INTRODUCTION

Distraction osteogenesis is now an established, standard method for bone lengthening. Although there exists a growing body of the histological studies, little is known about the exact cellular and molecular mechanisms. Histological observations indicated that abundant blood vessels intervened among the newly formed bone trabeculae in the distraction gap. This study was undertaken to investigate the temporal and spatial changes of angiogenesis during the periods of distraction osteogenesis; the three-dimensional microarchitecture of newly formed vessels and their origin; and the role of angiogenesis with reference to mineralization.

MATERIALS and METHODS

Sprague-Dawley rat's tibia was osteotomized subperiosteally and was distracted with a rate of 0.5 mm per day for two weeks after one week of latency period. Vascular corrosion casting using Mercox was done on the hindlimbs before osteotomy, and at the 1st, 2nd, 3rd, 4th, and 6th weeks postoperatively. Replicated microvascular structures and their distribution patterns at the distraction site and adjacent parent bone were observed temporally and spatially under scanning electron microscope.

RESULTS

In the normal rat's tibia, vasculatures including artery, vein, arteriole, venule and capillary were set in an orderly array. Both nutrient artery and vein penetrated the posterior aspect of distal 1/3 of tibia. Penetrated nutrient vein branched into one proximal and one distal branches, the central vein, while penetrated nutrient artery branched into two proximal and two distal main branches, which ran on each side of the central vein respectively. Numerous sinusoids were located in tiers, which eventually drained into the vein via collecting sinus, along the course of central vein.

At postoperative one week, there were noticeable, generalized dilatation and proliferation of periosteal vessels. In addition, microvascular branches derived from periosteal vessels began to direct into the osteotomy site. Intramedullary venules and sinusoids were also dilated. There were considerable resin leakages, in a globular shape, around the sinusoids, suggestive of the vessels in the process of active angiogenesis.

At postoperative second week, in accordance with distraction, periosteal vessels of proximal and distal parent bone proliferated and progressed towards midline of the distraction gap. Early formation of new vascular network, apparently derived from the medullary sinusoids and the periosteal vessels, was distinct in the vicinity of the osteotomy surface of the parent bone. Resin leakages were still observed around the newly formed sinusoids. Histologically, early subperiosteal new bone formation was evident.

At postoperative third week, proximal and distal periosteal vessels were connected each other covering the distraction gap. Adjacent to the osteotomized surface there were arterial branches which apparently arose from the medulla of the parent bone. Moreover, multiple longitudinal vascular branches, 20-40 µm in diameter, sprouted out from the newly formed vascular network, and ran parallel to the direction of distraction towards the interzone. Resin leakages around the sinusoids were only observed adjacent to the interzone. Histologically, there were active subperiosteal and endosteal new bone formations. Blood vessels ran alongside the newly formed bone trabeculae, so-called microcolumn formation and primary mineralization front.

At postoperative fourth week, dilated sinusoidal vessels also tended to run parallel to the direction of distraction. In the peripheral side of the interzone, there was vascular approximation between the vascular network at newly formed trabeculae and the vascular branches derived from the periosteal vessels. The center portion of the interzone was still relatively avascular, however. Resin globules were scantily observed at the ends of the sinusoids.

At postoperative fifth week, vascular networks of both sides of the parent bone connected completely including the interzone, particularly near the periosteal side. Newly formed blood vessels in the distraction gap were still dilated, but there was no visible active angiogenesis. Taken together with radiographical and histological findings, in the distraction and early consolidation periods, a unique vascular branching pattern, showing multiple longitudinal branches arising from the end of the vascular network towards interzone, occurred in advance of progress of formation of microcolumns and primary mineralization fronts. In the late consolidation period, medullary and periosteal vessels eventually connected throughout the distraction site, which corresponded to the progress of mineralization.

CONCLUSION

Based on the above observations, it is concluded that in distraction osteogenesis angiogenesis occurred actively during the distraction period and then gradually decreased with time. There was close temporal and spatial relationship between the angiogenesis and new bone formation at the distraction site.

At postoperative sixth week, vascular networks of both sides of the parent bone connected completely including the interzone, particularly near the periosteal side. Newly formed blood vessels in the distraction gap were still dilated, but there was no visible active angiogenesis. Taken together with radiographical and histological findings, in the distraction and early consolidation periods, a unique vascular branching pattern, showing multiple longitudinal branches arising from the end of the vascular network towards interzone, occurred in advance of progress of formation of microcolumns and primary mineralization fronts. In the late consolidation period, medullary and periosteal vessels eventually connected throughout the distraction site, which corresponded to the progress of mineralization.

VASCULAR PROLIFERATION AND BLOOD SUPPLY DURING DISTRACTION OSTEOGENESIS. A SCANNING ELECTRON MICROSCOPIC OBSERVATION

+*Choi, I Ho (A-Seoul National University); **Ahn, J Hoon; *Chung, C Youb; *Cho, T

*Seoul National University College of Medicine, Seoul, Korea. Dept of Orthop Surg, Seoul Nat'l Univ Children's Hosp, 28 Yongon-dong Chongno-gu, Seoul 110-744, Korea, 82-2-760-3640, Fax: 82-2-745-3367, inhoc@plaza.snu.ac.kr

**Eulji Medical College, Taejon, Korea.

+*Seoul National University College of Medicine, Seoul, Korea. Dept of Orthop Surg, Seoul Nat'l Univ Children's Hosp, 28 Yongon-dong Chongno-gu, Seoul 110-744, Korea, 82-2-760-3640, Fax: 82-2-745-3367, inhoc@plaza.snu.ac.kr