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REIMPLANTATION OF A TRAUMATICALLY EXPELLED TIBIAL DIAPHYSIS

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The successful reimplantation and healing of a traumatically expelled tibial diaphysis in a 16-year-old boy is presented. Radionuclide scintimetry with ^{87m}Sr and ^{85}Sr during the following months showed a pronounced diaphyseal activity corresponding to abundant periosteal bone formation around the dead cortical bone, increased activities over the fractures and the growth plates. Microscopical investigation after tetracycline labelling about 1 year after the accident showed a pronounced osteoblastic and osteoclastic activity in the superficial part of the cortex of the reimplanted bone. The endosteal part consisted of necrotic bone and was only to a small extent replaced by new bone. The uncomplicated healing process observed in this case can be attributed to the youth of the patient, the absence of infection and, most important of all, the preservation of the periosteum and its blood supply.

Key words: bone regeneration; bone resorption; fractures; histology; oxytetracycline; reimplantation; strontium radioisotopes

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The management of excessive traumatic loss of cortical bone is a difficult problem. The use of autogenous transplants, artificial devices, as well as reimplantation of expelled pieces of bone (Strange 1963, Kirkup 1965, Abell 1966) has been described. The preoperative handling of expelled bone has also been discussed (Burwell 1969, Imamaliev 1969). However, to our knowledge successful reimplantation of a large, full-width piece of the tibial diaphysis has not been reported previously. The reorganization of the reimplanted bone was studied by radiography, scintimetry and microscopy.

CASE REPORT

Clinical course

A boy aged 16 years riding his motorcycle collided with a lorry in December 1973. On admission to a nearby hospital he had a large wound over the right tibia and a 15 cm long piece of expelled tibial diaphysis was found in his trousers. He also had a closed fracture of his right femoral shaft. The initial therapeutic suggestion was to perform an amputation but as the circulation and nerve supply of the limb were intact the surgeons contacted the central orthopaedic clinic. The boy was given high doses of penicillin and tetanus toxoid and the expelled bone was placed in a container with sterile Ringer solution. The boy and the bone fragment were then immediately sent to us, a journey of 1½ hours. On admission here the boy was in good general condition. He had a 25 cm long clean wound on the anterior side of the lower leg and the transverse ends of the tibia could be seen in the proximal and distal ends of the wound. The 15 cm long bone fragment comprised the whole missing part. Radiographs showed absence of the tibial shaft (Figure 1) but intact knee and ankle joints.

An operation was immediately performed. The loose bone fragment was carefully cleaned, replaced and fixed with a Rush-pin. The periosteal

