BONE-GRAFTING
IN THE
TREATMENT OF FRACTURES

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FOREWORD

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PREFACE

THE work of Albee and the other great masters of bone-grafting needs no acknowledgement by me. The value of their teachings and example in the development of this branch of Orthopædic Surgery cannot be over-estimated.

Unhappily the times in which we live have greatly increased the demands on reparative surgery of the locomotor system. This has led not so much to the discovery of any new or revolutionary principles of treatment as to an increased awareness of the vital importance of attention to the many details which can make or mar the final result.

The value and scope of bone-grafting in the treatment of fractures are obvious. In the practice of this particular branch of orthopædic surgery one is, inevitably, confronted by many problems and practical difficulties. On turning to the standard text-books I have been disappointed again and again by the lack of space allotted to the application of bone-grafting to the treatment of fractures. Descriptions of operative technique are curtailed, information regarding pre- and post-operative treatment is scanty, and many of the procedures described are of historic interest only.

Diagrammatic representations of fine examples of the joiner's art and radiographs showing spectacularly convincing results are poor consolation to a surgeon with a practical problem to solve. This book has arisen out of the difficulties I have encountered, and my aim has been to make it as simple and as practical as possible.

Arthodesis has been discussed only in connection with certain fractures of the tarsus and spine in which I believe it to be the best initial treatment, and I have quite frankly avoided any detailed discussion of the vexed question of the place of bone-grafting in the treatment of fractures of the neck of the femur.

Most of the radiographs, and the statistics included in the Appendix, were taken from the records of one of the Royal Air Force Orthopædic Centres, and I am indebted to the Director-General of the Royal Air Force Medical Service, Air Marshal Sir Harold Whittingham, for permission to use this material. Mr Watson-Jones has been kind enough to write a Foreword, and it is a pleasure to record the great debt which I, in common with all the other Orthopædic surgeons in the Royal Air Force, owe to him and to Air Commodore Osmond Clarke for their never-failing assistance, encouragement, and advice. The colour photographs were taken by Mr Hennell, whose services were made available through the Medical Research Council by the Directors of the Metal Box Company. Mr Hennell's colour photography has already set a new standard in the illustrating of medical text-books.

I have had much valuable assistance and advice from Mr Charles Macmillan of Messrs Livingstone; his patience and enthusiasm were a revelation to a completely inexperienced author. Finally I must pay tribute to every single member of the Orthopædic "team" in the centre to which I am attached. Without the stimulus of their keenness and pride in their work this book would probably never have been written.

J. R. ARMSTRONG.

ELY,
December 1944.

FOREWORD

THE principles of bone-grafting were known to John Hunter two hundred years ago. His study of the rich vascular bed of the antlers of the deer, grown with such lavish expenditure year by year, taught him the importance of blood supply in the formation of bone. He knew that in the healing of fractures, bone was formed by the growth of a vascular, cellular tissue from surrounding muscles and periosteum and from the bone ends themselves. He knew that in this process of repair it was possible for bone fragments, completely stripped of all soft-tissue attachments, to be incorporated in the mass of newly formed bone and even to contribute towards union by bridging the fracture. By implanting a human tooth in the comb of a cock he proved that transplanted tissues could survive long enough to await revascularisation. He even transplanted the bone spurs of hen chickens into the legs of young cockerels and saw them take root and grow. But Hunter did not establish bone-grafting as part of surgical technique. He was defeated by sepsis. The time was not yet ripe for the full development of his brilliant programme.

Seventy years after John Hunter's death Lister published his work on the control of wound infection; and a few years later, in the same building in Glasgow where Lister developed his technique, another young surgeon wrote a new chapter in surgical history. It was William Macewen, who at the age of twenty-nine had already introduced the operation of wedge osteotomy for the correction of rachitic deformity. A boy was brought to hospital for amputation of the arm; the humerus had been resected for osteomyelitis; regeneration had failed and the limb was flail and useless. Macewen was unwilling to amputate, and he decided to make use of fragments of osteotomised bone from other patients. Bone wedges were gathered from the legs of six bow-legged boys and transplanted to become intrinsic parts of the humerus of a seventh. The operation was successful. The reconstructed bone measured six inches in length, four inches of it consisting of transplanted bone. The patient grew to be a capable workman with a strong though slightly curved humerus eleven inches long.

