

ON THE RESULTS OF TREATMENT OF NON-UNION OF THE SHAFTS OF THE LONG BONES

By

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The causes of non-union and the methods and results of its treatment have continuously received great attention from orthopaedists as well as general surgeons. The high actuality of the topic is also indicated by the fact that it is still a subject of discussion in various congresses, e.g. at the Congress of the Société Internationale de Chirurgie Orthopédique et de Traumatologie in New York, 1960. On this occasion, *Boyd, Lipinski & Wiley* presented a series comprising 842 patients, dealing with the results of treatment of non-union of the shafts of the long bones. With advances in surgical technique, non-union should be less frequent but rather the opposite is true in actual practice. Most of all this is due to the increased number of serious traffic and working accidents, which result in open fractures with infection and comminuted fractures with circulatory disturbances.

In Finland the occurrence and treatment of non-union has been little treated in the literature and it is therefore difficult to form an overall picture of the results of treatment in different hospitals. *Rehnberg* (1955) presented the results of treatment relating to non-union in 277 war casualties, and *Biström* (1955) those from the treatment of non-union in 38 cases during peacetime. *Saarialho's* (1960) series of 332 patients with leg fracture contained 24 cases of non-union. For the above-mentioned reasons it is thought to be appropriate to present the results of treatment recorded in the Orthopaedic Hospital of the Invalid Foundation in the years 1945-1960. In his paper, read at a congress, *Nyberg* (1955) dealt with part of the same series, belonging to earlier years. This part, too, was included in our follow-up investigation for the reason that many of the patients have visited our hospital also in recent years for further examination, or the insurance companies have been able to advise us on their recent condition.

The series of non-union cases of our hospital presents a higher than normal degree of severity on the whole, because no fresh fractures at all are admitted, but the patients are sent to us in the non-union stage from other hospitals when their condition has been considered as requiring special treatment. Thus, in a major part of the series, one or several operations for the correction of non-union had already been made; this can be considered as having further worsened the conditions for successful recovery.

OWN MATERIAL

The series consists of patients treated in the Orthopaedic Hospital of the Invalid Foundation in the years 1945-1960, all of them with non-union of one of the long bones of the extremities. There are altogether 160 patients, 138 of them male, and 22 female.

TABLE 1
Age on Admission for Treatment.

Age group	Below 20	20-29	30-39	40-49	50-59	Over 60
Number	11	43	41	38	19	8

The youngest patient was 5½ years, the oldest 67. An overwhelming majority of the patients (altogether 122) were men between 20 and 50 years of age, in their best working years and therefore most susceptible to serious accidents. Each decade of this period is represented by approximately the same number of patients, as can be seen from table 1. The cases of non-union due to lesions received in the war numbered 36, all of them male patients.

Table 2 gives a short review of the patient data prior to admission into our hospital. In specifying the point of fracture, the fractures on the junction between the proximal and middle thirds of the bone have been referred to the group of proximal fractures, and those on the junction between middle and distal thirds, to the fractures with a location in the middle third. Most of the non-unions in our series occurred in the region of the middle third. An exception is noted in the case of the radius and ulna, the distal third having been most commonly affected in the first-mentioned, and the proximal third in the latter instance.

Open fractures constitute about 53 per cent of the series. They were

relatively least numerous in femur fractures, only one out of 18, and most numerous among the fractures of ulna and humerus. War-induced fractures have been included among the open fractures, but they have furthermore been separately grouped by the different bones.

TABLE 2
Presentation of the Material.

	Location of the non-union							Per cent
	Hume- rus	Both bones of forearm	Radius	Ulna	Femur	Tibia	Total	
<i>Number of patients</i>	23	12	13	23	18	71	160	
<i>Sex</i>								
Male	21	10	12	21	11	63	138	86
Female	2	2	1	2	7	8	22	14
<i>Point of fracture</i>								
Proximal 3rd	4	incl. in	3	14	3	6	27	17
Middle 3rd	10	radius or	5	11	11	41	76	47
Distal 3rd	9	ulna	17	10	4	24	57	36
<i>Initial conditions</i>								
Open fracture	15	5	7	16	1	40	84	53
War-induced fracture	7	1	4	12	1	12	37	23
Open reduction performed ...	4	9	3	4	10	17	47	29
Previous infection	11	1	3	7	2	25	49	31
<i>Operations for non-union prior to admission into our hospital</i>								
One operation	4	2	4	11	6	20	47	29
Two operations	3		1		1	4	9	6
3 or more	2	1		2		5	10	6
Patients altogether	9	3	5	13	7	29	66	41
<i>Average interval between occur- rence of fracture and operation for non-union in our hospital, months</i>	48	21	39	98	18	43	47	

