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OPERATIVE TREATMENT OF NON-UNITED FRACTURES OF LONG BONES

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Several operative methods are in use for the treatment of established non-union of diaphyseal fractures of the long bones. The incidence of successful results, as well as the duration of post-operative immobilization, until safe healing occurs, vary considerably in the different reports, this depending mainly on the operative method used by each author. Autogenous or homogenous bone transplants are commonly used as inlay, onlay or sliding grafts, with or without resection of the sclerotic bone ends and with or without internal fixation. Thick compact bone transplants are usually preferred by several surgeons, as securing good stabilizing as well as biological properties for the healing of the non-union.

An operative method for treatment of non-united fractures of the long bones is described in the present communication. The method is based on the following principles:

a) the fibrous and the sclerotic bone tissue at the site of the non-union are resected only partially,

b) the bone fragments are not dislocated and the fibrous connections around the non-union, stabilizing the bone ends are preserved, as advocated by *Phemister* (1947),

c) the obliterated medullary cavity is carefully opened and its continuity restored,

d) a block graft of cancellous iliac bone together with additional bone-chips are used as transplantation material and

e) internal fixation is used only in cases with pronounced instability of the bone fragments.

A series of non-united of diaphyseal fractures have been treated by this method and the obtained results are reported herewith.

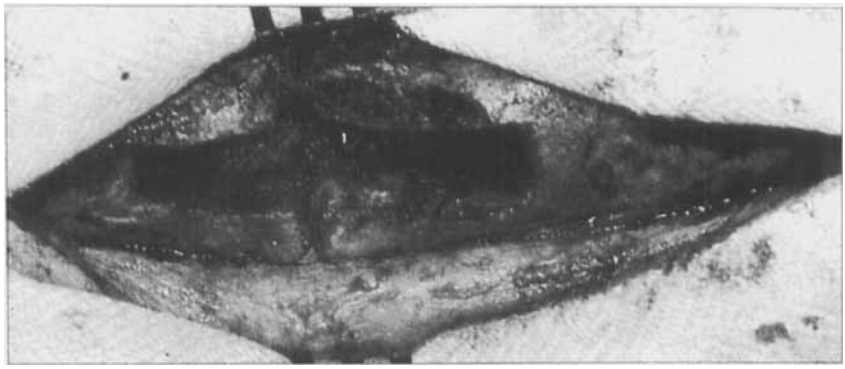

Fig. 1.
The longitudinal trench has been chiselled bridging over the space of the non-union. A part of the fibrous tissue intervening between the bone fragments and the sclerotic bone obliterating the marrow cavity have been removed through the trench.

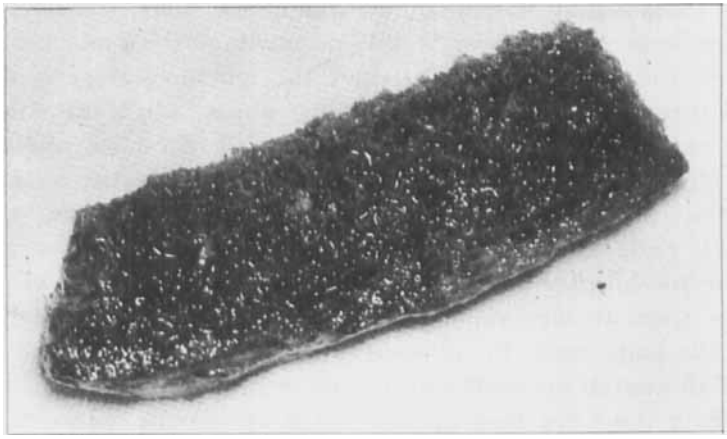

Fig. 2.
The graft.

