Bone loss after locked intramedullary nailing

Computed tomography of the femur and tibia in 10 cases

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10 patients with previous femoral shaft fracture treated with locked intramedullary nailing were examined by computed tomography (CT) a few days after nail removal. The bone density, cortical thickness and geometric shape of the fractured extremity were compared with those on the contralateral side. Only a small reduction in cortical density and thickness (4 and 7 percent, respectively) was revealed outside the fracture area in the diaphyseal part of the nailed bones. A distinct reduction in trabecular density was observed in the femoral condyles as well as in the ipsilateral tibial condyle (19 and 17 percent, respectively). Our results indicate that the stress-reducing effect of intramedullary nails on the femoral diaphysis is small.

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A stress-protecting effect of rigid metal plate fixation on diaphyseal bone has been documented in animal experiments (Akeson et al. 1976, Tonino et al. 1976, Terjesen and Benum 1983). A reduction in cortical bone density in the human femur after plate osteosynthesis was reported by Terjesen et al. (1985).

According to Mølster et al. (1986), stress in the rat femur is reduced when stiff intramedullary (IM) nails are employed. In keeping with this, Husby et al. (1989a) reported increased cortical porosity in the rat femur after implantation of IM nails. However, to our knowledge, no information exists concerning effects of IM nailing on human diaphyseal bone.

We analyzed to what extent bone density and thickness were altered by locked IM nailing of femoral shaft fracture in 10 patients.

Patients and methods

Ten patients with a previously locked IM nailing for femoral shaft fracture were examined. There were 1 woman and 9 men with a mean age of 28 (16–40) years. The nails were removed on average the 27 (15–44) months after insertion. All fractures were completely healed at the time of nail removal.

The slotted Grosse-Kempf nail (Howmedica, Kiel, Germany) had been used in all operations. The nail dimensions were 12 mm (4 nails), 13 mm (1 nail), 14 mm (4 nails), and 15 mm (1 nail). The fracture comminution was classified by Winquist et al.'s method (1984). There were 3 noncomminuted fractures, 2 fractures with Grade I comminution, 3 with Grade III comminution and 2 with Grade IV comminution.

7 patients had no other injuries in their lower extremities. One patient had a bilateral ankle fracture that had been treated with osteosynthesis, one patient had ipsilateral ankle and metatarsal fractures treated with osteosynthesis, and a third patient underwent bone transplantation of the femoral fracture 8 months after primary operation because of sparse callus formation. One year after the femoral fracture the latter patient sustained a contralateral ankle fracture, which healed uneventfully after osteosynthesis.

In all the patients, static locking had been employed, and the mean interval from fracture until full weight bearing was 9 (1–16) weeks. No dynamization was performed.

Scanning procedure

The patients were examined 2–3 days after nail removal. A Philips Tomoscan 60/TX scanner, which is a third generation, high-resolution whole body scanner, was used. A slice thickness of 5 mm and a pixel size of 0.55 × 0.55 mm were chosen, and the exposure factors were 120 kV, 300 mA and 4.5 s.

During the CT examination, the patients were lying in the supine position with parallel legs. After an initial scout view (Figure 1), scanning was performed at cross-sections of cortical bone outside the callus area in the proximal and distal femoral diaphysis, but within the span limited by the interlocking screws. The tibia was examined at the mid-diaphyseal level (Figure

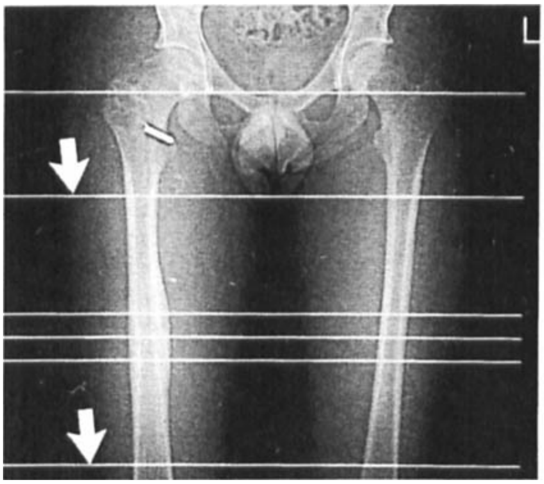

Figure 1. Scout view of both femora. Scanned levels are indicated by arrows.