Cases with associated infection have been treated as one single group independent of whether the initial wound or an operation performed prior to admission into our hospital was responsible. No distinction has either been made between already effaced infections and those still present on admission. At all events the infection frequently delayed the non-union operation proper, because the operation was not undertaken until 4 to 6 months after the disappearance of the infection.

Primary operative measures had been taken, that is, open reduction and osteosynthesis by different fixing methods had been performed on 47 patients (29 per cent), and actual operation intended for the correction of non-union had been performed on 66 patients (41 per cent) prior to their admission into our hospital. On 19 of the latter patients more than one corrective attempt had been made.

It would be interesting to study the length of the time in which positive non-union developed in each particular instance. The series does not furnish any direct answer to this question because as a rule the patients have still been under treatment in another hospital at the time in question. However, in Table 2 the average time from incurrence of the fracture to the first corrective operation in our hospital is listed.

HUMERUS

There were altogether 23 patients with non-union in the upper arm, but five of them refused corrective operations and one insisted on amputation owing to great pain; this was conceded as the patient furthermore had lesions of the radial and median nerve. Altogether 18 corrective operations were done on 17 patients.

TABLE 3
Operations for Non-union of the Humerus.

Method	Number of patients	Union successful	Failure	Cause of failure	
				Infection	Resorption
Z resection	15	13	2*	1	1*
Onlay graft	2	2			
Phemister type graft ...	1	1			

* Reoperated with graft.

Resection with fixing either with Parham band or with two screws was done 15 times, union failing to occur in two of the cases. In one of them incomplete fixation produced resorption at the fragment ends, but reosteosynthesis with onlay graft resulted in union. The other patient, with infection responsible for the failure, refused another operation and continued to use the supporting bandage he had had previously.

The operations resulted in union in 16 patients, and none of them retained a faulty position. The permanent shortening of the upper arm due to Z resection was considerably (10–15 cm.) in three patients and fairly remarkable (5–9 cm.) in three; in the others it was less. Stiffness

of the shoulder joint increased from the preoperative condition in three and that of the elbow joint in two patients. Particularly non-union in the lower third of the humerus tended to leave a permanent restriction of motion in the elbow joint, but not one of the patients was caused very great inconvenience on account of this.

BOTH BONES OF THE FOREARM

There were 12 patients with non-union of both bones of the forearm. For two of them corrective operation was not considered indicated, as the functional ability of their hand was almost nil after a serious open fracture and subsequent infection. In ten patients altogether twelve corrective operations for non-union were performed and union was achieved in all cases.

TABLE 4
Operations for Non-Union of the Forearm.

Method	Number of patients	Union successful	Failure	Cause of failure Resorption
Z resection	3	2	1*	1
Graft	7	6	1†	1
Medullary Nail & Graft	2	2		

* Reoperated with graft.

† Reoperated with medullary nail and graft.

In one of the three Z resections, union failed to occur owing to resorption of the fragment ends, but union was achieved on reoperation with graft. Of the seven graft osteosyntheses, one was a failure due to resorption of the ends of the fragments and of the graft. In this case also reosteosynthesis, with medullary nail and graft, was successful. Inadequate fixing of the fragments was responsible for the resorption in both instances. On Z resection both osteosynthesis points had been fixed with only one Parham band, while in the other case the transplant had partly been split when it was fixed and therefore failed to provide sufficient stability although four vitallium screws were used. This instance of osteosynthesis also differed from the normal procedure in that osteosynthesis was only performed on the ulna and the proximal fragment of the radius in its entirety was removed at the same time, as the non-union was of considerably proximal location. In one further operation also a departure from the conventional method was made in the respect that osteosynthesis was only performed on the ulna and

the non-union faces of the radius were resected, deliberately leaving a non-union. In this case, too, a functionally good result was achieved.

Union took place in all operated patients and no detrimental faulty positions remained. The shortening of the forearm was considerable, 4 cm. and 8 cm. respectively, in two cases. About the same mobility of elbow joint and wrist as at the time when the non-union operation was decided upon was restored in all cases. For increased rotation of the forearm, resection of the distal end of the ulna was performed on one patient and was to be done on another, but the latter did not consent.

