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Correction of femoral supracondylar varus malunions after condylar buttress plating by using retrograde locked intramedullary nailing

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Objective: The aim of this study was to evaluate the use of retrograde locked intramedullary nailing for the treatment of varus malunion occurring following condylar buttress plating (CBP) for femoral supracondylar fractures.

Methods: The study included 32 consecutive adult patients treated with retrograde locked nailing for varus malunion of femoral supracondylar fractures following CBP. Patient results were evaluated based on healing time, lower extremity alignment and knee functions.

Results: Average follow-up was 2.8 (range: 1.1 to 5.6) years for the 27 of the 32 patients who completed follow-up. All osteotomy sites healed at an average of 4.0 (range: 3.5 to 5.0) months. Average preoperative varus knee deformity was 19.6° (range: 14° to 26°). Immediate postoperative varus knee deformity was an average of 0.4° (range: valgus 2° to varus 3°) ($p<0.001$). At the final follow-up, the varus knee deformity was an average of 1.5° (range: valgus 1° to varus 3°) ($p<0.001$). Satisfactory knee function in patients improved from 0% to 93% ($p<0.001$). There were no serious complications.

Conclusion: Retrograde locked nailing appears to be an excellent alternative for the treatment of varus malunion of femoral supracondylar fractures after CBP treatment. It is a simple technique with high satisfaction rates.

Key words: Condylar buttress plate; femoral supracondylar; retrograde locked nail; varus malunion.

Although femoral supracondylar fractures are not uncommon, their treatment remains controversial.[1-3] The region is characterized by a thin cortex, a wide marrow cavity and an uneven contour, making it difficult for implants to provide sufficient stability.[1-4] Although antegrade reamed locked intramedullary nails can be used in fractures of the supracondylar region of the femur, the plate system is traditionally favored for most supracondylar fractures.[1-4]

Traditional plate systems include condylar buttress plates (CBPs), dynamic condylar screws and angled blade plates.[2,5] As all implants have distinct advantages and disadvantages, none can be considered absolutely superior. Advantages of the CBP method include technical simplicity, high union rates and its use of the minimally invasive percutaneous plate osteosynthesis (MIPPO) technique.[5-8] However, a high rate (26 to 42%) of varus deformity may occur due to the inability of the screw to provide sufficient stability to resist the huge compressive stresses in the medial aspect of the knee during daily activity.[5-8]

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When varus deformity of the knee occurs, compressive stresses in the medial compartment of the knee will increase exponentially and accelerate degeneration.[9,10] Correction of the varus knee by sharing the compressive stresses with the lateral compartment of the knee is the most reasonable treatment principle.[11,12] While, theoretically, all techniques used to treat femoral supracondylar fractures are possibly effective, each technique has unique advantages and disadvantages. Few articles have reported the treatment of varus malunion of a supracondylar fracture and a convincing technique has not been well defined. Retrograde locked intramedullary nails have been used recently to treat femoral supracondylar fractures and nonunion with great success.[13,14] We hypothesize that this technique may also be effective in the treatment of femoral supracondylar malunion. As the majority of femoral supracondylar varus malunions are caused by prior CBP treatment, patients with varus deformity in the supracondylar region caused by CBP treatment were studied.[6-8]

The aim of this study was to evaluate the use of retrograde locked intramedullary nailing for the treatment of varus malunion occurring following CBP for femoral supracondylar fractures.

Patients and methods

The study included 32 consecutive adult patients treated with retrograde locked intramedullary nails for varus deformity of the femur following supracondylar fractures previously treated with CBP between May 2004 and December 2010. The author treated and followed up each patient individually. All supracondylar fractures were caused by high-energy injuries and had been operatively treated with CBP. Articular surface involvement was present in 29 supracondylar fractures and extra-articular involvement in three. Eleven fractures were initially open and were debrided and immobilized by external fixation.[15] External fixation was removed 1 to 2 weeks following surgery and CBP was applied. Eight fractures were initially treated at our institution and 24 at other hospitals. No wound infections occurred during the original treatment course. The average period from initial injury to the present revision surgery was 1.7 (range: 0.6 to 3.2) years. Patients were aged between 19 and 64 years (average: 36 years) with a male-to-female ratio of 3.5 to 1. All patients had undergone only 1 previous surgery and the varus knee introduced a limp in all of them. The maximal knee flexion was an average of 110° (range: 40° to 140°).

