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SURGICAL TREATMENT OF NON-UNION AND DELAYED UNION OF LONG BONES

By

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Interest in the treatment of false joint has increased since the Second World War, as in the periods following all wars. The large fractures caused by shell-splinters, and often complicated by severe infection, frequently lead to formation of pseudarthrosis with large bony defect, the treatment of which must still be looked upon as an unsolved problem in many respects. Formerly, in normal times, pseudarthrosis of the long bones was considered fairly rare, but today there seems to be an increased frequency, even after peace-time fractures. This is a phenomenon which has been reported from numerous quarters, and upon reflection, the occurrence seems rather strange. There are now means by which infections affecting large shell-splinter fractures may be combatted and the methods for treatment of fractures in general have been developed and constantly improved over a period of tens of years.

Without doubt, one of the reasons for the increased frequency of false joint is the rising number of severe road and industrial accidents. Open splinter-fractures are often sustained in these accidents, and, in size, almost comparable with war-time fractures. Whether or not modern fracture treatment as such, particularly if erroneously applied, may be contributive in this respect is an open question. There are two important circumstances due to which pseudarthrosis is liable to develop: inadequately supervised traction treatment which readily causes too wide a distraction between the fragments, resulting in diastasis, and, too brief a period of immobilization. Numerous authors have stressed these two points. (*Böhler, Bätzner, Kaspar, Nusselt,* and others). Another question is whether the metal osteosyntheses contribute to the increased frequency of false joint. In these operations, large areas of the bone around the fracture are often laid bare, infections

naturally occur, and the role of metal as a foreign body cannot be ignored. As a matter of fact, formation of callus is sometimes markedly poor after metal osteosynthesis and this is often mentioned in the histories of patients with pseudarthrosis. *D'Aubigné* and *Bernbeck* state that uncritical use of metal osteosynthesis may render worse the natural union of the fracture. The statements of these authors are cited here in order to stress the importance of critical determination of indication for surgery, and the necessity of close supervision of conservatively treated cases.

Definite knowledge of whether there is pseudarthrosis or merely delayed union of a fracture would be invaluable in order to assess the results of surgical management. In many quarters it is held that pseudarthrosis cannot be spoken of until six months after the fracture, in others four months is considered sufficient. The scientific value of these intervals, which have been determined somewhat at random, is insignificant, but they may be helpful in a practical sense. Attempts have been made to fix the time limit on a more pathological basis and, accordingly, pseudarthrosis should not be spoken of until distinct sclerosis of the fracture ends is visible and complete closing of the medullary cavities occurs. But even this manner of assessment is not quite satisfactory, especially in the border cases. The problem of strict differentiation between cases of pseudarthrosis and delayed union thus remains unsolved as things are at the moment. For assessment of the results of the operation it is important, however, in each case, that the exact time since the fracture occurred is known. Attention will be paid to this fact in the following, as far as is possible.

As to treatment, conservative therapy in opposition to surgery may be spoken of. We know that conservative therapy rarely yields good results in cases of fully developed pseudarthrosis, but if there is delayed union, a walking cast may be employed as the resulting stress stimulates formation of callus, thus accelerating union.

Surgical treatment is divided into several groups, distinguished on the basis of the principle followed. The most important groups are:

I. Surgery of *Beck*'s type with boring, and *Kirschner*'s fragmentation. An endeavour is made to stimulate formation of new bone by refreshing the site of fracture. These methods are best suited to cases of delayed union and may be attempted, as no great risk is involved. However, in most cases there is no response; this is seen from the fact that previous use of these methods is often recorded in the histories of patients with pseudarthrosis. The results are generally poor if fully developed pseudarthrosis is present.

II. This group contains cases in which wires are inserted through the fragments for the purpose of compressing the ends of the fragments, according to

Greifensteiner's and *Wustmann*'s methods. The reader is referred to the works of these authors for particulars. Their methods have not, however, been extensively used so far.

III. Treatment of pseudarthrosis by various methods of metal osteosynthesis has been tested over the years. Medullary nailing according to *Küntscher*'s principles is probably the method still considered of significant value, but the results are not always satisfactory. (*Geissendörfer, Greifensteiner, Hellner, Kaspar, Rehnberg,* and others.)

