Nonunion of the Femur Treated with Conventional Osteosynthesis Combined with Autogenous and Strut Allogeneic Bone Grafts

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Background: In this study, we reviewed the results of conventional osteosynthesis combined with strut onlay allografts and autogenous bone grafts as the treatment for nonunion of the femur.

Methods: We conducted a retrospective study of 18 patients with nonunion of the femur treated with internal fixation (eight 95° fixed-angled blade plates, 7 intramedullary nails, 2 dynamic hip compression plates and screws, and 1 condylar buttress plate) and autogenous bone grafts and cortical strut allografts. There were 1.8 operations on average before surgery. The average time from the initial treatment of the fracture or osteotomy to surgery was 32.5 months. The average follow-up was 32.2 months.

Results: All 18 nonunions had healed by the time of follow-up. Positive intraoperative cultures (Staphylococcus epidermidis) in 2 patients were resolved by parenteral antibiotics with no additional treatment. Removal of implants was required in 5 patients because of screw irritation or bony union. One concomitant quadricepsplasty as well as 2 excisions of a protruding graft were required because of restricted knee motion or impingement.

Conclusions: For difficult nonunions of the femur in the current study, strict adherence to the principles of the treatment of nonunion and the addition of strut allografts to enhance stability and repair potential proved to be a good alternative.
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Key words: **nonunion, conventional osteosynthesis, autogenous, strut allogeneic bone graft.**

Despite recent advances and improved primary fracture treatment protocols, post-traumatic nonunion of long bones has remained a persistent and often difficult management problem.[1] Nonunions of the femur, regardless of the anatomic site, are most commonly due to severe open fractures with extensive comminution and segmental bone loss.[2,3] Another cause is infection after internal fixation.[2] There are numerous reported methods of operative treatment of these nonunions for providing stability and implant use.[2-8] Most nonunions of the femur can be successfully treated by osteosynthesis with or without bone grafting, electric stimulation, ultrasound, and growth factor administration. However, bone defects, osteopenia and poor bone quality at the nonunion site after repeat surgeries and widening of the canal as well as a thin cortex in the proximal and distal femoral regions render the treatment of femoral nonunions difficult.

In this study, we reviewed the results of conven-

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tional osteosynthesis combined with cortical strut allografts and autogenous bone grafts for nonunions of the femur including intertrochanteric, diaphyseal, and distal femoral areas with severe osteoporosis or significant cortical defects.

METHODS

Between February 1, 1996 and February 1, 2001 at Chang Gung Memorial Hospital, Kaohsiung, 18 femoral nonunions (in 18 patients) were treated with conventional osteosynthesis combined with cortical strut allografts and autogenous iliac bone grafts. There were 5 males and 13 females. The average age was 59 (range, 25-86) years. There were 2 intertrochanteric, 1 subtrochanteric, 6 diaphyseal, and 9 distal femoral nonunions (Table 1).

Two patients with intertrochanteric nonunions had associated severe osteoporosis and loss of bone stock after previous osteosynthesis had failed (Fig. 1). Interlocking nailing in 1 patient with subtrochanteric nonunion had failed twice before this definitive repair (Fig. 2). Diaphyseal nonunions in 6 patients were due to either failure of previous surgery, improper treatment, bone loss, or implant failure. Of the 9 patients with supracondylar nonunions, there were severe osteoporosis and cortical defects, while the average range of knee motion was 39˚ (range, 5˚-95˚) and the average alignment in the anatomic axis was 10˚ of the varus (range, 3˚ of the valgus to 16˚ of the varus). The average time from the initial treatment to the index repair of the nonunion was 32.5 months. The average number of prior surgeries for all patients was 1.8 (range, 0-5).

Eight fixed-angled blade plates and 1 condylar buttress plate were applied over the distal femoral nonunions; 2 dynamic hip compression plates were applied over the intertrochanteric nonunions; and 7 interlocking nails were applied over the diaphyseal or subtrochanteric nonunions (Table 2). Every patient had supplementary autogenous bone grafts, either from the anterior iliac crest or posterior iliac crest, along with 1 or 2 cortical strut allografts. Bicortical strut allografts were required in 5 diaphyseal nonunions due to a concomitant lengthening procedure in 3, a paper-thin cortex in 1, and osteopenia and bone loss in 1 patient. Two cortical strut allografts were placed opposite each other on the host bone across the nonunion and fixed with wires.

