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ON THE INFLUENCE OF INTERTROCHANTERIC OSTEOTOMIES UPON THE GROWTH AND VASCULARIZATION OF THE PROXIMAL PART OF THE FEMUR IN YOUNG RABBITS

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It is well known that stimulation of growth in long bones takes place following different interventions on the bones. This is especially the case after an osteotomy or a fracture, and references to the extensive literature are lately given in surveys by Sundén (1967) and Hedström (1969). The question of the causal relationship has been thoroughly discussed by these authors, and there seems to be general agreement as to the decisive influence of the vascular supply.

In the present investigation the growth rate at the proximal part of the femur in young rabbits has been measured by tetracycline labeling following partial or total osteotomies as an indicator of the vascular supply. At the same time direct visualization of the vessels has been attempted by microangiographic studies.

EXPERIMENTS

White female rabbits, 3 months old and weighing about 1.5 kg, were used for the experiment. They were kept in separate cages and fed on vegetables and given extra supplies of minerals and vitamins. Operations were performed with Nembutal anesthesia (40 mg per kg) under sterile conditions, exposing the left femur at the trochanter region. In 10 animals a partial intertrochanteric osteotomy was made with a hand-driven circular saw blade and the bone marrow eroded with a pointed knife, resulting in a profuse bleeding, of only short duration, however. As a fracture of the femur arose unintentionally in 5 of these animals either during the operation or immediately after, the osteotomy was somewhat restricted in the rest of the animals. In another

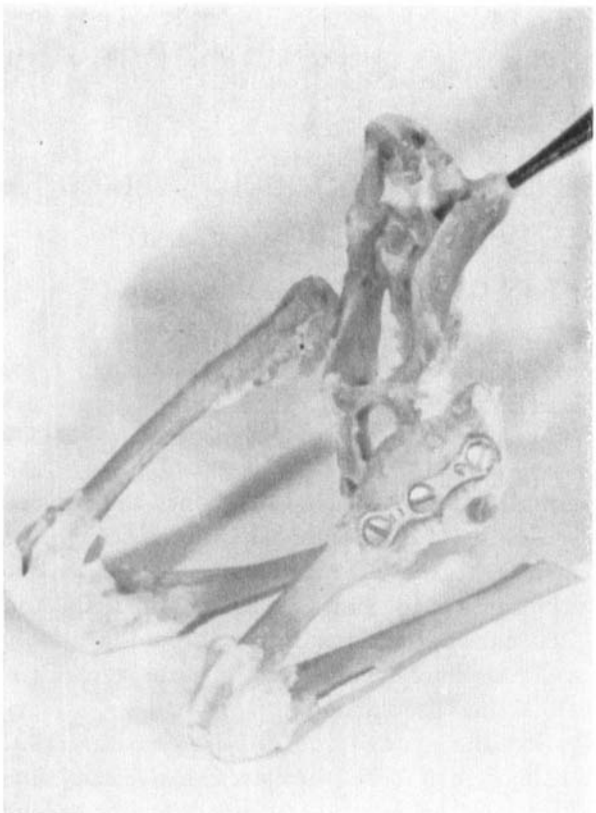

Figure 1. Dissection of animal No. 348, sacrificed 10 days following total osteotomy and internal fixation. Magnification × 1

series including 12 animals, a total osteotomy was performed in the same region using a Gigli saw and followed by application of a small plate with 2 or 3 screws for internal fixation (Figure 1). All the animals recovered from the operation, and no inflammation occurred. Between 6–33 days after the operation, tetracycline labeling on the bones was performed through i.m. injections of Reverin (Pyrolidino-methyl-tetracycline, 30 mg per kg). In the first series these injections were repeated twice with intervals of 6 days and in the last series with intervals of only 3 days. The animals were sacrificed one day after the second injection, and in the last series microangiography was performed according to a modification of the method of Trueta & Harrison (1953) as follows: During Nembutal anesthesia the peritoneum was opened and a cannula placed in the aorta, after which the animals, which had previously been heparinized, were bled from the veins.

