Treatment of Ununited Fractures of the Scaphoid by Iliac Bone Grafts and Kirschner-Wire Fixation*

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ABSTRACT: Of 151 ununited fractures of the scaphoid that were treated with iliac bone grafts and Kirschner-wire fixation through a volar approach, all but four (97 per cent) healed in an average of seventeen weeks. Three of the four failures resulted from obvious technical errors. Neither the preoperative existence of necrosis of the proximal fragment nor the location of the fracture affected the results. When there was mild radiocarpal arthritis preoperatively, it did not progress postoperatively; if there was moderate radiocarpal arthritis preoperatively, progression seldom was seen if a radial styloidectomy was done. Displaced and unstable ununited fractures healed even if the deformity was not corrected completely. The principal benefit of the procedure was relief of pain rather than an increase either in motion of the wrist or in strength of grip.

At least 5 per cent of acute fractures of the scaphoid fail to unite after conservative treatment. The failures have been attributed to delay in beginning treatment, inadequate immobilization, displacement of the fragments, instability due to ligamentous injury, or inadequate blood supply of the proximal fragment. The regimens of treatment that have been advocated for ununited fractures include prolonged immobilization of the wrist in a plaster cast, open reduction and internal fixation of the fracture fragments, intercarpal fusion, arthrodesis of the wrist, replacement of the scaphoid with a prosthesis, and radial styloidectomy. Some authors have advocated bone-grafting with or without internal fixation of the fracture, or multiple drilling of the fragments, or fascial arthroplasty, or proximal row carpectomy, or electrical stimulation, or partial or total excision of the scaphoid. Bone-grafting has been the most popular surgical treatment. Herbert and Fisher recommended discontinuing immobilization of the wrist in a plaster cast six weeks after an acute fracture, regardless of whether healing was evident on radiographs. If, after an additional two to three weeks, the fracture had not healed, he advocated open reduction using bone grafts and internal fixation with a special screw.

For undisplaced and stable fractures, many surgeons prefer to continue immobilization of the wrist in a plaster cast for four to six months before recommending an operative procedure. The fragments are grossly displaced or unstable because of ligamentous or osseous disruption, they recommend open reduction and internal fixation as soon as possible.

Materials and Methods

Since 1966, we have treated 151 ununited fractures of the scaphoid with iliac bone-grafting and internal fixation using Kirschner wires. All of the patients had had symptoms for at least six months before the operation. The location, displacement, and instability of each fracture; the presence or absence of avascular necrosis; and the degree of radiocarpal arthritis were recorded. Radiographs that were made preoperatively and during treatment, as well as those that were made at the most recent follow-up examination (which included at least six radiographs of the wrist), were reviewed. Subjective complaints, range of motion of the wrist, and strength of grip were recorded. The average length of follow-up was forty-two months (range, one year to more than ten years). Twenty-three patients were examined within

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one to two years after the index operation; ninety-five patients, within two to three years; eighteen patients, within three to five years; four patients, within five to ten years; and eleven patients, more than ten years after the operation.

There were 138 male and thirteen female patients. The dominant wrist was involved in more than half of the patients. The average age at operation was twenty-five years (range, twelve to fifty-nine years).

Eleven patients were less than seventeen years old. This shows that ununited fractures of the scaphoid in children and teen-agers are more common than has been generally realized. All of the pediatric patients had an established non-union, and none had radiocarpal arthritis. Often the fracture had occurred at the age of ten or twelve years, but symptoms did not arise until later. All eleven fractures in these patients united after the index procedure.

Seventy-eight of the 151 fractures (52 per cent) were attributed to an athletic injury; thirty-two (21 per cent), to a fall; and twenty-two (14 per cent), to a motor-vehicle accident. Twenty patients, including four who were less than seventeen years old, could not recall or were unsure when the fracture had occurred. All twenty had complained of pain in the wrist for more than six months, and all had cystic changes indicating that the fracture had been present for many months. For the 131 patients who had a definite injury, the time-interval between the injury and bone-grafting ranged from six to 108 months (average, twenty-three months). Thirty-two patients had the index operation more than two years after the initial injury and fifty-three, within twelve months after the injury. In twenty-nine of the 151 patients (approximately 20 per cent), the injury was work-related.

