

Subtrochanteric Fractures of the Femur

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ABSTRACT: The results of treatment of fifty-six patients with subtrochanteric fractures of the femur are presented and a new classification of these fractures is described. In forty-seven fractures treated with internal fixation there were nine failures of fixation. One type of lesion, the three-part spiral subtrochanteric fracture, occurred eighteen times and accounted for eight of the failures of fixation.

Subtrochanteric fractures of the femur are difficult to treat successfully. The incidence of mechanical complications (breakage or bending of fixation devices) has frequently exceeded 20 per cent^{2,4,8}. These failures of fixation usually are seen in the first six months after the operation, but occasionally they occur somewhat later, when there is delayed union or non-union. Subtrochanteric fractures occur in bone that is predominantly cortical. Therefore, they tend to take longer to heal than do fractures through cancellous bone. Biomechanical analyses of stress in the femur showed that there is a high concentration of stress in the subtrochanteric region^{6,7}. These two factors, involvement of cortical-bone tissue and concentration of stress, frequently have been mentioned as reasons for the high incidence of complications in the treatment of these fractures^{4,5}.

None of the previous analyses of subtrochanteric fractures^{3,4,8,9} except that of Fielding and Magliato have indicated that any particular type or types of fractures have a predilection for failure. Fielding and Magliato suggested that distal fractures have a greater risk of non-union; however, their method did not allow for the classification of oblique or spiral fractures. The recent report by Zickel did not clarify how to distinguish between short and long oblique fractures, and this distinction strongly influences whether an oblique fracture is at risk.

One purpose of a classification system is to distinguish varying types of fractures which require different methods of treatment and have different prognoses. In this paper the results of treatment of fifty-six subtrochanteric fractures are presented and a new system of classification is described which allows the identification of a certain type of fracture with a significantly increased incidence of failure of treatment.

Methods

In the records of the Massachusetts General Hospital, 102 subtrochanteric fractures of the femur which were

documented by roentgenograms and treated between 1965 and 1975 were available for examination. Insufficient roentgenograms of the initial fracture precluded classification of twenty-one fractures. Of the remaining eighty-one patients, roentgenographic follow-up of more than one year was available in fifty and follow-up by telephone (more than one year) was available in six. All patients followed up by telephone had healing of their fractures without complication.

The other twenty-five patients were lost to follow-up less than one year after injury.

Failure was defined as loss of fixation of the fragments of bone or breakage or bending (greater than 20 degrees) of the fixation device. Delayed union was not studied in particular because of the difficulty of determining time of union by roentgenograms. When the final available roentgenogram showed a persistent fracture line and follow-up was longer than one year, these cases were labeled persistent non-union. If there had been no failure of fixation in such a case it was counted as neither success nor failure when performing statistical calculations.

Classification

For a lesion to be included in this series of subtrochanteric fractures, part of the fracture line had to lie within the zone between a horizontal line even with the inferior aspect of the lesser trochanter and another horizontal line five centimeters below it. Therefore, intertrochanteric fractures with subtrochanteric extensions below the level of the inferior aspect of the lesser trochanter are included in our study, as are fractures of the femoral shaft with extension proximally above the distal line of this zone. Fractures were classified primarily by reviewing the post-injury roentgenograms, but the intraoperative roentgenograms of a partially reduced fracture sometimes displayed the number and shape of the fracture fragments more clearly than did the previous roentgenograms. In two patients the operative notes described three major fragments whereas the preoperative roentgenograms had demonstrated only two fragments. In these two cases we classified the fractures as having three fragments.

Fractures were classified according to the number of major fragments and the locations and shapes of the fracture lines. Any fragment whose largest dimension measured one centimeter or more was considered major. In comminuted fractures with four or more fragments, these frequently were 0.5 to 2.0 centimeters long. In two and three-part fractures we rarely encountered small fragments that caused difficulty in classifying the fractures. All frac-

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tures were classified without knowledge of the result of treatment.

The fractures were divided into eight categories (Fig. 1):

Type I — non-displaced fractures: any fracture with less than two millimeters of displacement of the fracture fragments.

Type II — two-part fractures: (A) a two-part transverse femoral fracture; (B) a two-part spiral fracture with the lesser trochanter attached to the proximal fragment; and (C) a two-part spiral fracture with the lesser trochanter attached to the distal fragment.

