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SKELETAL CHANGES OF THE AMPUTATION STUMP AND THE FEMUR ON THE AMPUTATED SIDE

A Clinical Investigation

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Amputation of an extremity is followed by changes affecting the soft tissues, the circulation, and evidently also the skeleton of the stump. Several investigations have been performed earlier concerning the circulatory condition of the limb after amputation (Leriche 1950, Abeatici & Ferrero 1962). The fact that hypervascularity of the stump occurs after amputation is now well established by these investigations. Furthermore a relation could be demonstrated (A) between symptoms from the stump such as local tenderness or pain, phantom pain, and ulceration and a higher mean resting blood flow and (B) between the degree of pain in the amputated leg and the degree of richness and the number of tortuous, spiralled arteries in the stump (Erikson 1965).

Micro-radiographic studies showed that the healing of the amputation stump in rabbits proceeds in the same way as the healing of experimental fractures with two fragments (Hulth & Olerud 1962). Studies of the healing of the amputation stump in rabbits with consideration to the vascularity of the bone have provided evidence for a relation existing between increased vascularity of the stump and formation of spurs (Erikson & Olerud 1966). Beyond the referred investigations research concerning the skeletal changes occurring after

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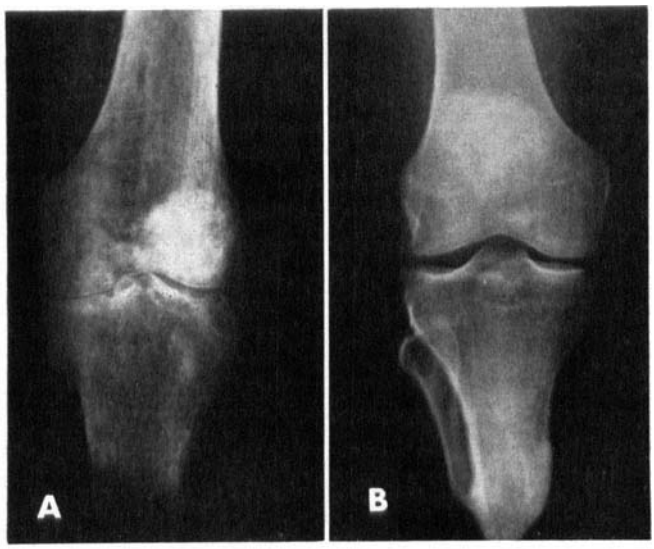

Figure 1. The roentgenologic appearance of the stump in two below-knee amputated patients. An extreme osteoporosis is present in the left stump one year after amputation; the right stump is sclerotic 9 years after the operation.

amputation are very scarce and the metabolic condition of the skeletal part of the stump has not yet been investigated. It is known, from clinical inquiries, that after amputation the bone stump shows on X-ray a more or less extensive atrophy, which sometimes affects the neigbouring parts of the skeleton too. In exceptional cases the skeleton of the stump develops, however, distinct signs of sclerosis (Figure 1).

In order to study the X-ray appearance and the changes in metabolic activity of the skeletal parts of the extremity after amputation, investigations have been undertaken concerning (A) studies of the roentgenological appearance of the skeleton in amputees and (B) kinetic studies of the skeletal parts of the extremities after experimental below-knee amputation in the rat.

The present report concerns observations on the appearance of the stump and femur on the amputated side on X-ray films as compared with the non-operated leg in a number of patients with unilateral below- or above-knee amputation. An attempt has also been made to correlate existent "pain syndrome" of the amputated extremity to its state of calcification.

MATERIAL AND METHODS

Forty-seven unilaterally amputated patients are included in the present material. Twenty-eight were above knee (Table 1) and 19 below knee (Table 2) amputees. Ten were female and the remaining were male patients. The cause of amputation was traumatic in 33 cases. In 14 cases amputation was necessitated because of pathological changes of the extremity as peripheral vascular changes or tumour. The average age of the patients at the time of amputation was 47 5/12 years, the youngest patient being 7 and the oldest 80 years old. The time elapsed between the amputation and the X-ray examination varied from 1 month to 54 years; average 8 2/12 years. Twenty-three of the patients were included in an earlier investigation (Eriksson 1965).

Table 1. Above-knee amputees.