Thirty-two fractures were in the proximal third of the bone; 106, in the middle third; and thirteen, in the distal third (Table I). In forty-two patients the fracture fragments were displaced at least one millimeter, and in twenty-five patients the fracture was considered unstable because of a dorsal intercalary-segment instability configuration of the carpal bones and a scapholunate angle of more than 60 degrees.

The treatment before the index operation included the use of a sling, taping of the wrist, the use of an elastic wrap or some other splint, immobilization with a short or long thumb-spica plaster cast, intra-articular injections of steroids, electrical stimulation, and internal fixation with or without bone-grafting. Eight patients had had a previous bone graft, and three others had had at least three months of electrical stimulation supplemented with immobilization of the wrist in a plaster cast.

The main indications for grafting were an ununited fracture with disabling pain in 107 patients; pain and stiffness in the wrist in twenty-two; stiffness and extreme weakness of grip in five; and pain, weakness, and stiffness in the wrist in seventeen. There was radiographic evidence of mild radiocarpal arthritis (increased prominence or loss of the rounded contour of the radial styloid process) in forty wrists; this was not a contraindication to grafting, and neither was the presence of moderate radiocarpal arthritis (in twelve wrists), as shown by narrowing or irregularity of the radiocarpal articulation, limited to the space between the styloid process and the distal pole of the scaphoid (Fig. 1). However, when moderate arthritis was present, a styloidectomy was performed either at the time of grafting or as a subsequent procedure after the fracture had united (Figs. 2-A through 2-D). The presence of severe radiocarpal arthritis was a contraindication for bone-grafting of an ununited fracture of the scaphoid.

Avascular necrosis of the proximal fragment, which was present in twenty-five wrists, was not a contraindication to grafting; however, when the proximal fragment was found to be sclerotic, fragmented, badly deformed, or devoid of cartilage, bone-grafting was not performed. The latter complex of abnormalities was encountered only twenty-eight times in nineteen years; in each patient, the proximal fracture fragment was replaced with a hand-carved silicone-rubber spacer. These patients were not included in the present study. Except for these exclusions, the series of 151 patients is consecutive.

Operative Technique

The scaphoid is exposed through a straight or zigzag volar incision. After the wrist capsule is incised longitudinally and the wrist is dorsiflexed, both parts of the scaphoid as well as the articular surface of the radius can be seen readily. A small, rectangular window of bone is removed from the volar aspect of the distal fragment immediately adjacent to the fracture. Through this opening, both fragments are cleared of fibrous tissue and dead bone, using a low-speed power burr or curet.

As emphasized by Matti,14, a large cavity is fashioned in both the proximal and distal parts of the scaphoid. A Chandler retractor is used to protect the articular cartilage of the radioscapophoid joint. It also helps to correct angulation, malrotation, and displacement of the fragments. The volar part of the cortex of the scaphoid is often deficient, and this deficiency permits an exaggerated volar tilt of the distal fragment. Realignment and reduction of the fracture, and

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**Table 1**

<table>
<thead>
<tr>
<th>Site of fracture</th>
<th>Total Wrist Fractures</th>
<th>Average Time to Union (Wks.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal third</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>Middle third</td>
<td>106</td>
<td>97</td>
</tr>
<tr>
<td>Proximal third</td>
<td>32</td>
<td>97</td>
</tr>
<tr>
<td>Preoperative</td>
<td>25</td>
<td>97</td>
</tr>
</tbody>
</table>

**Note:** The table shows the total number of wrist fractures (151) and the average time to union (17.0 weeks) for each site of fracture.
normal

mild

moderate

Fig. 1

Illustration of mild and moderate radiocarpal arthritis.

restoration of the bone to the proper length, is a difficult part of the procedure. Occasionally, intraoperative radiographs may have to be made. In the present series, correction of the displacement ordinarily was assessed visually and not radiographically. The scaphoid is transfixed with two 0.035-inch (0.9-millimeter) Kirschner wires, which are inserted through the distal fragment into the proximal one, while the articular cartilages of the scaphoid and the radius are protected with the retractor (Fig. 3). Correct placement of the wires is ensured by observing them through the volar window.

