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CLOSED INTRAMEDULLARY NAILING FOR FEMORAL AND TIBIAL SHAFT FRACTURES

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ABSTRACT

Closed intramedullary nailing is becoming a safer and more popular operative method. To this end, an original extension-apparatus has been developed, and the shape of the intramedullary nail and operative techniques have also been improved. Eighty-six femur fractures and 106 tibia fractures of adults have been examined and excellent clinical results have been reported.

Keywords: Fracture, Femur, Tibia, Intramedullary nailing, Closed mehtod

INTRODUCTION

Originated by Küntscher, Intramedullary nailing adapted to shaft fractures of the long tubular bone is a precise surgery[1] with its technical accuracy in the diameter of the intramedullary nail and medullary canal, characterizing the closed method without the exposure of the fractured site, and with elastic impingement between the intramedullary nail and the medullary canal.

The present author endeavored to develop the extension-apparatus and to improve the intramedullary nail and the details of operative techniques in order to establish this closed intramedullary nailing as a safe and widely accepted operation. Recent clinical applications have shown excellent results.

MATERIALS

A long-term experiment of the closed intramedullary nailing from July, 1972 to December, 1977 was done on 192 fractures, including 86 femur fractures for 85 patients and 106 tibia fractures for 105 patients.

Outline of Femur Fractures

Including one bilateral patient, there were 72 males and 13 females aged 15 to 75 (average age 34), of which 56 cases were caused by traffic accidents, 13 cases by labor accidents, 3 cases by sports accidents, 5 cases by a fall, one case by pathological fracture, and 7 cases by miscellaneous reasons. Seventy cases were closed fractures, 9 (10%) were open fractures, 6 were cases of non-union, and one of mal-union. The fractured sites and types are shown in Fig. 1.

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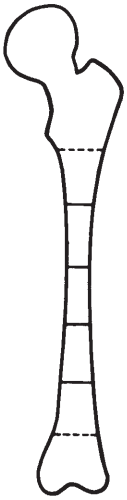
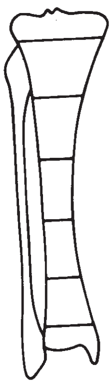


Type and site of fractures

Site \ Type	Transverse	Oblique	Spiral	3rd fragments exist: Comminuted	Butterfly	Segmental※	Total
subtrochanteric		1		5		3	9
shaft proximal	5	1	2	3			11
shaft middle	24	4	2	6	2	4	42
shaft distal	4	7		5	1	1	18
supracondylar	1	1	2	2			6
Total	34	14	6	21	3	8	86

※ main fragment exist.



Type and site of fractures

Site \ Type	Transverse	Oblique	Spiral	3rd fragments exist: Comminuted	Butterfly	Segmental※	Total
transcondylar							
subcondylar							
shaft proximal	1	1		3			5
shaft middle	8	8	2	12	2	3	35
shaft distal	8	7	13	11	3	3	45
supramalleolar	2	2	3	13		1	21
transmalleolar							
Total	19	18	18	39	5	7	106

※ main fragment exist.

Fig. 1.

Outline of Tibia Fractures

Including one bilateral patient, there were 83 males and 22 females aged 15 to 75 (average age 42), of which 38 cases were caused by traffic accidents, 35 by labor accidents, 16 by sports accidents, 8 by a fall, and 8 cases by other reasons. Fifty-nine cases were closed fractures, 39 (37%) were open fractures, 7 were cases of non-union and one of mal-union. The fractured sites and types are shown in Fig. 1. (Fig. 1)

As shown in Table 1, the intramedullary nails used most often were 14 mm in diameter and 380 mm in length for femur fractures, and 12 mm in diameter, 300 mm in length for tibia fractures. (Table 1) As an associated injury, fat embolism syndrome was recognized in 3 cases. 31% of the femur fractures and 54% of the tibia fractures stayed free from associated injuries.

Table 1.

