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Holding power impaired in rheumatoid femoral heads

Cadaveric study of fracture fixation devices

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A measurement was made of the holding strength and the energy needed to extract a NoLok™ hip screw, a von Bahr screw, and a Hansson hook-pin from cadaveric femoral heads. The specimens were obtained from female subjects aged 65 years or more, with 36 specimens each from rheumatoid (RA) and nonrheumatoid (non-RA) donors. Retraction of the implants was made by a continuous uniaxial pullout at 10 mm/min. For each type of device, the holding strength in rheumatoid femoral heads was less than in non-RA specimens. In rheumatoid specimens the maximum holding strength for the NoLok™ screw (1,622 N) was higher than that of the other two devices, whereas the von Bahr screw (1,177 N) had a higher maximum holding strength than the Hansson hook-pin (603 N). In non-RA, there was no difference in maximum holding power between the NoLok™ screw (2,549 N) and the von Bahr screw (2,282 N); however, both had a higher holding strength than the Hansson hook-pin (851 N). A rapid fall off was experienced in the force required to continue extraction of both types of screws, whereas for the Hansson hook-pin the strength decreased slowly. For each type of device, the energy needed for extraction of the implant was less in the RA group femoral heads, while there were no differences in total extraction energy between devices.

Implants used for internal fixation of femoral neck fractures often have screw forms to improve fracture stabilization. The holding strength is determined by bone quality and by implant design, and the maximum holding strength in cadaveric femoral heads has previously been studied for hip compression screws and cancellous screws. A decrease in holding strength in elderly subjects is attributed to reduced bone strength (Schwarz and Newald 1981, Frandsen and Madsen 1983, Frandsen et al. 1984, Hertz et al. 1985). Clinical studies have revealed that internal fixation of femoral neck fractures in patients with rheumatoid arthritis are associated with a higher postoperative complication rate compared with treatment in patients without arthritis (Vahvanen 1971, Stephen 1980, Hadden et al. 1982, Strömqvist 1984).

We have studied the holding strength and the total energy needed for extraction of three different fixation devices when extracted from femoral heads of rheumatoid subjects, as well as from donors of approximately the same age with no known bone disease.

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Material and methods

Cadaveric femoral heads from rheumatoid arthritic females aged 65–77 years, as well as from females aged 65–89 years without a clinical history of arthritis or macroscopic bone abnormality were obtained by a transcervical osteotomy. There were 36 femoral heads from 18 subjects in each group. The specimens were kept deep-frozen until the evening before testing, when they were thawed at room temperature. In a randomized way, one of the three implants (Figure 1) under test was inserted in each specimen: (a) a NoLok™ hip screw (shank Ø 8 mm, thread Ø 7–13 mm, thread length 24 mm); (b) a von Bahr screw (shank Ø 5.5 mm, thread Ø 7 mm, thread length 23 mm); and (c) a Hansson pin (shank Ø 6.5 mm, no threads, but a 12-mm hook at the distal pin end).

In clinical practice, the NoLok™ screw is used together with a plate, i.e., a sliding hip screw system, whereas for femoral neck fracture fixation, the von Bahr screw and the Hansson hook-pin are each used in pairs without a plate. Predrilling was used for the NoLok™ screw and the Hansson pin, but not for the von Bahr screw, in accordance with the technique recommended for each device. The implants were inserted perpendicular to the osteotomy through the central part of the femoral neck and into the femoral head with the tip of the screw/pin 4 mm from the articular surface.

Figure 1. The three different implants tested; the NoLok™ screw (left), the von Bahr screw (middle) and the Hansson hook-pin (right)

