Bone density and geometry after locked intramedullary nailing

Computed tomography of 8 femoral fractures

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8 patients with femoral shaft fracture treated with locked intramedullary (IM) nailing were examined by computed tomography (CT) a few days after nail removal. Cortical bone density, cortical thickness and geometrical shape of the fracture region were compared to those of the contralateral side. The cortical density was reduced by 23 percent at the mid-fracture level. However, at the same level the cortical thickness had increased by 47 percent, and the antero-posterior and medio-lateral diameters by 30 and 45 percent, respectively.

We conclude that the fracture region of the femoral shaft had regained its mechanical properties at the time of nail removal.

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In a previous CT study we found that locked IM nailing causes only a moderate reduction of cortical density and thickness in the femoral diaphysis outside the fracture area. Thus, the stress-protecting effect of IM nails on the intact human femoral diaphysis seems to be moderate (Bråten et al. 1992). We have now studied the same parameters in the fracture region in order to evaluate the mechanical properties of the entire femoral diaphysis.

Patients and methods

10 patients with previous locked IM nailing for femoral shaft fracture were examined. The nails were removed on average 2 (1–4) years after insertion. All fractures were completely healed at the time of nail removal. Details regarding patients, fractures, IM nails, CT equipment and statistical method were presented in the previous report (Bråten et al. 1992).

The CT examination was carried out 2–3 days after nail removal. After the initial scout view (Figure 1), scanning was performed at cross-sections of the healed bones at every 0.5 cm from proximal to distal in the callus area. After the initial scanning, 2 severely comminuted fractures were regarded as inappropriate for further examination due to abundant and irregular callus formation with cleft-like bony defects. The remaining 8 femurs displayed a uniform and regular bone structure in the fracture region. 3 levels were then chosen for further study: 1) 2 cm proximal to mid-fracture level, 2) mid-fracture level and 3) 2 cm distal to mid-fracture level (Figure 1). For statistical evaluation the averages of cortical density and thickness in each level were used.

Results

Figures for cortical density, cortical thickness and external AP and ML diameters are listed in Table 1. There was a mean reduction in cortical density by 16,

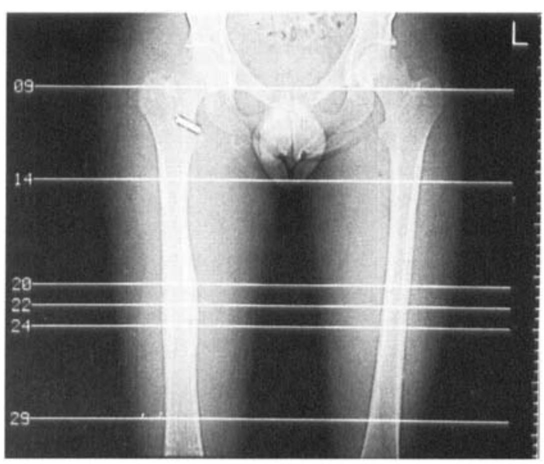

Figure 1. Scout view of both femora. Three levels were scanned: Level 1 = 20, Level 2 = 22, Level 3 = 24.

Table 1. Cortical density, cortical thickness and external antero-posterior (AP) and medio-lateral (ML) diameters of the previously nailed side, expressed as mean (range) percentages of the corresponding values for the contralateral control femur

	Level 1	Level 2	Level 3
Cortical density	84 (69–93)	77 (67–88)	85 (75–92)
Cortical thickness	130 (110–150)	147 (113–205)	128 (93–159)
AP diameter	131 (111–187)	130 (110–177)	121 (100–150)
ML diameter	139 (122–174)	145 (123–171)	129 (107–163)

Level 1: 2 cm proximal to mid-fracture level.
Level 2: Mid-fracture level.
Level 3: 2 cm distal to mid-fracture level.

23, and 15 percent at the 3 levels from proximal to distal, whereas cortical thickness was increased by 30, 47, and 28 percent, respectively. The mean increase in AP diameter was 31, 30, and 21 percent, and of ML diameter 39, 45, and 29 percent. All differences between fractured and normal femurs were significant ($P < 0.05$).

Discussion

This study was carried out to obtain data for an assessment of the mechanical properties of the healed femoral shaft fracture treated by locked IM nailing. Although there are some animal studies on biomechanical effects of IM nailing (Wang et al. 1981, Mølster et al. 1982, Reikerås 1990), to our knowledge human bones have not been studied.

Mechanical properties of a tubular structure depend on material properties as well as geometrical shape. Although bone has a complex structure, its mechanical properties are closely correlated to bone mineral content (Currey 1969, Bentzen et al. 1987, Rosson et al. 1991). The strength of a tubular structure is proportional to the third power of the outer diameter, minus the third power of the inner diameter. With regard to stiffness, the same diameters should be raised to the fourth power (Russell 1991). Thus, an increase in both external diameter and cortical thickness of a tubular bone will exert great influence on its mechanical behavior.

Bentzen et al. (1987) correlated CT measured density to penetration strength in trabecular bone from tibial condyles in patients. An increase in density was accompanied by an almost identical increase in penetration strength. In rabbit tibiae a strong positive correlation between mineral content and mechanical properties has been reported (Terjesen and Benum 1983, Rosson et al. 1991). A reduction in mineral content by 15–25 percent caused a 25 percent reduction in maximum bending moment (Rosson et al. 1991). Bone density and mechanical strength are thus closely related. We found a reduction of bone density at all levels in the fracture region, with a maximum reduction of 23 percent at the mid-fracture level. Thus, a considerable weakening of the bony structure occurs in the fracture region after IM nailing.

Healing of fractures after IM nailing proceeds with the formation of peripheral callus due to considerable micromotion at the fracture site (Tencer et al. 1984). Furthermore, medullary reaming preceding nail insertion causes a temporary avascularity of the medullary canal and the inner part of the cortex, leaving the periosteal and surrounding soft tissue vessels responsible for the nourishment of the fracture callus for a long period (Rhinelander 1974). This will further tend to increase the amount of external callus. These features associated with IM nailing were clearly demonstrated in the present study, as cortical thickness at mid-fracture level was increased by 47 percent, while AP and ML diameters at the same level were increased by 30 and 45 percent, respectively. Taking the effect of bone geometry into account, the healed bones in the present study probably are stronger in the fracture region than the control bones. A prerequisite for such a conclusion is the absence of holes and clefts in the callus mass. CT scanning did not reveal any such defects in the bones included in the present study.

The results from the previous (Bråten et al. 1992) and present reports indicate that the fractured femoral shaft treated with locked IM nailing will regain its strength and stiffness in the fracture area, whereas a slight reduction of mechanical properties is likely to occur outside the fracture area. The moderate alterations in the intact diaphysis are probably not of clinical significance, as refracture of the femoral shaft after removal of IM nails has not been reported to be a clinical problem.

The clinical implications of the previous and present study are first that removal of IM nails in the absence of nail-related complaints hardly is necessary from a stress-protecting point of view, and, secondly, if the nail is removed, that restricted weight bearing hardly needs to be recommended. This view might be modified in highly comminuted fractures, where an irregular callus mass is likely to occur.

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