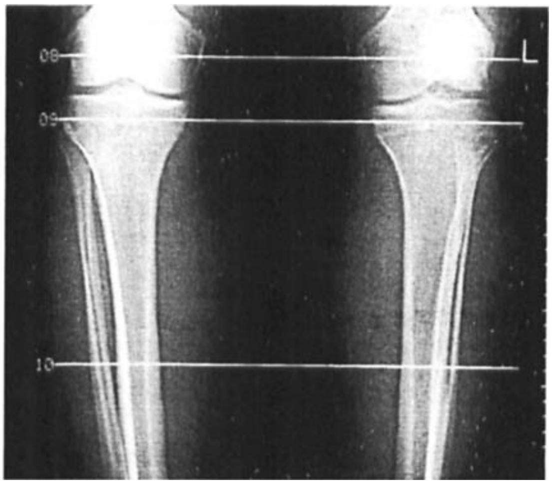

Figure 2. Scout view of both knee regions and tibiae. Lines indicate scanned levels.

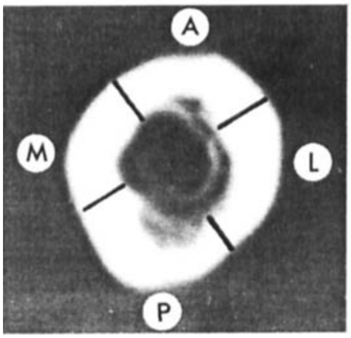

Figure 3. CT scan of the previously nailed femur. The lines indicate the four quadrants (A anterior, M medial, P posterior, L lateral) where cortical thickness and density were measured.

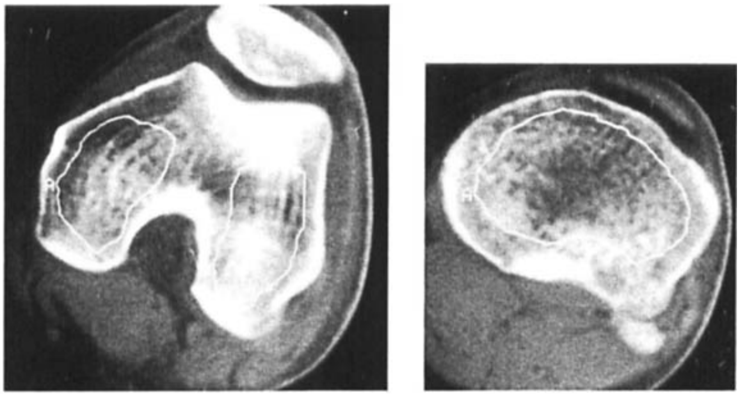

Figure 4. CT scans of femoral and tibial condyles. Trabecular bone density was measured in areas indicated by lines.

2). In addition, trabecular bone was examined by scanning the femoral and tibial condyles 1–2 cm proximal and distal to the knee joint (Figure 2).

Cortical density (Hounsfield Units), cortical thickness and external antero-posterior (AP) and medio-lateral (ML) diameters were measured from the CT scans, and the values on the fractured side were expressed as percentages of those on the contralateral control side. The cross-section of the femur was divided into four quadrants: lateral, medial, anterior and posterior, and the cortical density and thickness were separately measured for each quadrant (Figure 3). In two patients evaluation of the proximal femur was omitted due to a proximal fracture with abundant callus formation. The mid-tibial cross-section was divided into three parts: medial, lateral and posterior. Cortical density and thickness were separately measured for each part.

In the femoral condylar region, trabecular bone density was measured separately in the medial and lateral parts, whereas bone density in the proximal tibia was measured in nearly the whole condylar cross-section (Figure 4).

Statistics

The Wilcoxon signed rank test for paired samples (two-tailed test) was used to calculate the statistical differences between the previously nailed bones and the control bones. Differences were considered significant at P-values below 0.05.

Table 1. Cortical density outside the fracture area of the previously nailed side, given as percentages of the corresponding values for the contralateral control bones

Level	Total cross-section	Cross-sectional part of diaphysis			
		Anterior	Posterior	Medial	Lateral
Proximal femoral diaphysis					
Mean	97	95	93	101	100
Range		88–100	83–100	88–112	90–117
Distal femoral diaphysis					
Mean	95	92	98	96	94
Range		82–103	91–107	87–102	81–105
Mid-tibial diaphysis					
Mean	99		99	99	100
Range			93–104	90–108	94–106

Table 2. Trabecular bone density of the previously nailed side, given as percentages of the corresponding values for the contralateral control bones

Level	Total cross-section	Medial condyle	Lateral condyle
Femoral condyle			
Mean	81	85	77
Range		48–113	56–104
Tibial condyle			
Mean	83		
Range	20–121		

Results

There was a reduction of cortical density in the anterior and posterior quadrants of the proximal femoral diaphysis (*P* 0.02 and 0.01, respectively; Table 1). In the distal diaphysis the reduction was significant in the anterior, medial and lateral quadrants (*P* 0.005, 0.04 and 0.04, respectively). Mean reductions were 3 percent in the proximal part and 5 percent in the distal part. A reduction in trabecular bone density was found in both the medial and lateral parts of the femoral condyle (*P* 0.02 and < 0.001, respectively; Table 2) as well as in the tibial condyle (*P* 0.03; Table 2). The mean reductions were 19 percent in the femur and 17 percent in the tibia.