(mm) **Nail used** (Femur)

Length \ Diameter	11	12	13	14	15	16	Total
320	1		3				4
340	2	3	5	5			15
360	2	4	7	8	3		24
380	1	1	5	13	7	1	28
400		1	1	5	6		13
420				1	1		2
Total	6	9	21	32	17	1	86

(Tibia)

(mm)

Length \ Diameter	10	11	12	13	14	15	Total
255		2					2
260		2	3				5
270		7	7	3			17
280			3				3
285	1	5	9	6	1		22
290		2	2				4
300		4	12	8	5	1	30
310		1	3				4
315			4	4	5		13
320		1	1				2
330			3		1		4
Total	1	24	47	21	12	1	106

The operation for open fractures is generally performed after the wound is healed. In fresh tibia fractures, the average period from the time of injury to the operation was 9 days for closed fractures and 12 days for open fractures. In fresh femur fractures, the period averaged 11 days for closed fractures and 18 days for open fractures, with 43 days as the longest period. The operation time from incision to would closure was an average of 72 min. (ranging from 30 to 180 min.) for femur fractures and an average of 65 min. (ranging from 20 to 120 min.) for tibia fractures.

METHODS

[Development of the extension-apparatus (traction table)]

The extension-apparatus, as well as fluoroscopy and the flexible reamer, is indispensable to closed intramedullary nailing.

The author modified Küntscher's traction table by making a mobile extension-apparatus which handles the image intensifier freely, has strong extension power and a solid structure suitable to the Japanese physique, and can be used together with the ordinary operation table which was exhibited in 1974.[2] (Fig. 2)

[Use of bent nail]

In view of the femur's physiologically anterolateral convex curvature, and considering the necessity to use a bent nail with a radius equivalent to this curvature in order to prevent intraoperative complications, the author has used this bent nail commonly since 1973. A 1600

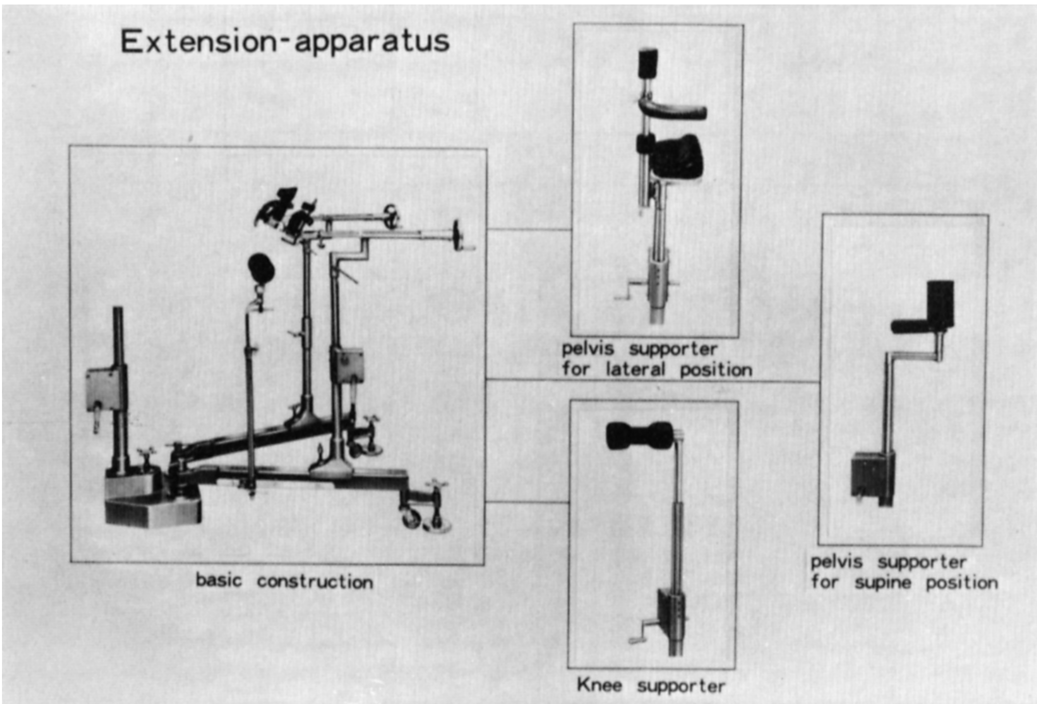


Fig. 2.

