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Stress protection by external fixation of the rabbit tibia

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Osteopenia of the tibia and femur caused by an external fixator in the tibia was studied in 14 rabbits. Eight rabbits were treated with a complete unilateral external fixator in one tibia, whereas the other tibia served as a control. The other 6 animals had one leg operated on with inserting of all the pins but without the frame. This technique was chosen to compare osteopenia caused by stress protection and the effect of the pins. After 6 weeks, we found a 7 percent reduction in the bone mineral content in the tibial diaphyseal segment between the pins of the external fixator and no bone loss in the tibia that were operated on with only pins. In the femurs, there was a smaller decrease in the bone mineral content: respectively 3.2 percent (complete frame) and 2.9 percent (only pins). On all the operated on tibiae, there was an increase in the bone mineral content around the pins both proximally and distally.

Stress protection of various types of osteosynthesis in diaphyseal bones has been described (Tonino et al. 1976, Låftman et al. 1980). Terjesen and Benum (1983b, c) showed that the degree was dependent on the type and the duration of fixation. They found a greater loss in stiffness/bending strength and a more pronounced bone mineral loss after rigid plate fixation in the intact rabbit tibia than after external fixation with transfixing pins and double frames.

We have studied whether osteopenia is caused by a unilateral external fixator. The surgical trauma caused by the pins may also influence the bone metabolism, and therefore it was analyzed to ascertain whether the pins caused any changes in bone mineral content.

Material and methods

Operative procedure

Fourteen New Zealand white rabbits of both sexes, weighing 3,200–4,520 g, were used. The animals were anesthetized with intramuscular injections of Hypnorm® Vet (Leo). One of the tibiae was chosen at random, whereas the other served as a control. All the operations were performed under strictly sterile conditions. The anteromedial aspect of the tibia was exposed by a longitudinal anterior incision. Three proximal and three distal threaded pins of 1.5 mm diameter were used (Jaquet Orthopédie S.A., Geneva). They were inserted after predrilling with a pin group separation of 68 mm between the middle pins in each pin group. The distance between the pins in each group was 10 mm, and thus the free bone segment between the inner pins was 48 mm. In 8 animals, a newly developed unilateral external fixator frame of stainless steel was mounted (Figure 1).

The dimension of the frame was designed so that the relation between the bending stiffness of the frame and the intact rabbit tibia was in the same order as a unilateral two-bar Hoffmann external fixator compared with the stiffness of the intact human tibia. In the other group, only the six pins were inserted without mounting a frame. The operative wounds were sutured with Dexon®. All the operated on legs were bandaged with a firm padded dressing (Elastoplast®).

The rabbits were kept in separate cages, where they could move freely. They received a standard laboratory diet and water *ad libitum*, and were observed daily. The postoperative course was uneventful in all the cases but 1; this latter animal had an external frame and sustained a fracture in the free tibial segment. This fracture was not revealed until

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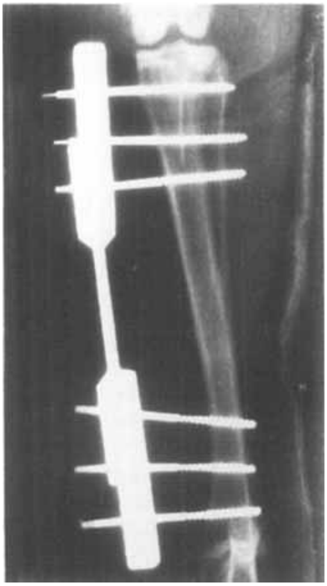

Figure 1. The unilateral external fixator applied on the rabbit tibia.

Table 1. Bone mineral content in the externally fixated tibiae and femoral diaphyseal segments, expressed as the percentage of the contralateral control bone. Mean (range)

	With frame (n 6)	Without frame (n 6)
Femur	97 (92–99)	97 (94–101)
Tibia		
diaphyseal segment	93 (85–99)	100 (97–104)
segment with pins	117 (110–120)	120 (110–126)

preparation, and it was then healed. This animal was excluded. The animals began partial weight bearing on the operated on leg immediately, and they resumed full weight bearing after a short time. After 1 week, all of their bandages were changed; no infection or abnormal swelling was seen. Two animals were excluded (both in the frame group): 1 with the fracture and the other because of a technical error when calibrating the bone densitometer. There were no problems with the pins, nor were there any wound infections.