Fracture and wound healing processes were carefully investigated in all patients in the outpatient department (OPD). Anteroposterior and lateral plain radiographs of the femur and knee and standing scanograms were taken. Patients with a leg length discrepancy (LLD) of more than 2 cm were advised to consider concomitant correction of the shortening and varus deformity using an antegrade locked nailing technique and were excluded from this study.[16] Patients with prior infection were also excluded and external fixation was applied. In the patients considered in this study, the average LLD was 1.1 (range: 0.5 to 2.0) cm and the average varus deformity was 19.6° (range: 14° to 26°). Average anatomic lateral distal femoral angle (aLDFA) was 100° (range: 95° to 107°; normal: 79° to 83°).[17] Indications for revision surgery were a varus knee deformity of more than 10° with medial knee pain or a limp for more than three months, no infection, intact lateral knee joint space, femoral shortening of less than 2 cm and no excessive anterior femoral bowing. Inclusion criterion was revision surgery for varus malunion of femoral supracondylar fractures after CBP treatment. Patients who underwent revision surgery for malunion caused by non-CBP treatment were excluded.

At admission, white blood cells, erythrocyte sedimentation rate and C-reactive protein were routinely checked. Patients with a suspicion of deep infection were treated with external fixation. In this study, all laboratory data were within the acceptable range.

Patients were placed on the operating table in the supine position under general anesthesia with intubation or spinal anesthesia. A sterilized pneumatic tourniquet was routinely used.

Along the prior incision wound, the CBP was completely identified (Fig. 1a). After the CBP was removed with a screwdriver, a 3-mm Kirschner wire was inserted in the intercondylar notch 5 to 10 mm anterior to the insertion of the posterior cruciate ligament.[18,19] The intercondylar bony inlet was enlarged to 8 mm with a flexible reamer (Fig. 1b).

The anterior cortex of the supracondylar region was exposed. An upward oblique line was marked, which started 3 cm proximal to the medial condyle and ended at the lateral cortex. The angle formed by two lines (the upward oblique line and a line perpendicular to the medial cortex) was equal to the desired angle of correction (Fig. 1c). With a power saw, the femur was osteotomized into two segments. A second line was marked in the lower femoral segment, which was located at the midpoint of the first cutting line and parallel to the perpendicular line (Fig. 1d). With a power saw, the distal femoral segment was osteotomized, and the upper fragment was removed.

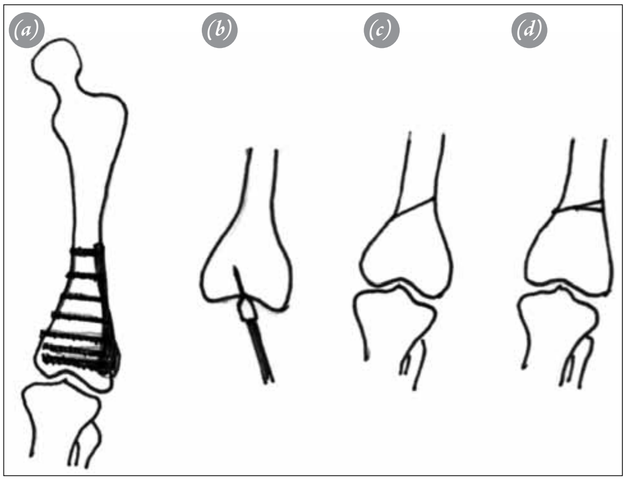

Fig. 1. Steps in the described technique. **(a)** A varus malunion of the femoral supracondylar fracture after condylar buttress plating requiring treatment. **(b)** A bony inlet is formed in the intercondylar notch. **(c)** An oblique supracondylar osteotomy is performed 3 cm proximal to the medial condyle. **(d)** An osteotomy is performed at the midpoint of the first cutting line with the second cutting line perpendicular to the medial cortex.

The femoral axis was realigned by rotating the lower femoral segment internally. The distal femoral segment was pushed medially and distally, so the second cutting line was close to the first cutting line. Thus, a normal femoral axis was achieved (Fig. 2a).