Through perfusion with saline under 1 m water pressure, the remaining blood was washed out of the vascular system in the lower half of the body. The perfusion was continued with saline containing 2 per cent Berline blue, followed by 25 per cent Micropaque with 2 per cent Berline blue, and concluded with a mixture of 25 per cent Micropaque with 10 per cent formalin. The lower half of the body was skinned and kept in 10 per cent formalin for several days.

The operation side in each animal was dissected, and in the case of microangiography, the skeleton of the lower half of the body was cleaned of soft tissue except periosteum and ligaments, as shown in Figure 1, in order to preserve the vessels to the bones. The proximal part of the right and left femur, including the head of the femur and the great trochanter, was removed from all animals. In the first series the whole specimen was embedded in methyl-metacrylate, while in the second series the specimen was first divided in equal halves, one of which was decalcified before embedding and the other half embedded directly in methyl-metacrylate. With a rotating saw each specimen was cut in the frontal plane perpendicular to the epiphyseal plate, and through wet grinding, sections about 50 μ thick were obtained from the undecalcified specimen while sections 2.5 mm thick were prepared from the decalcified bone specimen. The growth at the epiphyseal plate of the femoral head and the great trochanter was determined by the distance between the fluorescent lines corresponding to the primary calcification front at the time of tetracycline labeling. Measurements were performed by fluorescent microscopy of the undecalcified specimen with a graduated eyepiece and on photographs (Tapp 1966, Hansson 1967, Bohr 1968). Microangiographic pictures of the decalcified sections were obtained using soft X-rays from a Machlett A. E.G. X-ray tube with a Wolfram anode generated at 25 kV and 15 mA at a distance of 40 cm. Exposures were made on Kodaline X-ray films.

RESULTS

Several sections from each specimen were available for the determination of growth, and examples of fluorescent photographs from a case in the second series are shown in Figures 2 and 3. Between different sections from the same animal the measurements varied by about 20 per cent. The effect of the operation on the growth was determined as the difference between the growth rate on the operated left and the

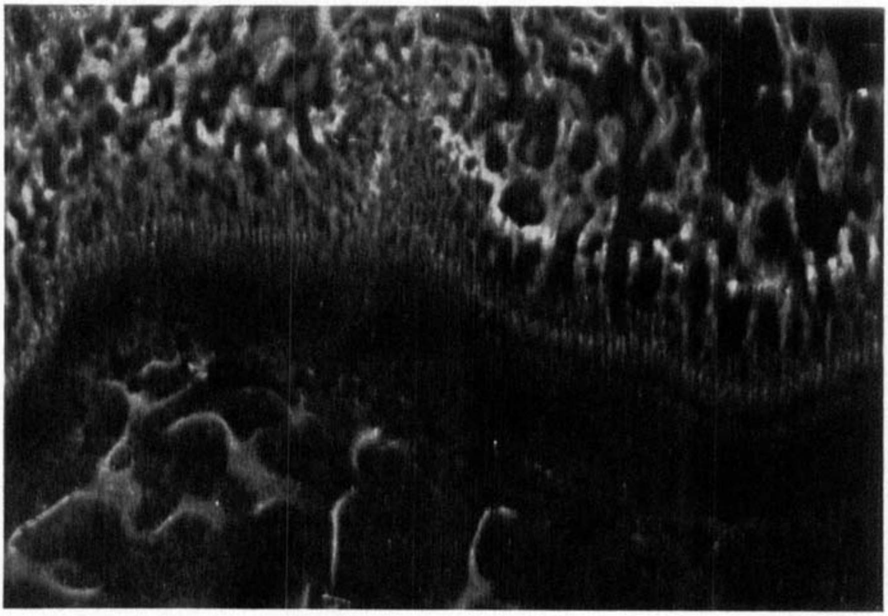

Figure 2. Fluorescent photograph of a 70 μ thick undecalcified section from the operated side of animal No. 056 sacrificed 10 days following total osteotomy and internal fixation. The lines from tetracycline labeling given 1 and 4 days before sacrifice are seen at the metaphyseal side of the epiphyseal plate.
Magnification × 25