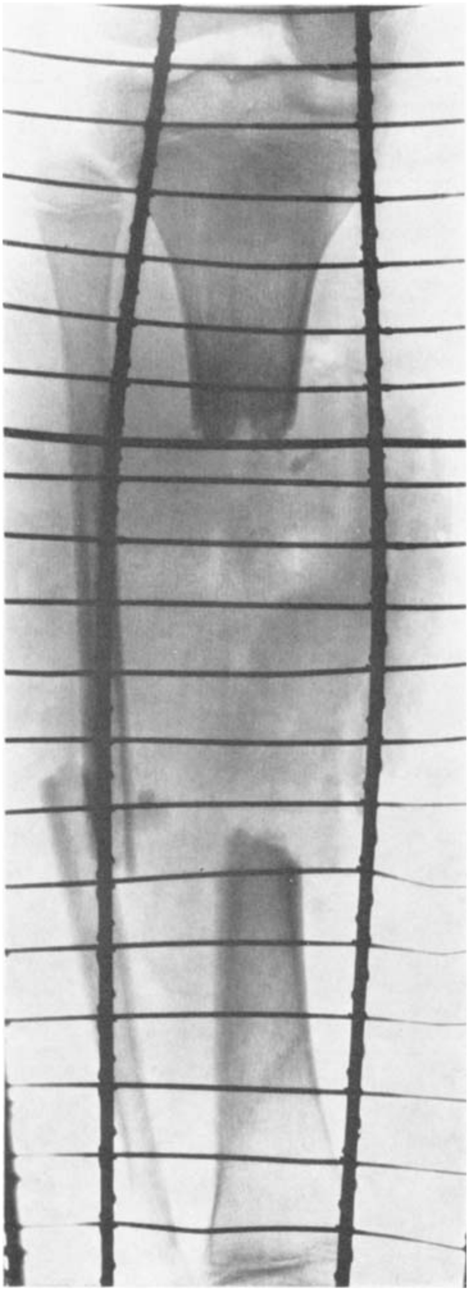


Figure 1. Radiogram on admission. Traumatic loss of 15 cm of the tibial diaphysis. The fractures are transverse. Note shortening of the leg as compared with Figure 2.

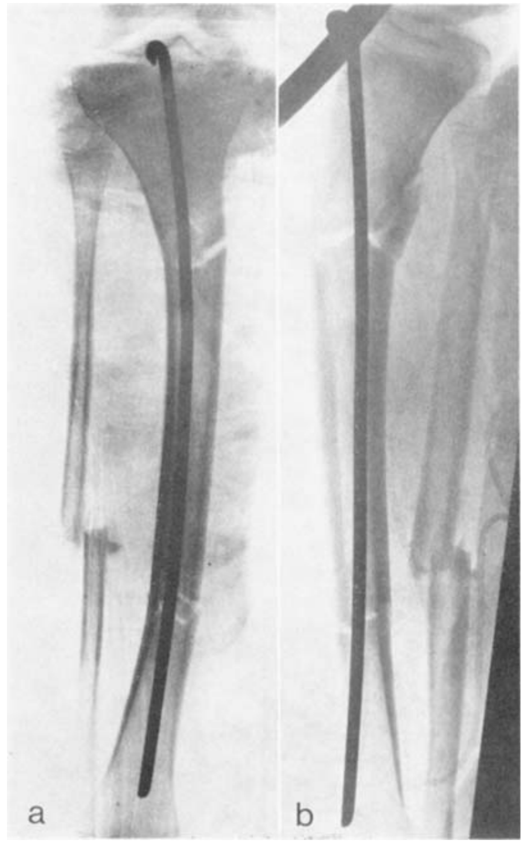


Figure 2. Radiograms 2 weeks after reimplantation and nailing of the expelled tibial diaphysis. Early signs of periosteal bone formation.

tube which had ruptured along the entire bone defect was sutured back over the bone. After closure of the wound the leg was immobilized in a plaster. Postoperatively a slight valgus deformity (Figure 2) was partially corrected with closed reduction.

Ten days after the accident the femoral shaft fracture was operated on and fixed with plate and screws. Healing of this fracture was uncomplicated.

The postoperative course was remarkably uneventful. He received 8 million international units V-penicillin daily for 4 weeks. The wounds healed without signs of infection. After 6 weeks he returned home. After 2 months a PTB-plaster was applied (Figure 3). Full weight-bearing was allowed after 3 months. After 4 months he could walk quite well and he could flex his knee 90°. Nine months after the accident knee flexion was quite normal and the boy could run in the forest and play football.

One year after the accident there was no difference in leg length and there was normal motion of the knee and ankle joints. The fractures had consolidated both clinically and radio-