THE OPERATION

Through a suitable skin incision and dissection of the soft tissues the periosteum is fried and opened longitudinally. Care is taken to preserve its continuity as much as possible. The non-union is exposed subperiosteally. A longitudinal trench, approximately 1 cm wide and 5–7 cm long, bridging over the space of the non-union, is chiselled into the cortical bone. Through the trench only a part of the fibrous tissue intervening between the bone fragments is excised. The remainder

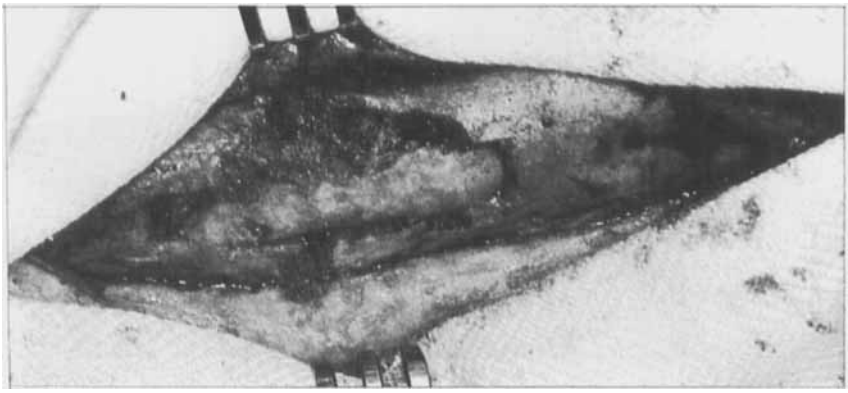

Fig. 3.
The graft has been pushed into the trench. Cancellous bone-chips are closely packed around the graft and the site of the non-union.

fibrous tissue filling the site of the non-union, together with the surrounding scar tissue prevents displacement of the bone fragments. The sclerotic bone which obliterates the marrow cavity is also removed through the trench with a fine chisel, until the continuity of the marrow cavity is completely restored. All bone and fibrous tissue pieces are carefully removed (Fig. 1). A cancellous-bone graft from the patient's iliac crest is decorticated on both its surfaces and it is fashioned to fit the trench exactly (Fig. 2). The graft is then pushed into the trench as a plug. If well fitting into the trench it gives a satisfactory stability and prevents rotation movement between the bone ends. In addition cancellous bone-chips are closely packed all around the graft and the site of the non-union (Fig. 3). The periosteum flaps are then approximated by cat-gut sutures and the wound is closed. No internal fixation is used, unless a pronounced instability between the bone fragments is present. A well fitting plaster cast usually secures a satisfactory immobilization of the extremity after the operation. The plaster cast is later changed at 6 to 8 weeks intervals. When clinical and X-ray signs of consolidation are present, the plaster is removed and normal use of the extremity is encouraged.

MATERIAL

The described method has been used for the treatment of 25 non-united fractures in 23 patients. One patient was treated for non-union of both tibiae (case no. 15 and 16). Another patient (no. 21) was operated upon twice before healing of the non-union could be obtained.

TABLE 1
The Material.

Case No.	Sex	Age of the patient (years)	Established non-union of the	Time elapsed between occurrence of the fracture and the operation (months)	Number of earlier operations (open reduction of the fracture included)	Time of immobilization by plaster (months)	Result
1	♂	26	ulna	22	2	2½	Union
2	♂	46	radius	15	2	2	Union
3	♂	36	tibia	35	1	3	Union
4	♂	34	tibia°	29	1	4½	Union
5	♀	16	tibia	25	3	4½	Union
6	♂	47	tibia	66	1	6½	Union
7	♂	37	ulna	24	1	2½	Union
8	♂	14	tibia	12	0	2¼	Union
9	♂	58	femur*	13	0	4	Union
10	♂	24	femur°	9	3	5	*Infection, non-union*
11	♂	65	femur*	42	0	1½	Union
12	♀	25	femur*	10	0	2	Union
13	♂	56	ulna	33	1	1½	Union
14	♀	65	femur*	23	0	7	Union
15†	♂	37	l. tibia°	11	1	3½	Union
16†	♂	37	r. tibia	11	0	3	Union
17	♂	26	tibia	4§	0	2	Union
18	♂	63	humerus	12	2	5½	*Non-union*
19	♀	33	med. malleol	16	2	1½	Union
20	♂	66	tibia	89	6	4	*Non-union*
21	♀	33	radius and ulna	13½	2	5½	*Non-union*
„	♀	„	„	34	4	5½	Union
22	♂	71	femur*	18½	0	5	Union
23	♂	69	tibia°	21	1	7	*Infection, non-union*
24	♂	57	tibia°	41	3	6	*Infection, non-union*

