Type of screw does not influence holding power in the femoral head

A cadaver study with shearing test

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We studied the holding power during cut-out tests of 4 different screw fixation devices of the femoral head, correlated to head size and bone density, on 48 paired deep frozen proximal femurs of fresh gross specimens. We found no significant effect of the device on the holding power. There was a significantly higher maximal load at failure in large and dense heads. It seems then unnecessary to advocate more sophisticated but also more expensive devices to fix femoral neck fractures.

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Numerous kinds of hardware for osteosynthesis of femoral neck fractures have been advocated, but there is no clinical evidence of the superiority of any of them (Parker and Blundell 1998). New devices with more efficient designs are supposed to have a better holding power in the femoral head. However, most of them were studied in experiments with pull-out tests (Frandsen and Madsen 1983, Crowell et al. 1985, Iversen et al. 1988, Larsson and Elloy 1990, Benterud et al. 1992), which may be less than optimal, since the clinically relevant forces might be shearing stresses between the femoral head and the device, due to their respective orientations. We investigated the influence of the design of 4 different screw fixation devices on the holding power in the femoral head with cut-out tests, correlated to head size and bone density.

Material and methods

56 paired deep frozen proximal femurs of fresh gross specimens were harvested. 4 pairs (n 3, 10, 11 and 12) were excluded because of macroscopic evidence of degenerative changes in the femoral head, leaving 48 paired femurs for this study. The femurs had been harvested from 13 men and 11 women, having a mean age of 68 (45–90) years, and no history of bone-related disease. Each femur was first analyzed with Densiscan (Scanco Medical, Zurich, Switzerland). Cross-sections through the head were performed perpendicular to the axis of the neck with a distance of 2.5 mm. The area of the 4 larger cross-sections was measured, and the mean value was considered as the cross-section area of the head (cm^2). Their density was measured too, and the mean value was considered as the bone density of the head (g/cm^3). Heads with an area exceeding or equal to the median area value of the whole material were considered as large heads, and the remaining heads as small ones. Heads with a bone density exceeding or equal to the median bone density value of the whole material were considered as high-density heads, and the remaining heads as low-density heads.

4 groups were then defined: group 1 (large heads with high density), 2 (large heads with low density), 3 (small heads with high density) and 4 (small heads with low density). All paired femurs had similar values and could be included in the same group, permitting paired comparisons. Each group was formed by 6 pairs of femoral heads.

4 kinds of hardware were studied (Figure 1): Gamma Nail (Kempf et al. 1993), Dynamic Hip

Figure 1. The 4 tested screws (from left to right): Gamma Nail, Dynamic Hip Screw, Uppsala Hip Screw, Ullevaal Hip Screw.

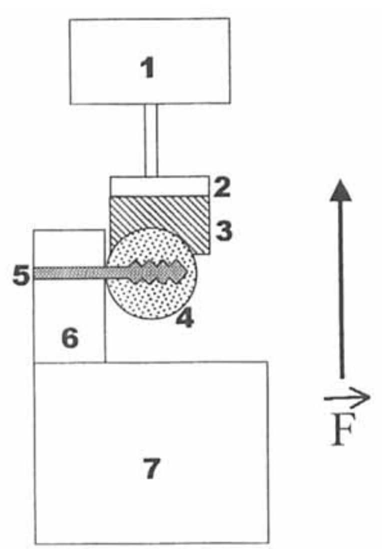

Figure 2. The experimental device. 1 load cell, 2 U-shaped metallic piece, 3 molded piece of cement, 4 femoral head, 5 tested osteosynthesis device, 6 specific clamp, 7 hydraulic jack

Screw (Regazzoni et al. 1986), Uppsala Hip Screw (Rehnberg and Olerud 1989) and Ullevaal Hip Screw (Benterud et al. 1992), resulting in 6 pairs of hardwares. Each pair of hardwares was allocated at random to one pair of femurs in each group. Each hardware in a given pair was allocated at random to the left or right side of the given paired femurs.