Cancellous bone from the ilium is packed into the cavity. The wires can be inserted after packing the cavity with bone, but it is easier to verify their location before inserting the graft. Often a cortical bone graft can be fashioned to fit snugly into the volar window, and then it should be immobilized with one additional 0.28-inch (0.7-millimeter) Kirschner wire. Theoretically, this technique helps to stabilize and support the volar aspect of the cortex, but in this study there was no statistical evidence that it improved the rate of union or the final result. The Kirschner wires are cut off beneath the skin. The capsule is approximated with absorbable sutures, the skin is closed, and the extremity is immobilized in a long thumb-spica plaster splint, while the forearm is held in supination with the wrist in neutral and the thumb in opposition. Two weeks postoperatively, the sutures in the skin are removed. A long thumb-spica plaster dressing is worn for six additional weeks, followed by a short thumb-spica cast that is worn until the fracture unites or the procedure is considered a failure. The Kirschner wires are removed, usually under local anesthesia, after the fracture has united. Once immobilization is discontinued, patients are permitted to use the wrist and hand for light activities, but strenuous and forceful activity is discouraged for an additional two months. Formal physiotherapy is considered to be unnecessary and a needless expense.

Results

Union was judged to be present when, on radiographic examination, there were definite trabeculae across the site of the fracture and the fracture gap had disappeared. We routinely made a posteroanterior radiograph of the wrist in maximum radial and ulnar deviation, a lateral radiograph, and both oblique radiographs, as well as a so-called fist radiograph of the wrist. In recent years, if healing was questionable, a tomogram or computerized tomography scan also was made. We were conservative in deciding when a fracture had healed, believing it better to immobilize the wrist longer than to risk an unsatisfactory result.

There were no infections or postoperative hematomas in either operative site, nor did we encounter problems with healing of the wound, tenderness of the scar, or damage to sensory nerves.

All but four of the 151 fractures healed, in an average of seventeen weeks postoperatively (Table I). The shortest time to union was eight weeks and the longest, thirty-three weeks. Thirty-one of thirty-two fractures through the proximal third of the scaphoid healed in an average of 16.5 weeks (range, 10.4 to twenty-four weeks); 103 of 106 fractures through the middle third, in an average of 17.4 weeks (range, eight to thirty-three weeks); and all thirteen fractures through the distal third, in an average of 15.3 weeks (range, 10.3 to seventeen weeks). Several authors have reported a lower rate of union or a longer time to union, or both, after bone-grafting of fractures of the proximal third of the scaphoid. This was not found in the present study, although the fractured wrists that had avascular necrosis as determined preoperatively on radiographs had a slightly lower rate of union than did those that did not have avascular necrosis: twenty-one (84 per cent) of the twenty-five fractured wrists for which there was radiographic evidence of preoperative avascular necrosis of the proximal fragment united within an average of 17.4 weeks (range,
TREATMENT OF UNUNITED FRACTURES OF THE SCAPHOID

Figs. 2-A through 2-D: A thirty-two-year-old man had injured the wrist while playing football.

Fig. 2-A: Preoperative radiograph, made in November 1985, showing an ununited fracture of the scaphoid fifteen years after the injury. Synovial pseudarthrosis and a large exostosis of the scaphoid are evident.

Fig. 2-B: Three weeks after the operation.

Figs. 2-C and 2-D: Eight months after the operation. The fracture had healed, exostosis was still present, and there was moderate radiocarpal arthritis.

Twelve to 28.1 weeks), while 100 per cent of the 126 fractured wrists that did not have avascular necrosis united (Table I). The necrosis eventually cleared in all twenty-one fractures that healed after grafting.

Sixteen patients who did not have avascular necrosis before the operation had radiographic evidence of necrosis in the proximal fragment afterward. Nevertheless, in these patients union occurred in an average of 17.9 weeks (range, nine to 27.9 weeks), and the necrosis cleared afterward. The fracture that required 27.9 weeks to unite also had progression of preoperative radiocarpal arthritis, necessitating a fusion of the wrist because of pain. Only one other patient in this group had radiographic evidence of mild radioscaphoid arthritis when examined eight years after the operation, and that patient did not have pain in the wrist.

All of the fractures that had failed to unite after previous bone-grafting (eight fractures) or electrical stimulation (three fractures) united after our procedure.