* Non-union after intertrochanteric osteotomy.

† Same patient. Non-union of both tibiae.

§ The fragments were superimposed with slight angulation. Delayed union. Operation was performed without resecting the scar tissue around the fracture.

° Primarily infected cases. No signs of infection at least 6 months before operation.

The average age of the patients was 49.5 years, the sex distribution 18 men and 5 women, and the average time between the occurrence of the fracture and the operation for the non-union by the present method was 27 months. The distribution of the material is demonstrated in Table 1. An established non-union was in every case diagnosed by clinical and X-ray examination. Case no. 17 concerned, however, a delayed rather than non-union of a 4 months old fracture of the tibia. In another case (no. 18) a real pseudarthrosis had developed at the time of the operation after an old fracture of the humerus. This case is reported in detail below.

There was no case of severe dislocation of the bone fragments in this material. However, in one case (no. 24) a 7 cm long defect of the tibia was present.

In five cases (no. 4, 10, 15, 23, and 24) the primary fracture had been complicated by infection but there were no signs of active infection at least six months before the operation for the non-union was performed.

RESULTS

In nineteen out of the 25 non-unions operated upon by this method healing occurred primarily after a postoperative immobilization of the extremity with a plaster cast for an average time of 3.25 months. The operation failed to secure healing of the non-union in altogether 6 cases. A postoperative infection developed in 3 previously infected non-unions (cases no. 10, 23 and 24). In case no. 24 a below-knee amputation was performed later. The other two patients refused a new operation and they are using a splint at present time.

Three more cases which failed to heal by the operation are described below.

Case no. 18 concerned a humerus fracture treated primarily conservatively, which developed a non-union. The patient was operated upon in another hospital for his non-union twice without success. At the admission in the department there was a severe pseudarthrosis of the humerus with an abnormal motion of more than 45° at every direction. At operation the hypermobile bone fragments were stabilized by help of a plate and screws and the non-union itself was treated as described above. However, because of postoperative signs of a partial lesion of the radial nerve a revision of the operation area was performed two months later. The site of the non-union was examined at that occasion too, and since there were both clinical and X-ray signs of consolidation, the screws and the plate were removed. A slight motion could, however, be identified at the site of the non-union after removal of the plate and a new grafting was performed in the same way as previously but without internal fixation. After 5½ months of immobilization in plaster there were no sure X-ray signs of healing but the plaster cast was removed by another surgeon and a leather splint was applied instead. A severe pseudarthrosis developed soon again. The patient is now using a splint as he refused a new operation.

The second case (no. 20) concerned an open fracture of the tibia which was operated upon primarily elsewhere. A non-union developed, for which the patient was operated upon 5 times without success before he was admitted to the depart-

ment. The non-union was again operated upon by the method used in this series, without internal fixation. After 4½ months of immobilization by plaster there were X-ray signs of periosteal callus formation around the non-union but no sure signs of healing. The plaster was then removed by another surgeon and the patient was supplied with a leather splint. A new non-union developed soon, for which the patient was operated upon by the same surgeon. A sliding graft was used this time and after another 6 months of immobiliization in plaster a sound healing of the non-union occurred finally.

