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Distraction osteogenesis and fracture healing. Differences and similarities

J. KURYSZKO, P. KUROPKA, I. JĘDRZEJOWSKA

Department of Histology and Embryology, Faculty of Veterinary Medicine,
Agriculture University of Wrocław, Kożuchowska 5, 51-631 Wrocław

In experimental research dealing with repair osteogenesis different aspects of its course are stressed. The osteotomy type influences osteoinduction and development of blood vessels, whereas biomechanical features of bone tissue are obtained by proper stabilisation of newly formed callus. Different directions of callus evolution create their final morphology. In this paper, similarities and differences in regenerate and callus morphology are compared in detail.

Key words: osteogenesis, distraction, fracture healing, sheep

Experimental research of repair and distraction osteogenesis concentrates on two main aspects of its course: initiation and exposition of arising callus depending on biomechanical conditions which provide callus evolution on the required path.

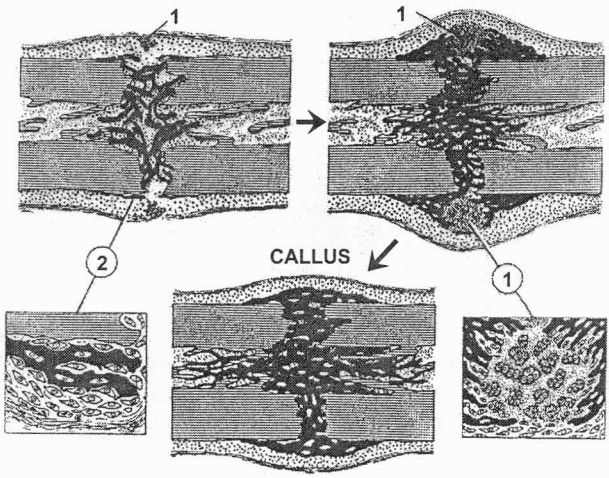

Fig. 1. Restitution of fractured bone: 1 – cartilaginous tissue, 2 – callus formed out of coarse-fibered bone tissue

Different aims, and thus different directions of callus evolution create significant differences in its final morphology. In this review, we are trying to compare fracture healing and distraction osteogenesis in experimental systems of sheep's tibia.

The occurrence of fracture initiates osteogenesis and results in destruction of bone matrix, blood vessels, periosteum and endosteum. Hematoma arises round the place of fracture and contains a great amount of growth factors [4], [6]–[9], [18]. Some of them, for instance, PDGF (platelet derived growth factor) and TGF-β (transforming growth factor β), influence growth, proliferation and differentiation of multipotential connective tissue cells and osteogenic cells. FGF (fibroblast growth factor) is considered as an initiator of angiogenesis. The matrix of bone after its resorption could be an accessory source of growth factors [3]. Moreover, oxygen level and micromovements between two ends of fractured bone increase osteoinduction [28]. As a result of proliferation of osteogenic cells of germinate part of endosteum and periosteum callus formation takes place in the central area and the thickening of endosteum and periosteum can be observed during the fracture healing [2], [14], [15], [24].

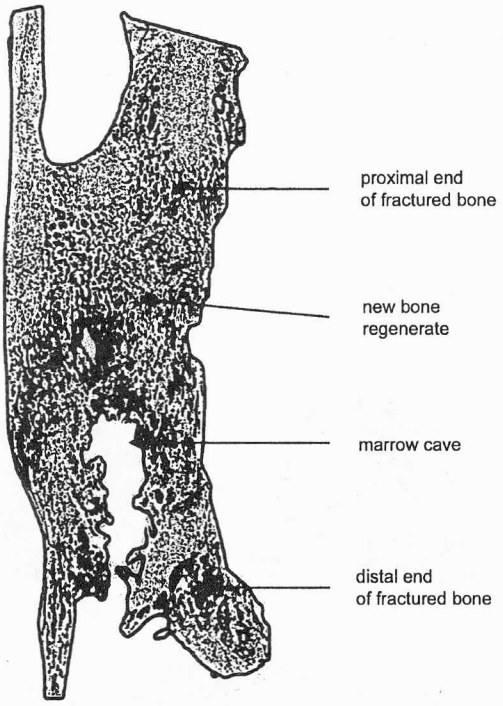

Fig. 2. Bone regenerate. As a result of distraction process elements of regenerate are arranged according to the course of distraction. (Note the lack of thickening of periosteum)

Ilizarov, in his previous studies, stressed the importance of the kind of osteotomy for initiation of inflammatory and proliferating phase [12], [13]. However,

KRAWCZYK et al. in their study on morphology of bone regeneration in distraction osteogenesis after applying five different osteotomy methods showed that well developed callus can be obtained independent of the level of damage to bone marrow [16].

It is obvious that during the osteotomy, a subsequent damage is done to periosteum with the vessels, bone tissue, endosteum and bone marrow. The damage level and level of osteoinduction depends on the number of cytokines and their target cells. The target cells for cytokines in such circumstances are the multipotential osteogenic cells.

The main source of multipotential osteogenic cells is endosteum and periosteum. An additional source of osteogenic cells is marrow stroma. However, distribution of stromal cells is not restricted to the specific area. Hence, damage of marrow stroma does not determine the destruction of osteogenic cells. On the other hand, damage of periosteum brings about destruction of osteogenic cells which are primarily located in its germinative part. Wide injuries of periosteum result in a decreased number of osteogenic cells weakening osteogenic response.