Case no.	Sex	Age at amp. (yrs)	Cause of amp.	Time between amp. and examin. (yrs)	Degree of decalcification of the stump	Thickness of the cortical bone			
						Intact femur (mm)	Stump (mm)	Diff. (mm)	Degree of pain
1	F	53	Pathol.	1 2/12	+	17.0	16.0	1.0	1
2	F	73	Pathol.	1 2/12	++	12.0	8.0	4.0	1
3	M	53	Pathol.	1 4/12	+++	19.0	8.0	11.0	1
4	M	69	Pathol.	1	++	16.0	9.0	7.0	1
5	F	80	Pathol.	10/12	0	20.0	16.0	4.0	1
6	F	44	Pathol.	1/12	0	21.0	19.0	2.0	1
7	M	80	Pathol.	1 3/12	+	17.0	15.0	2.0	1
8	F	73	Pathol.	7/12	++	17.5	14.0	3.5	1
9	M	40	Trauma	10	++	15.0	8.0	7.0	3
10	M	41	Trauma	1	+	13.0	12.0	1.0	3
11	M	51	Trauma	8	+	15.0	10.0	5.0	2
12	F	60	Trauma	6	++	17.0	5.0	12.0	3
13	M	22	Trauma	3 6/12	0	16.3	14.0	2.3	1
14	F	43	Trauma	7	+	11.5	8.5	3.0	2
15	M	35	Trauma	5	+	15.5	9.5	6.0	3
16	M	34	Trauma	7	++	17.5	13.0	4.5	1
17	M	38	Trauma	9	+	16.5	13.5	3.0	3
18	M	54	Trauma	1	++	16.0	14.0	2.0	3
19	M	51	Trauma	4	+	22.0	17.0	5.0	1
20	M	7	Trauma	46	+	22.0	9.0	13.0	3
21	M	36	Trauma	10/12	++	16.0	14.0	2.0	3
22	M	20	Trauma	7	+	18.0	9.0	9.0	3
23	M	31	Trauma	2/12	0	18.0	19.0	−1.0	2
24	M	45	Trauma	8	+	20.0	9.0	11.0	2
25	M	36	Trauma	12	0	21.0	15.0	6.0	2
26	M	55	Trauma	4	+	20.0	16.0	4.0	1
27	M	19	Trauma	49	++	19.0	10.0	9.0	3
28	M	34	Trauma	3	+	16.0	12.0	4.0	2

Table 2. Below-knee amputees.

Case no.	Sex	Age at amp. (yrs)	Cause of amp.	Time between amp. and examin. (yrs)	Degree of decalcification of the stump	Thickness of the cortical bone						
						Intact tibia (mm)	Stump (mm)	Diff. (mm)	Femur on the intact side (mm)	Femur on the amp. side (mm)	Diff. (mm)	Degree of pain
1	M	51	Pathol.	3	++	10.0	3.0	7.0	7.0	7.0	0	3
2	M	25	Pathol.	11	++	3.0	0	3.0	9.0	4.0	5.0	1
3	F	65	Pathol.	2	++	7.0	1.0	6.0	8.0	2.0	6.0	1
4	F	38	Pathol.	26	++	7.0	3.0	4.0	5.0	3.0	2.0	3
5	M	56	Pathol.	1/12	+	8.0	7.0	1.0	8.0	8.0	0	1
6	F	57	Pathol.	1	+++	6.0	0.0	6.0	—	—	—	1
7	M	12	Trauma	9	+	7.0	5.0	2.0	13.0	13.0	0	1
8	M	44	Trauma	3	sclerosis	13.0	8.0	5.0	9.0	9.0	0	1
9	M	60	Trauma	9	++	11.0	4.0	7.0	—	—	—	2
10	M	26	Trauma	3	+	9.0	6.0	3.0	24.0	20.0	4.0	1
11	M	19	Trauma	54	+	5.0	3.0	2.0	6.0	4.0	2.0	1
12	M	27	Trauma	12	++	9.0	5.0	4.0	14.0	11.0	3.0	3
13	M	45	Trauma	6	+	4.0	5.0	—1.0	7.0	7.0	0	3
14	M	25	Trauma	5/12	+	14.0	4.0	10.0	21.0	18.0	3.0	2
15	M	38	Trauma	3	+	14.0	13.0	1.0	7.0	6.0	1.0	2
16	M	24	Trauma	32	+	8.0	4.0	4.0	9.0	8.0	1.0	1
17	M	17	Trauma	1 6/12	++	14.0	11.0	3.0	—	—	—	1
18	M	45	Trauma	3	++	8.0	7.0	1.0	16.0	16.0	0.0	3
19	M	45	Trauma	9	sclerosis	4.0	6.0	—2.0	15.0	15.0	0.0	3

All patients with traumatic amputation complained at the time of examination of some degree of either local pain from the stump or phantom pain, which in this investigation has been called "pain syndrome". The degree of "pain syndrome" was evaluated on a 3-graded scale, according to Eriksson (1965) i.e., 1: no or insignificant pain, 2: moderate pain, and 3: severe pain in the amputated leg.