mm radius (R) is considered the most appropirate based on the average value of radiographic measurements of 50 femurs. The tip of the nail is taper-tipped to reduce slight lateral displacement, rounded in order not to split the cortex, and narrowed in order not to let the nail guide escape from the slit of the nail. (Fig. 3)

[Discussion of operative methods]

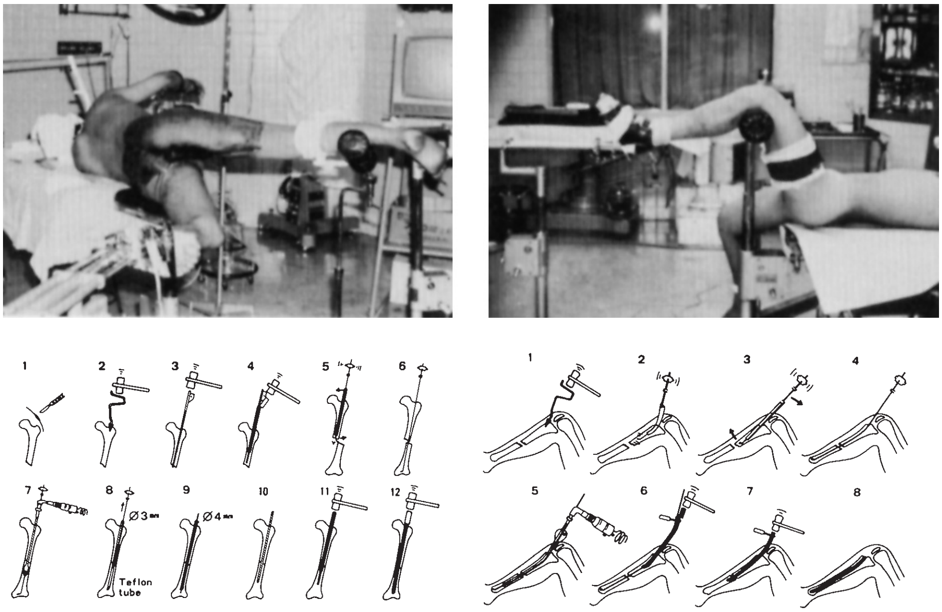
Using the extension-apparatus, fractures of the femoral shaft are reduced in the lateral position and fractures of the tibial shaft in the supine position and then the reduced position is maintained firmly during the operation. In fractures of femur shafts, in order to get the closed insertion of the reamer guide, an intramedullary nial of 10 mm in diameter is first inserted into the proximal fragment. Then, using it like the arm of a lever, lateral displacement is reduced, operating the blunt and bent point of the reamer guide with a holder to catch fractured pieces of bone. This insertion is taken into the operative routine. In principle, the diameter of the selected intramedullary nail should be the same as that of the last reamer used. (Fig. 4)

RESULTS

For fractures of the tibial shaft, radiographic continuity in fractured bone by callus, i.e., the cloudy shadow of callus filling the fragments, appeared in 33.6 days (average), and the bony union, i.e., the mature bridging callus connecting the fragments, was completed in 85.2 days (average). For fractures of the femoral shaft, the former appeared in 29 days and the latter was completed in 80 days. In seventy-eight stable cases (40% of all) partial weight bearing was possible within 8.8 days (average) for fractures of the femoral shaft in comparison to 6.1 days (average) for fractures of the tibial shaft. Full weight bearing was possible in one month for both. Clawson[3] reported the same reslults in femoral fractures and Alms[4] reported 6 weeks in tibial fractures. Reoperations were done to 2 femoral shaft fracture cases and to 1 tibia fracture case, all of which were renailed to thicker nail within 3 months.

No additional plating, screw fixation or cerclage wiring was done during the operations except in 2 femur fracture cases to which stacked nailing[5] was applied, 14 tibia fracture cases to which an antirotational wire was applied to fractured distal fragments, and 9 tibia fracture cases to which screw fixation in the proximal end was applied to the proximal fragment.