Using a rigid guide wire, a true bony tunnel was established (Fig. 2b). The marrow cavity was reamed as widely as possible after the rigid guide wire was changed to a flexible guide wire (Fig. 2c). Then, a 1 mm smaller traditional femoral locked nail (Russell-Taylor locked nail; Smith & Nephew Inc., Memphis, TN, USA) was inserted in a retrograde fashion. The nail end reached the level of the lesser trochanter and a lower diagonal screw was inserted. The rotational stability was checked manually. A humeral dynamic compression plate or buttress plate (Synthes Bettlach GmbH, Bettlach, Switzerland) might be added to reinforce the rotational stability. The gap was packed with the resected bone, a cancellous bone graft procured from the lateral tibial condyle or bone graft substitute (Fig. 2d). The wound was closed with absorbable sutures.

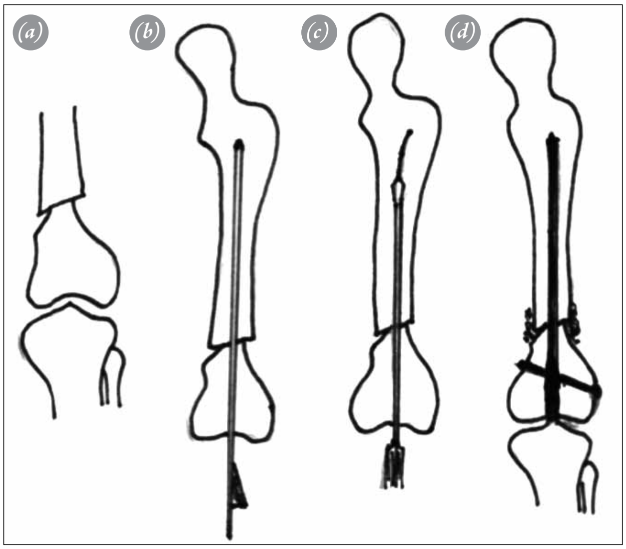

Fig. 2. **(a)** The distal femoral segment is internally rotated and the first and second cutting lines are brought close together. The distal segment is pushed medially and distally. **(b)** A rigid guide wire is used to reestablish a new tunnel. **(c)** The bone marrow is reamed as widely as possible. **(d)** A retrograde traditional femoral locked nail is inserted. The gap is packed with bone graft or bone graft substitute.

Postoperatively, early knee range of motion exercises and ambulation with partial weight-bearing were encouraged. Patients were followed up at the OPD at scheduled intervals of 4 to 6 weeks. Wound and fracture healing processes were recorded. After the fracture healed, patients were followed up each year and whenever necessary. At each OPD visit, plain knee radiographs were taken and the aLDFA was measured. However, a standing scanogram was taken only at the first and final OPD follow-up.

Clinically, fracture union was defined as the absence of pain or tenderness and the ability to walk without aid, and radiographically by the presence of a solid callus that connected both segments in three of four plain radiograph views.[20] Nonunion was defined as fractures remaining unhealed one year after treatment or as loss of stability due to implant failure which required a second surgery to achieve union. Malunion was defined as varus deformity >5°, valgus deformity >10° or shortening >2 cm.[21]

Knee function was evaluated using a modified Mize scoring system and patients were categorized into four grades.[21] Satisfactory outcomes were categorized as either excellent or good. An excellent grade was given to patients with flexion loss of less than 10°, the ability to perform a full extension, no varus, valgus or rotational deformities and no pain. A good grade was given to patients with no more than one of the following; greater than 5° varus deformity, greater than 10° valgus deformity, greater than 20° loss of flexion, greater than 10° loss of extension or minimal pain. A fair grade included two of the above defects and a poor grade included more than two. This evaluation system was used because of its relative simplicity and practicality.

For convenient comparison, the paired Student's *t*-test and Fisher's exact test were used. $P<0.05$ was considered statistically significant.

Results

Twenty-seven patients were followed up for an average period of 2.8 (range: 1.1 to 5.6) years (Table 1) and 5 were lost from regular follow-up.

All 27 fractures (100%) healed at an average union period of 4 (range: 3.5 to 5.5) months (Table 1). There were no serious complications of wound infection, neurovascular injuries, nonunion, malunion or implant failure.