Thus, 12 animals remained for further investigations. All were killed after 6 weeks with injections of mebumal. The pins were removed and both femurs and tibiae were dissected free from all soft tissue. The bones were wrapped in towels soaked with Ringer's solution and stored at –18 °C until testing.

Evaluation of bone mineral content

All the bones were thawed to room temperature before testing, and then grossly inspected. There was a visible periosteal thickening of the tibiae in the pin regions. The mineral content of the bones was measured by a modified computerized absorptiometer (ND 1100A Bone Density Scanner, Christiansen and Rødbro 1977). The scanner was monitored by a EPSON® PC AX2 computer equipped with specially developed software. The entire length of the bones was scanned with 1-mm distance. From these data, a region of interest in the free tibial segment was chosen for statistical evaluation (36–56 mm distal to the tibial condylar plateau). In the femurs, a segment in the middle diaphysis was chosen (36–56 mm proximal to the femoral condylar plateau). The control bones, both femurs and tibiae, were scanned at the corresponding levels.

Statistical analysis

The Wilcoxon signed-rank test for paired observations was used to evaluate differences between the bone pair, both on the femurs and the tibiae. The percentage difference in relative bone mineral content in the bone pair was calculated and thereafter the Mann-Whitney *U*-test (unpaired observations) was used to compare the differences between the two different animal groups. Differences were considered significant at *P*-values < 0.05.

Results

The relative mineral content in the middle section of the tibia with the external fixator decreased on an average of 7 percent compared with the control (*P* = 0.007; Table 1). There was also a small decrease (3 percent) in the femurs on the same side as the treated tibiae.

The tibiae treated with pins without a connecting bar had no decrease in bone mineral content in the middle section. Their corresponding femurs had a decrease of the mineral content of 3 percent.

In all the externally fixated tibiae, there was an increase in the bone mineral content in the bone segment around the pins both proximally and distally (Table 1). However, there was no difference in increased bone mineral around the pins between the two groups of tibiae—complete frame vs. only pins.

Discussion

Osteopenia caused by the stress-protecting effect of a metal plate on an intact diaphyseal bone is a well-known phenomenon (Uhthoff and Dubuc 1971, Akeson et al. 1976). Terjesen et al. (1985) have also demonstrated by computed tomography a reduction in cortical density of 11 percent directly after plate removal in 12 patients operated on for femoral fractures. Also studies comparing osteopenia after external fixation with quadrilateral systems of transfixing pins on the intact rabbit tibia against plating (Terjesen and Benum 1983b) concluded that the stress-protecting effect caused by a Hoffmann external minifixator on the rabbit tibia occurred later and was less pronounced than that caused by a metal plate. The ideal rigidity required for optimal fracture healing with external fixation is currently unknown (McCoy et al. 1983, Terjesen and Benum 1983a), and special attention to this problem has directed the development towards using unilateral external frames, dynamization, and biocompression (Lazo-Zbikowski 1986).

We found that the mineral content in the middle section of the external fixated tibia decreased on an average 7 percent after 6 weeks. Terjesen and Benum (1983b) found no changes after 6 weeks, but a decrease in mineral content on an average of 10 percent after 12 weeks. They, however, used a bilateral frame with four smooth 1.5-mm transfixing pins. A crucial part of the overall stability is the pin-bone interface (Briggs and Chao 1982, Egkher et al. 1980); perhaps, the use of six threaded half-pins of the same diameter offers a better fixation to the bone. They found no decrease in mineral content in the operated on tibia in a region outside the transfixed segment. We analyzed the femurs on the same side and found a decrease of 3 percent with the frame or with only pins, which we interpreted as being due to disuse.

The analyses of the segment around the pins showed an increase in the bone mineral content proximally and distally in all the tibiae (Table 1). This increase in mineral content may be caused by the dissection and the operative trauma, but may also be induced by irritation of the pins.

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