we recorded a compression force in more than half of the fractures. These forces were always greater than the hook pin forces measured in the cadaver experiments, but often less than the forces obtained with the other devices. In 5 of the 12 patients, no widening of the fracture gap could be observed at a distractive force of 200 N. In these cases any of the four tested internal fixation methods may have been used without a risk of implant-induced fracture displacement. There was no risk of displacement of the screw during these in vivo measurements because we always kept the pressure far below the pull out force for the sliding screw as found by Frandsen et al. (1984b).

In our study the hook pin was less traumatic than the other devices. Strömqvist et al. (1984a, b) found that the majority of femoral heads with intermediate circulation before surgery had more vascular damage postoperatively. Less traumatic internal fixation probably decreases the risk of avascular complications.

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