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DEFECT PSEUDARTHROSES

An Experimental Study on Rabbits

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One of the difficulties in assessing the results of experimental bone grafting is posed by the inability to decide with certainty whence the new-formed bone has developed.

It may have issued from the recipient site and have invaded the graft by creeping substitution. It may have issued from surviving cells in the graft. Lastly, it may have arisen from the surrounding soft tissues by metaplasia induced by the graft.

Most often grafting to fresh bone defects has been used. In long bones these have usually been small defects, as a circumferential total defect cannot be obtained without loss of stability. As a result, these studies have been disturbed by the response of the recipient site to the fresh bone injury: a pronounced regeneration of bone which often completely overshadows the weaker reaction of the graft.

In grafting to cancellous bone, as in the spongiosa test described by Maatz et al. (1954), such pronounced callus formation also takes place in the recipient site that one gets an impression rather of the acceptability of the graft than of its independent osteogenetic effect.

Ectopic bone grafting is well-suited for elucidating certain biological and immunological properties of bone tissue. It is less suited for direct evaluation of the clinical value of a bone graft, as it is not possible to observe the reaction of an indolent bony recipient site to the graft.

Therefore, an attempt was made to induce in the long bones of rabbits a defect which was stable and which did not heal spontaneously in order thereby to obtain a recipient site for use in comparative studies of various types of bone grafts.

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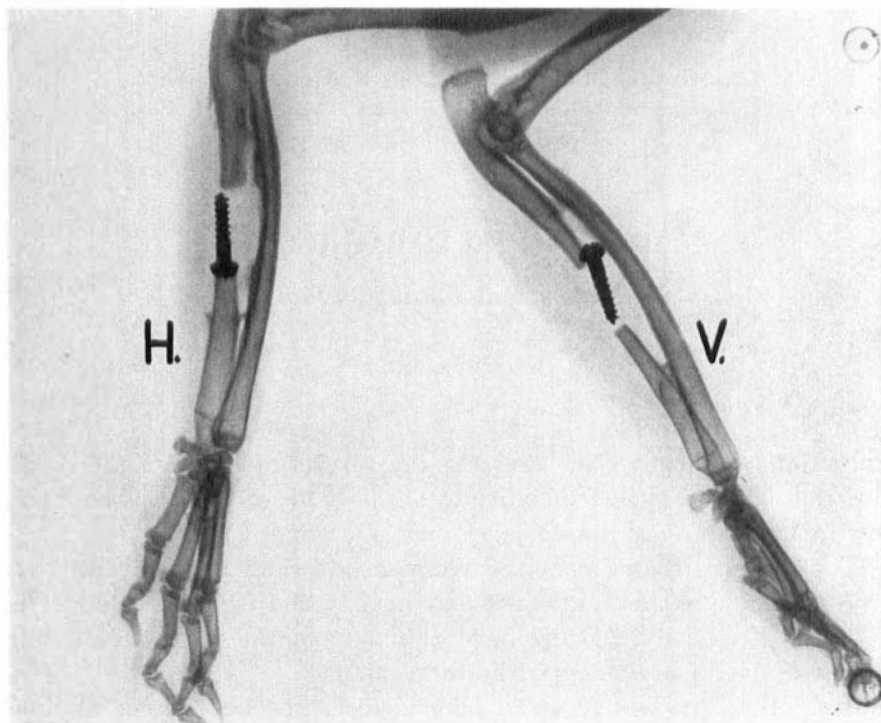


Figure 1. 6 weeks after the first operation. The polyethylene caps are fixed to each other by a screw. There is only sparse regeneration of bone at the edge of the polyethylene caps.

MATERIAL AND METHODS

The experimental animals were 30 adult or almost adult rabbits of mixed race, ranging in age from 6 to 12 months.

The rabbits were anaesthetized with Nembutal, approx. 40 mg/kg body weight. The operative sites were shaved and disinfected with iodine. As a prophylactic measure penicillin was administered locally and intramuscularly, a total of 300,000 units.