The femur was left at room temperature in a saline solution for 8–12 hours. The neck osteotomy was cut with an oscillating saw at its smaller part, perpendicular to the axis. Specially designed metallic clamps were used to standardize the implantation technique of each hardware according to the manufacturer's recommendations, and to fix the hardware on a hydraulic Instron press. A molded cement mantle was applied to the upper part of the head, in relation with a U-shaped metallic piece, to apply a vertical force on the upper part of the femoral head (Figure 2). The resulting load was then a shearing force between hardware and the femoral head.

Increasing load was applied on the femoral head, and the displacement of the femoral head, in comparison to the metallic support, was computerized through the Instron device, up to the hardware or fixation failure. Applied load and resulting displacement were plotted. The slope of the load-displacement diagram and the maximal load at failure were graphically determined. The influence of the device, the bone density and the head area were studied with a 3-way ANOVA test at a 0.05 level of significance. Slope and maximal load at failure were compared for each pair of devices used by paired femurs, with a paired t-test at a 0.02 significance level for multiple secondary comparisons.

Results

The mean head area was 16 (13–20) cm^2, mean bone density 0.49 (0.22–0.68) g/cm^3 and mean slope 145 (33–302) daN/mm. The mean maximal load at failure was 368 (75–598) daN (Table 1).

There was no significant effect of the device ($p = 0.2$), the bone density ($p = 0.06$) or of the neck area ($p = 0.2$) on the slope of the load-displacement diagram (Table 2). The device had no significant effect on the maximal load at failure ($p = 0.8$); there was a significantly higher maximal load at failure for large ($p = 0.04$) and dense ($p < 0.000,1$) femurs (Table 2). There was no significant difference for both slope and maximal load, when comparing the two devices of each pair used by paired femurs (Table 3).

Discussion

Stability of a femoral neck osteosynthesis is essential for a successful outcome in clinical prac-

Table 1. Experimental results

Head	Area (cm^3)	Density (g/cm^3)	G[a]	D[b]	Slope (daN/mm)	Max.load (daN)
1 R	20.3	0.41	2	1	107	260
1 L	20.3	0.42	2	4	250	285
2 R	13.5	0.23	4	1	33	75
2 L	14.0	0.22	4	3	282	118
4 R	17.7	0.52	1	1	74	404
4 L	18.9	0.50	1	2	191	481
5 R	13.1	0.43	4	2	128	330
5 L	13.0	0.43	4	1	108	348
6 R	13.8	0.63	3	3	140	345
6 L	13.7	0.68	3	2	87	226
7 R	16.8	0.55	1	4	112	414
7 L	15.6	0.63	1	2	169	438
8 R	14.4	0.65	3	1	178	525
8 L	14.8	0.63	3	3	193	560
9 R	14.3	0.41	4	4	146	253
9 L	13.3	0.42	4	2	146	255
13 R	19.5	0.43	2	2	112	410
13 L	19.1	0.45	2	3	139	325
14 R	15.6	0.55	3	4	190	413
14 L	15.7	0.61	3	1	134	490
15 R	19.4	0.47	2	1	140	483
15 L	18.9	0.49	2	2	189	490
16 R	18.6	0.44	2	1	64	265
16 L	18.0	0.39	2	3	136	289
17 R	18.8	0.63	1	3	215	536
17 L	20.4	0.54	1	4	302	598
18 R	16.3	0.43	2	3	141	388
18 L	15.9	0.44	2	4	162	400
19 R	15.5	0.46	4	3	82	326
19 L	15.8	0.44	4	4	134	336
20 R	18.4	0.50	1	1	196	338
20 L	18.5	0.55	1	4	212	410
21 R	14.6	0.59	3	1	208	385
21 L	14.4	0.61	3	2	170	365
22 R	18.9	0.50	1	1	123	432
22 L	18.6	0.55	1	3	147	520
23 R	15.3	0.54	3	3	94	369
23 L	14.9	0.53	3	4	113	450
24 R	15.8	0.54	3	4	159	496
24 L	15.6	0.51	3	2	153	373
25 R	13.8	0.47	4	4	78	240
25 L	13.4	0.46	4	1	71	225
26 R	17.1	0.31	2	4	167	275
26 L	17.2	0.30	2	2	105	198
27 R	17.4	0.47	1	2	153	424
27 L	17.5	0.50	1	3	134	438
28 R	14.6	0.44	4	2	106	335
28 L	14.2	0.44	4	3	102	323