IV. The most important group is the fourth which comprises different methods of bone grafting. Various modifications of these methods have been used, depending on the quality of the bone to be treated and on the mode of application. The methods worked out by *Lexer* and *Albee* may be considered the basic ones. The graft consists of a massive cortical graft from the tibia. It is inserted into a groove, chiselled to fit the graft, across the pseudarthrosis which is laid bare, and the graft is fixed with metal wire or screws. The essential point in these cases is to establish firm contact between the bone ends, and good internal immobilization. It was discovered at a later date that regeneration was more favourable in spongious bone and the use of spongious grafts, and spongious mass from the crista iliaca was suggested (*Matti, Blair, Zenker,* and others). *Phemister,* quite recently proved that the fixing of the graft by means of a metal wire and the removing of the connective tissue of the false joint is not always necessary. In many instances, the graft requires only the fixation effected by the periosteum, and the soft parts and the pseudarthrosis tissue become ossified during the course of repair. This method of operation which greatly simplifies matters has been tested on a large scale and the results proved successful (*Bishop, Stauffer* and *Alvin, Geissendörfer, Nusselt,* and others).

V. The last group comprises metal osteosynthesis and bone grafting combined. In some cases *D'Aubigné, Cauchoix, Nusselt,* and others have used *Küntscher*'s method of nailing and bone grafting together, and *Horwitz* and *Lambert,* and *Sauderi* and *Ippolito* and others have employed metal osteosynthesis with a metal plate attached with screws, and bone grafting.

The above is but a short survey of the most important methods of surgical treatment and the principles followed. In addition there are numerous modifications which do not require elucidation in this connection.

The results of treatment of patients with false joint and experiences gained at the Orthopedic Clinic, Helsingfors, will be given in the following since the methods employed are fairly recent in certain respects, and may be of technical interest.—In the last four years, a total of 38 patients with pseudarthrosis were operated on. Pseudarthrosis of the long bones appears here in 5 women and 33 men. Two of these were under 20 years of age, 11 between 21 and 30, 11 between 31 and 40, 7 between 41 and 50, and 7 over 50. It is thus seen that the majority were male patients at their most active ages which is quite to be expected since this is the period when men, more so than women, are liable to be exposed to these great injuries. The false joint was located

as follows: 22 in the tibia, 4 in the femur, 4 in the humerus, 7 in the forearm, and 1 in the basal phalange of the thumb. As the surgical method employed depends on the location of the pseudarthrosis, the cases in the report to follow will be classified on the basis of location.

Tibial pseudarthrosis.

This group contains 22 cases of tibial pseudarthrosis, the false joint appearing in 12 cases on the border between the lowest and middle

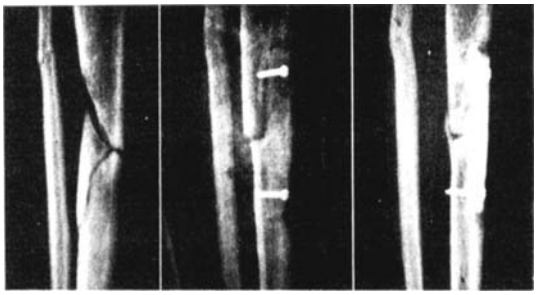

Fig. 1.
Tibial pseudarthrosis before surgical operation, immediately after grafting of cortico-tibial bone and fixing with vitallium screws, and, the united bone.

third of the tibia or in the lowest third; in 7 cases in the middle third of the tibia, and in 3 cases in the upper third. This distribution is typical. As to the surgical technique, there was some variation owing to the quality of the false joint. Bone was grafted in all cases.

A separate group is formed by the single case in which a tibial inlay graft fixed with *Parham*'s bands was used. A woman, aged 48 years, had broken her leg three months before the procedure. She had received traction treatment for a month and for two months her leg had been set in a plaster cast. Wide dislocation resulted, however, and there were no signs of union, the case being typical of non-union. In order to replace the ends of the fragments, they must be laid bare and osteotomy of the fibula performed. Union was rather slow and the bone was not clinically firm until 20 weeks later.