1. 13 rabbits had operations on both hindlegs. A defect, 1 cm large, was sawn out somewhat above the middle of the femur. The bone ends were covered with polyethylene caps, and osteosynthesis was performed, providing a strong metal splint, Küntscher nail, or a strong intramedullary vitallium screw.

2. 17 rabbits had operations on both forelegs. The ulna was exposed, leaving the periosteum intact on the bone. A total defect, 0.75 cm, was sawn 3.5 cm distally to the tip of the olecranon process. The calcified interosseous membrane was broken, so that both ulnar fragments were free of the radius. The cavity and the adjacent muscle surfaces were painted with trichloroacetic acid. The free bone ends of the ulna were covered with a polyethylene cap whose bottom was half the thickness

of the defect and which had 7 mm sides so that the caps were firmly fixed in relation to each other. Furthermore, the caps were fixed to each other by a screw (Figure 1).

6-10 weeks later the rabbits had re-operation, removing the screw and polyethylene caps, by a technique as atraumatic as possible. The resulting cavity and the bone ends were shielded from the radius by a 1 mm polyethylene membrane measuring 3×20 mm.

Every 2 weeks one rabbit was killed, the last one 6 months after the latter operation. The forelegs were X-rayed, the specimens dissected, and by the conventional histological technique haematoxylin-eosin-stained preparations were made, cut longitudinally. Three sections of each preparation, from different levels, were studied.

RESULTS

1. *Bone defects in the femur.* As stated above, it was endeavoured to maintain a defect in the femur by means of polyethylene caps and different osteosynthetic material. Out of the 13 rabbits thus operated, 9 had to be considered technical failures. During the osteosynthesis fracture occurred, or else the osteosynthesis material failed later, resulting in secondary displacement. In the remaining 4 cases the rabbits failed to thrive and had to be killed before the planned removal of the osteosynthesis material. It could be ascertained that healing may be prevented by covering the bone ends with polyethylene caps. Histological examination revealed necrosis of the bony tissue and bone marrow in the part which had been covered by the polyethylene.

2. *Bone defects in the ulna.* This operation was well tolerated. When a stable result was obtained, the rabbits used their forelegs normally immediately after the operation. All gained weight. In one case infection appeared on one side.

X-ray examination showed that in the course of the observation period the radius underwent increasing hyperthrophy. Synostosis occurred between the uncovered parts of the ulna and the radius proximally and distally. If the osteosynthesis material failed at an early stage of the course, stress fracture of the neck of the radius and displacement occurred. This was observed in 3 cases. But when the polyethylene caps and osteosynthesis material were removed later than the sixth week, the operated site was completely stable. When subperiosteal resection of the bone was avoided, regeneration of bone beyond the edge of the polyethylene caps was slight (Figure 1). During the further course there was, after the removal of the osteosynthesis material, only sparse regeneration of bone, mainly around the proxi-