A moderate reduction in the cortical thickness of the fracture side was observed in the femur (Table 3). Average reduction in the four quadrants was 7 percent in the proximal diaphysis and 6 percent in the distal diaphysis. The reduction was significant in the proximal diaphysis only (*P* 0.04). There were no differences in cortical density and thickness between fractured and control sides in the tibia. We found no differences in AP and ML diameters between the fracture and the control sides, except for the AP diameter in the distal femur where an increase of 4 percent occurred on the fracture side (*P* 0.02).

No significant differences in diaphyseal bone density or dimensions between patients with "thin" (12 and 13 mm) and "thick" (14 and 15 mm) nails were revealed. Nor were there any differences in these parameters when patients with additional injuries in the lower limbs were compared with patients with femoral fractures only.

Table 3. Cortical thickness outside the fracture area of the previously nailed side, given as percentages of the corresponding values for the contralateral control bones

Level	Total cross-section	Cross-sectional part of the diaphysis			
		Anterior	Posterior	Medial	Lateral
Proximal femoral diaphysis					
Mean	93	98	94	89	92
Range		75–129	67–114	70–100	70–117
Distal femoral diaphysis					
Mean	94	100	91	93	94
Range		85–120	71–117	80–128	71–120
Mid-tibial diaphysis					
Mean	102		106	93	107
Range			86–120	80–102	67–120

Discussion

Previous studies have reported CT to be a reliable method in the assessment of bone dimensions (Smith et al. 1982), bone mineral content (Reich et al. 1976, Revak 1980, Husby et al. 1989) and mechanical properties (Bentzen et al. 1987, Alho et al. 1988, Lotz et al. 1990). Mechanical studies show that the bending stiffness of IM nails is considerably less than the stiffness of intact bones (Allen et al. 1968, Martens et al. 1972, Aginsky and Reiss 1980), and slotted nails have a remarkably low torsional stiffness as compared to intact bones (Allen et al. 1968, Johnson et al. 1986). Consequently, only a moderate stress-protection should be expected after IM nailing. This assumption was confirmed by the present study. Our results indicate that the mechanical properties of diaphyseal bone outside the fracture area are only moderately affected by locked IM nailing with slotted nails.

A considerable increase in mechanical properties occurs with increasing nail diameter (Allen et al. 1968, Martens et al. 1972). However, even the thicker nails available are not as stiff as intact bone. This might explain the very moderate effect of increased nail stiffness on density values in our study.

The reduction in cortical density caused by IM nailing was less pronounced than that after plate osteosynthesis. A mean reduction of 11 percent in the plated bone segment of human femora was reported by Terjesen et al. (1985). The most likely explanation is that IM nails, even in the statically locked mode, give less stress-protection than rigid steel plates. Another explanation might be reduced inactivity osteoporosis due to early weight-bearing after IM nailing. However, Finsen et al. (1988), employing photon-absorptiometry after femoral fractures treated by plate osteosynthesis or IM nail, found no difference between the methods in bone density of the femoral and tibial condyles. Moreover, a decrease in the density of the tibial diaphysis should be observed if inactivity were a contributing factor. Neither Terjesen et al. (1985) nor the present study revealed any reduction in cortical density of the ipsilateral tibia.

Measurement of density in trabecular bone is reported to be more inaccurate than that of cortical bone due to the heterogeneous structure caused by areas of fat tissue in trabecular bone (Mazess 1983). This uncertainty must be kept in mind when interpreting the reductions of 19 percent and 17 percent in the femoral and tibial condyles, respectively. Finsen et al. (1988) observed a similar reduction in the femoral condyle, but no reduction in the tibial condyle. Whether the reduction in trabecular bone density is an effect of the trauma itself, of inactivity, or of the osteosynthesis, is not known. Previous authors have suggested that trabecular bone is more rapidly affected than cortical bone in an osteoporotic process (Falch et al. 1985, Eriksson and Widhe 1988). This might explain the greater reduction in trabecular bone in our study.

Cortical thickness was significantly reduced in the proximal femur only. This might be due to the cortical reaming, which affects cortical bone more in this part than in the infra-isthmal region.

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