DELAYED OPERATION IN THE OPEN REDUCTION OF FRACTURES OF LONG BONES

JOHN CHARNLEY, MANCHESTER, ENGLAND, AND ADLY GUINDY, CAIRO, EGYPT

From Park Hospital, Davyhulme, Manchester

Murray (1941) reviewed evidence for the opinion that the best time to carry out internal fixation of a fracture is as soon after the injury as possible. The advantages claimed for immediate operation are the minimal interference with the normal healing process of a fracture, the ease of exposure and reduction, and the accurate identification of damaged tissues unaltered by oedema and fibrosis.

In 1959 Smith recorded 130 fractures of the radius and ulna in adults treated by internal fixation. Fifty-two fractures treated by delayed internal fixation showed less delay in union than did the remaining seventy-eight fractures operated upon early. There was in fact no case of true non-union in the patients subjected to operation after a delay of one week, whereas there was an incidence of 21.8 per cent of non-union when the fractures were operated upon early. He concluded that the incidence of non-union after internal fixation can be reduced if operative treatment is delayed for one week, and preferably for two or three weeks, after the injury.

Smith and Sage (1957) reported results which were at variance with the findings of Smith. In a series of 253 fractures treated by medullary nailing Smith and Sage found 19.7 per cent of non-union in fractures nailed within fourteen days of injury, 19.3 per cent of non-union in those nailed fifteen to ninety days after injury, and 30.1 per cent of non-union in those nailed three months or more after the injury.

In view of this discrepancy it was decided to investigate again the relationship between delayed operation and non-union as illustrated by the results of intramedullary fixation of fractures of the shaft of the femur.

MATERIAL

The material consisted of thirty-seven patients with thirty-eight fractures of the shaft of the femur. Thirty-six fractures were closed and two were compound but healed without bone infection.

In all patients a Kuntscher nail of clover-leaf pattern was inserted by the retrograde method after open exposure of the fracture. Almost all these cases were operated upon by the same surgeon (J. C.). The review covers twelve years from 1948 to 1960.

METHOD OF INVESTIGATION

Assessment of the time required to obtain union—To assess osseous union after intramedullary fixation one is entirely dependent on radiological tests because the rigidity conferred by the nail makes clinical testing impossible. All patients in this study were radiographed approximately every month in the early period and every three months in the later period, and radiographic examinations were continued until union was definitely seen.

The criterion for osseous union was the presence of continuous bridging of bone at some part of the fracture, though not necessarily on all sides, combined with the absence of sclerosis. If sclerosis was present and the texture of the bone at the fracture site was not clearly revealed, a decision on the state of the union was postponed until further radiographic examination had been made three months later, and repeated again if necessary in the same way, until the sclerosis was diminishing and a bridge of bone was quite clearly visible.
In general, osseous union was proved by progressive improvement of the radiological picture after weight bearing had been started. When the radiological picture was not improving six months or more after the operation, in three cases, the fracture was explored for the purpose of applying a prophylactic bone graft, and the fracture was thereby proved to be ununited. In another three patients a spontaneous fracture of the nail drew attention to the non-union, and in one the femur immediately fractured again after removal of the nail which was made necessary by pain caused by excessive projection of the proximal end through the trochanter (Table I).

### TABLE I

**ANALYSIS OF PATIENTS WITH NON-UNION**

<table>
<thead>
<tr>
<th>Case number</th>
<th>Age (years)</th>
<th>Direction and site of fracture</th>
<th>Interval (days)</th>
<th>Radiographic appearance after three months</th>
<th>Callus value</th>
<th>Radiographic appearance after six months</th>
<th>Further state until grafting was done</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36</td>
<td>Transverse mid-shaft</td>
<td>1</td>
<td>No callus bridging the fracture</td>
<td>0</td>
<td>No callus bridging</td>
<td>Still no callus bridging at nine months; grafted after eleven months. Nail was replaced—fracture was immediately loose</td>
</tr>
<tr>
<td>2</td>
<td>42</td>
<td>Slightly oblique mid-shaft</td>
<td>1</td>
<td>Slight callus on medial side</td>
<td>20</td>
<td>No change</td>
<td>No evidence of union after ten months. Fracture found ununited at operation</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>Transverse mid-shaft</td>
<td>3</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Non-union after eight and a half months. Fatigue fracture of nail at ten months. Pseudarthrosis</td>
</tr>
<tr>
<td>4</td>
<td>46</td>
<td>Transverse mid-shaft</td>
<td>5</td>
<td>Faint callus on one side (medial)</td>
<td>32</td>
<td>No change</td>
<td>Fatigue fracture of nail after fifteen months. Ends of fracture freely mobile</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>Oblique mid-shaft</td>
<td>1</td>
<td>Only small bridge medially. Ischaemia about fracture on lateral aspect</td>
<td>20</td>
<td>No change—still ischaemic and fluffy</td>
<td>Bone grafting done after six months. Only small bridge of bone medially</td>
</tr>
<tr>
<td>6</td>
<td>72</td>
<td>Slight oblique mid-shaft</td>
<td>1</td>
<td>Small amount of callus anteriorly and doubtful if really bridging</td>
<td>120</td>
<td>No change</td>
<td>Nail removed because of pain in hip at seven months. Immediate refracture. Grafted and nail reinserted</td>
</tr>
<tr>
<td>7</td>
<td>28</td>
<td>Transverse mid-shaft</td>
<td>100</td>
<td>Slight callus</td>
<td>15</td>
<td>No change</td>
<td>Eighteen months: non-union with sclerosis of ends. Partial fracture of nail. Twenty-two months: nail partially fractured. Grafted and new nail inserted</td>
</tr>
</tbody>
</table>