Fig. 3.



Steps for closed intramedullary nailing of fractures of the femoral shaft.

Steps for closed intramedullary nailng of fractures of the tibial shaft.

Fig. 4.

Intraoperative complications[6)]

It was necessary to expose the fractured site in order to insert the reamer guide into the distal fragment in 3 cases, including a femoral segmental fracture, a femur non-union with an obstructed medullary canal, and a tibia fracture with intervention of fragment, (so called Semi-closed nailing).

Error in the inserted site and in the direction of the reamer guide was found in 4 cases, all of which were femoral shaft fractures. One case resulted in 2.5 cm shortening because of thin and split anterolateral cortex caused by eccentric reaming where the insertion position has been too lateral. Among the other 3 cases, one case came too close to the femoral head, one became lateral due to a deformity of the trochanter major, and the last one became anterior due to a comminuted fracture. However, no serious trouble has been seen in any of the 3 cases.

Complications during nailing are most frequently caused by the nail itself. Slight cortex fracture was seen in 7 cases, which received careful postoperative treatment. Diastasis in fractured sites was mostly seen in transverse fractures, but diminished with walking movements and posed no special problem in bone-union.

Postoperative complications

A short observation was made of 82 cases of fracture of the femoral shaft (95%) and 102 cases of fracture of he tibial shaft (96%). As for early complications, superficial layer infection was seen in one case of fracture of the femoral shaft and in three cases of fracture of the tibia; in addition, deep layer infection was seen in one case of fracture of the tibia, whose bacillus when examined proved to be Erwinia herbicola and which subsided after administration of antibiotics.

As for deformations, two cases of fracture of the femoral shaft showed external rotational deforming (15°) and valgus deforming (10°) respectively. And one case of tibia fracture showed internal rotational deforming (5°); all of which showed no clinical problems.

Late complications included non-union, which was seen in the case stated above with the deeply infected tibia, and delayed union, which was seen in another case. Excessive callus was seen in the two cases of femoral shaft fractures, but callus caps in hip joints were not observed.

As for leg shortening, a shortening of 2.5 cm was found in 4 cases, with neither further shortening nor elongation. Joint contractures were preceded by multiple fractures. (Table 2)

Table 2.

(according to Aoyagi)

Intraoperative complication
(in Closed intramedullary nailing)

	Femur	Tibia
1) In insertion of reamer guide		
a. Failure — Intervention of fragments		1
Intervention of scar		
Unskilled reduction	1	
Obstruction of medullary canal	1	
b. Error of site and direction	4	
2) In reaming		
a. Splitting of cortex		
b. Breakage of reamer		1
c. Deviation of reamer guide		
3) In Nailing		
a. Splitting of cortex	3	4
b. Incongruity to reamer guide		
c. Diastasis	2	4
d. Incarceration		
e. Malrotation		
f. Joint disturbance		
g. Skin necrosis		1

Postoperative complication
(in Intramedullary nailing)

	Femur	Tibia
1) Early		
a. Infection superficial	1	3
deep		1
b. Deformity (recurvatum, varus, valgus, rotation)	2	1
c. Neurovascular injury		
d. Shock		
e. Fat embolism		
2) Late		
a. Non-union		1
b. Delayed union		1
c. Refracture		
d. Excessive callus	2	1
e. Bending, breakage of nail		
f. Migratiom of nail		
g. Leg shortening, lengthening (> 3 cm)		
h. Contracture	3	2
3) Others		
serum hepatitis	3	
thrombophlebitis		1
agranulocytosis	2	2