The condition of the skeletal parts of the amputated and of the contralateral, intact extremity was examined on frontal projection of both legs on X-ray films and it was estimated (A) by a subjective judgement of the degree of radioopacity by each of the authors separately: the degree of bone atrophy was classified as uncertain (0), moderate (+), pronounced (++), extreme (+++), and as sclerosis. (B) According to Barnett & Nordin (1960) the thickness of the cortical bone was accepted as a measure of the degree of the bone atrophy. The difference between the outer and inner diameter of the diaphyses of the bones of the intact and the amputated leg was measured always equidistantly from skeletal landmarks, as the top of the intracondylar eminence of the tibia, the intracondylar groove of the femur, or the top of the major trochanter. Portions of the stump showing involvement on the healing process were avoided in these measurements. The results were expressed as difference in mm between the stump and the contralateral intact bone or the femur on the amputated and on the non-amputated side, respectively.

RESULTS

The distribution of the material and the obtained results are demonstrated in Tables 1 and 2.

The appearance of the stump on the X-ray films was found extremely atrophied in only two cases. A pronounced bone atrophy of the stump was present in 17 cases. In 21 cases the stump was moderately atrophic, in another 5 cases there were no certain signs of bone atrophy. In two cases pronounced sclerosis of the stump was present.

The cortical bone of the stump in above-knee amputees was in all cases, except one (No. 23, Table 1), thinner than that of the contralateral femur. The difference varied between —1 and 13 mm, the mean value being 5.1 mm.

In below-knee amputees the cortical bone of the stump was thinner in 17 and thicker in another 2 patients. The mean difference was 3.5 mm, and differences in thickness varied between —2 and 10 mm.

In below-knee amputees the femur could be examined in 16 cases. In cases Nos. 6 and 9 no X-rays of the femur were available. In case No. 17 there was a recently healed diaphyseal fracture, and any reliable measurement of the thickness of the cortical bone was, therefore, impossible. In the 16 below-knee amputees where measurements of the thickness of the cortical bone of the femurs were performed, there was no difference between the amputated and the non-amputated side

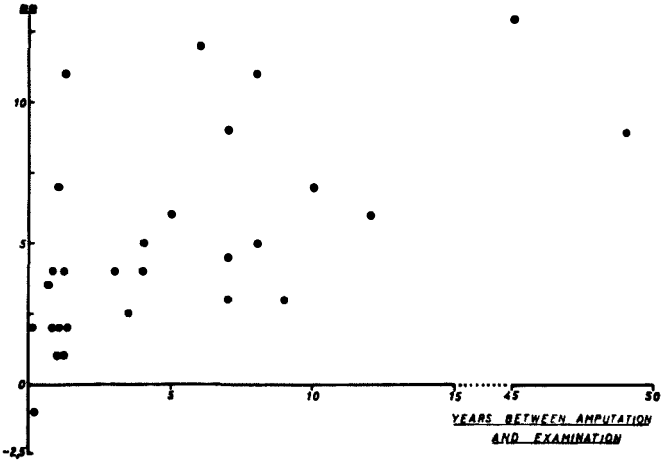

Figure 2. Difference in mm between the cortical thickness of the amputated and the non-amputated femur at different times after intervention.

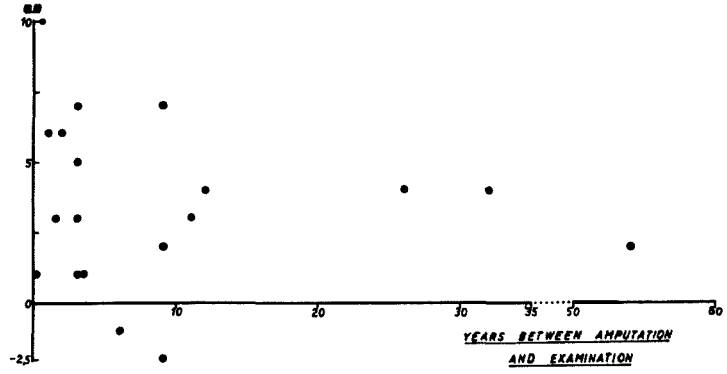

Figure 3. Difference in mm between the cortical thickness of the amputated and the non-amputated tibia at different times after the intervention.

in 7 cases. In the remaining 9 cases the cortical bone of the femur on the amputated side was somewhat thinner, the differences ranging between 1 and 6 mm. The mean value was 3.0 mm.

In Figures 2–4 the cortical differences of the individual patients related to the time elapsed between the operation and the examination are demonstrated. It seems from these figures that the amputation stump developed a more pronounced thinning of the cortical bone than the femur in below-knee amputees.