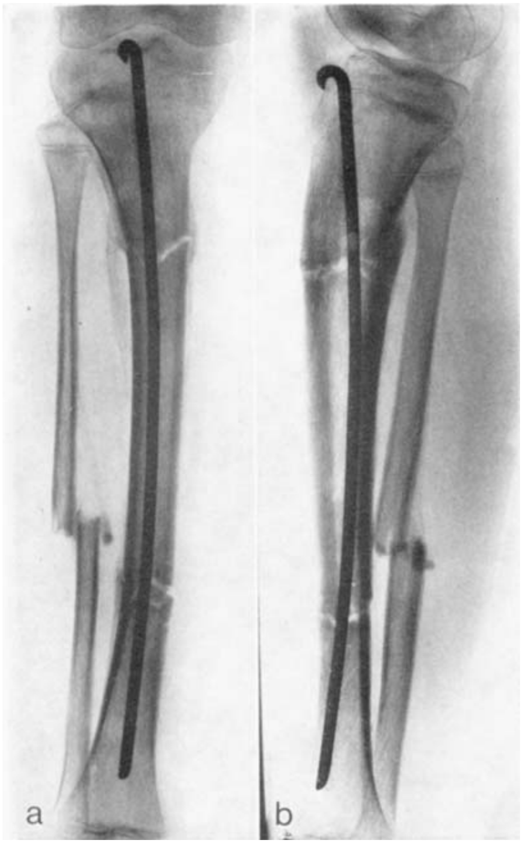


Figure 3. Radiograms 2 months after reimplantation. Abundant periosteal bone formation throughout the total diaphyseal area.

graphically (Figure 4), with a valgus deformity of the right tibia of 10° compared with the left.

Microscopical investigation

When the Rush-pin was removed a block of bone (Figure 4) was removed from the antero-medial cortex of the formerly extruded piece of diaphysis. One month before this biopsy 250 mg Terramycin® × 4 was given *per os*. Immediately before the biopsy 250 mg Terramycin® was given intravenously.

The specimen of cortical bone was sawn transversely into small pieces. Some of these were fixed in Bouin's solution and decalcified in formic acid (40 per cent) and sodium formiate (7 per cent). Transverse and longitudinal sections of this material were made with a thickness of about 12 mμ. These sections were stained in Ehrlich's haematoxylin-eosin, Azan and Schmorl's picrothionin staining.

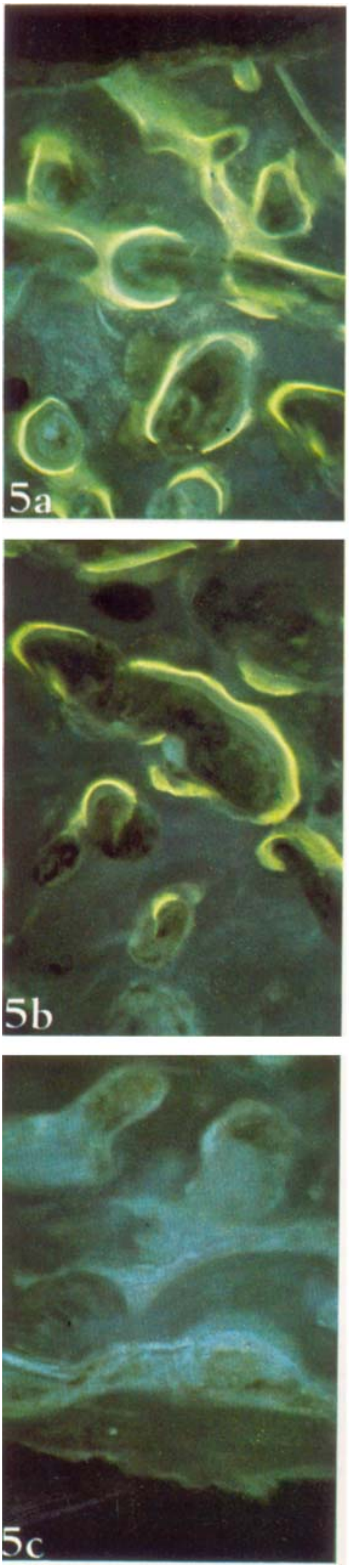
The other small pieces of cortical bone were fixed in absolute ethyl alcohol and transverse sections were cut with a rotating saw; the thickness of the sections was about 100 mμ. The sections were examined in incident and transmitted light in a fluorescence microscope (Leitz Orthoplan).

The thickness of the antero-medial cortex measured about 5–8 mm. In undecalcified and unstained sections there was a brown colour in the vascular channels of the periosteal areas. This colour was absent in the endosteal areas.

In the cortical bone there was an irregular mesh-work of necrotic and vital vascular channels and lamellar bone (Figures 5 and 6).

Both in the light microscopy and fluorescence microscopy there was no periosteal appositional bone formation. The bone tissue immediately beneath the periosteum was partly necrotic and partly vital and newly formed, the latter as-

Figure 4. Radiograms 1 year after reimplantation. The Rush-pin has been removed and a biopsy has left a cortical defect. Both fractures of the tibial shaft have healed. The abundant bone formation laterally is due to the valgus deformity.