Bone-grafting was thus introduced in 1880 in the wards of the Royal Infirmary, Glasgow. But the modern technique of bone-grafting received no less powerful an impetus in 1894 from the wards of Guy's Hospital, London. Arbuthnot Lane resolved "to treat the bones as one would the broken leg of a table or chair." He established the principle of internal fixation and set a new standard in the treatment of fractures. His methods of operative reduction were guided by rules of precision, and internal fixation was achieved by metal plates and screws. With similar purpose Fred Albee of New York devised "a surgical armamentarium for cutting and modelling bone which at least approaches that of the power-driven precision tools of the machinist or cabinet maker." Surgeons began to learn from other craftsmen. In recent years they have acknowledged one more debt, this time to the metallurgist, for stainless steel, vitallium and other alloys have made it possible to use screws without fear of reaction or loosening in the bone. The ideal device of the future may not be an alloy of metals—it may be an absorbable plastic. But meanwhile surgeons no longer fix bones to each other by the methods of the amateur—the twisted bits of wire and the fragments of catgut which any carpenter would laugh to scorn. They use nails, flanged nails and screws; they achieve reliable and lasting fixation; they have developed the modern technique of onlay bone-grafting.

In his monograph on bone-grafting in the treatment of fractures Mr Armstrong's work reflects the surgical development of two hundred years—the research of Hunter, the work of Lister, the inspiration of Macewen, the skill of Lane and the craftsmanship of Albee. On this very sure foundation, linked to recent research in metallurgy, is based a technique of bone-grafting which almost completely solves the problem of slow union, delayed union and non-union. Mr Armstrong has dealt faithfully with every detail of technique that the young surgeon must know. He has the advantage of being young himself—the age when many surgeons of the past have made their greatest contribution. He is a leading member of the team of orthopædic surgeons of which the Royal Air Force is proud, surgeons who have shouldered heavy responsibility, gained vast experience, and treated the fractures of pilots and aircrews which are characterised by astonishing severity and multiplicity. In all their work the highest possible standard has been set. It has been maintained by the vigilance of Osmond Clarke, who as Service consultant is also young in outlook but is nevertheless mature in judgment. But it has been achieved without standardisation or suppression of initiative. Central dictation of technique is the easy method of assuring a uniformly high standard, but from the point of view of surgical progress it is the pernicious method. And thus will be found in the work of Armstrong, in the technique of sub-astragaloid arthrodesis, the practice of bone-grafting the scaphoid, and in other operations, the provocative, stimulating approach of the individual.

A warning is necessary. The technique of onlay bone-grafting with vitallium-screw fixation is well established. Brilliant results can be achieved; deformity can be prevented; union can be accelerated; non-union can be avoided. But let it be remembered that John Hunter was defeated by sepsis. Let it be remembered that internal fixation was no more than part of the contribution made by Arbuthnot Lane; no-touch technique was the other part. Even to-day the general standard of asepsis in operative technique is far too low. To infect a closed fracture is a disaster of the first magnitude; it is no less worthy of a court of inquiry than a railway disaster. The surgeon who proposes to adopt the recommendations of this monograph must first achieve so perfect a command of aseptic technique that if, within a few days of operation, the patient develops a febrile reaction he can say with complete confidence: "He may have pleurisy; he may have pneumonia; but whatever he has, I am quite certain that he has no infection of the wound."

R. Watson-Jones

29th November 1944.