In 8 cases the bone graft was fixed with vitallium screws. In all, the false joint had been present for over a year, and, generally, there was a question of pseudarthrosis with dislocation, and in several cases some bony defect as well. For technical reasons the pseudarthrosis tissue had to be removed in several cases, and the ends of the fragments laid bare to make possible replacement. A suitable bone graft was taken

from the tibial cortex in 6 cases, and a spongious graft from the crista iliaca in 2 cases. A precisely fitting groove was chiselled across the false joint to hold the graft. This procedure opened the medullary cavities in all instances. The graft was fixed with two to four vitallium screws, and the surroundings were packed with spongious bone chips as a rule. There was no infection. Good stabilization was obtained in periods

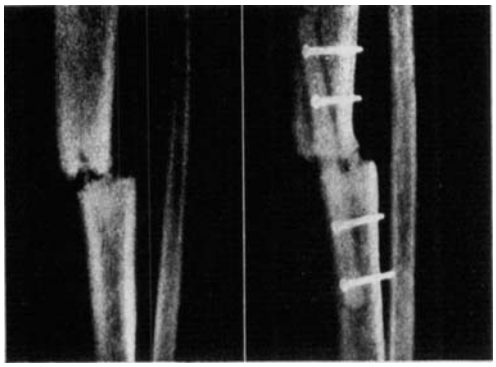

Fig. 2.
Tibial pseudarthrosis before and after grafting of cortical bone and fixing with vitallium screws. Intense formation of new bone occurs in the connective tissue of the pseudarthrosis which had not been removed.

varying between 11 and 43 weeks. The time mentioned as required for stabilization may be too long as it is based on the case histories only. Union may, of course, have occurred sooner in some instances, but this was not possible to check at a later date. Primarily, 3 of the patients had received traction and plaster treatment and 5 plaster treatment only. *Beck*'s boring was performed in one case, in another osteosynthesis according to *Lane*'s method, and in a third medullary nailing according to *Küntscher*'s method, as seen from the case histories.

The last group of cases operated on for tibial pseudarthrosis contains those in which metal fixation was not used in connection with osteosynthesis. It is the largest group and includes 13 cases. In one of these, pseudarthrosis had been present for over two years; in 4 between 1 and 2 years, in 4 between 6 and 12 months; in 3 between 4 and 6 months, and, finally, in one case for only about 3 and a half months. The interval was sometimes comparatively short, but union was not expected either in these cases. In the three-and-a-half month pseudarthrosis, in which there was double fibular fracture, a defect of 2 cm was observed between the fracture ends, and this was no doubt caused

by the traction treatment. Ten patients had been primarily treated with traction and plaster, and 3 with plaster only. In general, immobilization covered the period of time considered adequate. *Beck*'s boring had previously been performed in one case, cerclage in one case, and bone grafting, the graft being fixed with screws, in one case. The graft always consisted of spongious bone taken from crista iliaca, about

Fig. 3.
Tibial pseudarthrosis before surgical operation and after grafting of spongious bone from crista iliaca. Formation of new bone is seen in the right figure.

7–8 cm in length, and made pointed at both ends; large amounts of spongious bone chips were used in each case. Next, the false joint was laid bare and a groove made to fit precisely, but slightly shorter than the graft, was chiselled in the bone. The medullary cavity regularly opened itself when the groove was shaped. The ends of the fragments were not laid bare, however, and no more of the connective tissue of the false joint was removed than was found necessary for the graft. The tibia was slightly bent backwards to allow the pointed graft to be fitted into the groove and when the bone was allowed to revert to its original position the graft lay firmly with the pointed ends in the medullary cavities on both sides; masses of spongious chips were packed round the false joint. No infection occurred. Formation of bone seemed to be favourable, and in all instances union occurred in 8 to 21 weeks, average 12.5 weeks. The time was reckoned up to the moment when no instability was observed in the false joint. For safety, the patients naturally used the plaster cast for a longer time to avoid the risk of refracture of the recently united bone. Formation of new bone seemed to be better than in the case of a cortical graft being used and fixed with screws.

Femoral pseudarthrosis.

The problem in femoral pseudarthrosis differs from that in pseudarthrosis of the lower leg. The dislocation is usually large, and above all, severe axis deviations are frequent. This is confirmed by the corresponding contracture of the powerful muscles of the thigh. The present series includes only 4 cases in two of which primary osteosynthesis according to *Lane*'s method had been performed.