The last case (no. 21) concerned a patient with a fracture of both ulna and radius which was treated primarily conservatively in another hospital. Because of a developed non-union the patient was operated upon twice before admission in the department. The non-union was then operated upon according to the described principles without internal fixation. After 5½ months of immobilization in a plaster cast the case was considered as a delayed-union by another surgeon, and a reoperation was done using internal fixation with plates and screws and bone grafting. After 4 months of immobilization in plaster the fractures were considered healed. The plates and the screws were removed 11 months later but after another 4 weeks a spontaneous refracturing of both the bones occurred. X-ray examination showed signs of a non-union within both ulna and radius and at the same place as before. A new bone grafting operation according to the present method combined with internal fixation of both the bones by help of plates and screws was performed. Finally a good healing was secured after 5½ months of immobilization in a plaster cast.

The failure in healing of the non-union by the described method in the reported series is ascribed to post-operative complication, *viz.* infection in 3 cases. Inadequate post-operative immobilization was apparently the cause of failure in the other three cases.

DISCUSSION

There are certain biological principles for the management of non-united fractures which although well known are often neglected by many surgeons in the operative treatment of such cases. These principles may be summarized as follows. (i) Resection of the fibrinoid tissue filling the gap of the non-union. (ii) Restoration of the continuity of the obliterated marrow cavity. (iii) Stimulation of the osteogenesis. (iv) Sufficient immoblization of the bone fragments and (v) avoidance of extensive damage and necrosis of bone and tissues.

According to *Urist, Mazet & McLean* (1954) in established non-unions the resection of the fibrinoid tissue filling the space between the bone fragments is an important procedure. Fibrinoid tissue acts in this case as a barrier to the osteogenetic elements arising from the periosteum

Fig. 4.
Case No. 5. a) Established non-union of the tibia b) X-ray taken immediately after the operation. Note the cancellous transplant lying in the trench c) 4½ months later. Complete healing of the non-union by fusiform bone callus.

and the endosteum preventing them from traversing the fracture interval and securing the consolidation of the bone fragments by the development of bone callus. The authors found that even if the resection of the fibrinoid tissue is not necessary in cases of delayed-union, this is of definite importance in the operative treatment of established non-union.

The restoration of the continuity of the obliterated marrow cavity is important in the treatment of a non-union. The sclerotic bone blocking the cavity in the vicinity of the non-union acts also as a barrier preventing the endosteal elements from displaying their osteogenetic activity. Removing of the sclerotic bone provides sufficient blood supply and allows the endosteal osteoblasts and the undifferentiated marrow cells to contribute to the healing of the non-union. It is known that the periosteal external callus is usually more pronounced than the endosteal internal callus. However, in some bones and under certain circumstances

the internal callus may be of greater importance for the healing of a fracture than the external (*Ham & Harris*, 1956).

Bone transplantation for the stimulation of the healing of non-united fractures has been applied to an increasing extent during the last decades. Many experimental works concerning bone transplantation have been published and are reviewed in an article by *Chase & Herndon* (1955). However, the majority of the authors report that fresh autogenous bone is superior to any other type of bone transplant (*Siffert*, 1955, *Bonfiglio*, 1958 and others). Transplanted compact bone either autogenous or homogenous dies, is absorbed and replaced slowly by new bone provided by a proliferative reaction of the osteogenetic elements of the host (*Urist et al.*, 1954). The transplant is used by the host as a framework for the building of the new bone, furthermore, osteogenesis may be stimulated in these cases by an inductive process (*Urist & McLean*, 1952). Cancellous autogenous bone grafts have been proved by experimental and clinical studies to be superior to compact autogenous bone transplants (*Dick*, 1946, *Higgs*, 1946, *Abbot et al.*, 1947, *Merle d'Aubigné*, 1949, *Campbell et al.*, 1953, *Siffert*, 1955 and others). In this case some endosteal osteogenic cells of the cancellous chips do survive transplantation and give rise to new bone formation (*Ham & Harris*, 1956). Furthermore, the transplant because of its architectural structure presents more abundant possibilities for blood vessels and granulation tissue to intrude upon it. The graft is thus absorbed soon and new bone formation occurs in a considerably shorter time than with compact bone.

