# Impaction bone-grafting increases the holding power of cancellous screws in the femoral head

## A pull-out study in human cadaver hips

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**We studied the effect of impaction of fresh cancellous bone or demineralized bone matrix (DBM) around cancellous screws in 25 cadaver femoral heads. The bone mineral content (BMC) of femoral heads was measured to determine if greater relative increase in holding power will be achieved by impaction-grafting, as the BMC of the specimen decreases. A 60% ($p < 0.001$) relative increase in the pull-out force was achieved by impaction-grafting with DBM, compared to non-grafted controls. The augmenting effect of fresh cancellous bone graft and DBM did not differ significantly. The relative improvement in holding power was not inversely correlated to femoral head BMC, but was inversely related to the pull-out resistance of non-grafted control screws. These findings suggest that impaction-grafting provides significantly better hold of cancellous screws in femoral heads.**

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Many authors have shown the critical role of trabecular bone quality or BMC in influencing the outcome of fixation in femoral neck fractures (Høgh et al. 1982, Clark et al. 1990, Swiontkowski 1994). Early loosening, defined as redisplacement within 8 weeks, is estimated to occur in about 10% of displaced femoral neck fractures treated with internal fixation (Frandsen and Andersen 1981, Høgh et al. 1982). One contributory factor in early loosening is the poor hold of screws or nails in the osteoporotic cancellous bone of the femoral head (Müller et al. 1979, Frandsen and Andersen 1981, Skinner and Powles 1986), which leads to microinstability of the implant under functional loading.

The first goal of this study was to determine if augmentation with impacted fresh cancellous bone graft or demineralized bone matrix (DBM) improves the holding power of AO cancellous screws in cadaver femoral heads. The second goal was to determine whether greater relative increases in holding power could be achieved if the BMC of the specimen decreases.

## Material and methods

25 fresh cadaver femoral heads were obtained from persons over 50 years of age, without a history of hip pathology. A transverse osteotomy was made through the femoral neck 1 cm below the femoral head. The femoral heads were preserved at 4 °C for no longer than 3 days until used in the tests. 6.5 mm AO cancellous screws (16 mm thread length) were used to evaluate the pull-out strength.

The bone mineral content (BMC) of 17 femoral heads was measured with the help of quantitative computed tomography (QCT), using a commercial CT scan and a bone mineral reference standard to calibrate each scan. Single 8 mm thick sections were obtained in the plane that coincided with the insertion plane of screws. BMC was measured in the subchondral area of the femoral head, where the threaded ends of the screws were expected to reach. A region of interest was manually positioned. The CT density was converted to mg/cm$^3$ by comparing the CT value to that of the compartments of the calibration standard. The precision and accuracy errors of QCT are 2–4% and 4–15%, respectively.

Perpendicular to the osteotomy, two channels were drilled with a 4.5 mm drill, parallel to the longitudinal axis of the femoral neck, both reaching into the subchondral bone of the femoral head. In the lateral plane, both the anteriorly and posteriorly drilled channels were placed in the plane that coincided with the middle of the head in the anterior-posterior plane.

After that, both channels were tapped with a 6.5 mm thread-cutter. As shown earlier (Benterud et al. 1992), there is only a marginal difference in holding power between these positions.

Placement of the control or DBM-impacted screw anteriorly or posteriorly was done randomly. To measure the holding power, we used a specially constructed pull-out device consisting of a jackscrew system to lock the femoral head with the screw inserted and a strain gauge transducer connected to it, all fixed to the outer frame. To generate a uniaxial pull-out force, the jackscrew was driven manually at a speed of 10 mm/min. The accuracy error of the strain gauge was 0.5%. However, as the device was driven manually, the force applied was still more or less intermittent by nature. The maximum load needed to pull out the screw was recorded as maximum holding power.

The 25 femoral heads were tested in two groups. In the first group, the 17 femoral heads with measured BMC were tested. A control screw was inserted first and advanced to the subchondral bone in the femoral head. The femoral head with the inserted screw was placed in the testing device, where the pull-out force was applied until the maximal holding power of the screw was exceeded. Then the screw was removed and the other drill channel was impacted with 2 mm particle-size morselized DBM. Impaction was performed manually with the aid of a cylindrical 4.5 mm custom-made pusher, until the whole channel was tightly packed with DBM. Impaction force was not measured. Then additional tapping with a 4.5 mm thread cutter was performed. The screw was inserted and the pull-out force measured, as described above. The relative difference in holding power was calculated for every pair of screws.

In the second group we compared the augmenting properties of DBM and fresh cancellous bone. Here, the first drill-hole was impacted with fresh cancellous bone from the proximal part of the femur in the above-described way and loaded to failure. Then the second hole was impacted with morselized DBM and also loaded to failure.

A Wilcoxon ranked-sign comparison was used to test for differences in holding power between treatments. A Spearman rank correlation analysis was performed between the holding power of control screws and relative improvement in holding power and when DBM-impaction was used. Spearman correlation analysis was also done between the BMC and holding power of control and DBM-impacted screws.