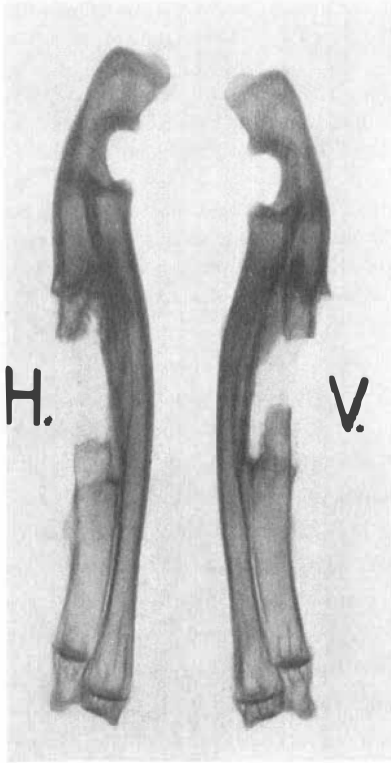
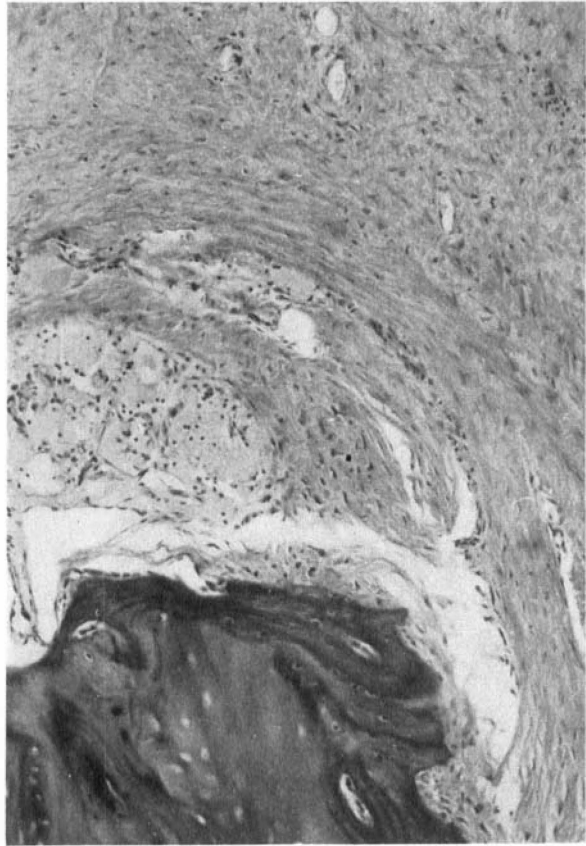


Figure 2. 8 weeks after removal of the osteosynthesis material. Hypertrophy of the radius. The defect has not healed.

mal fragment (Figure 2). Healing of the defect did not occur in any case.

Histological examination showed from the second week incipient vascularization, osteoclastic resorption, and creeping substitution of the corticalis in the bone ends. This increased during the experimental period, but even the 6-month-old preparations showed distinctly necrotic remnants of bone. At an early stage periosteal and endosteal callus appeared, spreading towards the defect which it seldom entered (Figure 3). The medullary cavity filled with normal bone marrow and closed with callus against the defect. In the second week the defect contained remnants of haematoma and granulation tissue. Gradually this tissue assumed the nature of denser connective tissue, and from the sixth week it was sprinkled with minor areas of fibrocartilage, premyeloid, and myeloid tissue (Figure 4). At times, the oldest preparations would show a small islet of bony tissue, but osseous healing did not occur in any case. The defect was always surrounded by a dense connective-tissue membrane.

*Figure 3. 6th week.
Necrotic bone end in the
process of creeping
substitution. Fibrous
tissue in the defect.*



DISCUSSION

Only a few experimental studies on pseudarthroses on animals have been reported previously. Martin (1920), Lexer (1922), and Willich (1924) induced pseudarthroses on dogs by segmental resection of the ulna or radius, maintaining the periosteum or marrow, and studied the aetiology of pseudarthrosis.

According to Key (1934) a total defect in the ulna of dogs does not heal if the defect measures more than $1\frac{1}{2}$ times the diameter of the bone. He used such fresh defects as recipient sites in his transplantation experiments. However, in 2 out of 6 control experiments the empty defect healed spontaneously. Heiple et al. (1967) induced defects in the dog ulna twice the diameter of the bone and found that 1 out of 7 empty defects healed spontaneously. At 3 months only 4 out of 11 fresh autologous grafts showed bony union to both fragments. From



*Figure 4. 10th week.
Fibrous and myeloid
tissue in the defect.*

these findings it seems evident that fresh defects in the dog ulna have a certain tendency to spontaneous healing and that the operative site is so unstable that even autografts often fail to take.

The method used in the present study gives a stable operative site which does not heal spontaneously in 6 months. The defect is surrounded by a fibrous membrane and contains fibrous tissue, fibrocartilage, and small amounts of osteoid tissue. Proximally and distally it is delimited by necrotic and new-formed bone. Pathologically, the condition is similar to pseudarthrosis and appears to be well-suited as the recipient site for bone grafting.

SUMMARY AND CONCLUSION

A method for inducing a pseudarthrosis-like defect in the rabbit ulna is described.

It is concluded that such a defect is well-suited as a recipient site for bone grafts in studies of their osteogenetic effect.

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