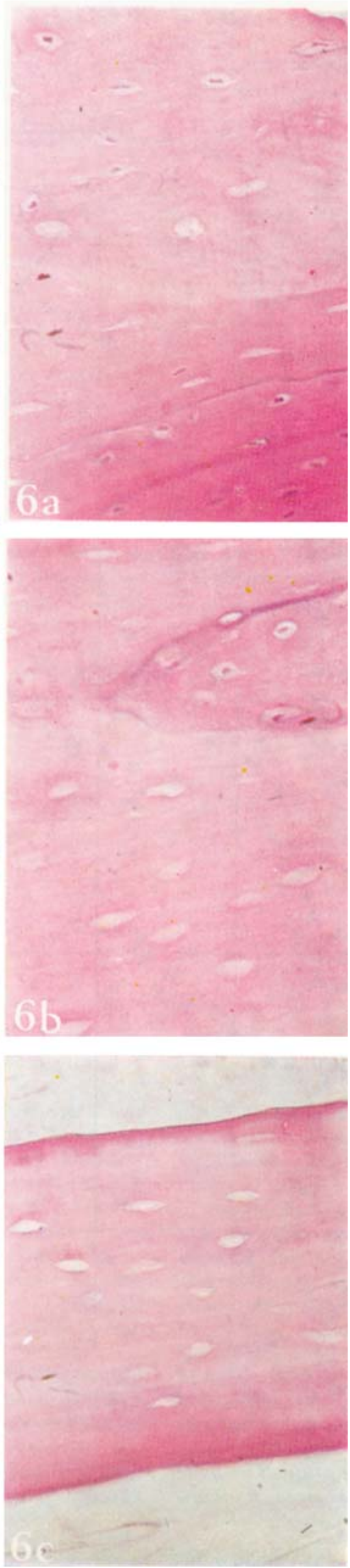


Figure 5. Fluorescence microphoto. Undecalcified transverse section from a) periosteal region, b) middle region and c) endosteal region of the cortex. Note two fluorescent yellow zones indicating bone apposition between the two injections of oxytetracycline. The revitalization is prominent in the superficial parts (a and b) but almost absent in the deeper part of the cortex (b and c).

Figure 6. Microphoto. Decalcified, longitudinal section, from a) periosteal region, b) middle region and c) endosteal region of the cortex. Ehrlich's haematoxylin-eosin. Note necrotic as well as living bone in the superficial regions (a+b). Deeper regions are characterized by almost necrotic bone and acellular bone marrow (b+c).