control right side, expressed in per cent of the growth rate at the control side. The growth rate at the femoral head and the trochanter at different days after the operation is given in Table 1. It is seen that growth on the control side may vary more than 100 per cent from one animal to another, but this individual variation is not considered influential in the difference in growth between the right and left leg in the same animal. There was, in general, good agreement between the results obtained at the epiphyseal plate of the femoral head and the great trochanter. A summary of the results is shown in Figure 4, demonstrating that partial osteotomy did not have any significant influence on the growth, whereas the fracture did stimulate the growth significantly. This effect was further increased in the cases of total osteotomy with internal fixation. The mean values for growth stimulation at the epiphyseal plate of the femoral head for partial osteotomy was –14 per cent, for the fractures + 90 per cent, and for total osteotomy + 170 per cent, with a standard deviation of ± 10 per cent. For growth stimulation at the epiphyseal plate of the great trochanter, the corresponding mean values were –14, + 50, and + 105 per cent respectively, ± 10 per cent. At the control side the average growth at the trochanter was about twice that of the femoral head. The average increase in growth after total osteotomy was almost equal at both places, showing that the stimulative effect on growth was of the same order.

Microangiographic studies in the cases of total osteotomy showed that hyperemia was present in the proximal part of the femur on the operated side. This is demonstrated in Figure 5 and 6 showing sections of both femora from animals sacrificed 19 and 32 days after the operation. It is seen that the increased vascular supply on the operated side is derived mainly from periosteal vessels, whereas the central vessels in the bone marrow are less developed than on the control side in accordance with the results of Guida et al. (1969). The accumulation of vessels at the metaphyseal side of the epiphyseal plate is most distinct and the vascular supply to the epiphysis is increased to a lesser degree. In some cases vessels seem to penetrate the epiphyseal

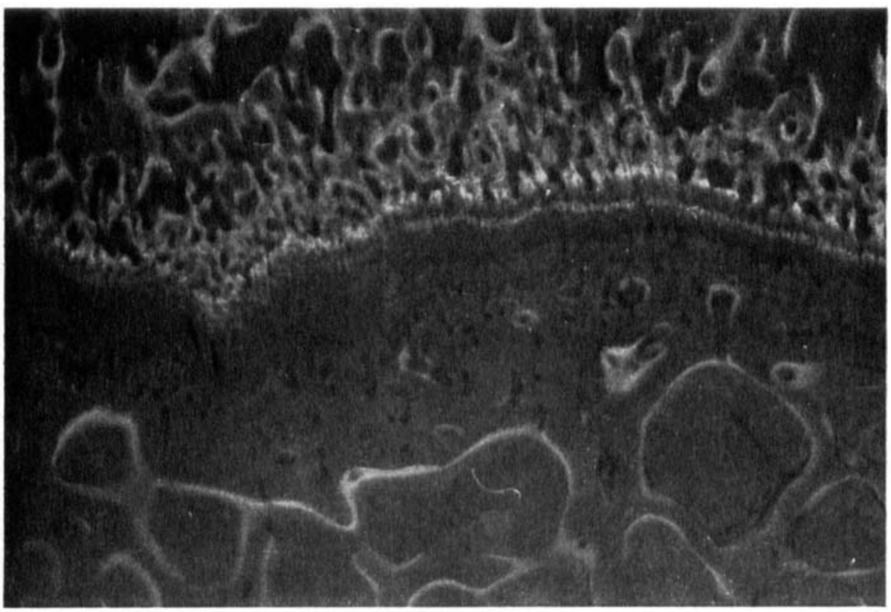

Figure 3. Fluorescent photograph of a 50 μ thick undecalcified section from the control side of the same animal as in Figure 2.

Table 1. Growth at the epiphyseal plate (ep. pl.) of the femoral head and the great trochanter following intertrochanteric osteotomy and fracture, according to the postoperative day of sacrifice of the animal.