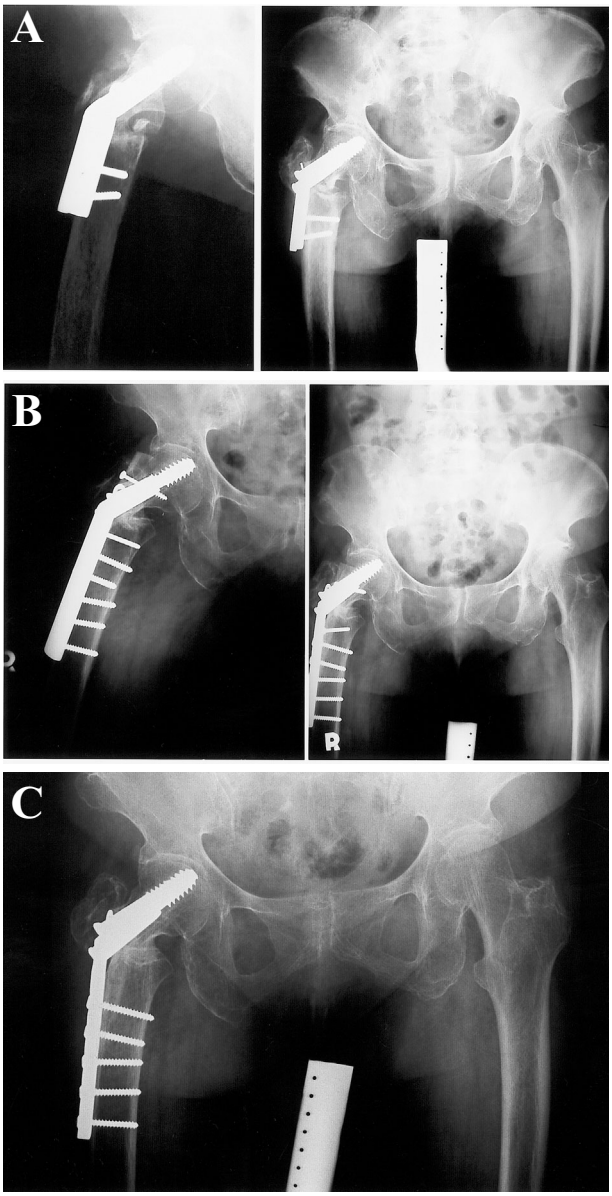

Fig. 1 (A)-(C). An 84-year-old woman (case 1) with nonunion of an intertrochanteric fracture of the right femur after dynamic hip compression plate fixation. (A) Anteroposterior radiography of the pelvis and lateral radiography of the right hip taken before index repair of the nonunion. (B) Anteroposterior radiography of the pelvis and lateral radiography of the right hip taken 6 months after dynamic hip compression plate fixation combined with cortical strut allograft and autogenous iliac bone grafts showing the healed nonunion. (C) Anteroposterior radiography of the pelvis and lateral radiography of the right hip taken 8 months after the index repair operation showed union. She had had excision of a protruding graft 2 months previous.

Table 1. Preoperative Clinical Data of Patients

Case no.	Age (yr)/ Gender	Initial event	Nonunion site	Number of prior surgeries	Nonunion duration (mon)
1	84/F	fracture	intertrochanteric	1	4
2	65/F	fracture	intertrochanteric	1	4
3	25/M	fracture	subtrochanteric	2	36
4	59/F	fracture	diaphyseal	0	260
5	26/M	ABC with fracture	diaphyseal	2	11
6	71/M	osteotomy	diaphyseal	3	4
7	25/F	fracture	diaphyseal	1	2.5
8	67/M	fracture	diaphyseal	3	27
9	39.M	fracture	diaphyseal	5	96
10	67/F	fracture	supracondylar	3	9
11	48/M	fracture	supracondylar	2	16
12	79/F	fracture	supracondylar	2	18
13	86/F	fracture	supracondylar	1	5
14	70/F	fracture	supracondylar	1	7
15	56/F	fracture	supracondylar	1	14
16	61/F	fracture	supracondylar	1	13
17	70/F	fracture	supracondylar	1	60
18	72/F	fracture	supracondylar	2	18

Abbreviations: ABC: aneurysmal bone cyst.

