TREATMENT OF INTRACAPSULAR FRACTURES OF THE FEMORAL NECK WITH THE CHARNLEY COMPRESSION SCREW

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In 1956 Charnley described his method of using a spring-loaded compression screw in the treatment of fractures of the femoral neck (Figs. 1 and 2). Charnley, Blockey and Purser (1957) later reported the results of this method in thirty-three patients who were followed up for one year. They found that they had obtained 80 per cent success with the compression screw, compared with only 50 per cent success in patients treated with a Smith-Petersen nail.

Charnley's apparatus has now been in use at the Manchester Royal Infirmary since 1954 and has been used on more than 200 occasions for fractures of the femoral neck of all types.

This paper reviews the first 100 patients with intracapsular fractures of the femoral neck treated with the Charnley compression screw at the Manchester Royal Infirmary. The operations were performed between March 1954 and March 1959, the follow-up period varying from one year to five years. The operations were performed by nine different surgeons.

Because of the difficulty of carrying out a clinical follow-up study in patients with this type of injury, the review is based entirely on a radiological study of the hip fractures after treatment and is concerned primarily with: 1) the incidence of bone union as determined radiologically; and 2) the incidence of avascular necrosis, its time of onset and its relationship to bone union.

Determination of bone union—Union was considered to have occurred when a radiograph indicated unequivocally that bone trabeculae were crossing the fracture site. As this is not always easy to assess we studied the radiographs independently and then compared results. When there was a difference of opinion we accepted the later date at which union was assessed.

FIG. 1

FIG. 2

Figure 1—The Charnley compression apparatus. a) The sleeve and plate; b) the central screw; c) the compression spring; d) the cylindrical compression nut. Figure 2—The apparatus assembled.

REVIEW OF PATIENTS

Sex—Seventy-six of the 100 patients were women and twenty-four were men.

Site of fracture—Seventy-nine patients had subcapital fractures and twenty-one had transcervical fractures. We have adopted the classification used by Böhler (1935), who defined a subcapital fracture as being near the head, and a transcervical fracture as being through the middle of the neck. In all patients the fracture occurred through bone that appeared normal or showed no more than the usual porosis of old age.

Age incidence—The highest incidence was in the eighth decade, and the next highest in the ninth (Fig. 3).

FIG. 3

Age of 100 patients with intracapsular femoral neck fractures.

Mortality—Four patients died within a month of the operation. Three of these patients were over eighty years old and one was seventy-seven. One died of broncho-pneumonia and three of cardiovascular failure.

Follow-up—Eight patients were lost to review within three months of the operation. Two had died, and no information was available about the other six. In thirteen patients the time of follow-up was not long enough to allow a final assessment of treatment. This left seventy-five patients in whom the outcome of treatment was known.

The length of follow-up varied from under one year to five years (Table I). It is stressed that the survey was continued until the result of treatment was known. For instance, if a patient developed avascular necrosis of the femoral head with non-union in the first few months, then the record was accepted as complete.

Of the seventy-five patients there were eleven in whom the fracture of the neck of the femur was either undisplaced or not sufficiently displaced to require manipulative reduction. Since the incidence of union in undisplaced fractures is much higher than in displaced fractures (Crawford 1960) they were not included in the detailed analysis. In nine of these patients the fracture united quickly.

TABLE I
LENGTH OF FOLLOW-UP IN SEVENTY-FIVE PATIENTS

Period of follow-up	Number of patients
Less than 1 year	12
1-2 years	25
2-3 years	29
3-4 years	7
4-5 years	1
5-6 years	1
Total	75

The operation was not successful in eight patients, two of whom had undisplaced fractures. The causes were as follows. 1) Breaking of the compression screw (four cases). In one patient another screw was inserted and it is probable that the fracture has now united. One patient was treated by displacement osteotomy. No further treatment was undertaken in the other two patients. 2) Poor reduction and poor internal fixation (one case). This patient, a man aged twenty-five, was treated by displacement osteotomy a month after the original operation. 3) Poor internal fixation (one case). The central screw was placed along the anterior margin of the head of the femur and cut out within a month. No further treatment was undertaken. 4) Head of the femur unable to withstand compression (one case). Immediately the cylindrical nut was tightened the central screw began to cut out. A further attempt with a "life-saver" screw (Charnley 1960) also failed. No further treatment was undertaken. 5) Sepsis (one case).