TABLE I

Age (Yrs.)	Male	Female	Total
0-9	0	1	1
10-19	5	2	7
20-29	3	2	5
30-39	1	1	2
40-49	6	3	9
50-59	3	4	7
60-69	1	6	7
70-79	0	9	9
80-89	0	8	8
≥90	0	1	1

Type III — three-part fractures: (A) a three-part spiral fracture in which the lesser trochanter was part of the third fragment, which had an inferior spike of cortex of varying length; and (B) a three-part spiral fracture of the proximal one-third of the femur with the third part a butterfly fragment.

Type IV — comminuted fractures: four or more fragments.

Type V — subtrochanteric-intertrochanteric fractures: any subtrochanteric fracture with extension through the greater trochanter.

Results

Forty-seven patients were treated by open reduction and internal fixation and nine were treated in traction. The age and sex distribution of all patients are shown in Table I. There were nineteen men with an average age of thirty-five years and thirty-seven women with an average age of sixty-three years. The fourteen men treated with internal fixation had an average age of thirty-four years and the thirty-three women so treated had an average age of sixty-six years. Of the patients treated in traction, the five men had an average age of thirty-eight and the four women, an average age of thirty. The follow-up of patients treated with internal fixation averaged thirty-three months (range, twelve to 105 months). There were nine failures of fixation (19 per cent) and three patients treated with internal fixation had persisting non-union on their last roentgenogram. The results in patients treated with internal fixation will be presented separately from the results of those treated in traction.

Results of Internal Fixation According to Type of Fracture (Table II)

The one undisplaced Type-I fracture in this series was a spiral fracture similar to Type II-C. This fracture occurred in an eighty-three-year-old woman who was treated with an AO blade plate, and her fracture healed.

The one fracture classified as Type II-A was a transverse two-part fracture in a fifteen-year-old boy who had fallen ten floors and landed on the top of a car. This boy was treated with a Zickel nail and his fracture healed.

Of the ten patients with fractures classified as Type II-B, seven were treated surgically. Their average age was fifty years (range, seventeen to eighty-nine years). Three McLaughlin nails (with variable-angle side-plates), two Jewett nails, one Küntscher rod, and one sliding hip-compression screw were used for fixation. One fracture fixed with a Jewett nail became infected and had delayed

TABLE II

SUBTROCHANTERIC FRACTURES TREATED WITH INTERNAL FIXATION

Type	Incidence			Failures of Fixation	Persistent Non-Union	Average Age (Range) (Yrs.)	Average Length of Follow-up (Mos.)
	Male	Female	Total				
I	0	1	1	0	0	83	14
II-A	1	0	1	0	0	15	16
II-B	2	5	7	0	1	50 (17-89)	33
II-C	0	1	1	0	0	47	12
III-A	3	15	18	8*	2	63† (20-90)	39
III-B	2	2	4	0	0	53 (19-85)	29
IV	4	3	7	1	0	47† (25-73)	23
V	2	6	8	0	0	62 (25-81)	39

* p < 0.005 by the standard chi-square test.

† p < 0.025.

TABLE III
TYPE-III-A FRACTURES TREATED WITH INTERNAL FIXATION

	Incidence			Average Age (Range) (Yrs.)			Average Length of Follow-up (Yrs.)
	Male	Female	Total	Male	Female	Total	
Entire group	3	15	18	31 (20-49)	71 (41-90)	63 (20-90)	39
Successful fixation	1	7	8	20	64* (41-81)	58* (20-81)	59
Failed fixation	2	6	8	24,49	74* (56-85)	65* (24-85)	25
Persistent non-union	0	2	2	—	80,90	80,90	14

* $p = 0.10$

union, but eventually the fracture healed. The other fracture that was fixed with a Jewett nail had delayed union at the last follow-up twelve months after operation and is listed as a case of persistent non-union. The other five fractures treated with internal fixation healed without incident. Three of the ten patients in this subgroup, all elderly, had been injured in simple falls to the floor. The other seven patients incurred high-energy trauma, either in a motor-vehicle accident or from being hit by an automobile.

There were only two Type-II-C fractures. One was in a forty-seven-year-old woman who had had a fall and the other was in a fifteen-year-old girl who had been hit by a car. The first patient was treated with a sliding nail and variable-angle side-plate, and her fracture healed uneventfully. The second patient was treated in traction.