Ten above-knee and six below-knee amputees suffered from severe

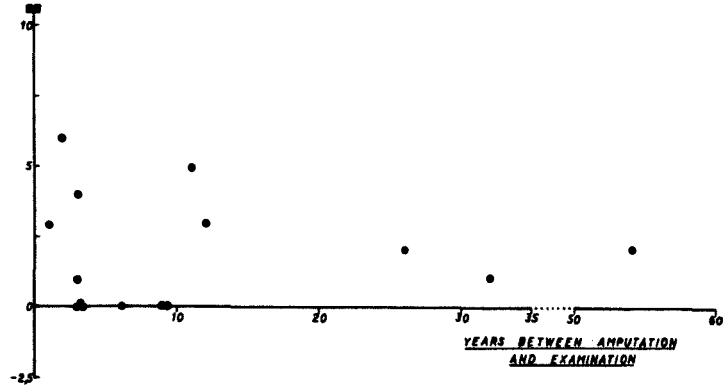

Figure 4. Difference in mm between the cortical thickness of the femur on the amputated and the non-amputated side in below-knee amputees, at different times after the intervention.

pain. Two of the 14 patients amputated because of pathological changes, both below knee amputees, had severe pain. Among the 33 traumatic amputees, 23 complained of severe pain. The frequency of severe pain was thus much higher in patients amputated because of traumatic than pathological causes (Table 3). No distinct correlation existed between cortical atrophy and the degree of pain (Table 4). The observation was made, however, that in patients with extreme bone atrophy of the stump there was practically no "pain syndrome" present (Table 5).

DISCUSSION

The reported results demonstrate that the stump in below- or above-knee amputees, compared with the non-amputated contralateral leg, develops some degree of bone atrophy expressed as decreased radio-

Table 3. Relation between the degree of "pain syndrome" and the cause of amputation in above-knee (AK) and below-knee amputees (BK).

Type of amputation	Cause of amputation	Degree of "pain syndrome" 1	2	3
AK	Trauma	4	6	10
	Pathol	8	0	0
BK	Trauma	6	3	4
	Pathol.	4	0	2

Table 4. Relation between the degree of "pain syndrome" and the difference in the cortical thickness of above-knee (AK) and below-knee amputees (BK).

		Degree of "pain syndrome" 1	2	3
Difference in the cortical thickness in mm	AK			
	mean	3.5	4.7	6.2
	number	12	6	10
	range	—4–11	—1–11	1–12
	BK			
	mean	3,5	6.0	2.7
	number	10	3	6
	range	1–6	1–10	—2–7

Table 5. Relation between the degree of "pain syndrome" and decalcification of the stump in above-knee (AK) and below-knee (BK) amputees.

	Degree of decalcification	Degree of "pain syndrome" 1	2	3
AK	+	4	4	5
	++	4	0	5
	+++	1	0	0
BK	+	5	2	1
	++	3	1	4
	+++	1	0	0

opacity of the bone on X-ray films as well as a decrease of the thickness of the cortical bone of the stump.

The observation made that some degree of atrophy of the bone stump was present in 44 out of 47 cases indicates that this phenomenon is extremely common after amputation. These stump changes seem to be irreversible as indicated in Figures 2 and 3. Sclerosis of the stump was present in only two cases of below-knee amputation (Nos. 8 and 19, Table 2) where the thickness of the cortical bone of both the stump and the femur on the amputated side was somewhat greater than that of the bones of the non-amputated side.

The observations regarding the femur on the non-amputated side in cases of below-knee amputations show that bone atrophy was present in 9 out of 16 cases. This suggests either that this change is less

common than the respective change of the stump or that it has a regressive character. In the latest case the bone atrophy affecting the femur should be dependent upon time, decreasing gradually and disappearing later. Experimental data, to be reported elsewhere, may support this evidence (Sevastikoglou & Larsson, unpublished). Nilsson (1966) in a clinical study concerning post-traumatic osteopenia found bone atrophy of the ipsilateral femur long after fracture of the tibia and thus concluded that these changes are irreversible.

Symptoms of pain from the stump were present in some degree in practically every case. No relation could be found between the presence of "pain syndrome" and the roentgenological appearance of the skeletal parts in this material except for the fact that in patients with extreme bone atrophy of the stump there was no "pain syndrome". However, since this observation concerned only two patients, its validity is questionable.

SUMMARY

The degree of radioopacity of the amputation stump and, in cases of below-knee amputation, of the femur on the amputated side has been examined in 28 above-knee and 19 below-knee amputees.

Determinations were based on estimations of the appearance of the skeletal parts as well as on measurements of the thickness of the cortical bone made on X-ray films. Comparison was made to the corresponding parts of the non-amputated leg.

The amputation stump itself both after below- or above-knee amputation undergoes bone atrophy which seems to be of a permanent character. In below-knee amputees the femur on the amputated side showed signs of bone atrophy in some cases, but not consistantly. The bone atrophy of this skeletal part might be of a transient character.

There was no certain evidence of a correlation existing between "pain syndrome" after amputation and the radiological appearance of the bone stump.

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