In one case a supracondylar fracture occurred in a woman with several other fractures. The dislocation was so large that union was not expected. Osteosynthesis was therefore performed as soon as 10 weeks had passed after the fracture. The fragment was replaced in the normal position and stabilized by a massive tibial graft in the femoral condyle, the upper end of the graft fitting into a notch made in the femoral diaphysis; the surrounding parts were packed with spongious bone chips. The post-operative course was uneventful, and 10 weeks later the fracture was stabilized. In the other 3 cases, pseudarthrosis had been present for 6, 7 and 13 months at the time the osteosynthesis was performed. There was a wide deviation, and for that reason, wedge shaped resection of the site of pseudarthrosis was necessitated to straighten out the axis of the bone. The tibial graft was fixed across the false joint with vitallium screws, and the surroundings were packed with spongious bone chips. Infection occurred in one of the cases, yet union of the bone was not prevented. In another case there arose hematoma and, due to it, slight infection. In one case the result cannot be definitely assessed because of the short time which has elapsed since the operation. There is intense formation of new bone, however, in this case. In the others, union was achieved. As seen from the above, fixing of the graft by means of metal screws in femoral pseudarthrosis is often unavoidable in order to retain the position obtained at operation.

Humeral pseudarthrosis.

The series consists of only 4 cases. In 2 of these patients with pseudarthrosis of a year's standing, medullary nailing according to *Küntscher*'s method had primarily been performed. No particular formation of new bone occurred and the medullary nails, which evidently were too fine, gave no true stability as there was abnormal mobility, and roentgenologically the ends of the bones were distinctly sclerosed. In both cases a notch was chiselled across the pseudarthrosis and a suitable spongious graft was fitted into it; the surroundings were packed with spongious bone chips. Formation of bone started well and union was observed in 8 and 14 weeks. In one case fragmentation

according to *Kirschner*'s method was performed when the false joint had been present for 13 months. A bony defect of several centimetres resulted, and there was severe sclerosis and atrophy of the bone ends. A strong tibio-cortical graft was fitted on to the shaped bone ends and fixed with vitallium screws; the surrounding parts were packed with spongious bone chips. In 8 weeks the bone seemed to be stable and ultimately repair was complete. In one case where the false joint had been present for 12 months, osteosynthesis according to *Parham*'s method had primarily been performed, and since stabilization did not occur, step-shaped plasty with cerclage fixation was performed, likewise without result. Also in this case spongious bone from the crista iliaca was grafted, in the manner described above. The patient's mental condition prevented post-operative immobilization, and six months after the operation there was still no union. Severe osteoporesis contributed to the poor result. This is probably the only case of complete failure in the series described.

Pseudarthrosis of antebrachium and ulna.

This group comprises 7 patients, 5 of which were cases of pseudarthrosis of the antebrachium, and 2 of pseudarthrosis of the ulna. Initially, medullary nailing according to *Küntscher* had been performed in 3 of these cases. In 4, a bone graft was fixed with *Parham*'s bands. In 3, there was a question of pseudarthrosis of the forearm and in 1 pseudarthrosis of the ulna. In 3 cases union was observed after 8, 15 and 16 weeks. The internal immobilization obtained after the operation does not seem to have been particularly effective as seen from the roentgenograms. No final follow-up examination was performed in one of the cases. Spongious bone from the crista was grafted in one case and union resulted in 11 weeks. No mental fixation was used. In two cases, strong cortical grafts from tibia were grafted and fixed with vitallium screws. In one of these cases there was a question of pseudarthrosis of the ulna and union occurred in 11 weeks. In the second case the problem was pseudarthrosis of the antebrachium with marked radial deviation. Primary stability was here imperative to maintain the results of replacement. Union was observed in 19 weeks.

Pseudarthrosis of pollex.

A patient with a fracture of the first phalanx of the thumb received traction treatment. Pseudarthrosis developed, also a defect and atrophy of the fragmental ends. A cortical bone needle from the tibia

was inserted into the medullary cavities of both fragments, and the surroundings were filled with some amount of spongious bone tissue. Union occurred in 16 weeks.