TABLE II
THE INCIDENCE OF AVASCULAR NECROSIS IN UNITED
AND UNUNITED FRACTURES

	Number of patients	Without necrosis	With necrosis
Union	38	29	9
Non-union	20	0	20

TABLE III
RELATION OF UNION AND NON-UNION TO SITE OF FRACTURE

Site of fracture	Number of patients	Union	Non-union
Subcapital	40	23	17
Transcervical	18	15	3

TABLE IV
ANGLE OF FRACTURE IN RELATION TO UNION AND NON-UNION

Angle of fracture (degrees)	Number of patients	Union	Non-union
0-30	3	26	15
30-60	38		
60-90	17	12	5

TABLE V
ACCURACY OF REDUCTION IN RELATION TO BONE UNION

Type of reduction	Number of patients	Union	Non-union
Good	34	22	12
Fair	22	15	7
Poor	2	1	1

TABLE VI
ACCURACY OF INTERNAL FIXATION IN RELATION TO
BONE UNION OR NON-UNION

Position of screw	Number of patients	Union	Non-union
Central	28	19	9
Eccentric	30	19	11

In consequence of post-operative infection the hip dislocated and the head of the femur collapsed. Six months after the original operation the apparatus and the head of the femur were removed.

These eight cases of operative failure have been excluded from the detailed analysis.

There remain fifty-eight patients, all of whom had displaced fractures and in all of whom the operation worked as planned. These fifty-eight patients were divided into two groups, depending on whether or not bone union had occurred, and in each group the incidence of avascular necrosis of the head of the femur was determined (Table II).

FACTORS AFFECTING BONE UNION

Site of fracture—The site of the fracture was of considerable importance. Non-union occurred in 42.5 per cent of subcapital fractures, but in only 16.5 per cent of transcervical fractures (Table III).

Angle of fracture—The angle of the fracture was determined on the post-reduction radiograph and was measured against the vertical line of the femoral shaft (Linton 1944). The fractures were divided into three groups, in which the angle was less than 30 degrees, between 30 and 60 degrees, and between 60 and 90 degrees. The incidence of union and non-union in these three groups was then assessed (Table IV), and as the number of fractures with an angle of less than 30 degrees was so small, they were included with those having an angle between 30 and 60 degrees. From these figures it seems probable that the angle of the fracture is not a significant factor in this method of treatment.

Accuracy of reduction—The accuracy of reduction was assessed in each case. The term *good* reduction was used to describe fractures showing perfect anatomical reposition after manipulation or those with only a minor degree of rotation. A *fair* reduction implied a moderate degree of lateral rotation with or without valgus deformity. Table V shows that of thirty-four fractures regarded as being well reduced twelve (35 per cent) failed to unite compared with seven out of twenty-two (32 per cent), the reduction of which had been regarded as only fair. Accuracy of reduction in this series did not appear to affect the rate of union.

Accuracy of internal fixation—Ideally, the central screw of the compression apparatus should be placed in the centre of the femoral head. The position of the central screw was assessed in each case as being either central or eccentric, and the relation of the position to bone union is shown in Table VI. The incidence of union was the same irrespective of the position of the central screw. It seems probable that if the femoral head is alive the compression screw maintains a firm hold on the fragments, allowing union to proceed even if it is not placed centrally.

Effect of tightening the cylindrical nut to maintain compression—In forty-six cases some extrusion of the outer cylindrical nut occurred in the first one or two months. When this was more than 3 millimetres (seventeen cases) the wound was reopened and the outer cylindrical compression nut tightened. This was repeated on two occasions in order to maintain the compression force (Table VII).

Even when no extrusion occurred two of the twelve fractures failed to unite. In twenty-nine cases in which a small amount of extrusion occurred but was not considered sufficient to require tightening, six fractures failed to unite; and in the seventeen cases in which the compression apparatus was tightened, twelve fractures failed to unite.

Effect of weight-bearing—Patients remained in bed and weight-bearing was prohibited in all cases until three months after operation, but as some of the more senile patients were incapable of learning to walk, even when their treatment was completed, we are unable to express an opinion about the effect of weight-bearing on the fate of the fracture.

Comminution of the fracture—An attempt was made to relate the degree of comminution of the fracture with the incidence of union. Comminution in displaced fractures is not always

obvious in the radiographs and we think we have underestimated the incidence of comminution. In performing primary replacement arthroplasty we have been impressed by the incidence of previously unsuspected comminution, and it seems likely that most displaced fractures of the femoral neck are comminuted to some degree. We have been unable to draw any conclusions regarding the effect of comminution on the incidence of union or non-union.

TABLE VII
BEHAVIOUR OF SCREW AND EFFECT OF TIGHTENING THE SCREW IN RELATION TO
UNION AND NON-UNION

Behaviour of screw	Number of patients	Union	Non-union
No extrusion	12	10	2
Screw extrusion—not tightened .	29	23	6
Screw extrusion—tightened once	15	5	10
Screw extrusion—tightened twice	2	0	2

Age—Table VIII shows the relationship between age and the incidence of non-union.

Of the factors that influence union, the most important appear to be absence of displacement, the site of the fracture and possibly the age of the patient. When operative failures are excluded, the ultimate cause of non-union in every case was avascular necrosis of the femoral head. When the Charnley compression screw is used, the angle of the fracture, the accuracy of reduction and accuracy in the placing of the screw appear to be of secondary importance.