Table 1. The holding power of control and DBM-impacted screws with respective BMC values

| Pair no. | Holding power (N) Controls | DBM-impact.[a] | Percent improvement | BMC (mg/cm³) |
|---|---|---|---|---|
| 1 | 410 | 1126 | 175 | 256 |
| 2 | 610 | 1499 | 146 | 191 |
| 3 | 615 | 1365 | 122 | 206 |
| 4 | 677 | 1117 | 65 | 231 |
| 5 | 803 | 2214 | 176 | 357 |
| 6 | 970 | 1339 | 38 | 203 |
| 7 | 1036 | 1794 | 73 | 257 |
| 8 | 1059 | 1145 | 8 | 249 |
| 9 | 1071 | 1329 | 24 | 242 |
| 10 | 1176 | 1206 | 3 | 270 |
| 11 | 1246 | 1829 | 47 | 305 |
| 12 | 1470 | 2272 | 55 | 323 |
| 13 | 1747 | 1876 | 7 | 269 |
| 14 | 1928 | 2237 | 16 | 299 |
| 15 | 2132 | 2750 | 29 | 205 |
| 16 | 2143 | 3151 | 47 | 394 |
| 17 | 3051 | 2783 | –9 | 373 |
| Median | 1071 | 1794 | 47 | 257 |
| Mean | 1303 | 1825 | 60 | 272 |
| SD | 696 | 647 | 60 | 61 |

[a] $P < 0.05$

Table 2. The holding power of fresh cancellous bone- and DBM-impacted screws

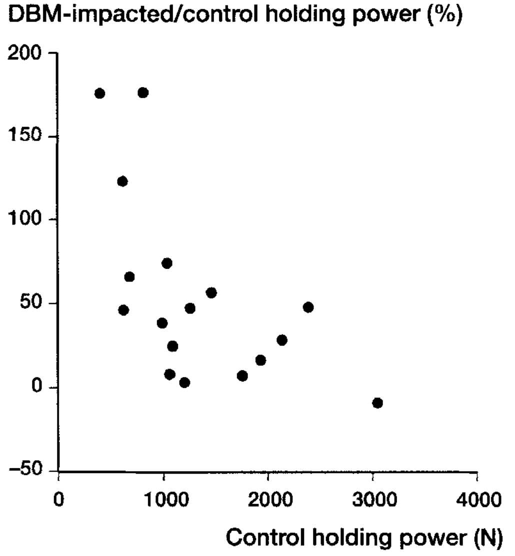
| Pair no. | Holding power (N) Cancellous bone | DBM[a] | Percent improvement |
|---|---|---|---|
| 1 | 1550 | 1670 | 8 |
| 2 | 1672 | 2946 | 76 |
| 3 | 1690 | 1752 | 4 |
| 4 | 1720 | 1770 | 3 |
| 5 | 2053 | 2783 | 36 |
| 6 | 2162 | 3232 | 49 |
| 7 | 2344 | 1589 | –32 |
| 8 | 2793 | 2129 | –24 |
| Median | 1887 | 1950 | 6 |
| Mean | 1998 | 2234 | 15 |
| SD | 424 | 654 | 38 |

[a] $P > 0.05$

## Results

Bone mineral content values in the subchondral area of the femoral head were in the range of 190–394 mg/cm³ (average 272 mg/cm³, SD 61). The mean screw holding power was increased by 60% (n 17, $p < 0.001$, SD 59) when screws were impacted with DBM, compared with controls (Table 1).

Comparing the augmenting properties of fresh cancellous bone and DBM, the impaction-grafting with DBM provided a slightly better hold, but in our test it was not statistically significant (n 8, $p = 0.6$, SD 36) (Table 2).




The percentage of improvement in the holding power of DBM-impacted screws as a function of the absolute holding power of the controls.

Both for control and DBM-impacted screws, the holding power showed a positive correlation with BMC (n 17, r = 0.57, p = 0.02 and n 17, r = 0.56, p = 0.02, respectively).

A substantially greater relative increase in the holding power of DBM augmented screws was achieved in femoral heads where the holding power of control screws was lower (n 17, r = –0.7083, p = 0.001 (Figure).

## Discussion

Our findings for the control screws do not differ substantially from those of Benterud et al. (1992), who tested the holding power of different screws in various areas of the femoral head. The average result in their study for AO 6.5 mm cancellous screws (16 mm thread length) was 1187 N, compared to 1302 N in our study.

In 1984, Frandsen et al., in a similar set-up, found the median pull-out strength for 6.5 × 15 mm OSTEO AG screws to be approximately half of that which we found for control screws. As the holding power of the screw is a function of the individual screw and of the cancellous bone in which it is lodged, such discrepancies might be due to different screws used in tests and possible differences in the BMC of femoral head specimens.

A similar relative increase in the holding power of augmented screws was reported in an in vitro study (Kleeman et al. 1992) on biodegradable polymeric material to reinforce the holding power of surgical screws in osteoporotic bone. The authors reported an approximate doubling of the holding power of screws after reinforcement.

The holding power of metallic screws in cancellous bone in vivo was tested in 60 rabbits (Lapinsuo et al. 1992). Metallic screws were fixed without support or with the support of polymethylmethacrylate or autogenous bone graft. After 6 and 12 weeks the holding power of screws with polymethylmethacrylate was better than fixation without support or fixation with bone graft, whereas fixation with bone graft was better than fixation without support.

One of the main contributing factors in fixator loosening is the defective engagement of screws or nails in osteoporotic cancellous bone of the femoral head (Müller et al. 1979, Frandsen and Andersen 1981, Swiontkowski 1994). This mechanical microinstability will lead to bone resorption, growth of fibrous tissue around a screw and secondary loosening of the implant (Perren et al. 1975, Schatzker et al. 1975). Thus it would be rational to augment the screw grip in surrounding osteoporotic bone by impaction-grafting to minimize micromotions and diminish the threat of the screw cutting out of the osteoporotic bone.

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