Of the four fractures that failed to heal, three were through the middle third of the bone. In one, the displacement measured more than one millimeter and the scapholunate angle, more than 60 degrees. Three fractures were undisplaced and stable, and one of them was through the proximal third, but all four had preoperative avascular necrosis of the proximal fragment. Technical error rather than avascular necrosis was considered to be the most likely cause of three of these four failures. In two, the Kirschner wires were not placed correctly and did not immobilize the frag-
ments. In another, one of the wires, although it had been placed correctly, backed out of the bone within eight weeks after the operation, and all of the wires had to be removed before the bone united (Figs. 4-A through 4-D).

Of the 147 patients whose fracture united, ninety-nine denied having pain on follow-up. Thirty-four had slight pain after strenuous use of the wrist, but the pain did not interfere with work or recreational pursuits, and they did not use analgesics. Fourteen denied having pain, but they were occasionally annoyed by residual stiffness of the wrist. On average, the grip strength as measured with the Jamar dynamometer (Fred Sammons, Burr Ridge, Illinois) increased from 37.4 kilograms of force before operation to 39.6 kilograms of force afterward. The average grip strength of the opposite (uninjured) hand was 46.6 kilograms of force. Only seventeen patients had normal grip strength after the surgical procedure. On average, dorsiflexion of the wrist increased 2 degrees, from an average of 53 degrees preoperatively. On average, radial deviation of the wrist increased 3 degrees from 16 degrees preoperatively, while palmar flexion and ulnar deviation remained unchanged (average, 60 and 31 degrees).

Preoperatively, fifty-two patients had mild or moderate radiocarpal arthritis. The operation was successful in all of them, in that all united after bone-grafting and internal fixation. None of the patients who had mild arthritis had progression of the arthritis after the fracture healed. Five of the twelve patients who had moderate arthritis had a styloideotomy of the radius at the time of grafting. In these five patients, at the most recent examination (twenty-five, twenty-seven, forty-eight, sixty-four, and sixty-six months postoperatively), the arthritis had not progressed; three of the five denied having pain and two had mild discomfort after heavy work. Five others who had moderate arthritis preoperatively had a radial styloideotomy as a secondary procedure for pain after the scaphoid had united. Four had complete relief of the pain. The fifth failed to obtain relief even after an intercarpal fusion, and later the wrist also was fused. At the time of writing, two patients had not yet had a styloideotomy although it had been recommended.

It has been mentioned already that severe radiocarpal arthritis was a contraindication to our grafting procedure. Because of two theoretical advantages of performing a styloideotomy as a secondary procedure after the scaphoid has healed — because the styloid process provides some support to the scaphoid, and because if the fracture fails to unite, fusion of the wrist is easier when the styloid process is still present — we sometimes (in five of ten wrists) did the styloideotomy as a secondary procedure. At the time of writing, none of the forty patients who had mild arthritis had had progression of the arthritis or had had a styloideotomy.

Four patients, three of whom had moderate radiocarpal arthritis preoperatively, continued to complain of pain in the wrist after the fracture had healed. At the time of writing, two had been advised to have a radial styloideotomy as a secondary procedure. The other two had progressive radioulnar arthritis even though the fracture had healed. In one we fused the wrist. The patient who did not have arthritis preoperatively had the proximal portion of the scaphoid replaced with a hand-carved silicone-rubber spacer two years after bone-grafting; when last seen, nine years later, there was no more pain in the wrist.

Ununited fractures of the scaphoid have been termed displaced and unstable when the scapholunate angle is more than 45 degrees, but in this study we considered the fracture to be unstable when the scapholunate angle exceeded 60 degrees. According to our criteria, 126 of the fractures were stable and the other twenty-five were unstable. Forty-two fractures, of which fifteen were classified as unstable ac-
Figs. 4-A through 4-D: A fifty-nine-year-old woman did not know when she had injured the wrist. There had been pain in the wrist for three years before the operation.

Fig. 4-A: Preoperative radiograph, made in June 1977.
Fig. 4-B: Three weeks after the operation.

According to our criteria, had a displacement of one millimeter or more as measured on the posteroanterior radiographs. Since all but one or two of the unstable, or stable and displaced, or undisplaced fractures united, it was evident in our patients that neither displacement nor instability was an important factor in achieving union (Table I).