Intraoperatively, 9 patients required an augmented plate to prevent torsional instability of the lesion site (Fig. 3). The other 23 patients achieved good torsional stability after retrograde nail insertion and required no plate augmentation (Fig. 4).

Immediately postoperatively, the average varus deformity in the 32 patients was 0.4° (range: valgus 2° to varus 3°) ($p<0.001$). At the final follow-up, the average varus deformity in 27 patients was 1.5° (range: valgus 1° to varus 3°) ($p<0.001$).

At the final follow-up, knee function improved from a satisfactory rate of 0% (0/27) to 93% (25/27) ($p<0.001$). The unsatisfactory knee function in the 2 patients was associated with poor knee flexion (40° and 50° of flexion, respectively) although the knee pain was mild. Quadricepsplasty to improve the knee flexion was suggested when the implant was removed or whenever necessary.

At the final follow-up, the average LLD in 27 patients was 0.8 (range: 0 to 1.5) cm ($p<0.001$).

Discussion

Factors favoring fracture healing are a minimal gap, adequate stability and sufficient nutrition supply.[22] Malunion of femoral supracondylar fractures is gener-

Table 1. Varus malunions of femoral supracondylar fractures after treatment by condylar buttress plates were treated with retrograde locked nails (n=27).

Case no.	Gender/Age (yrs)	Period after CBP (yrs)	Initial varus deformity (deg)	Post-op varus deformity (deg)	Union period (mos)	Latest varus deformity (deg)	Function outcome of the knee	Follow-up period (yrs)
1	Male/62	1.8	26	-2	4.5	2	Excellent	5.6
2	Male/29	1.6	19	0	3.5	1	Excellent	5.2
3	Female/34	1.5	16	2	3.5	3	Good	4.8
4	Male/45	2.4	22	-1	4.5	3	Good	4.6
5	Male/38	3.2	16	0	4.0	2	Good	4.3
6	Female/48	2.2	14	0	4.0	0	Good	4.0
7	Female/36	1.4	18	-2	3.5	0	Excellent	3.8
8	Male/64	2.6	22	2	4.0	2	Good	3.6
9	Male/29	1.9	18	-1	3.5	0	Excellent	3.5
10	Male/44	1.8	23	0	4.0	2	Good	3.4
11	Male/25	0.6	22	0	3.5	0	Excellent	3.2
12	Female/30	0.9	18	-2	3.5	-1	Excellent	3.0
13	Male/40	1.8	20	2	4.5	2	Good	2.8
14	Male/26	1.0	18	0	3.0	0	Excellent	2.8
15	Male/36	1.6	14	1	4.0	2	Good	2.6
16	Male/24	1.4	16	0	4.5	2	Good	2.4
17	Male/42	2.0	23	2	4.0	3	Good	2.2
18	Female/34	2.8	18	0	3.5	0	Fair	2.1
19	Male/48	1.8	22	2	4.0	1	Fair	1.9
20	Female/24	1.4	20	1	3.5	0	Good	1.8
21	Male/46	2.2	23	3	5.0	3	Good	1.7
22	Male/32	1.1	19	0	4.0	3	Good	1.7
23	Male/37	2.1	24	2	4.0	2	Good	1.5
24	Male/58	2.3	22	0	5.5	2	Good	1.4
25	Male/44	1.5	18	1	4.0	2	Good	1.2
26	Male/27	1.7	18	2	3.5	2	Good	1.1
27	Male/50	1.8	20	2	4.5	2	Good	1.1