DISCUSSION

Previous treatment of the cases of pseudarthrosis reported are noteworthy to a certain degree. Twenty-one of the 38 patients received traction treatment. Their histories include surgical operations of the following kinds: medullary nailing according to *Küntscher*'s method 6 times, osteosynthesis according to *Lane*'s method 3 times, osteosynthesis according to *Parham*'s method once, osteosynthesis with bone grafts fixed with screws once, cerclage twice, *Beck*'s boring twice, and *Kirschner*'s fragmentation once. In the histories of 38 patients with pseudarthrosis there thus occurred surgical operations sometimes recommended for treatment of pseudarthrosis, 16 times in all. This fact illustrates, in some measure, their suitability for treatment of pseudarthrosis. However, erroneous and deficient technique was probably used in some instances, for instance too fine medullary nails, too early mobilization, etc.

Osteosynthesis and bone grafts, on the other hand, yielded good results, except in one case included in this series. Infection occurred in one case only and this very low incidence is probably due to the operation regularly being performed under the screen of antibiotics. As to the graft, it definitely seems as if formation of new bone were more rapid with the use of spongious bone. Union was generally more rapid in the cases in which spongious substance was grafted and no metal fixation used. The time mentioned as required for union in the various cases in the present series must not be regarded as conclusive evidence of the period of repair. Individual factors may play a part in the separate cases and, moreover, a vast series must be studied to find reliable mathematical evidence. The difficulty in determining the exact time of union in cases of pseudarthrosis is common knowledge. The method of grafting spongious bone across the false joint, omitting fixation by means of metal adjuncts, and the use of spongious bone chips for filling yielded good results as a rule, provided the dislocation or the defect was moderate. Complete ossification occurred in the later stages of repair in spite of the pseudarthrosis tissue not having been removed, even in longstanding cases. This fact may be of some value in order to prove that so-called metaplastic bone formation takes place during the process of repair. (*Levander, Annersten*). The new bone was of cortical type, and no fracture of the spongious graft was observed.

In the cases with large deviations, dislocations, and true bony defects, large massive cortical bone grafts were attached to the ends of the fragments with vitallium screws. In addition, the surrounding parts of the false joint were packed with spongious bone chips. In order to achieve satisfactory replacement, the ends of the fragments were often laid bare, and due to this, union was delayed. However, even this method yielded good results. Adoption of a universal method is evidently out of the question as the operative technique depends on the type of pseudarthrosis. Some general rules may, however, be given.

In tibial pseudarthrosis, a spongious graft may be used, provided there is moderate dislocation, and if some firmness is required the graft may be applied as an inlay graft which does not render the technique more difficult. The pseudarthrosis need not be removed. If the defects or the dislocations are large and if maintenance of a certain firmness is required at least in the early stages of repair, then a cortical inlay graft fixed with vitallium screws is advantageous and, in that case, the use of spongious bone chips in addition may prove expedient. A longer period is required for repair in these cases.

In femoral pseudarthrosis, the dislocation and the incorrect axis deviation are often large. A cortical onlay graft attached with vitallium screws to the levelled bone is often used in these cases.

In humeral pseudarthrosis, as in that of the antebrachium, the technique requiring the use of screws is generally considered the correct procedure. There is often severe axis deviation which interferes with the function. In very special cases only, for instance when an ineffective medullary nail gives stability in some measure, a spongious graft attached without metal screws may be advantageous.

Metal bands or wires are hardly more expedient for fixation than are screws. In the former case the ends of the fragments have to be laid completely bare, which no doubt delays repair. The firmness obtained is generally not so good as that obtained with screws, and the metal bands which, one might say, strangle the bone, may be another cause of delayed repair.

Infection is a complication which should not be ignored, in spite of antibiotic prophylaxis being available. The condition of the skin covering the area to be operated on must be good, and if not, correction by means of scar excision, grafting, etc. must be done. Surgical operation should not be attempted until some months after complete healing of an open fracture or subsidence of infection. During the operation, meticulous care with regard to hematoma is required as post-operative effusion is often the source of infection.

