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Screw fixation in the femoral head

Pull-out tests in cadavers

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The aim of our study was to determine whether a subchondral or a capital position of the thread of the gliding screw provided the best fixation. A pull-out test was performed on pairs of femoral neck cadaver specimens. The capital position of the thread provided the best fixation in all the pairs. A correlation was found between bone mineral content of the femoral heads and the holding power of the screws in both positions.

Garden (1961) recommended that the hip-fracture nail be positioned in the central sector of the femoral neck, and several authors have rated the position of the gliding screw tip as good in the central sector of the femoral head, acceptable in the posterior and inferior sectors, and poor in the anterior and superior sectors (Frandsen et al. 1979, Brown and Court-Brown 1979, Iversen et al. 1986). However, recommendations on how far medial in the head the tip of the gliding screw should be placed do not appear to be published. The aim of our study was to determine which distance from the joint surface is optimal.

Materials and methods

Eighteen femoral neck specimens from 9 women, median age 72 (63–93) years, were acquired at autopsy and stored at −23 °C. Criteria for exclusion were former steroid treatment, malignant disease, paralysis, arthrosis, or lower limb fracture.

The femoral neck/diaphysis angle was ranked in ascending order based on radiographs. Bone mineral content of the femoral head was determined by dual photon absorption (Gammtec GT 50) according to Krølner and Pors-Nielsen (1980). Scanning was performed perpendicular to the axis of the femoral neck. The mean of the five scans covering the greatest diameter of the head and the mean of the five scans covering the most medial part of the head were recorded.

An indexed-threaded Kirschner wire was inserted through the central part of the femoral neck paralleling the neck axis. When the femoral head was perforated, the length of the track was measured and drilled to exactly 12 mm within the articular surface in one specimen and 4 mm in the contralateral specimen of the same subject. Pretapping was omitted to avoid weakening due to screws cutting their own threads beside

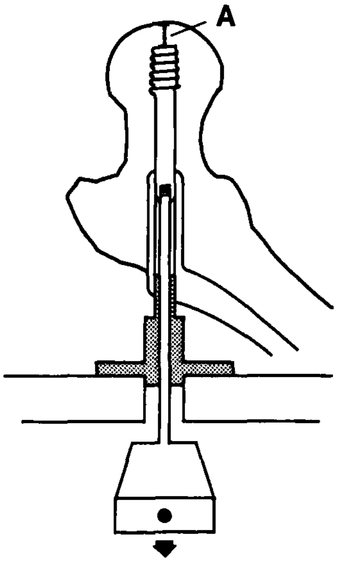

Figure 1. The instrument used for the pull-out tests. The distance A between the tip of the screw and the articular cartilage was 4 mm in one specimen of a pair and 12 mm in the other specimen.

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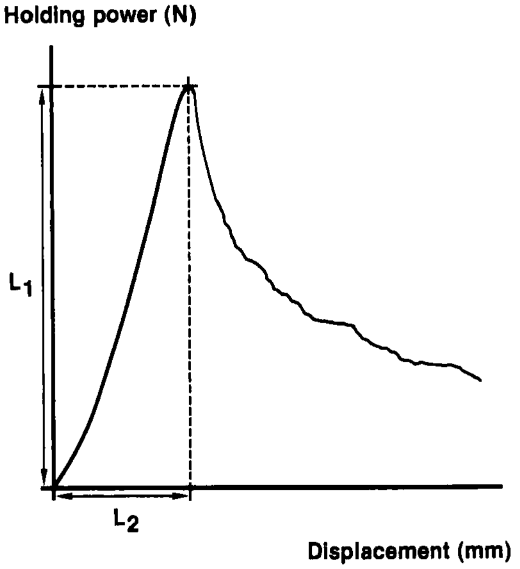

Figure 2. Example of a force-displacement plot recorded at retraction of the screws. Maximal holding power was recorded as the highest point of the curve. L^1/L^2 was recorded as an expression of the stiffness of the cancellous bone.

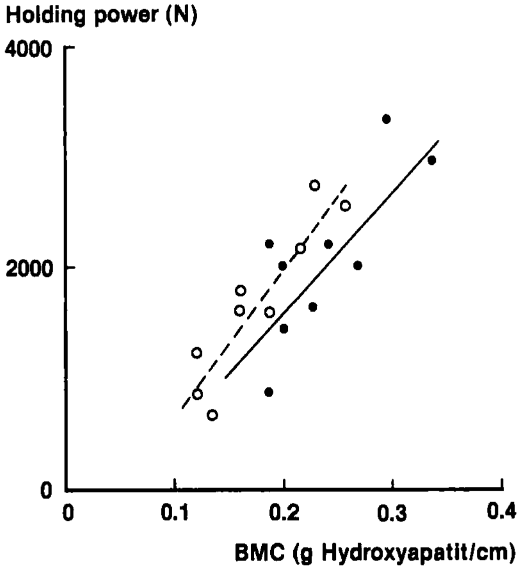

Figure 3. Holding power versus BMC.
● Unbroken line. Specimens tested in the 12-mm position.
○ Broken line. Specimens tested in the 4-mm position.