Preoperatively, thirteen of the twenty-five patients who had an unstable fracture had mild or moderate radiocarpal arthritis, whereas only thirty-nine of the 126 patients who had a stable fracture had mild or moderate radiocarpal arthritis. This demonstrated that radiocarpal arthritis is more likely to be present when the fracture is unstable. After union of the fracture, the scapholunate angle was diminished (by an average of 11 degrees) in fifteen of the twenty-four unstable fractures that healed. The scapholunate angle was restored to normal in six of the fifteen wrists, and in nine the scapholunate angle was larger than it had been preoperatively. The increase in the scapholunate angle was con-

Fig. 4-C: Eight weeks after the operation. One Kirschner wire had lost purchase in the distal fragment.
Fig. 4-D: Five months after the operation. All Kirschner wires were removed nine weeks after the operation because of irritation of the skin. The fracture was ununited and the operation was a failure.
considered to be major in only two patients (10 and 15 degrees). Of the other seven patients, the angle was increased by 1 degree in one patient, by 2 degrees in two, by 3 degrees in one, and by 6 degrees in three. Once an unstable fracture had healed, radiocarpal arthritis seldom progressed even if the scapholunate angle and the abnormal configuration (dorsal intercalary-segment instability) still were present. We tried to correct displacement, malrotation, and malalignment as well as to restore the length of the scaphoid and a normal relationship between the lunate and scaphoid, but, even when we did not accomplish that objective, most of our patients had satisfactory function of the wrist and were free of pain once the fracture of the scaphoid had healed. However, the length of follow-up for most of our patients was too short to be sure that the results will not deteriorate over time.

Five patients, who had had avascular necrosis but not radiocarpal arthritis preoperatively, had radiocarpal arthritis after the fracture of the scaphoid had healed. In four of these patients, the arthritis was mild and did not cause pain. The wrist of the fifth patient became painful and stiff, and serial radiographs showed disintegration of the proximal pole of the scaphoid.

Discussion

From a technical standpoint, the volar approach that was popularized by Russe affords a clear view of any ununited fracture of the scaphoid and eliminates the need for a radial styloidectomy. However, this approach may have no advantage over a dorsal or lateral approach in terms of preserving the supply of blood to the bone. It does provide excellent access to the volar part of the cortex of the scaphoid, which, if deficient, can be reconstituted easily with a cortical bone graft.

Our experience as well as that of others has shown that radiographic evidence of avascutarity of the proximal fragment is not a contraindication to a grafting procedure. Fractures that are associated with avascular necrosis of the proximal fragment usually unite after grafting and internal fixation, but we found that degenerative arthritis sometimes develops later in the wrists of such patients. If it did not, the result was satisfactory.

While in the operating theater, we were unable to determine whether there was sufficient vascularity of the proximal fragment to ensure union after grafting. If the proximal fragment was large enough to accept a graft and a Kirschner wire, we did the procedure as described. When the proximal fragment was fragmented or badly deformed, or the articular cartilage was damaged, or the proximal fragment was too small for Kirschner-wire fixation, we used various screws, as well as special instruments for insertion of the screws, have been designed for this purpose. For example, insertion of the Herbert compression screw requires special equipment. It also demands technical skill of a high order. One disadvantage of this method is that it violates the scaphotrapezial joint, and if the screw is misdirected, it can damage the articular cartilage. This method does have an advantage in that it provides more rigid fixation than do Kirschner-wires.

We are not the first to recommend Kirschner-wire fixation in conjunction with bone-grafting for an unstable fracture, but, as far as we know, we are the first to recommend the use of Kirschner wires in all grafted fractures. Because it may be difficult to judge the stability that will be achieved with a bone graft, and because fixation with Kirschner wires is easy to accomplish and adds little to the operating time, we prefer to fix all grafted fractures with them. We use at least two wires to immobilize the fracture after grafting. To supplement the wire fixation, we use a cast, as mentioned, for about eighteen weeks. Patients readily accept postoperative immobilization in a cast for that prolonged period, because of the rate of success of the procedure. Rasmussen et al. reported no correlation between the duration of postoperative immobilization and the ultimate range of motion of the wrist after grafting of an ununited fracture of the scaphoid.