However, today the safety margin is wider, and the surgical

technique is simpler. Therefore, indications for bone grafting might be extended to include even cases of delayed union. If development of pseudarthrosis seems likely, grafting will no doubt be considered permissible at a fairly early stage. To delay confirmation of the diagnosis pseudarthrosis for months is a lamentable loss of time to the patient. Faulty positions which limit the range of movement may develop, stiffness of the joint due to shrinking of the joint capsule and, in all cases, marked atrophy of the muscles will ensue. After-treatment which is laborious and wasteful of time is required for correction of all these complications. Finally, scrupulous deliberation of each case separately is imperative prior to early surgery.

SUMMARY

The author reports 38 cases of pseudarthrosis treated with bone grafting. Traction treatment and metal osteosynthesis were often mentioned in the case histories: for instance, medullary nailing according to *Küntscher*'s method in six patients. In tibial pseudarthrosis, a spongious graft from crista iliaca was most often used for grafting and then without metal fixation. On no occasion was the false joint removed. If defects and large dislocations occurred, a cortical graft fixed with vitallium screws was employed. In femoral and humeral pseudarthrosis and in pseudarthrosis of the forearm, with extensive axis deviation or bony defect, cortical onlay graft fixed with vitallium screws was the mode of treatment. With this procedure, some firmness was established and the high dislocation tendency reduced. Infections occurred in only two cases. Union of the bones resulted in all the cases, except one, a case of humeral pseudarthrosis. Repair seemed to be particularly rapid when spongious graft without metal fixation was employed. Distinct ossification occurred in spite of the connective tissue of the pseudarthrosis not being removed.

RESUME

L'auteur rapporte 38 cas de pseudarthrose traités par greffe osseuse. Le traitement par la traction et l'ostéosynthèse métallique a souvent été mentionné dans l'histoire de ces cas! par exemple enchevillement médullaire d'après la méthode de Küntscher chez six malades. Dans les pseudarthroses tibiales, une greffe spongieuse prélevée de la crête iliaque a souvent été utilisée. Dans aucun cas la fausse articulation n'a été enlevée.

Lorsqu'il y avait déformité ou large dislocation, une greffe corticale

fixée par des vis de vitallium ont été utilisées. Dans les pseudarthroses fémorales et humérales et dans les pseudarthroses de l'avant-bras avec une déviation extensive de l'axe ou des déformités osseuses, la greffe corticale fixée par des vis de vitallium a été le mode de traitement. Grâce à cette manière de procéder, une certaine fermeté a été acquise et la forte dislocation a été réduite. Des infections se sont manifestées dans deux cas. La consolidation de l'os s'est effectuée dans tous les cas excepté dans un cas de pseudarthrose humérale. La remise en état semble particulièrement rapide lorsque l'on a utilisé la greffe spongieuse sans fixation métallique. Une ossification distincte apparaît bien que l'on n'ait pas enlevé le tissu conjonctif de la pseudarthrose.

ZUSAMMENFASSUNG

Der Verfasser berichtet über 38 Pseudarthrosefälle, die mittels Knochenspahnung behandelt wurden. Streckbehandlung und Metallosteosynthesen werden oft in den Krankenvorgeschichten erwähnt: beispielsweise die Marknagelung nach Küntscher in sechs Fällen. Bei der Pseudarthrose der Tibia wurde meist ein Spongiosaspahn von der Crista ilii verwendet. Das falsche Gelenk wurde in keinem Falle entfernt. Wenn Defekte und bedeutende Verschiebungen vorhanden waren, wurde ein mit Vitalliumschrauben fixierter Corticalisspahn angewendet. Bei Femur- und Humeruspseudarthrosen sowie bei Pseudarthrosen des Unterarmes mit schwerer Verschiebung ad axim oder Knochendefekt war ein angelegter Corticalisspahn, der mit Vitalliumschrauben fixiert wurde, die Art des Eingriffes. Mit diesem Vorgehen wurde ein gewisser Grad von Festigkeit erzielt und die ausgesprochene Neigung zur Verschiebung wurde verringert. Infektion trat nur in 2 Fällen auf. In allen Fällen mit Ausnahme von einem, einer Humeruspseudarthrose, kam es zur knöchernen Vereinigung. Heilung schien besonders rasch in den Fällen aufzutreten, in denen Spongiosaspähne ohne Metallfixation angewendet wurden. Es kam zu ausgesprochener Ossifikation obwohl das Bindegewebe der Pseudarthrose nicht entfernt wurde.

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