Morphological and Computer-Aided Tomographic Analysis of Tibial Reparative Regeneration in Distraction Osteosynthesis

Yu. A. Amiraslanov, G. G. Karmazanovskii, A. M. Svetukhin, D. S. Sarkisov, V. P. Tumanov, and V. A. Mitish

UDC.616.718.5−089.84]−073.756.8:681.31

Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 115, № 2, pp. 206−208, February, 1993
Original article submitted July 13, 1992

Key Words: *reparative regeneration; tibia; distraction osteosynthesis*

It is well known that dosed distraction osteosynthesis permits replacement of extensive defects of long tubular bones in the presence of a purulent infection without resorting of free osteoplasty. The bone defect in such cases is replaced with a vascularized restricted bone fragment obtained by osteotomy [2]. The majority of workers regard the nondifferentiated bone marrow cell as a source of reparative osteogenesis. Still, there are reports on a contribution of the pericytes to bone regeneration [1].

Computer-aided tomography (CAT) permits an assessment of the transverse structure of bone regenerate as early as at the initial stages of its formation, when distraction of the osteotomied fragment of a long tubular bone with external fixation apparatus is still in progress. Although metal pieces of the distraction apparatus are seen on tomograms as characteristic linear artefacts, our studies have revealed only a negligible effect of the latter on the densitometric parameters. In contrast, the presence of metal structures at the site of scanning is a contraindication against the use of magnetic resonance tomography.

A. V. Vishnevskii Institute of Surgery, Russian Academy of Medical Sciences

We have not seen in the available literature any reports about CAT examinations of osteogenesis in distraction osteosynthesis. This investigation was aimed at a morphological analysis of tubular bone reparative regeneration in distraction osteosynthesis and a comparison of the results of this analysis with CAT findings.

MATERIALS AND METHODS

Morphological studies were carried out during the course of distraction osteosynthesis. For monitoring of the course of tibia formation and for determination of the schedule of distraction apparatus removal, bone regenerate biopsy specimens were obtained in 12 patients immediately after the cessation of distraction and at the moment of removal of the external fixation apparatus, when the picture of healthy bone regenerate was detectable by X-ray. The specimens were decalcinated and histologically stained.

CAT studies of bone regeneration processes were carried out in 25 patients with a SOMATOM DR2 computer tomograph (Germany). The limb was positioned strictly perpendicular to the scanning plane. The upper and lower borders of the bone regenerate were seen on the tomograms, and scanning was carried out within these borders at 4-8 mm intervals at