CONTENTS

CHAPTER I

PRINCIPLES, GENERAL INDICATIONS, CONTRA-INDICATIONS

PRINCIPLES

THE autogenous bone-graft has two functions, being both an internal splint and a scaffolding by or from which new bone is formed. Bone-grafting, properly carried out, is a valuable measure in the treatment of a wide range of fractures and, in certain circumstances, is the only effective treatment. It is not sufficient, however, simply to place a graft of indeterminate size across a fracture, so that it is more or less in contact with the host bone, and then immobilise the limb. To produce really satisfactory results certain basic conditions must be fulfilled.

1. *There should be close and stable contact between large areas of raw bone on the graft and host.*—It is unlikely that an autogenous bone-graft lives and " takes " in the way that a free epithelial graft " takes " on a granulating surface. More probably it dies and is replaced by living bone by a process of creeping substitution. In either event revascularisation is the essential process whereby the graft becomes living bone. The host bone is the source of this revascularisation; capillary vessels grow from it and spread throughout the graft. Several factors influence this growth. The graft should be in contact with a vascular area; the deeper layers of the cortex and the medullary cavity are a much more effective source of capillary growth than the hard superficial cortex. Similarly, the graft will be more easily revascularised if it consists at least in part of soft cancellous endosteal bone into which capillaries can grow easily, and this layer of the graft should be in immediate contact with the host. Finally, the larger the areas of graft and host brought into contact, the more rapid will be the revascularisation of the graft and its subsequent replacement by living bone.

2. *Fixation of the graft and fracture must be mechanically stable.*—Any movement at all between graft and host tears the fine capillaries, and delays or prevents revascularisation. In the same way, movement between the fractured surfaces delays union by traumatising

the delicate tissues which are the framework of repair. External fixation reduces to a minimum the mechanical strains and stresses to which the graft and fracture are exposed, but absolute immobilisation can be ensured only by a combination of external and internal fixation.

To produce adequate internal fixation the graft must be strong enough to withstand the forces to which it may be subjected, without bending or breaking. It must, therefore, be large and consist in part of hard cortical bone. Soft cancellous bone, while of a high osteogenic value, is not strong enough to form an efficient internal splint. Fixation between the graft and the fragments of the host above and below the fracture must be mechanically efficient and must remain stable until consolidation is complete.

Provided fixation is effective the use of cancellous bone or bone chips packed around the fracture is logical. Under these circumstances such fragments are not subjected to any strains and act as a supplementary source of new bone.

3. *Before grafting the fractured surfaces should be cleared of fibrous tissue and sclerotic bone.*—If allowed to persist, these form a barrier to the process of repair.

4. *Normal apposition and alignment of the fragments of the host bone should be restored.*—Accurate apposition of the fractured surfaces reduces to a minimum the new bone formation necessary to effect union. If actual bone loss has occurred the gap should be filled with cancellous bone after it has been bridged by a stout graft. Mal-alignment, if uncorrected, causes dysfunction and disturbs the mechanical efficiency of the joints above and below the fracture.

5. *The architecture of the reconstructed bone as a whole should as far as possible approximate to normal at the conclusion of operation.*—This reduces to a minimum the amount of bone absorption and new bone formation necessary in the process of repair.

GENERAL INDICATIONS FOR BONE-GRAFTING

The decision to treat a fracture by operative rather than conservative methods should never be made lightly. Serious though the failure of conservative treatment may be, an unsuccessful operation may well result in tragedy. This applies particularly to bone-grafting, which is always a formidable procedure. In certain

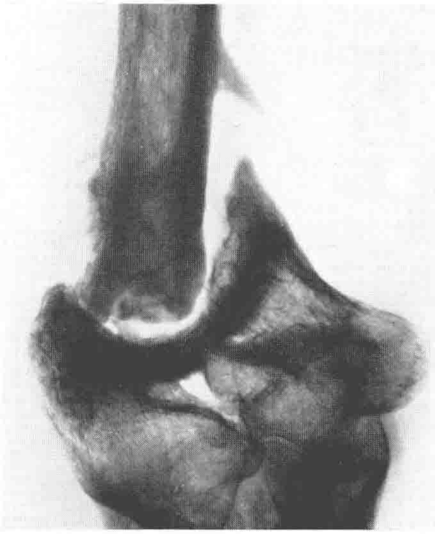

Fig. 1
Established non-union. Fracture surfaces sealed off by a layer of avascular sclerotic bone.