It is possible to argue that two of these cases were not truly cases of non-union and should more accurately be described as cases of refracture. From a practical point of view, however, they were both cases of defective consolidation in which a tenuous bridge of bone refused to hypertrophy in a time considerably longer than is necessary for consolidation in the normal process of fracture union.

**Amount of callus**—As a side issue on the relationship between the time elapsing between injury and internal fixation we tried to assess whether the volume of periosteal callus was noticeably different after different intervals of delay.

The amount of callus was estimated by making tracings direct from a radiograph and measuring the surface area on a transparent grid having 144 small squares to the square inch.
The grid was superimposed on the tracing of a radiograph, and the area occupied by the callus was counted on the grid and called the "callus value." No account was taken of the internal architecture of the callus, or of variations of its density, and the total area enclosed by the external outline of the callus was the criterion of the amount of callus. The radiological view which showed the greater amount of callus, usually the antero-posterior, was the one used for assessment.

![Figure 1](image1.png)
![Figure 2](image2.png)

**Figure 1**—Histogram indicating the amount of callus in cases arranged in order of duration of the interval between injury and operation. **Figure 2**—Histogram using the same material as in Figure 1 but with cases arranged in ascending order of callus value in the two groups "early" and "delayed."

The callus value was not estimated before the end of the first three months. It was hoped in this way to express the volume of consolidating callus rather than what might be the greater volume of the cloud or haze of early callus which is often present six weeks after a fracture of the femoral shaft in young adult patients.

**RESULTS**

**Osseous union**—Of the thirty-eight fractures, twenty-four were treated by nailing between one day and six days after injury, and fourteen by nailing between seven and twenty-eight days after injury. In one patient the fracture was nailed 100 days after injury without any bone graft being used.

The cause of delay between injury and operation was either that conservative treatment had been tried and had failed to achieve an acceptable position, or because the general condition of the patient with multiple injuries was unsuitable for immediate surgery. In these latter, once the emergency treatment had been completed, internal fixation of the femur was postponed till a convenient operation session.

Of the twenty-four fractures treated by nailing between one and six days after injury six failed to unite and were caused to unite only after bone grafting—an incidence of non-union of 25 per cent. The rest (eighteen patients) were discharged with osseous union proved radiologically after periods varying from four and a half to eighteen months.
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Of the fourteen fractures treated by nailing seven or more days after injury only one failed to unite—namely, the one that was nailed after 100 days. The remaining thirteen all showed radiographic evidence of solid union in a period varying from four to thirteen months and the patients were discharged within that period (Table II).

**Amount of callus**—The amount of callus three months after operation showed a striking difference in the patients operated on within six days of the injury and those operated on after that period. In the early group the range of callus values was from 0–185 units, with only one exception. The exception had a callus value of 360 units in a spiral fracture involving almost half the length of the shaft. In the delayed group the callus value ranged from 185 to 750, with one exception. The exception had a callus value of 15 units and was the case operated upon and nailed 100 days after injury, and this resulted in non-union.