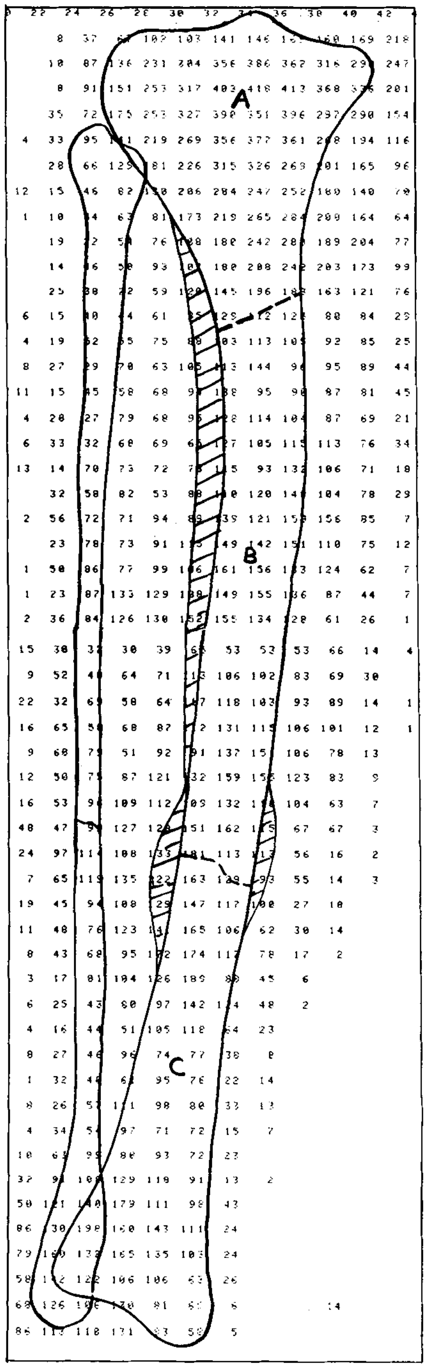


Figure 7 a. Scintimetry of fractured tibia 2 weeks after reimplantation. Note epiphyseal activities, high activities around the fractures and a pronounced diaphyseal activity corresponding to periosteal bone formation. The bone mass here is dead (B). Shadowed area = abundant callus formation later seen on radiogram (Figure 3).

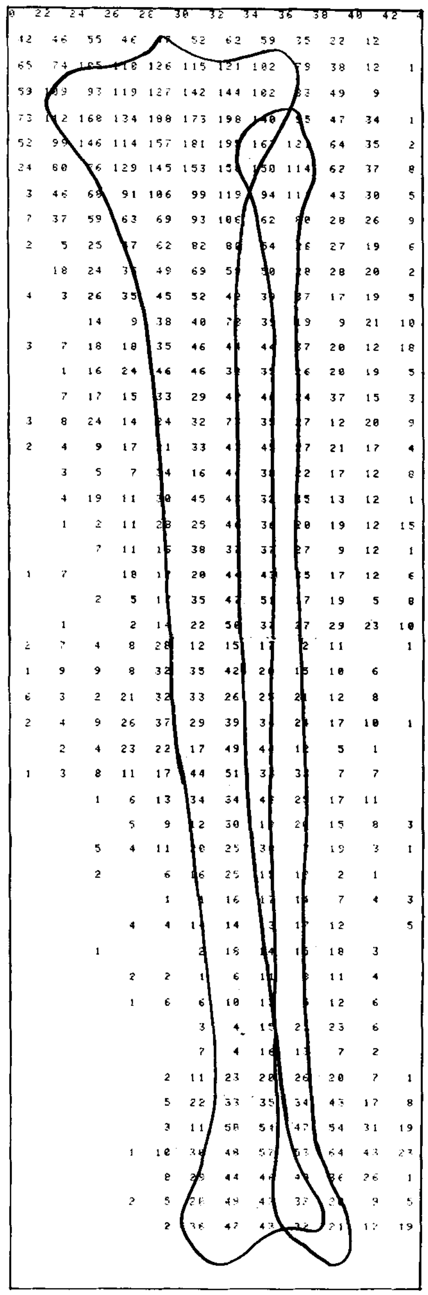


Figure 7 b. Scintimetry of left intact tibia. Note epiphyseal activities and the difference in comparison with the fractured tibial diaphysis.

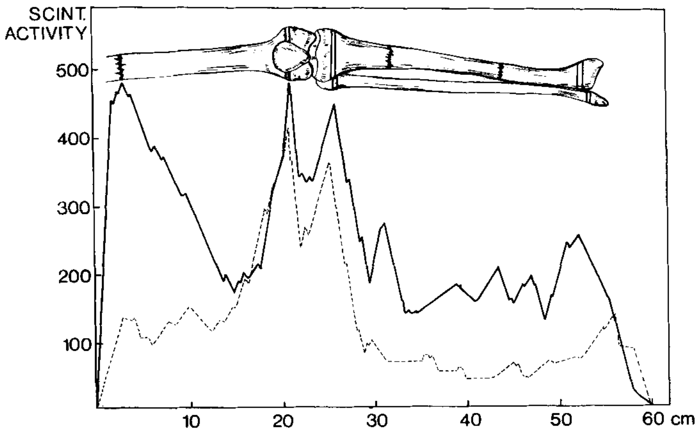


Figure 8. Profile diagram of fractured (———) and normal (– – – –) tibia 2 months after reimplantation. Note the high activities of the growth zones. Generally higher activity in the fractured tibia despite necrotic diaphysis. The localized activity over femur corresponds to the fracture.