RADIUS

There were 13 patients with non-union only of the radius, and a corrective operation was performed on twelve of them. For one patient the operation was considered unnecessary because he had become accustomed for nearly ten years to the non-union, which was moreover painless. Altogether 13 corrective operations were performed.

TABLE 5
Operations for Non-Union of the Radius.

Method	Number of patients	Union successful	Failure	Cause of failure Fracture of the graft
Graft	10	9	1*	1
Medullary Nail & Graft.....	1	1		
Z resection & ulnar osteotomy	2	2		

* Reoperated with medullary nail and graft.

An onlay or inlay graft was employed ten times; it was fixed either with Parham band or with screws. In one of these cases there was no union; resorption took place in the transplant at the point adjacent to the non-union and it broke obviously due to stress. Reoperation with medullary nail and graft, fixed with screws, resulted in union also in this case. Ulnar osteotomy followed by Z resection of both bones of the forearm was performed in two cases. This procedure was chosen on account of a very faulty position of the forearm, which would not have been possible to correct without ulnar osteotomy. Even so one of the patients has a residual faulty position, but this is the sole case with a permanent faulty position in this group.

The motions of elbow joint and wrist were otherwise restored to about the condition prior to operation, except that rotation of the forearm was almost without exception more or less restricted. In order to improve rotational mobility, resection of the distal end of the ulna was performed in four cases.

ULNA

There were altogether 23 patients but no corrective operation was undertaken in eight cases, either for the reason that the non-union caused very little inconvenience, or because the patient himself did not wish to be operated, or because the non-union was so heavily aggravated as a result of suppuration and bone defect that operation was not thought to have any chance of success. 15 patients were subjected to 17 corrective operations.

TABLE 6
Operations for Non-Union of the Ulna.

Method	Number of patients	Union successful	Failure	Cause of failure	
				Infection	Other cause
Graft	14	9	5*	2	3
Medullary Nail & Graft ...	3	1	2	1	1

* Two cases reoperated with medullary nail and graft

In five of the 14 patients operated by the grafting method union failed to occur, which is a relatively high proportion. This was obviously due to the fact that all cases were initially open fractures, moreover three of them were previous war-induced wounds, and manifest infection had been present before in all of them. In three cases resorption of the graft occurred, obviously not due to incomplete fixing but to the poor osteogenetic capacity of the fragment ends. Two of the cases in which union failed to occur were reoperated with medullary nail and graft. Union was successful in one case but the other retained permanent non-union, as did also a third patient initially operated by this method.

In none of the ten cases with successful union was there any permanent faulty position, and mobility of the elbow joint and wrist was not impaired from the condition prior to operation. For improved rotation, resection of the capitulum radii was performed on altogether six patients either simultaneously with the osteosynthesis, or at a later stage.

F E M U R

There were 18 patients belonging to this group. Three of them were not operated: one owing to poor condition caused by pulmonary tuberculosis and renal insufficiency, two others because they were psychically unfit to be subjected to a major operation requiring prolonged immobilization. On 15 patients, 16 operations for non-union were performed, one of them having non-union of both femora.

TABLE 7
Operations for Non-Union of the Femur.

Method	Number of patients	Union successful
Z resection	5	5
Graft	6	6
Medullary Nail & Graft	4	4

Z resection was carried out in the case of a patient with non-union of both femora, and the shortening of the extremities due to the operations caused no inconvenience for this reason. The same method was applied in the case of a patient with congenital dislocation of the opposite hip and consequent shortening of the leg, so that Z resection furnished, at the same time, a means of equalizing the previous difference in length. In the other two cases there should not have been any well-justified reason, in our opinion, to employ this method, in view of the fact that the patients retained the drawback of a leg shorter by 6 cm. and 5 cm., respectively.

For immobilization, a hip cast was employed in all cases except in two with medullary nailing and graft, in which no plaster at all was applied. Union was successful in all operations. A faulty position ensued in one case with grafting, obviously owing to premature stress. Harmful stiffening of the knee resulted in one case, and for its correction a quadricepsplasty was performed, by which the knee mobility of 180°-90° was attained.