Gross displacement of three millimeters or more or a scapholunate angle of more than 60 degrees, or both, in an acute fracture indicates instability. Such a fracture has been thought to be less likely to unite, when treated conserva-
TREATMENT OF UNUNITED FRACTURES OF THE SCAPHOID

TABLE II

RESULTS OF BONE-GRAFTING FOR UNUNITED FRACTURES OF THE SCAPHOID AS REPORTED IN THE ENGLISH-LANGUAGE LITERATURE

<table>
<thead>
<tr>
<th>Year</th>
<th>Series</th>
<th>No. of Wrist(s)</th>
<th>Rate of Union (Per cent)</th>
<th>No. of Fractures Fixed with Kirschner Wires</th>
<th>Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>Russe57</td>
<td>22</td>
<td>90</td>
<td>0</td>
<td>Russe (volar inlay graft)</td>
</tr>
<tr>
<td>1962</td>
<td>Pennsylvania Orthop. Soc.46</td>
<td>21</td>
<td>76</td>
<td>0</td>
<td>Peg graft, some with styloidectomy</td>
</tr>
<tr>
<td>1968</td>
<td>Verdan and Narakes48</td>
<td>45</td>
<td>98</td>
<td>0</td>
<td>Russe, some grafted if unhealed after three months</td>
</tr>
<tr>
<td>1968</td>
<td>Dooley49</td>
<td>23</td>
<td>86</td>
<td>0</td>
<td>Russe</td>
</tr>
<tr>
<td>1968</td>
<td>Mulder41</td>
<td>100</td>
<td>97</td>
<td>0</td>
<td>Russe, grafted if unhealed after four months; failures thought to be due to inadequate immobilization</td>
</tr>
<tr>
<td>1969</td>
<td>Unger and Stryker44</td>
<td>42</td>
<td>79</td>
<td>0</td>
<td>Russe, grafted if unhealed after four months; failures thought to be due to inadequate immobilization</td>
</tr>
<tr>
<td>1974</td>
<td>Töngren and Sandqvist50</td>
<td>45</td>
<td>71</td>
<td>0</td>
<td>Peg graft inserted through lateral approach</td>
</tr>
<tr>
<td>1975</td>
<td>McDonald and Petrie51</td>
<td>48</td>
<td>80</td>
<td>0</td>
<td>Russe</td>
</tr>
<tr>
<td>1980</td>
<td>Cooney et al.7</td>
<td>44</td>
<td>86</td>
<td>20</td>
<td>Russe</td>
</tr>
<tr>
<td>1982</td>
<td>Schneider and Auticicco52</td>
<td>31</td>
<td>87</td>
<td>9</td>
<td>Dorsal inlay graft, some with radial styloidectomy</td>
</tr>
<tr>
<td>1984</td>
<td>Boeckstyns and Busch6</td>
<td>28</td>
<td>86</td>
<td>0</td>
<td>Peg graft (Murray technique), some grafted if unhealed after four months</td>
</tr>
<tr>
<td>1984</td>
<td>Fisk13</td>
<td>41</td>
<td>73</td>
<td>*</td>
<td>Wedge bone graft through lateral incision, styloid of radius used as graft</td>
</tr>
<tr>
<td>1985</td>
<td>Rasmussen et al.51</td>
<td>28</td>
<td>71</td>
<td>0</td>
<td>Russe</td>
</tr>
<tr>
<td>1985</td>
<td>Green53</td>
<td>45</td>
<td>75</td>
<td>0</td>
<td>Russe</td>
</tr>
<tr>
<td>1986</td>
<td>Steichen and Schreiber54</td>
<td>25</td>
<td>92</td>
<td>†</td>
<td>Russe, using graft from radius; non-union present for at least five months in all wrists</td>
</tr>
<tr>
<td>1987</td>
<td>Stark et al.59</td>
<td>27</td>
<td>81</td>
<td>0</td>
<td>Russe; non-union present for at least seven months in all wrists</td>
</tr>
</tbody>
</table>

* Kirschner wires were used occasionally.  
† Kirschner wires were used if the fracture was thought to be unstable.

A summary of the results that have been reported by several authors after bone-grafting of ununited fractures of the scaphoid (Table II) shows rates of success of 50 to 98 per cent. We achieved union in 147 (97 per cent) of 151 long-standing ununited fractures of the scaphoid, and ours is a much larger series than those reported previously. We believe that our success was due, at least in part, to the stabilization of the fracture and graft with Kirschner wires.

References

TREATMENT OF UNUNITED FRACTURES OF THE SCAPHOID