Table 1. Mean scintimetry values and indices of areas A–C of the fractured tibia and corresponding values of the normal tibia (within brackets).

	Area A		Area B		Area C		Ref. index
	Mean act.	Index	Mean act.	Index	Mean act.	Index	
2 weeks postop.	247.4	380.6	121.8	187.3	102.9	158.3	0.65
2 months postop.	144.6 (99.1)	267.9 (183.5)	58.1 (30.5)	111.3 (56.2)	46.1 (22.7)	85.4 (42.1)	0.54
9 months postop.	–	–	59.0 (27.6)	105.4 (49.5)	–	–	0.56

sociated with invaginated vascular channels. Osteoclastic activity was found in both vital and necrotic bone tissue.

In the middle region of the cortex there was an increase in necrotic bone but vital bone was here also found in association with vascular channels. In some regions there was osteoclastic activity of necrotic bone while in other regions there was more appositional bone formation. Most of the vascular channels were made up of ordinary fibrous tissue with many blood vessels. In some of the channels there was necrotic fibrous tissue without signs of osteoblasts and osteoclasts.

The endosteal region showed a 2–4 mm deep zone of mainly necrotic tissue. The osteocyte lacunes were empty. Osteoblasts and osteoclasts as well as osteoid were absent. Most of the vascular channels consisted of an almost acellular fibrous and cystic tissue. Most of the endosteal surface was necrotic. The marrow cavity was filled with an almost acellular, fibrillar tissue but in some areas there were signs of fibroblasts, fat-cells and phagocytosis. There was no sign of infection. Some of the veins were occluded by old thromboses without signs of revascularization.

In conclusion, the microscopic investigation showed pronounced osteoblastic and osteoclastic activity in the superficial part of the cortex originating from the periosteum and the vascular channels invading the necrotic cortical bone. The lack of actual periosteal bone formation was probably the result of the fact that the biopsy was taken from the antero-medial aspect of the tibia where judging from the radiograms the initial periosteal bone formation had turned into periosteal resorption (Figures 3 and 4). Thus 1 year after the accident, despite full weight-bearing, the endosteal regions of the cortical bone consisted of necrotic bone tissue and were only replaced to a small extent by new bone.

Scintimetric investigation

Radionuclide scintimetry was done with ^{87m}Sr at 2 weeks (Figure 7) and 2 months (Figure 8) and with ^{85}Sr at 9 months after the accident. Scintimetry was performed in two ways, (1) with the detector, equipped with a focusing collimator, stepwise scanning the entire tibia and fibula in the frontal plane (Figure 7 a and b) and (2) with the uncollimated detector moving at a constant height and speed from the groin along the centre of the bone to the foot so that a profile diagram was obtained (Figure 8).

The scintimetries were used for topologic and quantitative definition of the reparative process. The fractures divided the tibia into three areas (Figure 7 a): the proximal (A), the diaphyseal (B), and the distal area (C). After correction for background and soft tissue radiation, the mean values of each area were calculated. For standardization with relation to individual retention and decay, these values were related to a reference index obtained from the normal tibia. Values thus obtained were called activity indexes of areas A–C.

The scintimetry values here are directly related to the accretion rate of the bone tissue (Bauer 1968). The four maxima observed over the tibia correspond to the growth zones and the two fractures (Figures 7 a and 8).

In the growth zones the values were 2-3 fold increased, probably reflecting the hyperaemia and overgrowth of a fractured bone.

The high values observed around the fractures also reflected the reparative process. The increased values over the reimplanted bone were more surprising. However, even though the bone was dead, the periosteal reaction was 2–3 times that of the periosteum and bone on the normal side.

DISCUSSION

There are two reasons why an expelled tibial diaphysis should be reimplanted. Firstly, it provides an automatically adequate spacer which preserves the shape and length of the bone during the rebuilding process. Secondly, it is an immunologically compatible substance which acts as a meshwork for the osteoblastic activity, and is capable of being removed gradually so that the physical strength of the bone is preserved. The remarkably swift and uneventful healing process observed in our case can be attributed to the youth of the patient, the absence of infection, and, most important of all, the preservation of the periosteum and its blood supply.

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