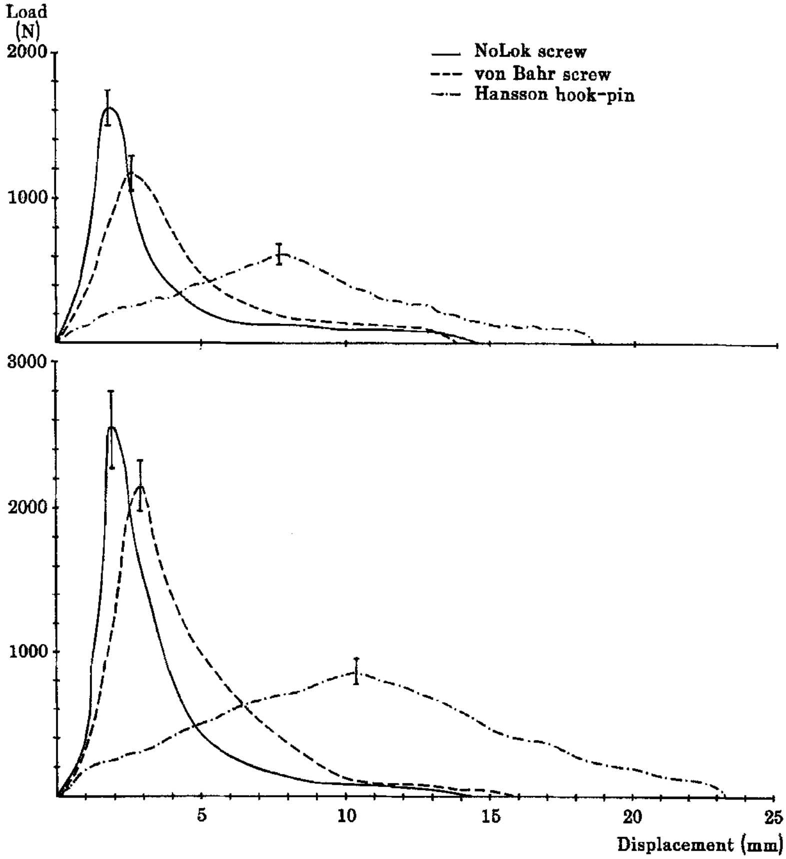

Figure 2. Load/displacement diagrams describing mean holding strength (newton) for each type of device in relation to extraction (mm). Maximum holding strength ± 1 SEM is given. Nonrheumatoid (bottom) and rheumatoid specimens (top).

Table 1. Maximum holding power (newton) and total extraction energy (newton meter) needed for extraction of the three devices from rheumatoid (RA) and nonrheumatoid (non-RA) femoral heads given as mean *SEM*

	Maximum holding power				Total extraction energy			
	Non-RA		RA		Non-RA		RA	
NoLok™ screw	2,549	*262*	1,622	*119*	7.0	*0.9*	4.7	*0.5*
von Bahr's screw	2,282	*170*	1,177	*106*	9.1	*0.7*	5.3	*0.7*
Hansson's hook-pin	851	*60*	603	*56*	11.3	*1.1*	5.9	*0.6*

The specimen with the inserted screw/pin was placed in an MTS universal material testing machine, and the implant was pulled out at a constant rate of 10 mm/min by means of a continuous axial load applied along the implant. During extraction the load and displacement were continuously recorded, load/displacement plots drawn, and the energy of extraction calculated.

The statistical probability was calculated with analysis of variance and the Student's *t*-test. The chosen level of significance was $P < 0.05$. The mean and standard error of the mean (SEM) are given.

Results

For all three devices the maximum holding strength was lower in the rheumatoid (RA) femoral heads. On an average, the percentage reductions in maximum holding power in the RA femoral heads were 48 (von Bahr) 36 (NoLok™), and 29 (Hansson).

Both types of screws provided a higher maximum holding power than the Hansson hook-pin, for both the non-RA ($P < 0.001$) and the RA ($P < 0.001$) femoral heads. There were no differences in maximum holding strength between the two types of screws when inserted in the non-RA specimens, whereas in RA femoral heads, the NoLok™ screw provided a higher maximum holding power than the von Bahr screw ($P < 0.02$; Table 1). The load/displacement diagrams revealed only small differences between the two screws, while the differences between the screws and the hook-pin were considerable. For both types of screws the initial extraction required a rapid increase in force to a maximum, after which the resistance to further extraction decreased rapidly. For the NoLok™ the maximum holding strength was reached after 1.9 mm (non-RA) and 1.7 mm (RA) of retraction, respectively, while the corresponding figures for the von Bahr screw were 2.7 mm (non-RA) and 2.5 mm (RA). Neither the NoLok™ nor the von Bahr screws retained any holding strength after 15-mm extraction. For the Hansson hook-pin, the load/displacement diagram was more constant, reaching a maximum after 10 mm (non-RA) and 7.7 mm (RA), and substantial holding strength maintained up to 23 mm of extraction for the non-RA and 18 mm for the RA (Figure 2).

The total energy necessary for extraction (area below curves in Figure 2) of the implants was lower for the RA femoral heads for each of the devices tested. However, there were no differences in total energy needed for extraction between the three types of implants tested (Table 1).

Discussion

In order to secure fracture stability, a firm grip in the femoral head is aimed for with most implants used for fixation of femoral neck fractures. For the NoLok™ device, the option to apply mechanical fracture compression obviously necessitates an adequate holding strength in the femoral head to counteract this pullout force. Measuring holding strength of von Bahr screws and Hansson pins, clinically not subjected to any obvious pullout force, might seem irrelevant. However, in the clinical situation, secondary fracture dislocation due to the screw/pin losing its grip in the femoral head is a known complication. The retraction is probably induced by small movements at the fracture when repetitive loading such as weight bearing is applied, as shown experimentally for trochanteric fractures (Larsson et al. 1988). An adequate holding strength is therefore important also in these implants. If, in the experimental model, the pullout load is increased intermittently (Schwarz and Newald 1981, Frandsen and Madsen 1983, Hertz et al. 1985) a similar timing of the load increase in all the specimens is essential, otherwise the result become unpredictably influenced by the viscoelastic properties of bone (Larsson et al. 1987). By using a constant pullout rate that was repeated in all the specimens that possible methodologic error was neutralized. In clinical practice, the von Bahr screws and Hansson pins are each used in pairs, whereas only one NoLok™ screw is used. Because the aim of our study was to define the relation between implant design and holding strength, all the implants were inserted in a similar position in the femoral neck and head to reduce differences in holding strength related to variations in bone quality.