Animal no.	Operation	Day postop.	Ep. pl. femoral head growth (μ/day)			Ep. pl. trochanter growth (μ/day)		
			Right	Left	Diff. %	Right	Left	Diff. %
289	total osteot. + int. fix.	6	20	45	+120	30	80	+170
70 E	– –	9	35	115	+230	60	115	+ 90
056	– –	10	35	115	+230	75	120	+ 60
348	– –	10	35	150	+330	75	220	+190
787	– –	10	20	80	+300	45	135	+200
750	– –	15	70	125	+ 80	65	105	+ 60
40 E	– –	19	20	55	+175	45	130	+190
022	– –	22	40	65	+ 60	70	105	+ 50
745	– –	23	40	140	+250	110	190	+ 75
366	– –	29	30	55	+ 85	30	75	+150
61 E	– –	32	60	140	+135	100	160	+ 60
328	– –	33	30	50	+ 65	40	25	— 35
75 E	part. osteot. + fracture	13	20	40	+100	25	45	+ 80
88 E	– –	13	30	60	+100	50	?	?
10	– –	19	40	50	+ 25	80	110	+ 35
11	– –	20	40	90	+130	80	145	+ 80
311	– –	20	35	35	0	40	45	+ 10
79 E	part. osteot. — fracture	7	100	90	— 10	110	120	+ 10
X (0)	– –	7	55	65	+ 20	90	100	+ 10
451	– –	10	85	80	— 5	110	100	— 10
506	– –	13	80	50	— 35	80	50	— 35
335	– –	32	85	50	— 40	110	60	— 45

plate from the metaphysis to the epiphysis of the head of the femur, and enlarged vessels from the periphery encircle the epiphysis of the trochanter.

DISCUSSION AND CONCLUSION

In the work of Trueta et al. (1960 a, b, c) the growth reaction to disturbances of the vascular supply to the epiphyseal and metaphyseal side of the growth plate has been studied. It appears that the proliferation of cartilage cells is mainly dependent on the blood supply to the

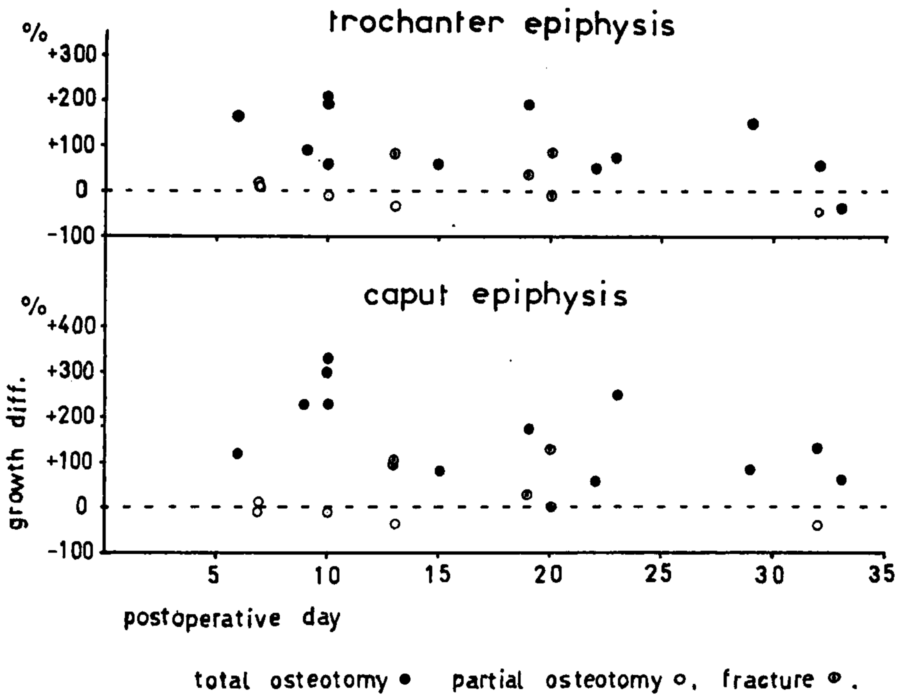

Figure 4. Growth stimulation following total osteotomy, partial osteotomy, and fractures.