0007−4888/93/0002−0212$12.50

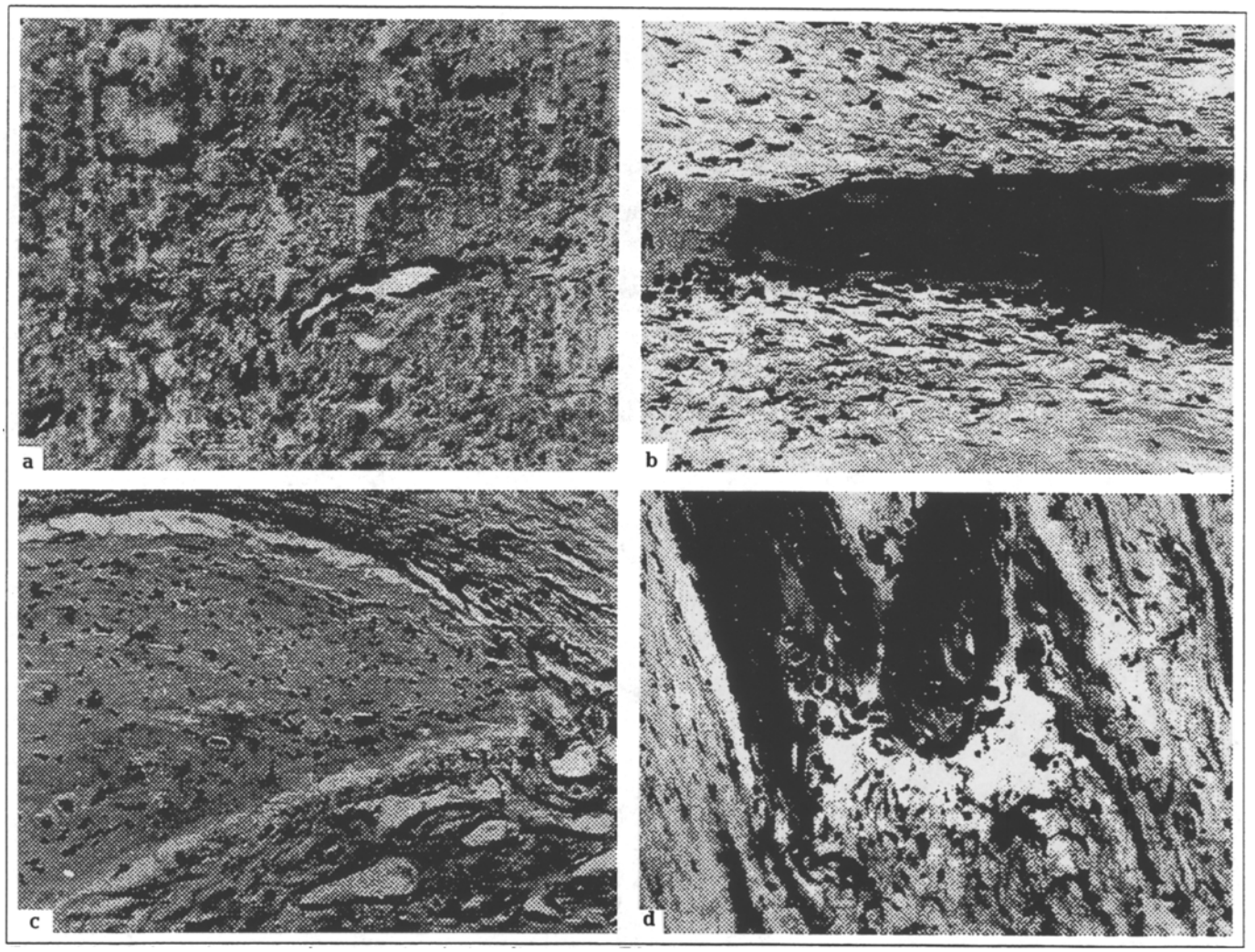

Fig. 1. Morphological picture of regenerate: *a*) at earliest stage. Fibrous connective tissue with numerous blood vessels and single fibroblasts found in a mass of collagen fibers. ×160 ; *b*) osseous beam formation with osteoblasts around it. ×260 ; *c*) hydroxyapatite crystals at site of osteoid tissue. ×200 ; *d*) sites of regenerated bone tissue. ×200.

a bundle width (section) of 4 mm. The examination parameters were as follows: 125 kV, 350 mAs, image matrix 256×256.

RESULTS

The regenerate tissue biopsy specimen obtained immediately after distraction cessation is characterized by a dense elastic consistency and grayish-whitish color. Microscopic examination showed that it consists of fibrous connective tissue represented by fine collagen fibers, longitudinally directed, a large number of small blood vessels, and single fibroblasts found inside the collagen fiber mass (Fig. 1, *a*). Small areas of regenerating bone are detected among the collagen fibers and fibroblasts (Fig. 1, *b*). Some of them present as osteoid tissue, surrounded by osteoblasts, with initial signs of mineralization in the form of small hydroxyapatite crystals (Fig. 1, *c*); others look like fully formed bone beams.

At the initial stages of distraction osteosynthesis CAT examination clearly shows the contours of an oval-rounded regenerate with the same profile as the bone at the level of osteotomy. The structure of the regenerate section is homogeneous, and the densitometric parameters 15-96 H with a mean value of 50.3 H correspond to the soft-tissue structure density. The cortical layer of the same (1-2 mm) thickness along the entire perimeter of the section is clearly imaged. Its density varies from 80 to 213 H (mean density 111.4 H). Eccentric accumulations of dot-size (1-2 mm) calcifications are seen against the background of the soft-tissue structure of the regenerate, the size and compactness of these calcifications increasing with time. The compactness of the calcifications in the indicated periods varies from 80 to 180 H. We believe that these CAT characteristics should be regarded as the early stage of regenerate formation, characterized mainly by a soft-tissue structure (Fig. 2). These changes correspond to the dis-

