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Function promotes fracture healing

Plate-fixed osteotomies studied in rabbits

Unilateral midshaft tibial osteotomies in rabbits were fixed with 6-hole steel plates. In half the animals, no additional fixation was used, whereas in the other half, a plaster bandage from the toes to the midthigh was applied. At 6 weeks all the osteotomies had healed radiographically with little or no periosteal callus. The median strength of bones without plaster was 107 per cent of the normal value compared with 55 per cent in the plaster group. The results indicated a severely adverse effect of plaster immobilization on the healing of plate-fixed osteotomies.

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The main advantage of rigid fracture fixation is that the stability permits immediate active movements of muscles and joints. The axiom that this has a stimulating effect on the bone-healing process was first emphasized by Murray (1934) and later by Danis (1949) and the AO group (Müller et al. 1965), and is now a widely accepted clinical view.

Strangely enough, no experimental evidence seems to exist about the supposedly adverse effect of joint immobilization per se on bone healing. The aim of our study was to answer the following question: To what extent is the speed and quality of fracture healing after rigid plate fixation influenced by additional plaster immobilization?

Materials and methods

Nineteen male Chinchilla rabbits weighing from 2520 to 3470 grams were used. A transverse, unilateral osteotomy of the midshaft tibia was fixed with a 45 x 5 x 1 mm stainless steel plate (Terjesen 1984). In 10 animals no additional fixation was applied (Group A).

In the others (Group B), a plaster bandage from the toes to the midthigh was applied, immobilizing the ankle joint in the zero position and the knee joint in 90° of flexion.

Three animals were discarded because of peroperative fracture through one of the screw holes (2 rabbits in Group A) and redislocation of the osteotomy due to loosening of the screws in the distal fragment (1 rabbit in Group B).

The animals were killed after 6 weeks, and both tibiae were dissected free of all soft tissue. The bones were radiographed after plate removal and stored at −18°C until testing.

Evaluation of bone healing. The outer anteroposterior (AP) and transverse distances of the test bone were measured at the osteotomy site with a caliper, and at the corresponding level of the control bone. The cross-sectional area was calculated, assuming it to be triangular. The amount of periosteal callus was determined by subtracting the cross-sectional area of the control bone from that of the test bone.

Both tibiae were tested in 4-point bending in an Instron machine. The load was applied at the osteotomy site and the deformation measured with a linear variable differential transformer (Terjesen 1984). From the load-deformation diagram, the bending strength and elastic stiffness were determined, and the values for the healing tibiae expressed as the percentages of the corresponding values for the control bone.

The differences between the two groups were calculated with the Wilcoxon two-sample test (two-tailed test). Differences were considered significant at P values below 0.05.

Results

In Group A, partial weight-bearing was resumed a few days postoperatively, and full

Table 1. Periosteal callus (mm^2), bending strength and elastic stiffness of the healed tibiae. The biomechanical values are expressed as the median (range) percentages of the corresponding values for the control bones.

	Plate n = 8	Plate and plaster cast n = 8	Significance
Periosteal callus	23.8 (14.2–39.9)	14.1 (8.9–47.0)	NS
Bending strength	107 (55–125)	55 (37–76)	$P = 0.009$
Elastic stiffness	126 (103–153)	87 (65–135)	$P = 0.005$

function of the limb was apparently regained after 2–3 weeks. The animals in Group B had impaired functional use of the limb throughout the experiment. Because of the plaster cast, partial and full weight bearing were resumed later than in Group A.

Although the osteotomy line was still visible in most bones, all the osteotomies were radiographically healed at 6 weeks, albeit with little or no visible periosteal callus. The angulation of the fragments was less than 5° in both planes in all the animals in both groups.

The amount of periosteal callus was less in Group B than in Group A, but the difference was not significant (Table 1). The bending strength was greater in Group A than in Group B; the median strength was almost the double in bones without plaster immobilization as compared with those with plaster. The same clear difference was found regarding the elastic stiffness.