Nineteen patients had Type-III-A fractures. This is the largest group of patients in the present report and these cases are tabulated separately (Table III). Eighteen patients were treated by internal fixation, with an average age of sixty-three years (range, twenty to ninety years). The three men were an average of thirty-one years old (range, twenty to forty-nine years old) and the fifteen women were an average of seventy-one years old (range, forty-one to ninety years old). The various devices used for fracture fixation in this subgroup included six McLaughlin nails (with variable-angle side-plates), three Jewett nails, one Zickel nail, and one Küntscher rod.

There were eight failures of fixation in the Type-III-A fractures treated with internal fixation, an incidence of 44 per cent. These failures were associated with two of six McLaughlin nail-plates, two of three sliding nail-plates, three of four AO blade-plates (Figs. 3-A through 4-C), and the single Küntscher rod. One fracture treated with a Jewett nail had delayed union at thirteen months, and one treated with an AO blade-plate had a delayed union at sixteen months. These last two cases were listed as persistent non-union at final follow-up (Tables II and III). Fixation was judged technically satisfactory in all cases except for the patient who was treated with a Küntscher rod.

The most important point in this study was the frequency of failures of fixation in the Type-III-A fractures.

When compared with the other subgroups of fractures (two-part fractures were combined), this difference was highly significant statistically (standard chi-square test, $p < 0.0005$). The average age of all patients whose fractures healed was fifty-eight years and the average age of all patients with failed fixation was sixty-five. The average age of women whose fractures healed was sixty-four years and the average age of women with failed fixation was seventy-four. These differences are not statistically significant ($p = 0.10$).

In Type-III-A fractures, the length of the spiral aver-

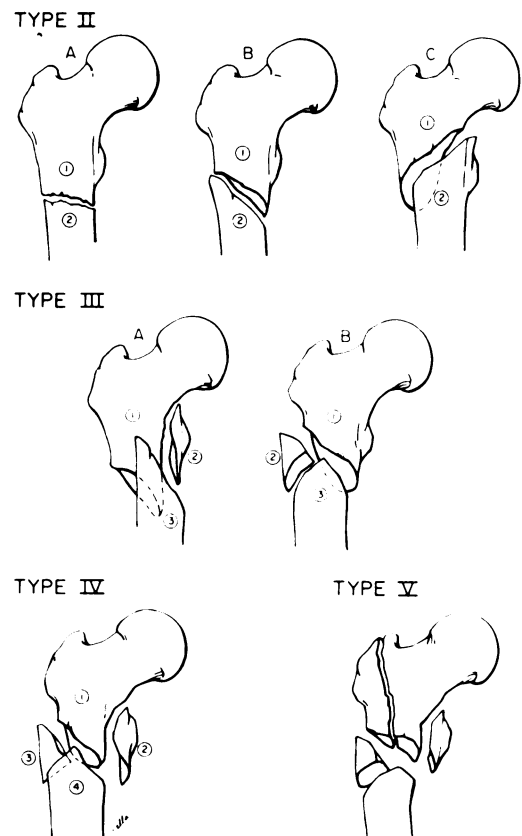


FIG. 1
Diagrammatic representation of classification of subtrochanteric fractures.

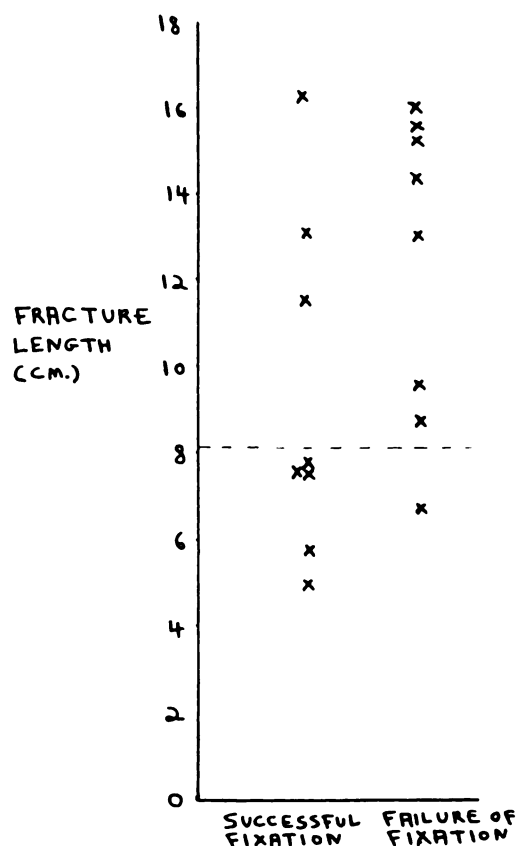


FIG. 2

A comparison of fracture lengths for Type-III-A lesions: those with successful fixation versus those in which fixation failed. Only one of six fractures less than 8.0 centimeters long failed, whereas seven of ten that were more than that length failed.