**TABLE II**

**Comparison of Results with Early and Delayed Treatment**

<table>
<thead>
<tr>
<th>Type of treatment</th>
<th>Number of fractures</th>
<th>Number with non-union</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early operation (0–6 days)</td>
<td>24</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Delayed operation (7 days -)</td>
<td>14</td>
<td>1</td>
<td>7.14</td>
</tr>
</tbody>
</table>

**TABLE III**

**Age Factor in Patients Treated with Early and Delayed Operation**

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Early operation (patients)</th>
<th>Delayed operation (patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15–19</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>20–29</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>30–39</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>40–49</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>50–59</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>60–69</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>70–75</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Total patients</td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td>Total fractures</td>
<td>24</td>
<td>14</td>
</tr>
</tbody>
</table>

**TABLE IV**

**Site of Fractures Treated**

<table>
<thead>
<tr>
<th>Site of fracture</th>
<th>Early operation (fractures)</th>
<th>Delayed operation (fractures)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction of uppermost and middle thirds</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Mid-shaft</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Junction of lowest and middle thirds</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
When the cases within each group were compared with each other it was seen that the callus value did not necessarily increase in direct proportion to the number of days elapsing between the fracture and the operative fixation. This feature is brought out in alternative arrangements of the same data in the histograms of Figures 1 and 2.

A brief check was made of other factors—such as the degree of displacement, the age of the patient and the site of fracture—which might have a bearing on union (Tables III and IV). All these fractures which had been selected for intramedullary nailing showed a full diameter displacement in the pre-operative radiographs, because in this clinic cases with less displacement are routinely treated by conservative means; so it may be presumed that all the fractures in this series were associated with considerable soft-tissue damage.

Six of the seven patients with fractures ending in non-union were aged from twenty-eight to forty-six years; only one was seventy-two years old. Five were men and two women.

All the fractures that showed non-union were situated in the middle third of the shaft. Four fractures were transverse and three slightly oblique.

One case is considered worthy of description in considerable detail because it provides the opportunity to compare the healing of two femoral shaft fractures sustained at the same time in the same patient and in whom one fracture was nailed on the day of the accident and the other twelve days later. Unfortunately, the mechanical efficacy of the internal fixation was not exactly the same in both femora, and delay in consolidation on one side could be the

FIG. 3
Figure 3—Radiograph of right femur showing fracture united but with varus deformity. Figure 4—Radiograph of left femur showing sound union.
result of less perfect fixation on that side. The fact that the side of defective consolidation was operated upon on the same day as the injury might therefore be pure coincidence, but nevertheless the case merits description.

**CASE REPORT**

A man aged twenty-two years sustained closed fractures of both femora at nearly the same level (junction of middle and lowest thirds) in a traffic accident in October 1951, at the same time receiving a compound fracture of the left tibia and a fracture of the neck of the right mandible. The right femur was nailed on the day of the accident. The fixation was not absolutely rigid; so the limb was supported by external fixation in a Thomas’s splint for twenty-five days. At the same time the left tibia was plated. The fracture of the left femur was treated by traction on a Thomas’s splint.

Under traction the position of the fracture of the left femur remained unsatisfactory, and it was nailed twelve days after the accident and twelve days later than the right femur. This time the rigidity of fixation was very good and no external support was considered necessary.

**Progress. Right femur**—After three months the callus value was 120 and a varus deformity of 5 degrees developed. After four and a half months the callus value was 294 and the varus deformity had increased and become detectable clinically. The patient complained of pain in the lower end of the thigh on walking. When seen two years after the accident the fracture was solidly united (Fig. 3). **Left femur**—After three months the alignment was good and union was progressing; at four months the callus value was 240 and sound bridging by callus was evident. Weight bearing was permitted and union thereafter was uneventful (Fig. 4).

**Comment**—Although neither fracture failed to unite in the end, and quite good callus values were present on both sides, the fact is that the fractured femur treated by early operation was slow in consolidating whereas the fracture on the opposite side treated by operation after twelve days united excellently.

It is true that a mechanical factor may have contributed to the difference in rate of union of the fractures of the right and left femora: on the right side the intramedullary nail reached only three and a half inches below the fracture line compared with nearly five inches on the left side: but the right limb was fixed post-operatively for nearly four weeks on a Thomas’s splint to reinforce the fixation. Though not conclusive, it would seem not unreasonable to suggest that early operative intervention in a youth aged twenty-two years depressed the power of union on the right side, but that the delay of operative intervention on the left side enabled union to proceed in the same vigorous way that one would expect under conservative treatment in a young patient.

**DISCUSSION**

Comparison of the results of early and delayed internal fixation in this series shows that the incidence of non-union in the early group was 25 per cent and 7 per cent in the delayed group. The isolated instance of non-union in the delayed group will receive special comment because the delay was as long as 100 days, and it can be argued that this might justify its exclusion from the series, in which case the difference in the rate of non-union between the early and late cases would be as 25 per cent to nil.