T I B I A

Altogether 71 patients have been under treatment in our hospital for non-union of the tibia. No corrective operation was undertaken in 14 of these cases; amputation on account of severe infection was performed in two, and the other twelve were not operated because

of their refusal or their poor general condition, or because they were well-accustomed to their condition and could manage satisfactorily. The remaining 57 patients were subjected to a total of 71 corrective operations.

TABLE 8
Operations for Non-Union of the Tibia.

Method	Number of operations	Union successful	Failure	Cause of failure	
				Infection	Other cause
Inlay graft	30	20	10	6	4
Onlay graft	11	10	1		1
Apposition	11	8	3		3
Kirschner's operation	9	5	4	1	3
Hahn's operation	5	3	2		2
Compression	5	1	4		4

Union after one operation was achieved in 40 patients, after two or more operations in 7, while non-union remained the ultimate result in ten. The inlay graft method was applied 30 times and it failed to produce union ten times. In six of these cases infection was responsible. Obviously in most instances there was a latent infection after previous inflammation at the non-union point, which was again inflamed by the surgical measure. It is likely that the inlay graft method causes considerable tissue damage in the operated area, and since there is little surrounding soft tissue, the risk of infection is remarkable. In this respect a distinct difference is noted in comparison with onlay graft, not one infection having been recorded in connection with the latter. In cases of oblique non-union, joining of the bone ends was effected after freshening, either by screws or with Parham band. Kirschner's fragmentation was employed if the bone ends of the non-union were broad and sclerotic, but spongy bone chips taken from elsewhere were added in all instances. Hahn's tibio-fibular osteosynthesis was performed on three patients, with union as its ultimate result in all cases, although two had to be reoperated once. This method was employed when there was a large defect in the tibia. Osteocompression as recommended by Judet was applied to five cases of non-union but it resulted in union in one case only. This manipulation has also been counted among the operations here.

Among the 47 patients with successful union, eight retained permanent faulty position of the leg to the extent of 5-10°; it was varus in most cases and recurvatum in two. The fault was not detrimental

enough in any instance to require corrective measures. Total arthrodesis of the ankle was made in three cases on account of ankle pain and restriction of motion in the ankle ensuing from the prolonged treatment. Three further patients retained a permanently restrictive mobility of the knee to the extent that flexion to a right angle was impossible. One of the cases with unsuccessful union had an infection of such severity that amputation in the upper part of the leg had to be carried out later. The ultimate condition of the other failures was the same as prior to operation.

RESULTS AND DISCUSSION

It can be seen from Table 9 that 98 of 126 operated non-unions, or 78 per cent, showed successful union after the first corrective operation. The corresponding figure in the series of 842 patients of *Boyd et al.* (1961) is 88 per cent. Repeated corrective operations raised the ultimate result in our series to 110 successfully treated non-unions, or 87 per cent, against 94 per cent in Boyd's series. It may also be mentioned for the sake of comparison that the percentage of ultimately successful unions in the series of 126 patients of *d'Aubigné* (1949) was similarly 94 per cent. Quite certainly the ultimate percentage of successful union would have been higher in our series too if all patients with an unsuccessful first operation had been reoperated. However, only 19 of 28 such patients were reoperated, nine of them declining any further measures.

Scrutiny of the 36 cases in which the first corrective operation (in 28 cases) or repeated operation (in 8) failed to produce union reveals that infection was responsible in 11 cases. This may appear a high proportion, but it is largely due to the fact that there was an infection prior to the corrective operation in 31 per cent of the whole series. The infection probably continued in a latent form in most instances and became inflamed in connection with operation in spite of all precautions. The relatively highest incidence of infection was recorded for the ulna, the non-union operations on the tibia ranging next.

About 80 per cent of the operated persons were given prophylactic antibiotic treatment, most frequently by penicillin injections. In earlier years this was not administered but nowadays it is considered pertinent in our hospital.

Fracture of the graft subsequent to operation occurred altogether six times and was obviously the cause of failure in the cases in question,

TABLE 9
Results of operation, time required for union to take place, and periods of incapacitation.