epiphysis, whereas the processes of primary calcification and enchondral ossification are dependent on the blood supply to the metaphysis. Stimulation of growth thus seems to presuppose an increased vascular supply primarily to the epiphysis. It has been shown by Jabsley et al. (1965) that periosteal stripping and destruction of the nutrient artery in the proximal part of the femur in rabbits had only little influence on the vascularization of the epiphysis in the head of the femur. This corresponds to the comparative small growth stimulus observed, and according to these authors the vascular reaction in the epiphysis was secondary to necrosis in the central part of the growth plate. In the present investigation such necrotic changes were not observed, and it is assumed that the stimulation of growth following total osteotomy and fractures was due to a more extensive hyperemia. The failure of growth following partial osteotomy indicates that the vascular supply to the epiphysis is not increased through such an intervention. As growth stimulation was greater in cases of total

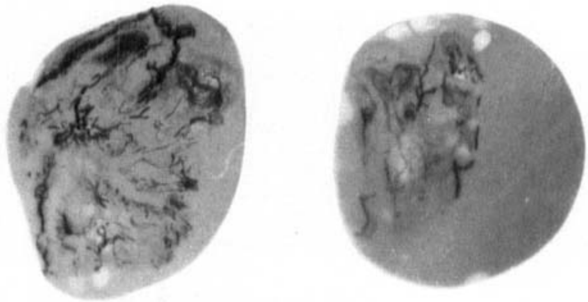

Figure 5. Microangiographic exposure of a 2.5 mm thick decalcified section from the proximal part of animal No. 40 E, sacrificed 19 days following total osteotomy and internal fixation. Operated side to the left, control side to the right.
Magnification × 1

osteotomy with internal fixation than in cases of fractures, it indicates that internal fixation with plate and screws promotes hyperemia. This effect may also be applied to less extensive interventions such as partial osteotomy.

In this connection the beneficial influence on coxarthrosis obtained by subtrochanteric osteotomy without interfering with weight-bearing forces (Nissen 1963) should be considered. It may be assumed that an increase in the vascular supply to the hip will improve the nutritional state of the cartilage and promote restitutional processes, but further investigations are needed in order to elucidate these problems.

SUMMARY

In three-month-old rabbits the growth rate at the epiphyseal plates of the femoral head and the great trochanter has been studied through

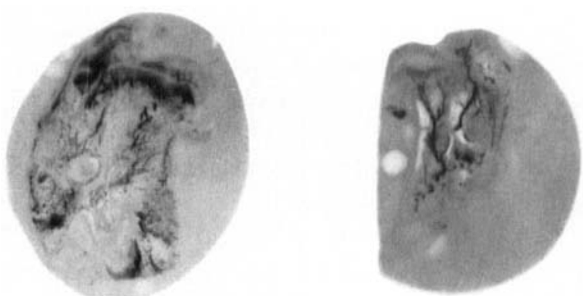

Figure 6. Microangigraphic exposure of 2.5 mm thick decalcified section from the proximal part of animal No. 61 E, sacrificed 32 days following total osteotomy and internal fixation. Operated side to the left, control side to the right.
Magnification × 1

tetracyline labeling during 1–4 weeks following osteotomies at the proximal part of the femur. It was shown that partial intertrochanteric osteotomies did not have any significant influence on the growth, but when fractures occurred during such an intervention, the growth rate at the epiphyseal plate of the femoral head was increased by 70 per cent and at the epiphyseal plate of the trochanter by 38 per cent. In 12 rabbits where a total intertrochanteric osteotomy was performed and followed by internal fixation, the average increase in growth rate was 170 per cent and 105 per cent respectively. Through microangiographic studies in these animals, an increased blood supply to the metaphysis and epiphysis was also demonstrated. It is concluded that the increased growth was due to hyperemia also comprising the epiphyseal bone.

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