An explanation of the difference in the rate of osseous union after early and late internal fixation might lie in a difference in the circulation of the blood in the ends of a fractured bone when the operation is done early or late. When a fracture is exposed under a tourniquet within a few days of injury the ends of the bones have the appearance of ivory cortical bone which is almost as white as that seen in a cadaver. When a fracture is exposed some weeks after injury, also under a tourniquet, the bones vary in colour from pink to a deep maroon as a result of the enlargement of Haversian spaces in the cortical bone. In some cases when operation is undertaken for non-union there is a detectable difference in colour between the two fragments, one being pale and the other maroon. In other cases a sharp demarcation may exist between a pale part of the bone, usually at the fractured end of one fragment, and the maroon-coloured bone with which it is in continuity.
It is becoming increasingly recognised that when a long bone is fractured the longitudinal circulation of the Haversian systems cannot continue at the broken surface of cortical bone which presents to the fracture-haematoma. When a fracture is left to unite under conservative treatment the ends of the bones eventually take part in the general hyperaemia of the fracture, though enlargement of the Haversian systems in the ends of the fragments will lag behind the enlargement of the Haversian systems in undamaged parts of the bone. If the periosteum is stripped near the ends of the bones in a fresh fracture it seems probable that the start of hyperaemia in the ends of the bone is delayed artificially and that in the conditions of a fresh fracture the reposition of soft parts against the denuded ends of the bone does not secure entry of blood vessels in sufficient number to cause hyperaemia. When operative intervention is delayed until the ends of the bones have started to take part in the hyperaemic process, it seems possible that the bone ends do not suffer similar ischaemia or, if they are rendered ischaemic at the moment of operation, that this is only temporary and the preceding hyperaemia renders them capable of recovering a good supply very quickly.

In this connection figures for the "callus value" of femoral fractures studied in this paper three months after operation are of interest because it cannot be denied that profuse callus formation must be linked with a good blood supply. The average amount of callus, measured three months after the operation, on the whole was greater in the cases in this series which had been operated on after a delay of six or more days than in those operated on after one to six days.

The potential for osseous repair which can be evoked from bone by a second mechanical insult some weeks or months after a fracture that is showing delayed union is evident in those methods of treating non-union which do not rely primarily on a bone graft. Naughton Dunn (1939) treated non-union of the tibia merely by "shingling" the bone ends without disturbing the fibrous intersection at the site of the fracture. Phemister (1947) did more or less the same with the addition of an autogenous free graft laid on the side of the fracture, and Jarry and Uhthoff (1960) in their "petal" technique have recently drawn attention to the latent powers of osteogenesis which can be liberated in an ununited fracture by mechanical trauma.

It seems reasonable to suggest, therefore, that delayed internal fixation may be beneficial in two quite different ways. Firstly, it is beneficial in that it withholds the harmful effects of early intervention, which tends to increase the volume of ischaemic cortical bone in any fresh fracture (Urists, Mazet and McLean 1954). Secondly, delayed internal fixation may be beneficial in applying a second stimulus for osteogenesis in fractures which are in imminent danger of passing into delayed union. When delayed union is threatened one can visualise the ends of the bones becoming invested in fibrous tissue, with a danger that they may become sealed off and insulated from each other. The addition of more mechanical trauma at this stage may break down the process of investment at a critical phase and thus precipitate union.

This line of thought would be compatible with the occasional experience after open reduction and internal fixation which has been delayed for four or five weeks, and when no bone graft is used, that the line of the fracture will become radiographically invisible with surprising speed and remarkable completeness, and in these cases the bone is perceptibly porotic in comparison with a fresh fracture.

The significance of the solitary case of non-union which occurred in a series of patients subjected to delayed primary intervention demands special comment. In this solitary failure the interval between injury and internal fixation was 100 days. (It is not stated in the case records why a bone graft was not used as an adjunct to internal fixation in this instance, as would be the normal procedure in this clinic.) The failure to obtain osseous union might indicate that after 100 days the original stimulus to union caused by the fracture had been lost, that traumatic hyperaemia after this time had disappeared, and that the mechanical insult of internal fixation at such a late date should be regarded not as delayed intervention but as a primary intervention on quiescent bone.
SUMMARY AND CONCLUSIONS

1. The findings in this series of fractures of the shaft of the femur treated by intramedullary nailing confirm the observation of Smith (1959) that the incidence of non-union is significantly diminished when operative intervention is postponed more than one week from the time of the injury.

2. The series is too small to afford conclusive proof, and it offers no explanation of the opposite findings of Smith and Sage (1957), but it indicates that this very important aspect of the operative treatment of fractures ought to be submitted to thorough investigation by many more observers.

REFERENCES