Ability to withstand extraction has previously been described only in terms of the maximum holding strength, while the energy needed for extraction has not been reported. For screws, measurement of the maximum holding strength alone might be adequate, because further displacement is followed by a rapid decline in holding strength (Schwarz and Newald 1981, Fransen and Madsen 1983, Frandsen et al. 1984, Hertz et al. 1985, Iversen et al. 1988). For implants that exhibit extended load/displacement profiles, as does the hook-pin in the present study, it is obvious that a combination of maximum holding strength and total extraction energy is a better measure of ability to resist extraction.

The grip is dependent not only on implant design, but also on bone quality and probably implant position. In vitro studies have revealed a lower holding strength in specimens from women older than 80 years compared with less aged women, as well as a lower holding strength in specimens from females than those from males. These differences have been interpreted as caused by a more advanced osteoporosis in elderly subjects, especially in females (Frandsen and Madsen 1983, Frandsen et al. 1984, Hertz et al. 1985). In a recent cadaver study, a correlation between bone mineral content and holding strength of screws in the femoral head was confirmed (Iversen et al. 1988).

Internal fixation of femoral neck fractures in patients with rheumatoid arthritis is followed by a higher complication rate than with nonrheumatoid patients, even though the rheumatoid patients as a rule are younger (Vahvanen 1971, Hadden et al. 1982, Strömqvist 1984). The complications are usually early mechanical problems with secondary fracture displacement. Prosthetic replacement has therefore been suggested as primary treatment for displaced femoral neck fractures in rheumatoid patients (Stephen 1980, Hadden et al. 1982, Strömqvist 1984). Our findings—i.e, holding strength and the total energy needed for extraction of each one of the three devices tested were 30 to 50 percent lower for the rheumatoid femoral heads—might explain the high frequency of early complications in internal fixation of femoral neck fractures in rheumatoid patients (Hadden et al. 1982).

Differences in holding strength in different parts of the femoral head caused by variations in bone quality have been described, although previous results are conflicting (Brodetti 1961, Schwarz and Newald 1981). Rehnberg and Olerud (1989) stated improved holding strength by advancing the tip of the screw to the subchondral bone, although no measurements of the holding strength were made. On the other hand, Iversen et al. (1988) reported better holding strength when the tip of a hip compression screw ended 12 mm from the articular surface than when the tip, as in the present study, ended 4 mm from the surface in what they defined as the subchondral bone. The better holding power when the screw ended 12 mm from the surface was interpreted as a result of denser trabecular bone in that part of the femoral head.

Characteristic for the load/displacement curves for the screws was a high maximum holding strength reached after just a short retraction of the screw, after which further displacement was followed by a rapid decline in holding strength, findings that accord with Iversen et al (1988). The decrease in holding power after a maximum load had been reached was especially marked for the NoLok™ screws, probably because the proximal threads had a reduced diameter. The tapered shape of the screw tip was intended to make the screw self-tapping. This had the disadvantage of reducing holding strength as the proximal threads passed into an enlarged space after a small degree of retraction, thereby losing their grip in the surrounding trabecular bone. The von Bahr screw had smaller outer and core diameters of the threads than the NoLok™ screw. Still, there was no difference in maximum holding strength between the screws for the non-RA specimens. Further, the decline in holding strength after maximum load had been reached was less marked for the von Bahr screws than the NoLok™ screw. These findings were probably accounted for in the differences in the thread design. The outer diameter of the threads in the von Bahr screw were parallel to the tip, although the depth of each thread increased towards the tip of the screw due to reduction in the core diameter. The observed decline in holding strength after the maximum was reached, for both screw types in the present study, as well as for screws in previous studies (Frandsen and Madsen 1983, Iversen et al. 1988), was explained by simultaneous shearing of all the cancellous bone threads surrounding the core (Scott et al. 1985). However, increasing the length of the threaded part of a cancellous screw, or by using screws with a larger diameter of the threads, an increase in maximum holding strength has been reported (Schwarz and Newald 1981, Frandsen et al. 1984). This is because a greater area of cancellous bone is made available to support the screw. The Hansson hook-pin revealed a more flattened load/displacement diagram compared with the screws. This was because the hook had to pass through relatively undamaged cancellous bone as extraction proceeded. Obviously the hook did not provide the same maximum holding power as the screws, because the surface of the hook was smaller than the total surface of the threads. The net result was that there were no differences in total extraction energy between the screws with their high maximum holding strength and the hook-pin with the more constant, though lower, resistance to extraction.

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