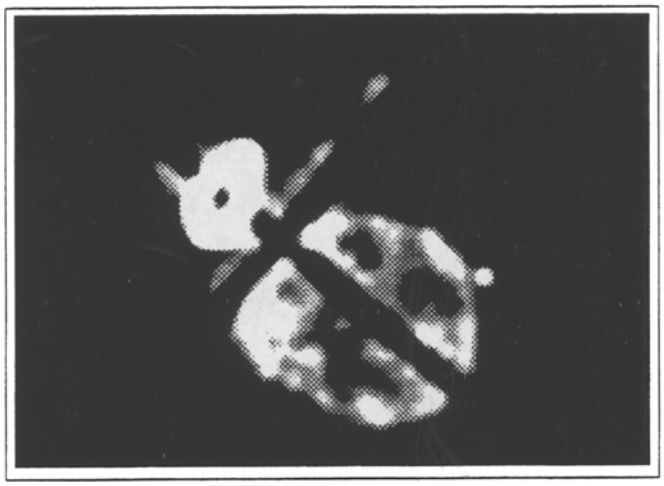

Fig. 2. Computer tomogram of patient K., aged 15. Tibial regenerate in the upper third. 5 months after injury.

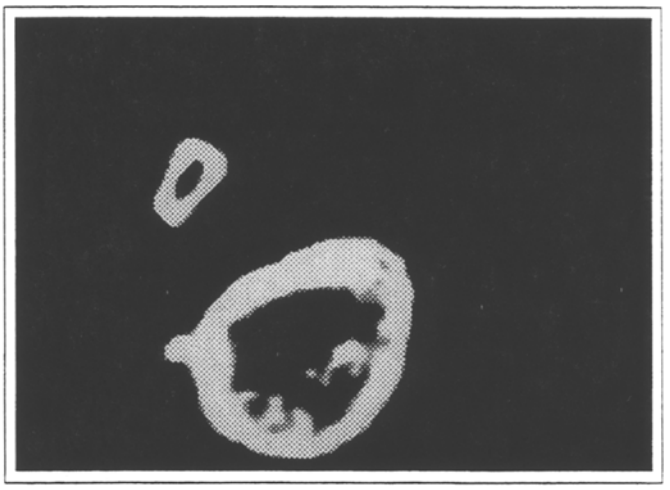

Fig. 3. Computer tomogram of patient M., aged 29. Tibial regenerate in the upper third. 3.5 years after injury.

traction period in which the defect is replaced or the length of the tubular bone is restored, this depending on the variant of distraction osteosynthesis chosen.

At later stages of distraction osteosynthesis (the period of bone regenerate "maturation"), when X-ray data present the regenerate as full-value bone tissue, histological studies demonstrate normal osseous tissue with the so-called fibrous-reticular tissue containing numerous sinusoidal vessels interspersed betweenindividual sites of this bone tissue (Fig. 1, *d*).

CAT studies in the same period show that the bone regenerate section virtually duplicates the shape and structure of intact bone. The density of the compact layer increases to 1500H, and the "lumpy" structure is preserved, particularly along the external contour. The cortical layer is as thick as in health, and in two patients it is even thicker. A homogeneous structure of 60-80 H density was always detected inside the cortical layer, resembling a sclerosed bone marrow canal (Fig. 3).

Hence, the morphological and CAT findings are in good correlation, demonstrating the formation of a bone regenerate in distraction osteosynthesis that duplicates the anatomical shape and structure of a regenerated tubular bone at the site of its osteotomy. CAT helps follow up the process of new bone tissue formation and detect deviations in this process, permitting timely correction of distraction osteosynthesis and specification of the rate of distraction and the time of removal of the external fixation apparatus.

REFERENCES

1. Yu. A. Amiraslanov, *Active Surgical Treatment of Patients with Open Fractures and Extensive Purulent Wounds under Conditions of a Controlled Abacterial Environment.* Dissertation submitted for the degree of Doctor of Medical Science, Moscow (1986).
2. A. A. Sveshnikov and V.E. Degtyarev, *Ortoped.Travmatol.*, №10, 23-26 (1985).