aged 10.8 centimeters (range, 5.0 to 16.3 centimeters). Those fractures that healed had spirals that averaged 9.1 centimeters (range, 5.0 to 16.3 centimeters), while those with failure of fixation had spirals that averaged 12.4 centimeters (range, 7.0 to 15.8 centimeters). I attempted to determine whether fractures with long spirals are at a greater risk of failure than those with short spirals but found the difference not statistically significant ($0.05 < p < 0.10$) (Fig. 2). However, only one (17 per cent) of six Type-III-A fractures with a spiral of less than 8.0 centimeters had failure of fixation, whereas seven (70 per cent) of ten fractures with spirals longer than 8.0 centimeters had such failure. This may indicate that there is a threshold of stability in the shorter spiral fractures.

The devices in fractures with failure of fixation failed at an average of seven months postoperatively (range, one to sixteen months), and seven of the eight failures occurred during or before the ninth month following surgery. In all but three patients in the Type-III-A subgroup, the initial fracture resulted from minor trauma such as falling to the floor.

Four of the five patients with Type-III-B fractures were treated with internal fixation. Their average age was fifty-three years (range, nineteen to eighty-five years). The devices used for fracture fixation were two AO blade-plates and two Küntscher rods. The mechanisms of injury

included two minor falls and three motor-vehicle accidents (two passengers and one pedestrian). In all four patients the fracture healed.

Seven of the nine patients with Type-IV fractures were treated with internal fixation. Their average age was forty-seven years (range, twenty-five to seventy-three years). Four were men and three were women. Four McLaughlin nail-plates, two sliding hip-compression screws, and one sliding nail-plate were used. In one fracture treated with a McLaughlin nail-plate, the device failed at eleven months and non-union resulted. All the other fractures healed uneventfully. Four patients had suffered minor falls, three had been hit by cars, and two had had severe falls. The patients in this group were younger than average for this series, and were more likely to be men. The energy of trauma was greater than average. The difference in age between patients in this group treated with internal fixation and the patients in Type-III-A group treated with internal fixation was statistically significant ($p < 0.025$).

Eight of nine patients with Type-V subtrochanteric fractures were treated with internal fixation. Their average age was sixty-two years (range, twenty-five to eighty-one years). These fractures were treated with four Jewett nails (three with medial displacement), two sliding nail-plates, one McLaughlin nail-plate, and one AO blade-plate. All eight fractures healed. Five patients had had minor falls and four had had major automobile accidents.

Fractures Treated with Traction

Nine subtrochanteric fractures were treated with traction and all healed primarily. Four fractures healed with excellent alignment (less than 12 degrees of varus angulation compared with the normal side). These included three patients with Type-II-B fractures who were six, fifteen, and sixteen years old and one patient with a Type-III-B fracture who was sixty-three years old. The fractures of five patients healed with between 15 and 29 degrees of varus angulation when compared with the normal side. This occurred in one Type-II-C fracture, one Type-III-A fracture, two Type-IV fractures, and one Type-V fracture. The single Type-III-A fracture treated with traction healed with 29 degrees of varus angulation. The average age of patients treated in traction was thirty-four years (thirty-eight years for the men and thirty for the women).

Discussion

The most noteworthy observation in this paper is the identification of a specific type of subtrochanteric fracture that has an increased risk of failure of internal fixation. A review of the published failures in the literature on subtrochanteric fractures reveals that the majority were three-part spiral subtrochanteric fractures. The two failures reported by Fielding and associates appeared to be Type-III-A fractures⁵. In the paper by Watson and co-workers the failures shown in Figures 2, 4, and 7 are all Type-III-A fractures.