the pretapped one. Screws of 90-mm length, 7.5-mm shank and core diameter and a thread of 19-mm length and 12.2-mm diameter were used. The pull-tests of the gliding screws were performed in a Zwick universal testing machine using a special device (Figure 1) and a constant pull of 20 mm/min. From the displacement/load plots (Figure 2), the maximal holding power and stiffness were calculated.

Results are presented by the median ± 95 percent confidence limits of the median. The Spearman rank correlation test and the Wilcoxon test were applied.

Results

The median holding power was greater in all the pairs in the 12-mm position, 2,043 (1,358–2,980) N, than in the 4-mm position, 1,683 (813–2,625) ($P = 0.001$). The median stiffness was 377 (141–596) N/mm and 291 (150–476) N/mm in the 12-mm and 4-mm positions, respectively (NS). The bone mineral content in the 12-mm position was 2.31 (1.91–2.88) g hydroxyapatite/cm (gHA/cm) on the right and 2.14 (1.92–2.93) gHA/cm on the left side (NS). In the 4-mm position the mineral content was 1.63 (1.38–2.44) gHA/cm on the right side, whereas in the left specimens the figure was 1.64 (1.33–2.58) gHA/cm (NS).

The holding power was positively correlated with the BMC, with $r = 0.765$ ($P = 0.025$) in the 12-mm position and $r = 0.901$ ($P = 0.001$) in the 4-mm position (Figure 3).

Increasing holding power was not correlated with neck/diaphysis angle.

Discussion

The modest variation in bone mineral content within patients demonstrated in this study justified comparing the measurements of holding power and stiffness between the two specimens of a pair.

We found a firmer fixation of the gliding screw in the central part of the femoral head than subchondrally. A feasible explanation of this result is suggested by the denser trabecular pattern in the central part of the head due to the intersections of the differentially inclined stress lines (Figure 4, Pauwels 1973, Hirsch and Brodetti 1957, Frankel 1960). Indeed, Brown and Ferguson (1980), in an extensive investigation of the mechanical properties of 5-mm cancellous cubes obtained from proximal femur bone, found a distinctly increased elastic modulus in a contour corresponding to the primary (compression) trabecular system. They also found progressive distal stiffening in the femoral head and increased yield strength in the central sector of the head, which may offer some explanation of our results.

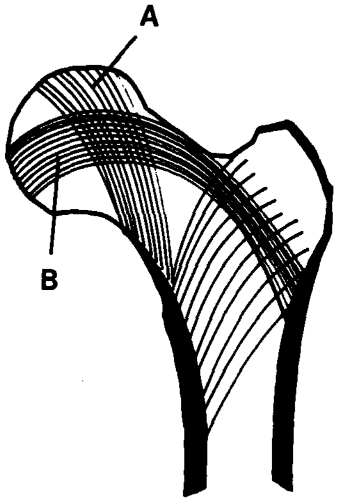

Figure 4. The denser anisotropic pattern centrally than subcortically might account for the firmer fixation in this position.
A. Primary trabecular system (compression).
B. Secondary trabecular system (tension).

Obviously our experimental design only allowed conclusions as to the use of instrumented compression. The feasibility of extrapolating the results to the weight-bearing situation is uncertain due to the anisotropic structure of the cancellous bone in this region. Brown and Ferguson (1980) and Martens et al. (1983) concluded that the direction of loading of the specimens influenced the results markedly.

Other parameters than fixation play a role with regard to redislocation after osteosynthesis of femoral neck fractures. The drill channel in the femoral head fragment becomes shorter with increasing distance of the screw tip from the joint surface, involving increased risk of tilting of the head upon weight bearing.

We found a correlation between bone mineral content and holding power of the screws. Frandsen and Madsen (1983) found that gliding-screw holding power was lower in women over 80 years of age than in women below this age, which is probably also the consequence of differences in bone density. They reported maximum retractability with standard operating instruments in the range of 1,600 N. However, the holding powers recorded in that study were much lower than those recorded by us, probably due to methodologic differences. Thus, it seems justified to warn against instrumental axial compression in markedly osteoporotic patients.

In a previous report on complications of gliding-screw osteosynthesis (Iversen et al. 1986), the quality of reduction seemed more important than screw placement. However, in that and other previous studies, no attention was paid to distance between the screw tip and the articular surface, screw placement being rated as good whenever the tip was placed in the central sector of the head.

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