Discussion

Internal fixation by a metal plate provides satisfactory conditions for fracture healing in diaphyseal bone (Schenk & Willenegger 1963, Rhinelander 1974), and the mechanical properties of the healing tibiae in rabbits have regained approximately normal values in 6 weeks (Paavolainen et al. 1979, Terjesen 1984). This was confirmed in the present study, since the bones without a plaster cast were as strong and stiff as their control bones.

The mechanical qualities of the osteotomized bones with additional plaster immobilization were substantially reduced. The reason was not a different pattern of healing, because no significant difference in the amount of periosteal callus was found. The probable explanation lies in the fact that the function of the limb was different in the two groups.

In experiments on intact rabbit bones, joint immobilization causes muscle atrophy and bone loss (Geiser & Trueta 1958, Kharmosh & Saville 1965, Claes & Burri 1979); lack of muscular action was thought to be the most important factor in inducing bone atrophy. Claes & Burri (1979) reported a reduction in femoral strength by one third after immobilization of the hind limb in a plaster cast for 6 weeks. Thus, the adverse effect on the quality of intact bones due to immobilization is considerable, and the present study showed that the same is true regarding the healing process after fractures. Early, active mobilization not only restores joint and muscle function more promptly, but promotes more rapid healing of the bone as well. Bone blood flow and mineral deposition in fractured bone are closely related (Holden 1972, Paradis & Kelly 1975). When the muscles surrounding the osteotomy on the rabbit radius were made ischemic, there was a delay in bone healing (Holden 1972). On the basis of these studies, the most likely explanation of the delayed healing due to plaster immobilization in our investigation appears to be the reduced function of the muscles, which leads to a decreased blood flow to the fracture area.

According to Danis (1949) and the AO group (Müller et al. 1965), the main benefit of plate osteosynthesis is lost if the joints have to be immobilized by a plaster cast. The findings of our present study confirm this view. Hence, one should be cautious with the use of plate fixation in patients where optimal stability of the fixation cannot be achieved owing to osteoporotic bone or severe comminution of the frac-

ture, and in patients who might not cooperate during the healing period.

References

Claes, L. & Burri, C. (1979) Mechanische und histologische Befunde bei Inaktivitätsosteoporose. *Unfallheilkunde* **138**, 297–302.

Danis, R. (1949) *Théorie et pratique de l'osteosynthèse*. Masson, Paris.

Geiser, M. & Trueta, J. (1958) Muscle action, bone rarefaction and bone formation. *J. Bone Joint Surg.* **40-B**, 282–311.

Holden, C. E. A. (1972) The role of blood supply to soft tissue in the healing of diaphyseal fractures. *J. Bone Joint Surg.* **54-A**, 993–1000.

Kharmosh, O. & Saville, P. D. (1965) The effect of motor denervation on muscle and bone in the rabbit's hind limb. *Acta Orthop. Scand.* **36**, 361–370.

Müller, M. E., Allgöwer, M. & Willenegger, H. (1965) *Technique of internal fixation of fractures*. Springer Verlag, Berlin, Heidelberg, New York.

Murray, C. R. (1934) Healing of fractures: Its influence on the choice of methods of treatment. *Arch. Surg.* **29**, 446–464.

Paavolainen, P., Slätis, P., Karaharju, E. & Holmström, T. (1979) The healing of experimental fractures by compression osteosynthesis. *Acta Orthop. Scand.* **50**, 369–374.

Paradis, G. R. & Kelly, P. J. (1975) Blood flow and mineral deposition in canine tibial fractures. *J. Bone Joint Surg.* **57-A**, 220–226.

Rhinelander, F. W. (1974) Tibial blood supply in relation to fracture healing. *Clin. Orthop.* **105**, 34–81.

Schenk, R. & Willenegger, H. (1963) Zum histologischen Bild der sogenannten Primärheilung der Knochenkompakta nach experimentellen Osteotomien am Hund. *Experientia* **19**, 593–595.

Terjesen, T. (1984) Bone healing after metal plate fixation and external fixation of the osteotomized rabbit tibia. *Acta Orthop. Scand.* **55**, 69–77.