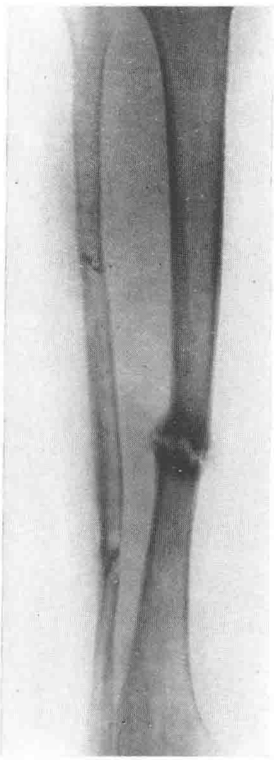

Fig. 2

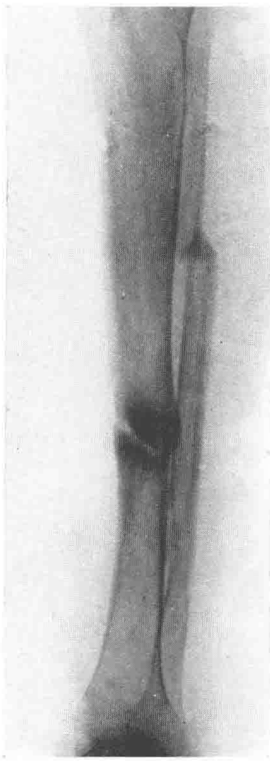

Fig. 3

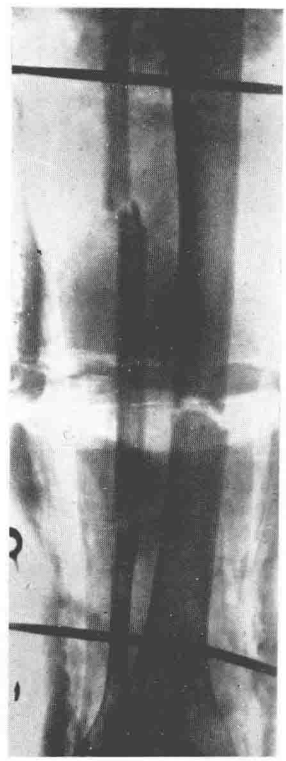

Fig. 4

Figs. 2 and 3.—Delayed union. A nine-months-old fracture showing fibrous union only, with early sclerosis of the bone-ends.

Fig. 4 shows the same fracture two weeks after the initial reduction. The distraction present accounts for the subsequent delay in union.

types and conditions of fracture, however, conservative methods alone are not enough. When operation is necessary bone-grafting may be definitely indicated, or may simply be one of several alternative procedures which might be employed successfully.

Established non-union.—An un-united fracture in which the bone-ends have become sealed off by an avascular sclerotic layer will not unite, however long it may be immobilised (Fig. 1). Such operative measures as drilling or " freshening " of the bone-ends are not always followed by union, and adequate bone-grafting is by far the most effective procedure.

Delayed union.—There are wide individual variations in the period of immobilisation necessary to allow bony union in any particular fracture. Such factors as infection, a poor blood supply, repeated manipulations, distraction, or inadequate immobilisation may, however, cause union to be delayed far beyond the normal limits (Figs. 2, 3, and 4). At this stage the fractured surfaces are joined by soft fibrous tissue containing little callus, the bone-ends are relatively avascular and are beginning to " round off," and atrophic decalcification is evident elsewhere throughout the limb. If adequate immobilisation is continued and combined with the maximum possible functional activity of the limb most of these fractures will ultimately unite. In suitable cases, however, the period of treatment can be substantially reduced and ultimate union ensured by timely bone-grafting.