Speed of union—The time required for bone union varied from three to eighteen months (Table IX), any fracture still ununited eighteen months after operation being regarded as

TABLE VIII
AGE OF PATIENTS IN RELATION TO UNION AND NON-UNION
(Fifty-eight patients)

Age (years)	Number of patients	Union	Non-union
30–39	2	2	0
40–49	3	3	0
50–59	9	7	2
60–69	9	6	3
70–79	27	17	10
80–89	8	3	5

TABLE IX
TIME REQUIRED FOR BONE UNION
(Thirty-eight patients)

Time required for bone union (months)	Number of patients
3	8
4	6
5	2
6	10
6–9	2
9–12	7
12–18	3

having established non-union. In one patient the outcome was doubtful after this period. In this case the compression screw fractured and a second one was inserted. It is now nearly three years since the original fracture, the femoral head is alive and union has possibly occurred.

Significance of extrusion—The amount of extrusion that occurred each month was measured. The average amount of extrusion in the united and ununited fractures is shown in Figure 4.

Two distinct patterns emerge. In the fractures that unite despite some extrusion it is small in amount (4 millimetres or less) and practically ceases after three months. On the other hand, the ununited fractures show continued extrusion of the compression screw, and

FIG. 4

To show the average amount and rate of extrusion of the compression apparatus in thirty-eight patients with union and twenty with non-union.

occasionally the extrusion is complete. All the cases of non-union developed total avascular necrosis of the femoral head, and the extrusion in these cases occurred as the collapsing head became unable to withstand the compression force. The small amount of extrusion that occurs in the fractures that unite may be due to an ischaemic factor (Charnley *et al.* 1957) or may be due to settling of the fracture. Continued extrusion indicates non-union associated with avascular necrosis of the femoral head, and this can be determined at three months before the necrosis becomes visible on the radiographs. If necessary, further treatment can then be instituted.

Necrosis of the femoral head—This occurred both in the fractures that united and those that did not. In those that failed to unite necrosis appeared early; it seemed to be total and was the cause of non-union. In the fractures that united, necrosis occurred in 24 per cent.

It became apparent after the fracture had united, sometimes even in the second year, and was more frequently partial than total.

DISCUSSION

The Charnley spring-loaded compression screw provides compression at the fracture site and allows for bone absorption by extruding. It also secures fixation to the shaft of the femur.

In the series reported by Charnley *et al.* (1957) a clinical success rate of over 80 per cent after one year was reported. In the present series our assessment was radiological and by this method we have found that 65.5 per cent of the intracapsular femoral neck fractures united.

We have confirmed the findings of Charnley *et al.* (1957) that the rate and amount of extrusion of the central screw and cylindrical compression nut indicate whether union is proceeding satisfactorily and frequently reveal ischaemia of the femoral head before it is seen in the radiographs. Extrusion within one month occurred both in fractures that united and in those that did not. In practice, when this extrusion amounted to 3 millimetres or more the cylindrical compression nut was tightened; seventeen patients had the compression nut tightened at a second operation, and two of these on a third occasion. Five of these patients obtained bone union. Tightening of the compression spring does not appear to affect the rate of union. Charnley (1960) considers that if full compression is maintained by retightening the cylindrical compression nut then some contact will be made with the living portions of the head and a higher rate of bone union will be obtained. This did not occur in this series for it did not seem a practical proposition to retighten the compression spring on more than two occasions.

Provided extrusion has stopped at the end of three months, patients are allowed to bear weight. If extrusion continues weight bearing should be deferred until the fourth or fifth month. At the end of four months, however, it is possible to say with some certainty what the fate of the fracture is likely to be. After four months the average total extrusion of the screw in the fractures that did not unite was 9 millimetres, compared with 3.5 millimetres in the fractures that united (Fig. 4). Treatment can be changed at that time if considered necessary.

Because of the high incidence of non-union (43 per cent) we do not consider that patients over seventy should be treated by internal fixation with the Charnley compression screw. It is our practice to treat these patients by replacement arthroplasty.

In all other patients with intracapsular fractures the Charnley compression screw is to be recommended. The initial reduction and internal fixation should be reasonably accurate, although small degrees of displacement do not mean inevitable failure. The central screw should be placed in the middle of the femoral head if possible. After operation radiographs are taken every two weeks and extrusion of 3 millimetres or more should be taken up when it occurs, certainly not later than the end of the first month. Treatment will then continue on the lines indicated above.

SUMMARY AND CONCLUSIONS

1. A series of 100 intracapsular fractures of the femoral neck treated with the Charnley compression screw is reported.
2. There were six deaths, and in patients reviewed long enough (seventy-five) there were eleven undisplaced fractures, with successful union in 81.8 per cent, and sixty-four displaced fractures, with a union rate of 59.6 per cent.
3. If we exclude six failures of operative technique, there remain fifty-eight patients in whom the fracture was judged radiologically to have united in 65.5 per cent.
4. The Charnley compression screw is an effective method of internal fixation in such fractures, and non-union with this method is usually due to causes other than mechanical failure.

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