Immobilization of the bone fragments has a quite different aspect in the treatment of fresh fractures than in that of a non-union. In the former case an internal fixation might be in certain cases necessary to keep unstable fragments in contact with each other during the healing of the fracture. However, in non-union risk of displacement of the fragments hardly exists. The scar tissue around the bone fragments is sufficient to secure immobilization. Any kind of internal fixation is therefore usually unnecessary in such cases (*Phemister*, 1947). A well-fitting plaster is usually sufficient to give an appropriate immobilization of the fragments.

Studies of the physiopathology of fracture healing have shown that the regenerative processes do not start before damaged bone and tissues are absorbed at the site of fracture (*Urist et al.* 1954). Therefore, an important principle in the treatment of non-unions is to avoid, as much as possible, interventions which because of their character or

extent result in excessive damage to the tissues. The use of electric saws or drills results in necrosis of the bone. The insertion of metals has also been found in recent studies (*Emneus*, 1956/57) to cause a pathologic reaction of the bone. Such factors as these retard fracture healing.

The results obtained by different authors in the treatment of non-united fractures show varying frequency of healing and time of immobilization depending on the operative method used (Table 2). Healing of a non-united fracture can be obtained by any kind of operative procedure. However, the operative method based on the biological principles described above should give a high incidence of healing and in a shorter time.[1]

TABLE 2

Cases of Non-Union Treated by Different Procedures with the Incidence of Healing and the Time of Immobilization.

Author	No. of non-unions[1]	Percentage of healing[2]	Time of immobilization (months)
Merle d'Aubigné (1949)	126	81.9	4.2[3]
Bertelsen (1955)	276	87	...
Biström (1955)	39	97.5	...
Nyberg (1955)	81	83.9	...
Amako and Goto (1955)	296	66.3	...
Roasenda and Perez (1956) ...	89	76.0	4.5
Nicoll (1956)	27	100.0	3.5
Redini and Bendinelli (1959)	29	84.0	8.0
Pedroca and Bardini (1960)	12	100.0	6.7
Rivero (1960)	286	81.1	6.8

1 Cases of non-union of different localizations. In certain series cases of delayed-union are included. Similarly infected cases and cases with severe bone defects are included in some series.

2 In some series healing was obtained by more than one operation.

3 Cases with extensive defects are not included.

SUMMARY

An operative method for the treatment of non-united fractures based on certain biological principles is described. Twenty-five cases of diaphyseal fractures with established non-union have been operated upon

1 *Note on the proof.* In a recent publication (1964) a similar technique has been used by *Williams* for the treatment of 15 cases of non-union of long bones. Boiled homologous cancellous bone was used as grafting material. Healing was obtained in all the cases after an average immobilization in plaster of 4.5 months.

by this method. Union was obtained in 19 cases after an average time of immobilization of 3.25 months.

RESUME

Il est décrit une méthode opératoire pour le traitement des fractures non soudées, basée sur certains principes biologiques. Veingt cinq cas de fractures diaphyséales dans lesquelles la non-soudure était établie ont été opérés d'après cette méthode. La soudure a été obtenue dans dix neuf cas après une période moyenne d'immobilization de 3.25 mois.

ZUSAMMENFASSUNG

Eine operative Methode zur Behandlung von nichtgeheilten Brüchen, die auf gewissen biologischen Prinzipien beruht, wird beschrieben. Fünfundzwanzig sicher ungeheilte Diaphysenbrüche wurden mittels dieser Methode operiert. Vereinigung der Brüche wurde in 19 Fällen nach einer Ruhigstellung von durchschnittlich 3.25 Monaten erzielt.

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