So, it seems that preservation of periosteum and endosteum is essential to obtain required mobilisation of bone cells, however, preservation of bone marrow is not so important, which fact has been observed in different studies.

Another problem not well explained yet is the type of osteogenesis responsible for callus formation: endochondral or membranous?

One of the elements which determine differentiation of osteogenic cells is development of blood vessels. As already mentioned, low oxygen level in the tissue is conducive to differentiation of mesenchymal cells towards chondroblasts, from these areas of cartilage that are frequently observed in regenerates and callus [17], [23]. Depending on different factors such as sex, age, species, these differences can be more distincive [19]–[21], [26]. This is caused by bone morphogenetic factors, which induce the osteogenesis independent of local environment, always by endochondral osteogenesis, with the bone contents being species specific [4].

The most desired is membraneus osteogenesis, because it significantly reduces the time of formation phase and allows its earlier remodelling into the lamellar bone.

During the phase of callus formation it is necessary to pay special attention to biomechanical properties of bone tissue. In the course of this phase, besides essential stabilisation which permits earlier load of fractured bone, micromovements stimulate that what can be achieved through removal of stabiliser from bone surface [1], [5], [10], [11], [17], [22], [25], [27]. Response to mechanical loading is one of the most unique features of bone. The strains such as stress or tensions can induce resorption or formation of a new bone. The cells responsible for this phenomena in healthy bone are osteocytes, which are interconnected by processes creating a three-dimensional net. This net transmits physical signals from bone matrix to bone surface, where resorption and formation can occur.

Over that period, in distraction osteogenesis, the removal of bone ends creates accessory load-bearings, which promotes bone formation. This creates the alterations in morphological view of bone regenerate compared to bone callus within zones, arising

from different promotion of osteogenic process. From the central zone towards proximal and distal ends connective tissue is subsequently replaced by woven bone with areas of cartilagineus tissue. At both ends, the remodelling of woven bone as well as cartilage into the lamellar (secondary) bone takes place.

Having been divided into zones, the bone regenerate should be well stabilised, especially in early periods of distraction.

On the basis of our own research on distraction osteogenesis we may say that the Ilizarov fixator is characterised by very good stabilisation and additionally enables the operator to control the direction of distraction. These advantages seem to be the most important in distraction of long bones of legs.

Another factor influencing the distraction osteogenesis is the speed and rate of distraction. This shall return the biological potential of bone tissue. It is clear that too fast or too slow a speed can induce complications such as microfractures, and, consequently, disturb the osteogenesis. Moreover, fast rate of distraction or its inappropiate rhythm (e.g., 1 cm per 24 hrs) leads to disturbance in surrounding tissues, mainly in muscles and their insertions, blood vessels, nerves and can cause abnormalities in articulations of the whole leg.

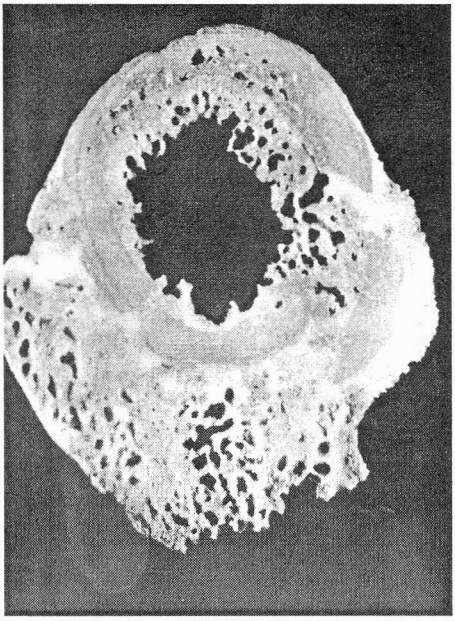

Fig. 3. Microphotograph of bone section during 11th week of fracture healing in osteosynthesis ZESPOL

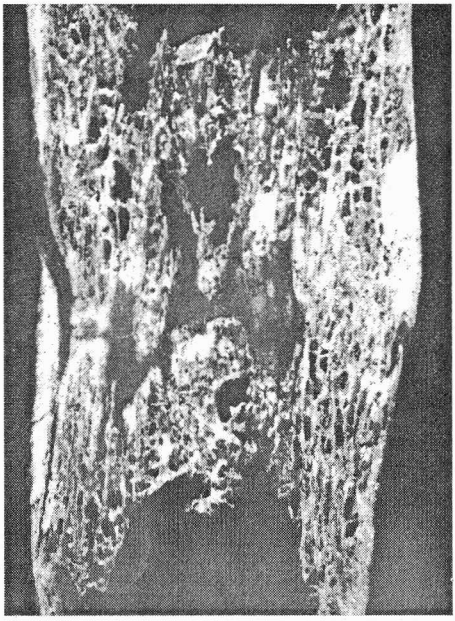

Fig. 4. Microphotograph of bone regenerate obtained according to the Ilizarov method; 11 weeks after an operation. Parallel arrangement of bone trabeculae and the lack of periosteum thickening

The speed of 0.5–1 mm/day divided into 3–4 rates seems to be optimal for most of the distractions, independent of the bone osteotomy method.

In spite of morphological differences both regenerate and callus undergo similar biological processes.

In conclusion, it must be emphasized that significant differences in development of both types of osteogenesis are the result of different treatment of callus in the forming phase, but basic interrelations are the results of biological and biomechanical properties of bone tissue, so research on more optimal fracture healing and distraction osteogenesis should be based on present knowledge of bone biology.

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