Table 2. Postoperative Data of Patients

Case no.	Type of implant in index procedure	Operative condition	Pieces of strut allograft	Time to union (mon)	Duration of follow-up (mon)
1	DHS	osteoporosis	1	8	17
2	DHS	bone loss	1	6	18
3	ILN	bone loss	2	10	24
4	ILN	bone loss	2	5	24
5	ILN	paper-thin cortex	2	12	74
6	ILN	osteoporosis	1	5	79
7	ILN	bone defect of 2 cm 60% circumferential cortex loss	1	12	36
8	ILN	osteoporosis, bone loss	2	7.5	7
9	ILN	osteoporosis, bone loss	2	24	46
10	CP	lateral cortex bone loss of 3 cm medial cortex bone loss of 5 cm osteoporosis	5	5	22
11	BP	cortical bone loss of 2.5 cm	2	5	18
12	BP	cortical bone loss of 3 cm osteoporosis	2	7	8
13	BP	osteoporosis	1	33	33
14	BP	osteoporosis	2	11	40
15	BP	lateral cortex bone loss of 3 cm medial cortex bone loss of 1 cm	2	9	48
16	BP	cortical defect of 3 cm	1	5	30
17	BP	osteoporosis	1	13	28
18	BP	cortical defect of 2 cm	1	8	28

Abbreviations: DHS: dynamic hip compression plate and screw; ILN: interlocking nail; CP: condylar plate; P: blade plate.

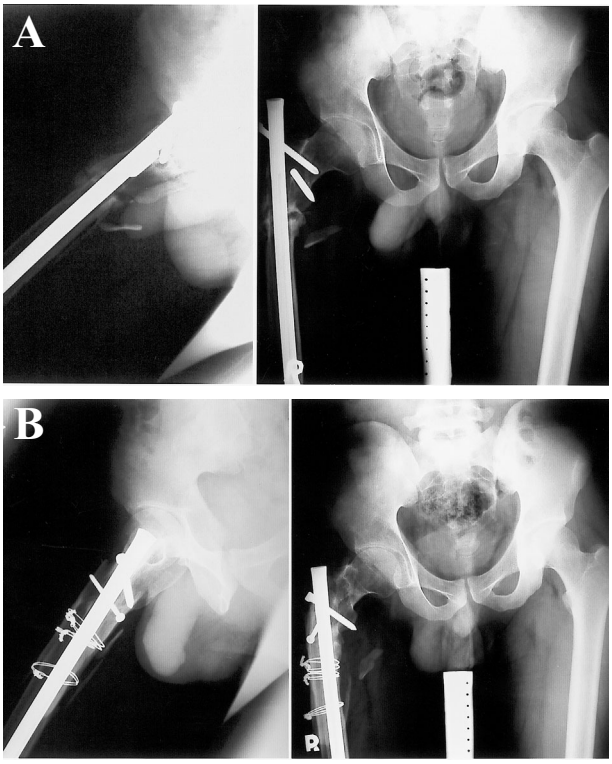

Fig. 2 (A), (B) A 25-year-old man (case 3) with nonunion of the subtrochanteric fracture of the right femur after 2 attempts at intramedullary nail fixation. (A) Anteroposterior radiography of the pelvis and lateral radiography of the right hip before the index repair of the nonunion. (B) Anteroposterior radiography of the pelvis and lateral radiography of the right hip taken 8 months after open reduction internal fixation with a locked nail, bicortical strut allografts, and autogenous iliac bone grafts showing a perfect union and good incorporation of the allografts.