[a] Groups: 1 large heads with high density, 2 large heads with low density, 3 small heads with high density, 4 small heads with low density.
[b] Device: 1 Gamma nail, 2 Dynamic hip screw, 3 Uppsala hip screw, 4 Ullevaal hip screw.

tice. Loading tests, using a complete femur with a fixed fracture, depend on both the holding power of the device in the femoral head and the stability of the experimental fracture (Sjöstedt et al. 1994). Holding power in the femoral head alone has mostly been studied in experiments with pull-out tests (Frandsen and Madsen 1983, Crowell et al. 1985, Iversen et al. 1988, Larsson and Elloy 1990, Benterud et al. 1992). However, because of Pauwels' balance and the respective orientations of the femoral head and the fixation devices, only compressive and shearing forces act on an osteosynthesis device of the femoral head, leading to cutting-out or perforation of the device more than pulling-out. Most clinical failures are related to a varus displacement of the femoral head, due to the predominance of shearing forces. The clinical relevance of pull-out tests is therefore unknown (Iversen et al. 1988, Benterud et al 1992). Cut-out tests permit studies of the holding power of osteosynthesis devices of the femoral head independently of the stability of the osteotomy, in a more physiological loading situation than pull-out tests (Richards et al. 1990). Pins or nails were reported to have less than optimal clinical results (Parker and Blundell 1998), therefore we chose to test only screw devices.

We were unable to detect any significant difference in the holding power of the four different devices, as already reported for pull-out tests (Sjöstedt et al. 1994). Since they represent some of the more commonly advocated devices for fixation of a femoral neck fracture, one could assume that the choice between current devices is of no importance, as confirmed by several clinical studies (Parker and Blundell 1998). It seems then unnecessary to advocate more sophisticated, but also more expensive, devices to fix femoral neck fractures, and perhaps to develop new devices in the future.

Only the relation between bone density and head size had a significant influence on the holding power in this study, as already reported for other mechanical tests (Sjöstedt et al. 1994). It could be interesting to perform a clinical prospective study to determine the importance of bone density for the success of osteosynthesis for femoral neck fractures.

Table 2. Slope of load-displacement diagram (A; daN/mm) and maximal load at failure (B; daN). Mean (SD)

Device	Group 1		Group 2		Group 3		Group 4	
	A	B	A	B	A	B	A	B
Gamma nail	131 (61)	391 (49)	104 (38)	336 (127)	173 (37)	467 (73)	71 (37)	216 (136)
Dynamic hip screw	171 (19)	448 (30)	135 (46)	366 (151)	137 (44)	321 (82)	131 (27)	307 (45)
Uppsala hip screw	166 (44)	498 (53)	139 (3)	338 (44)	142 (49)	425 (118)	115 (110)	255 (119)
Ullevaal hip screw	209 (95)	438 (107)	195 (49)	320 (69)	154 (39)	453 (42)	119 (36)	276 (52)

Groups: 1 large heads with high density, 2 large heads with low density, 3 small heads with high density, 4 small heads with low density.

Table 3. Paired comparisons in each pair of devices. Mean (SD)

1st device	Slope (daN/mm)	Maximal load (daN)	2nd device	Slope (daN/mm)	Maximal load (daN)
Gamma nail	133 (57)	405 (57)	Dynamic hip screw	169 (81)	416 (81)
Gamma nail	100 (64)	327 (198)	Uppsala hip screw	189 (66)	371 (207)
Gamma nail	127 (52)	328 (118)	Ullevaal hip screw	182 (74)	337 (88)
Dynamic hip screw	114 (28)	349 (90)	Uppsala hip screw	129 (18)	357 (54)
Dynamic hip screw	146 (28)	316 (109)	Ullevaal hip screw	146 (24)	359 (116)
Uppsala hip screw	133 (60)	405 (91)	Ullevaal hip screw	178 (85)	446 (11)

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