DISCUSSION

1. Probability of Success in Closed Nailing

Many clinical reports on intramedullary nailing support the superiority of closed nailing for the following reasons: a) the certainty of bony-union due to the closed fractured site, b) less blood loss and invasion, which decreases the rate of infection, c) early functional recovery without contracture or lowered muscle power, d) simplification of physical therapy and shorter hospitalization due to rigid stability, and e) no scars remaining on visible regions of the legs. Due to these advantages, this method was regarded as "Ideal Osteosynthesis". But referential reports on this closed intramedullary nailing startd to appear here and there in 1960 for tibia fractures and in 1970 for femur fractures, and its probability of success was surprisingly low, 16-96% (16% Zimmermann,[7] 38% Hamza,[8] 68% Solheim,[9] 88% Alms,[4] 96% Bohler, L[10]) in cases of tibia fractures and 46—84% (46% Rokkanen,[11] 71% Rascher,[12] 84% Aoyagi[6]) in femur fractures. In this respect, the author's rate of success in the closed nailing was 84 out of 86 cases (98%) in femur fractures and 105 out of 106 cases (99%) in tibia fractures, regarding the semi-closed method as a failure.

Several factors which increased the rate of success in femur fractures should be especially mentioned: preoperative skeletal traction, the development of extension-apparatus, the technique of putting the reamer guide into the bone fragment recovering lateral displacement by using a 10 mm nail as a lever, and the use of bent nail. The space to handle this 10 mm nail freely is necessary and the lateral position is preferable to the supine.

2. Bent Nail for Femur Fractures

As the femur has a phisiologically anterolateral convex curvature, a straight nail occasionally incarcerates the medullary canal or causes posterior angulation in the fractured site. This occurs even with a thinner nail, whose limited length and diameter might lead to inferior stability.

The first clinical report on the bent nail, which was presented by J. Böhler[13] in 1968, stated that a bent nail with a 12 mm high arch at the mid-point was used in 308 cases. Later, an A0 bent nail was presented by Schneider[14] in 1970 and by Kashiwagi[15] in 1971. The author made a bent nail with a 11 mm high arch at the mid-point, defining the radius (R) as 1600 mm from the index of bow of the femur, and has been using it since 1973. At about the same time, Onoue[16] (1974) also presented a (R) 1150 bent nail. Further discussions seem to be needed to decide the optimum rate of curvature but the use of a bent nail should not be contradictory to the Küntscher theory. It facilitates safer and easier insertion of a longer and thicker nail and it can be expected to resist rotation deformity, but not to cause posterior angulation. Moreover, it has other advantages which widen the application to the dilated medullary canal.

3. Intramedullary nail and Reamer's diameter

In Japan, the diameter of the nail was generally 0.5[6,15] or 1 mm[17] less than the diameter of the last reamer, while the reports presented so far had three different interpretations on the diameter of a nail, as being the same[12,13,18] as that of the reamer, as being thinner,[11] or as being thicker.[5] Likewise, there was clinical and theoretical confusion in deciding the diameter of the nail and reamer due to the elastic impingement of the nail with the medullary canal.

In 1964 Küntscher[19] changed the two-point measurement of the nail to a three-point measurement. He thought a nail 1 mm thinner than the last reamer should actually have the same diameter as the reamer, since the two-point measurement by caliper had shown 1 mm less value than one of three-point measurement by drill gauge template. Thus he used a nail and reamer with the same diameter, both measured by a drill gauge template. (Fig. 5)

Concerning the question of elastic impingement, since the small and short head of a flexible