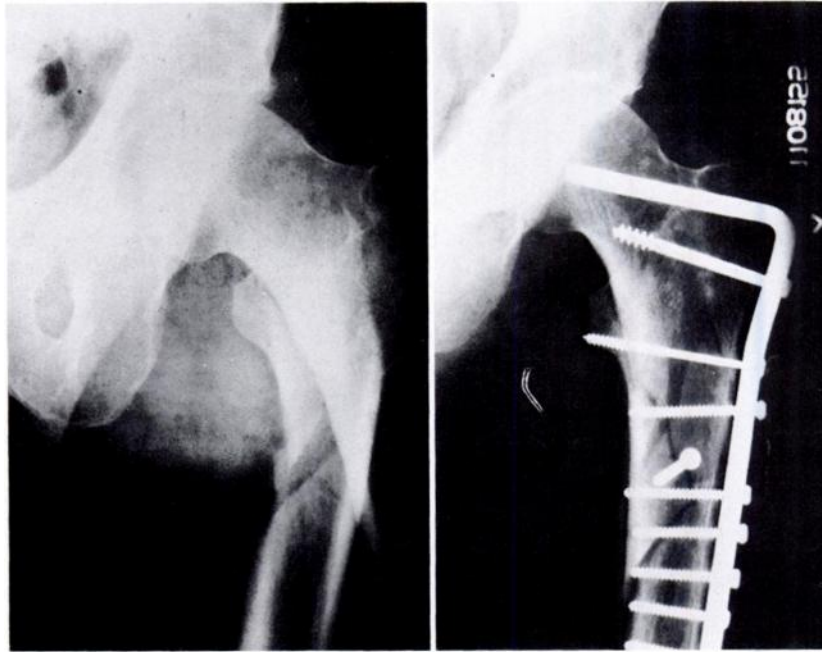


FIG. 3-A

FIG. 3-B

Figs. 3-A through 3-D: A typical Type-III-A fracture and breakage of the plate at the fracture line.

Fig. 3-A: Three-part spiral subtrochanteric fracture.

Fig. 3-B: The fracture was treated with an AO blade-plate and an interfragmentary compression screw. The lesser trochanteric fragment was lagged in with two screws. (Overlapping spiral fracture lines give a false impression of more than three fragments on this roentgenogram.)

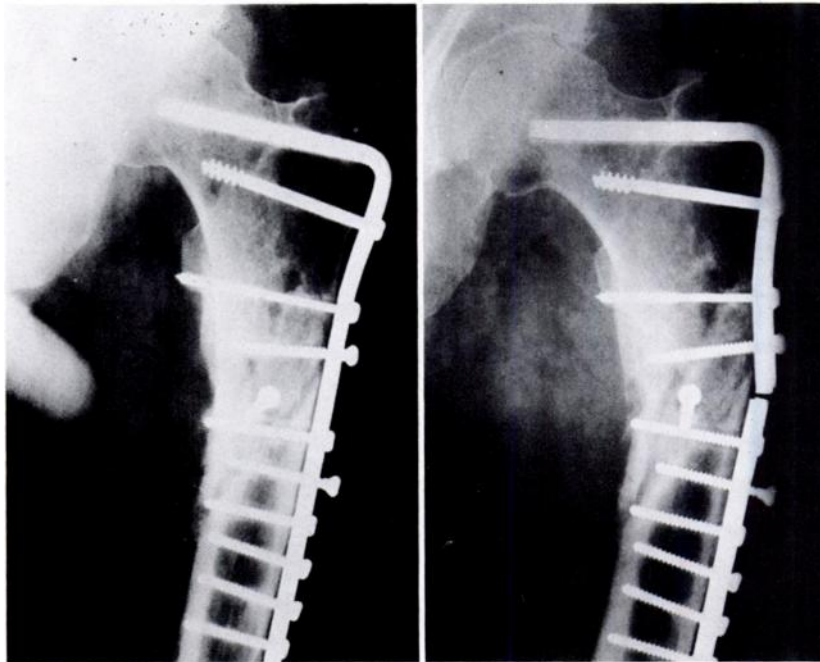


FIG. 3-C

FIG. 3-D

Fig. 3-C: Nine and one-half months postoperatively there is a non-union.

Fig. 3-D: Fourteen months postoperatively there is a fracture of the plate. After removal of the fixation apparatus a sliding hip-compression screw was inserted, and union occurred twenty months after the initial injury.