One piece of strut allograft on the medial femoral cortex was required in 9 supracondylar nonunions for bypassing the nonunion site and to act as a medial support, while an additional strut allograft on the posterior aspect of the femur to provide additional stability was required in 5 patients. The average width of the strut allograft was 2 cm, and the length varied from 8 to 15 cm. Two cerclage wires were applied for provisional fixation of the graft to the femur. Additional cortical screws were applied to transfix the strut allograft to the host femur as needed for further stability. The autogenous bone grafts of all patients were packed at the nonunion site as well as between the strut allograft and the host femur. Routine microbiological cultures of surgical specimens were obtained for all patients.

In supracondylar nonunions, rehabilitation of the quadriceps muscle with isometric exercise was begun immediately after the operation and continuous passive motion was initiated as tolerated 48 hours later. All patients were allowed progressive weight-bearing at 6 weeks and returned for radiographic examinations at 6, 12, 16, and 24 weeks and then every 6 months postoperatively. Union was judged by a radiographic examination.

RESULTS

The average duration of follow-up after repair of the nonunion was 32.2 (range, 7-79) months. All nonunions had healed by the time of follow-up. Two patients, 1 with previous surgery had failed 5 times and 1 with severe osteoporosis, had delayed union. The other 16 patients achieved union in an average of 8 (range, 5-13) months. The 9 distal femoral nonunions healed within 13 months except in 1 patient (33 months); the range of knee motion improved from an average of 39˚ before surgery to an average of 65˚ (range, 15˚-105˚) after surgery; and knee alignment improved from a preoperative average of 10˚ of the varus to an average of 4˚ of the valgus (range, 3˚ of the varus to 7˚ of the valgus).

Additional procedures and complications

Positive Staphylococcus epidermidis infections in 2 patients were resolved by parenteral antibiotics with no additional treatment. There were no postoperative infections. The implants were removed in 5 patients because of union or screw irritation. Additional surgeries including 1 quadricepsplasty and 2 excisions of a protruding graft were required to improve joint motion. The complications included 1 problem with wound healing, 4 donor site morbidities, and 1 case of avascular necrosis of the ipsilateral femoral head. The ipsilateral avascular necrosis of the femoral head was a late complication of an intertrochanteric fracture. A total hip arthroplasty was performed 1 year later in this patient.

DISCUSSION

The factors contributing to nonunion are divided into 3 categories: deficiencies in vascularity, chondro-osseous response, and stability.[9] Frequently,

deficiencies in more than 1 category are present, thus complicating the approach to therapy. Once the nonunion is sustained, the success rate will decrease in proportion to the number of repeat operations.[8] Repeat surgeries increase the possibility of infection, devascularization of bone fragments, and loss of bone stock because of prior implant and disuse osteopenia. Fragments often have poor bone quality that makes stable fixation and healing difficult. In the proximal and distal femoral regions, a widened canal, thin cortex, and poor bone stock also make rigid fixation difficult, and when there is nonunion of these femoral fractures, treatment becomes more difficult.[2-5,8,10,11]

Wu and Shih reported 5 unions of 7 supracondylar nonunions treated with standard antegrade locked nail and bone graft.[8] Bucholz in 1987 suggested that at least 5 cm should be maintained between the proximal screw hole and the fracture site to avoid nail breakage.[12] Inadequate fixation of the distal fragment above the knee using an antegrade locked nail is an issue of concern, and rotation, angulation, and translation deformities cannot be prevented. Recently a newly designed retrograde Green-Seligson-Henry nail was introduced and successfully applied for acute supracondylar fracture of the femur.[13] However, its use in nonunion of a distal femoral fracture was unsuccessful. Koval et al. reported 9 failures of 16 nonunions treated with this technique.[3]

The use of allograft struts in the treatment of difficult fractures was first reported by Chandler et al.[14,15] In their study, 16 of 19 patients with fracture of the femur after hip or knee arthroplasty with a femoral stem achieved anatomical union of the fracture. Chandler and Danylchuk described another technique, that of using a metal plate on 1 cortex and an allograft strut on another for the comminuted distal femoral fracture above a total knee arthroplasty in osteopenic patients.[16] Hornicek et al. reported 10 humeral nonunions treated by onlay bone plate allograft augmentation,[7] all of which healed within 3 months.