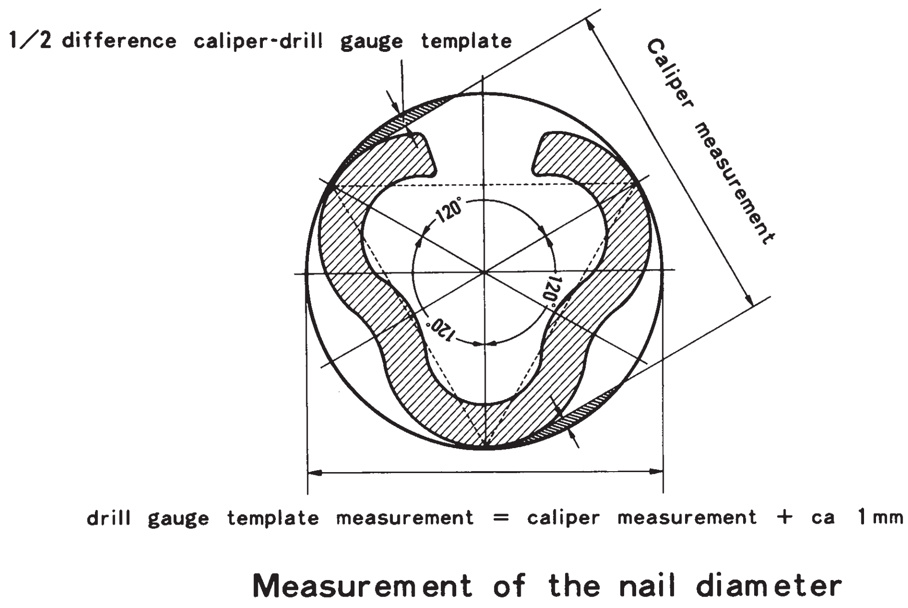


Fig. 5.

reamer reams idolly or spirally in the medullary canal, the medullary canal is not accurately mathematical, but smaller than the diameter of the reamer. A nail of the same diameter, being relatively bigger, capacitates elastic impingement.

In view of the above points, the author firmly believes that the diameter of a nail should be the same as that of the reamer, and he is presently putting this belief into practical use.

4. Indication of Closed Intramedullary Nailing

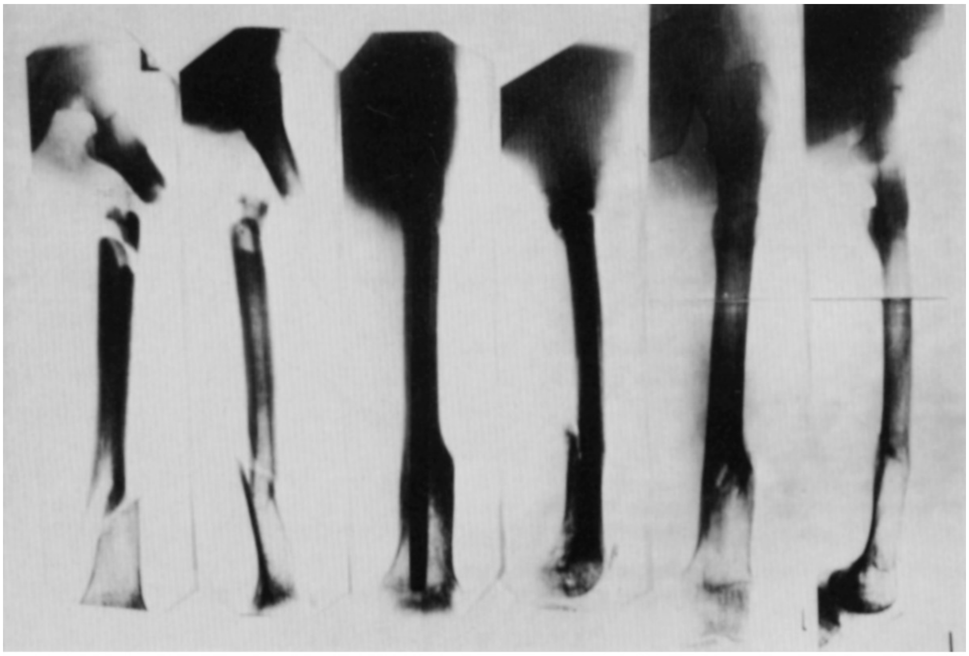
Fractures of the middle 1/3 part of the diaphysis, transeverse, short oblique and short spiral fractures are considered to be absolute indications for closed intramedullary nailing. The indication can be expanded further to include fragmented fractures, fractures accompanied by a third large fragment, comminuted, long oblique, pathological and multiple fractures.

As for the indication extent in femur fractures, Böhler[13)] defined it as being from 10 cm distal of the trochanter major to 10 cm proximal to the knee joint, while Rascher[12)] defined it as being from the same 10 cm distal to 12 cm proximal to the knee joint.