Type-III-A fractures with spirals longer than eight centimeters had a greater tendency to have failure of internal fixation (seven of ten) than those with shorter spirals (one of six). This suggests that there is a threshold of increased stability following internal fixation when the length of the fracture spiral is less than eight centimeters.

In Type-III-A fractures the lesser trochanteric fragment contains much of the femoral calcar. If there is excessive obliquity of the fracture line it may be difficult, if not impossible, to provide good cortical load-bearing medially between the fragments during reduction and fixation. The longer the spiral the more oblique the fracture line,

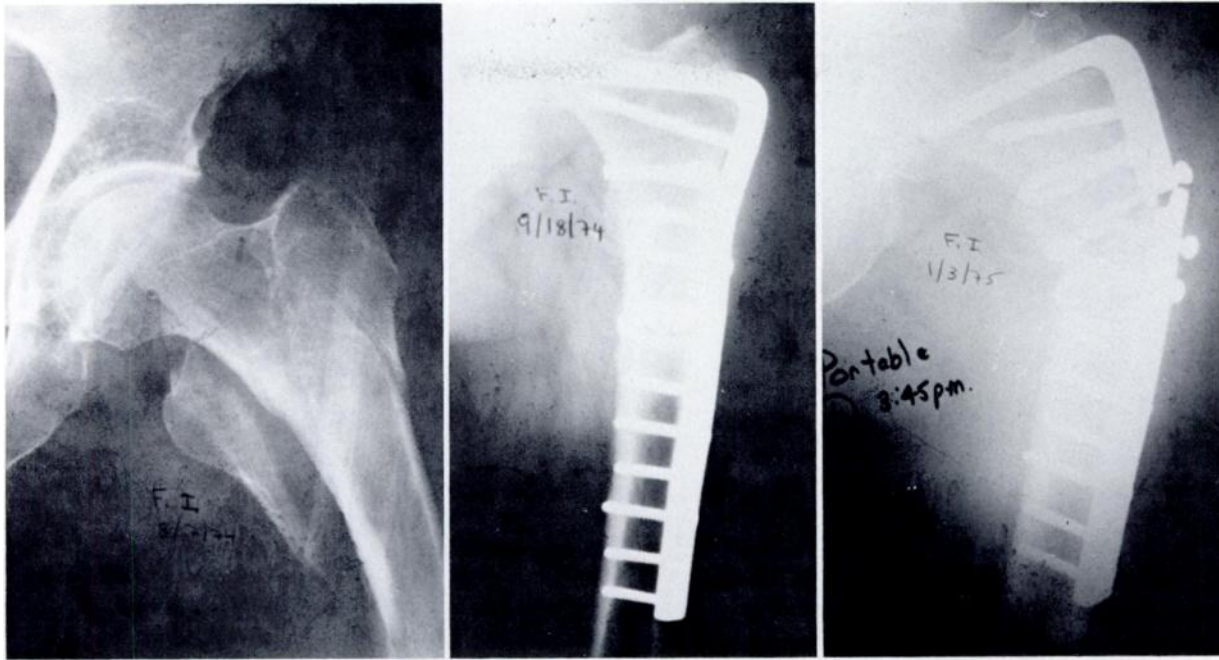


FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: A three-part spiral subtrochanteric fracture (Type III-A).

Fig. 4-B: Six weeks after insertion of an AO blade-plate, interfragmentary compression screw, and Parham bands.

Fig. 4-C: The plate fractured at the level of the fracture of bone five months postoperatively. The patient then was treated with a proximal femoral-replacement total hip prosthesis.

and thus the greater the difficulty in obtaining medial cortical load-bearing. If medial cortical support is inadequate, a lateral plate will not act as a tension band as it should, but will be subjected mainly to bending stress, and the loads applied will concentrate in one small area of the plate. All the failures of fixation in this series involved bending or breaking of a plate at the region of the fracture. There were no instances of loss of fixation to bone proximally or distally. This finding supports the concept that the stresses on the plate are localized to the area of the fracture because of the lack of medial cortical load-bearing by the bone fragments.

The patients with Type-IV fractures (average age, fifty-three years) had stronger bone and thicker cortices than those with Type-III-A fractures (average age, sixty-three years) because of the differences in age and incidence of osteoporosis in the two groups. It is easier to obtain some cortical contact medially if the cortex is thick. This may explain why Type-III-A fractures which were less comminuted and resulted from lower forces of injury were more likely to result in failure. The use of medial displacement fixation in three of the eight Type-V fractures may have contributed to the good results in this group.