	Location of the non-union					Total	Per cent
	Humerus	Both bones of forearm	Radius	Ulna	Femur	Tibia	
<i>Number of patients</i>	17	10	12	15	15	57	126
<i>Result of 1st operation</i>							
Union successful	15	8	11	9	15	40	98
Failure	2	2	1	6		17	28
<i>Result of 2nd or last subsequent operation</i>							
Union successful	1	2	1	1		7	12
Failure				1		7	8
<i>Number of patients with successful union</i>	16	10	12	10	15	47	110
<i>Time for union to take place (immobilization period), weeks</i>							
Range	8-29	15-30	13-26	13-28	6-46	14-38	
Mean	17	24	19	21	30	23	
<i>Period of incapacitation after successful operation, months</i>							
Range	3-15	4-13	5-10	5-16	2.5-15	0.5-5	
Mean	8	8.5	6.5	7.5	8	8.5	

five of them concerning the tibia and one, the radius. In the last-mentioned instance there had been a faulty position, which had been corrected at the operation; but there had probably been residual stress on the graft, gradually leading to its fracture. In three of the cases of fractured tibial graft walking had been commenced without walking cast; this probably produced stress fracture of the graft and therefore failure of treatment. Since 1956 our hospital has applied the rule of interposing a walking cast stage after union has taken place, in the after-treatment of an osteosynthesis in the lower extremity, which is continued until osteoporosis has disappeared. It has not been positively clarified from which agents the fracture in the other unsuccessful tibial grafts resulted.

The other causes for failure of the bones to unite have been highly variegated and it is frequently impossible to point out the ultimate cause of failure. Usually several unfavourable partial factors together have contributed to a poor end result. Among them there may be mentioned: insufficient fixation, strong sclerosis of the fragments, and too sparing use of spongy bone.

No attempt at mutual comparison of the results obtained by different operating methods has been attempted for the reason that, as a rule, the principle was to employ the technique that was considered most appropriate in each instance. So far the treatment of non-union has not been solved by any single method of treatment; it is rather a fact that different states and conditions require different measures. In order that the best possible results may be achieved, not only complete mastery of the surgical technique is required but there should also be good surgical judgment. If these conditions exist, the results obtained by different techniques will be largely similar.

SUMMARY

In the Orthopaedic Hospital of the Invalid Foundation 160 patients were under treatment during the period 1945-1960 for non-union of the shafts of one of the long bones in the extremities. The initial cause of non-union was open fracture in 53 per cent of the cases, and one or several operations for correction of non-union had been performed prior to admission into our hospital in 41 per cent of the cases. There had been infection in altogether 31 per cent of the cases.

Corrective operation for non-union was performed on 126 patients and successful union was achieved in 110 (87 per cent) although 12

patients required more than one operation. The operative method varied according to circumstances; no positive differences between the methods can be seen on the strength of this series.

RESUME

A l'Hôpital Orthopédique de la Fondation des Invalides, 160 malades ont été traités durant la période 1945-1960 pour une non-soudure de la diaphyse des os longs des extrémités. La cause initiale de la non-soudure était une fracture ouverte dans 53 pour cent des cas. Une ou plusieurs opérations en vue d'obtenir la soudure avaient été pratiquées, avant l'admission dans notre hôpital, dans 41 pour cent des cas. Il y avait eu des infections dans 31 pour cent des cas.

Une opération corrective fut pratiquée chez 126 malades et la soudure a été obtenue dans 110 cas (87 pour cent) bien qu'il ait fallu plus d'une opération chez 12 malades. La méthode opératoire a varié selon les circonstances. En se basant sur cette série de cas, il n'a pas été constaté de différences positives entre les méthodes.

ZUSAMMENFASSUNG

Im Orthopädischen Krankenhaus der Invalidenstiftung sind während der Zeit 1945-1960 160 Patienten wegen Pseudarthrose eines der langen Röhrenknochen der Extremitäten behandelt worden. Die Originalursache der Pseudarthrose war offener Bruch in 53 Prozent der Fälle und eine oder mehrere Operationen zum Korrigieren der Pseudarthrose sind in 41 Prozent vor dem Einliefern in unser Krankenhaus ausgeführt worden. Infektionen sind in insgesamt 31 Prozent vorhanden gewesen.

Operation zur Behebung der Pseudarthrose wurde bei 126 Patienten vorgenommen, mit Wiedervereinigung der Knochenbruchstücke in 110 Fällen (87 Prozent), obwohl bei 12 Patienten mehr als eine Operation notwendig war. Die Operationsmethoden variierten je nach den Umständen und es ist an Hand des vorliegenden Materials kein deutlicher Unterschied zwischen den verschiedenen Vorgehen zu verzeichnen.

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