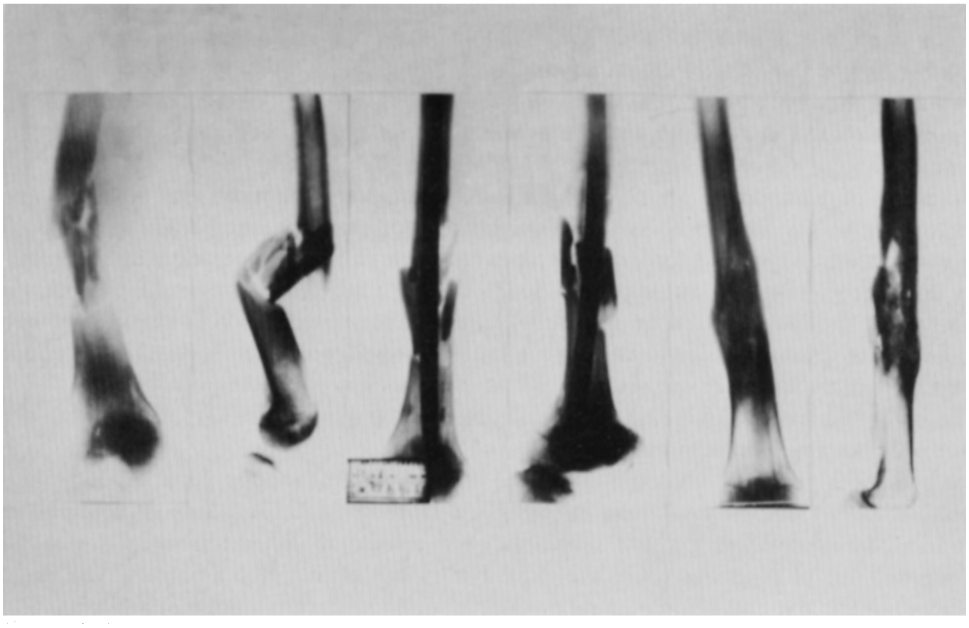
The proximal indication is regarded as possible by Clawson[3)] in case there is a cortex ring 1 cm under the trochanter minor.

According to the author's expeirence, the most proximal case is 2 cm distal from the trochanter minor and the most distal case is 11 cm from the knee joint Non-infected and easy repositionable delayed union and non-union are also good indications because of bony healing without bone graft. There are some contraindications such as lack of equipment, infection, shock, fat embolism and cases unable to take operative position.

Although Küntscher[17)] said, "There is no obvious limit since the indication will be enlarged constantly by the technical progress, "the fixative force for rotation is taken into question. A below the knee winged-cast or skeletal traction is continuously applied to femur fracture cases as proximal nail fixation, and antirotational wire is applied to tibia fractures. Küntscher and Müller aim at fixation which does not involve external fixation, but this author thinks



At injury | 3 months after closed intramedullary nailing | 12 months after closed intramedullary nailing



At injury | 3 months after closed intramedullary nailing | 9 months after closed intramedullary nailing

Above: Segmental fracture. The bent nail fits in with the physiologic curvature of the femur.
Below: Comminuted fracture. The delayed osteosynthesis brings the early consolidation.

Fig. 6.

minimum external fixation or traction can be applied to cases in which early bony healing seems possible, even including highly commminuted fracture cases on which delayed osteosynthesis is performed to obtain unexpectedly early bony healing. (Fig. 6)

SUMMARY

1. Closed intramedullary nailing was performed on 86 femur fracture cases and 106 tibia fracture cases, out of which 3 cases received semi-closed nailing. The rate of success in the closed nailing was 98% in femur fractures and 99% in tibia fractures. As a complication, 5 infected cases (4 cases in the superficial layer, 1 case in the deep layer), 3 deformed cases, and one non-union and one delayed union (both in fracture tibia cases) were seen.
2. An originally developed extension-apparatus, specific methods discussed in detail and the use of the bent nail for femur fractures made this closed intramedullary nailing safer and firmer.
3. Thus, this closed intramedullary nailing should be selected first as a bone fixation to fractures of femoral and tibial shafts.

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