In a recent report, Zickel described eighty-four subtrochanteric fractures treated with his device. He had only one failure of fixation. It is impossible to determine how many fractures in his series were Type-III-A. His

classification of short and long oblique fractures with comminution includes Types III-A, III-B, and IV. The fewer instances of mechanical failure in his series compared with the present one may be attributed to any of several factors, or to a combination of them. Perhaps he had fewer patients with Type-III-A fractures, or his personal supervision of all cases may have ensured a more consistent technical performance; or, perhaps his device was better than those used in the present series. I analyzed one recent article¹ which reported good results using the compression blade-plate, and found that a maximum of two of the twenty reported fractures were Type-III-A. In that series, therefore, the absence of mechanical failure with the use of the compression blade-plate may be attributed to patient selection.

In all of our patients who were treated with traction the fractures healed. The maximum varus deformity was 29 degrees. The fact that these patients were younger adults precludes any meaningful comparison of results of treatment in patients treated with internal fixation who were much older. It is unlikely that the treatment by traction of fractures in elderly patients with Type-III-A fractures would yield similar results because of the high mortality of older patients subjected to prolonged bed rest. It is tempting to speculate that the younger patients with Type-III-A fractures might have had better results than those reported here if the treatment pursued had been traction instead of internal fixation.

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Total Hip Arthroplasty

A REVIEW OF THREE HUNDRED AND THIRTY-THREE CASES WITH LONG FOLLOW-UP

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ABSTRACT: A review of 333 consecutive Charnley total hip arthroplasties four to seven years after operation showed that twenty-eight patients had died, and three deaths were directly related to the surgery. The survivors had an average improvement of 46.6 points in their evaluation scores to a level of 91.3 points. Four deep infections occurred for which removal of the prosthesis was required. Thirteen hips dislocated post-operatively, and five of them required additional surgery. There were four sciatic-nerve injuries and all but one resolved. Wear of the acetabular component was evident in seventeen hips, measuring two millimeters in six and one millimeter in eleven. With the marking system used, accurate measurement of wear was not possible. Roentgenographic evidence of loosening of the femoral component was found in 24 per cent of the hips, attributable more often to the quality of cement fixation than to the position of the components (varus-valgus). Varus loosening of two millimeters or more was associated with lower evaluation scores.

Total hip arthroplasty done by the Charnley method, slightly modified¹⁻⁵, was begun at the Mayo Clinic on March 1, 1969. During the following year, 333 joint replacements were done in 300 patients. In this paper we report long-term follow-up of the clinical results, complications, and roentgenographic findings on these hips. At follow-up, twenty-five patients had died from natural causes and three had died from causes related to the operative procedure. Clinical follow-up of 271 of the surviving 272 patients (301 hips) was completed forty-nine to ninety

months after surgery (average, sixty-nine months). The missing patient was evaluated forty-three months after surgery but could not be located or contacted for further follow-up. He was excluded from the study because we wanted to have a minimum of four years of follow-up. Roentgenographic follow-up was available after forty-eight months in 227 (83.5 per cent) of the 271 patients (255 hips).

Materials and Methods

During 1969 and 1970, all patients who underwent total hip-replacement arthroplasty had a significant degree of disability caused by degenerative or rheumatoid arthritis or recurrent pain after previous surgical procedures performed on the hips. The patients were about equally distributed as to sex, and their ages ranged from thirty-nine to eighty-four years. Of the 300 patients, 93 per cent were fifty to seventy-nine years old. The preoperative indications for surgery were as follows: osteoarthritis, 56.0 per cent; rheumatoid arthritis, 7.5 per cent; congenital hip dysplasia, 3.0 per cent; traumatic arthritis, 1.8 per cent; avascular necrosis, 3.0 per cent; failed prosthesis, 15.6 per cent; failed osteotomy, 3.6 per cent; failed cup arthroplasty, 6.0 per cent; and other, 3.5 per cent. Previous surgery had been done in 25 per cent of the hips.

The operation was performed by a number of the orthopaedic staff or a resident (under staff direction) according to a strict and uniform protocol. Before surgery, each patient's condition was evaluated thoroughly and a modified Harris hip-evaluation form was completed. Written permission to use methylmethacrylate was obtained from every patient.

Patients were given methicillin (1.0 gram) the night

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