Osteogenic effects of a cortical strut allograft for the reconstruction of a cortical bone defect have been demonstrated in animal models as well as in revision total hip arthroplasty.[17-19] The cortical strut allograft provides mechanical support to the host bone with osteoporosis or bone defects and osteoconductive potential, and increases the bone diameter by eventual incorporation into the host bone.

In 1999, Chapmann et al. reported a series of treatments using single and double plate fixation combined with autogenous bone grafting for supracondylar nonunions.[2] Results of rigid plate fixation and autologous bone grafts were successful, and the average time to union was 8 months, with only 1 case experiencing delayed union. Of these, 13 patients were treated using double plate fixation. The spirit of medial buttressing was similar to that for the 9 distal femoral nonunions in the current study. The difference is that the strut allograft provides both stability and robustness of the chondro-osseous response. Moreover, increases in the bone diameter after strut allograft incorporation provide the best benefits to defective, osteoporotic bone.

Locked intramedullary nailing remains the gold standard treatment for fractures of the femur at the isthmus. In general, nonunion of the femoral shaft is rare, and up to 99% of femoral shaft fractures achieve uneventful union following intramedullary nailing.[20] However, its application is limited to fractures of the femur in the subtrochanteric or infraisthmal area because of inadequate stability, as well as in nonunions of the femoral shaft with cortical bone defect and severe osteopenia. The vast majority of intertrochanteric fractures occur in the osteoporotic bone in geriatric populations. Once nonunion develops, the loosened implant can precipitate a condition of bone loss. A better option is the additional healing potential and mechanical support provided by our technique. The cortical allograft strut acts as an adjunct support to the host femur weakened from osteopenia or bone defects. It provides rotational stability to the non-united femur by fixing it with a locked nail or plate.

In the current study, all nonunions successfully healed. The complications included 1 wound problem, 4 cases of donor site pain, and 1 osteonecrosis of the femoral head. For these difficult femoral nonunions with bone defects, poor bone quality combined with insufficient local stability due to repeat surgeries or at the proximal and distal femoral regions in our study, the use of strut allografts in conjunction with autogenous bone grafts along with conventional osteosynthesis achieved stable reduction which was provided by internal fixation and the strut allograft and by the robustness of the chondro-

osseous response of the autograft and allograft. Strict adherence to the principles of nonunion treatment including good reduction, sufficient bone grafting, and firm stabilization of the fragments with the addition of a strut allograft is a good alternative for the treatment of difficult femoral nonunions.[21]

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使用傳統內固定合併自體骨及異體骨板移植來治療股骨不癒合

翁聆修 王俊聞

背 景： 本篇在探討使用傳統內固定合併自體骨及異體骨板移植來治療股骨不癒合的結果。

方 法： 回顧追蹤18個病人使用內固定 (8位九十五度固定角度鋼板、7位骨髓內釘、2位可動式髖固定鋼板、及1位髁頂鋼板) 及自體骨和異體骨板來治療股骨不癒合，在接受手術前，平均開刀的次數爲1.8次，從事件發生起迄的期間是32.5個月，我們的追蹤時間平均是32.2個月。

結 果： 在最後追蹤時，所有18個骨折不癒合皆已經癒合，有兩位病人手術中的細菌培養呈陽性 (表皮葡萄球菌)，經抗生素治療後，並不需要額外的治療，5位病人因已癒合或合併骨釘刺激周圍組織而將內固定拔除，其中1位同時接受股四頭肌成形術來治療膝活動受限，有2位病人因膝關節活動受限或嵌入而需將突出的異體骨板切除。

結 論： 對於股骨的不癒合，遵守處理不癒合的原則，以好的內固定再加上異體骨板以增加穩定度及癒合潛力是一項很好的解決方式。

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關鍵字： 不癒合，內固定，自體骨，異體骨板。

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