Bone loss.—A high-velocity missile, a too enthusiastic debridement, or infection and subsequent sequestration can result in considerable loss of bone in a compound comminuted fracture. This may be of an extent sufficient to delay unduly or even to prevent union. When all infection has subsided the actual loss of bone can be made good and union accelerated by bone-grafting (Figs. 5, 6, and 7).

After osteotomy.—Occasionally a fracture is allowed to unite in malposition sufficient to cause material disability, which can only be relieved by an osteotomy and correction of the displacement at the site of fracture (Fig. 8). This should be done, provided the malposition has not been of sufficiently long standing to cause permanent secondary changes in the joints above and below the fracture. Bony union after an osteotomy through the site of a recent fracture is often delayed and, if osteotomy is followed by bone-grafting, not only is union accelerated but the danger of redisplacement is minimised by the combination of internal with external fixation.

After open reduction.—It is not always possible to effect adequate reduction of a fracture without operation (Figs. 9 and 10). Interposition of soft tissue or buttonholing of the periosteum may prevent

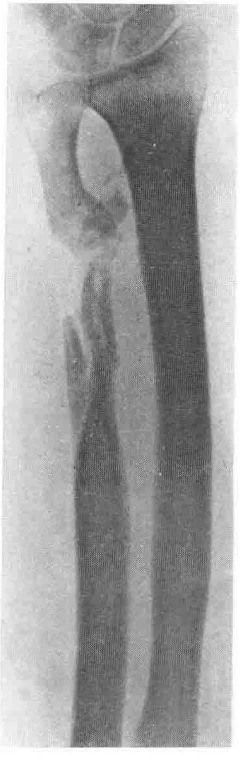

FIG. 5

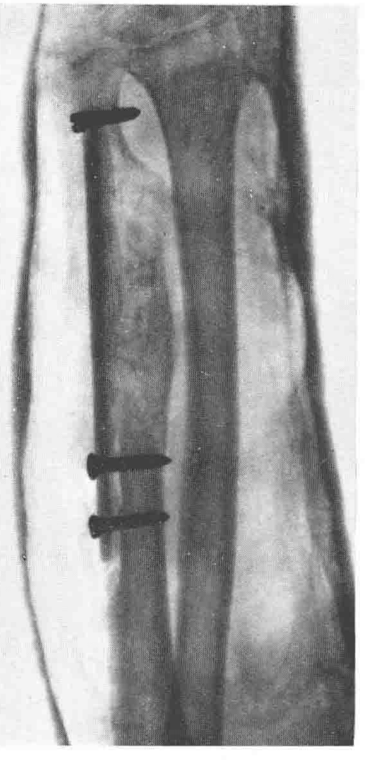

FIG. 6

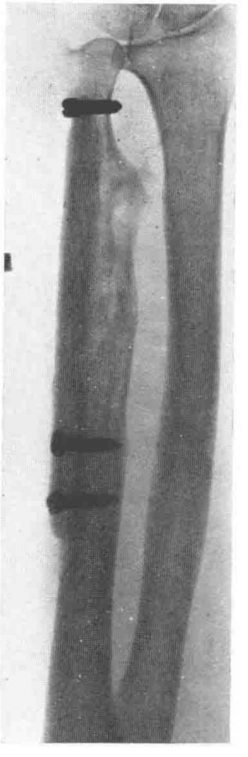

FIG. 7

FIG. 5.—Bone loss. A four-months-old fracture due to a gunshot wound. FIGS. 6 and 7 show the same fracture eight weeks and four months after grafting.

reduction by manipulation or traction, even if these measures are tried immediately after injury. Later, reduction becomes increasingly difficult in all fractures, and after three or four weeks may be impossible using conservative methods only. Moreover, repeated manipulations or continued strong traction substantially delay union. For these reasons open reduction is often necessary and should always be combined with some form of internal fixation. Transfixion screws, or plates and screws, are effective means of fixation,