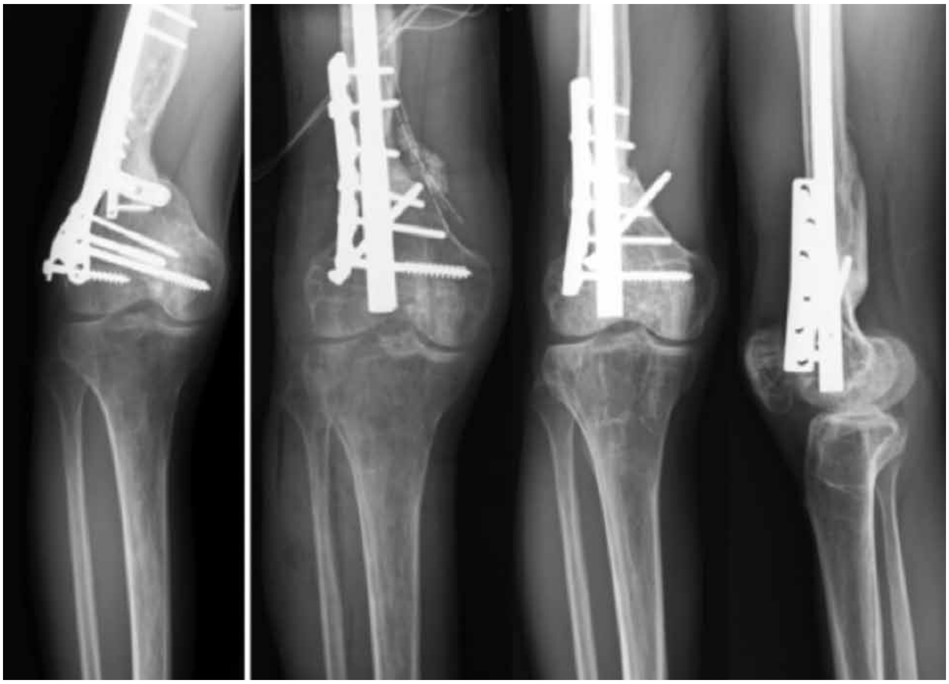

Fig. 3. Case 1. A 62-year-old man suffered varus malunion in the right femoral supracondylar region 1.8 years after condylar buttress plate treatment. The deformity was 26° varus. The varus malunion was treated with the described technique, and the osteotomized site healed at 4.5 months. Immediately postoperatively, the deformity was 2° valgus. At the 5.6-year follow-up, the deformity was 2° varus. The knee function was excellent.

Fig. 4. Case 4. A 45-year-old man suffered varus malunion of the left femoral supracondylar fracture 2.4 years after condylar buttress plate treatment. The deformity was 22° varus. The varus malunion was treated with the described technique, and the osteotomized site healed at 4.5 months. Immediately postoperatively, the deformity was 1° valgus. At the 4.5-year follow-up, the deformity was 3° varus. The knee function was good.

ally caused by huge compressive stresses in the medial aspect of the knee during ambulation, against which the implant cannot provide sufficient stability.[9,10] In the literature, most varus malunions of femoral supracondylar fractures are caused by CBP fixation.[7,8] However, despite this disadvantage, CBP is still widely used because of its technical simplicity, high union rates and the possibility of using a MIPPO technique.[5-8] In other words, similar situations may continue to occur.

Once a varus deformity is formed, the medial compartment of the knee will suffer more compressive stress in the stance phase of a gait cycle. Normally, the knee sustains compressive loads of 3 to 5 times body weight during walking, and 60 to 75% of these loads are borne through the medial compartment of the knee.[23-26] To prevent deterioration of the knee, correcting the varus deformity so as to share the compressive stresses with the lateral compartment should be the most reasonable treatment principle.[11,12] In this study, all severe varus knees were corrected to near-normal alignment and satisfactory knee function was achieved. Theoretically, over-correction to a mild valgus alignment may be more favorable.

Generally, when the prior plate is removed and the knee alignment is adjusted, the ragged, eroded, and uneven lateral cortex may greatly restrict the adequate placement of a new plate.[1,13,27] Furthermore, prior screw holes may endanger the screw stability of a new plate. In this situation, bone cement is sometimes added to reinforce the fixation stability.[6,28] However, this may greatly increase the technical difficulty. Using retrograde locked nailing may avoid the disadvantages related to the lateral cortex and screw holes.

This technique simplifies realignment of the lower extremity. The angle formed by the first cutting line and the line perpendicular to the medial cortex is equal to the designed correction angle. The second cutting line is parallel to the line perpendicular to the medial cortex. Therefore, once the second cutting line is moved close to the first cutting line, the desired correction angle is achieved. However, we cannot ignore the fact that the distal femoral segment must be pushed medially to prepare for insertion of a rigid guide wire. The proximal femur is more laterally located than the distal femur (6° to 7° valgus of the anatomic axis).[29,30] When the distal femoral segment is internally rotated, the retrograde rigid guide wire will impact the lateral cortex of the proximal femoral segment if the distal femoral segment is not displaced medially. Medial displacement of the distal femoral segment has the additional advantage of preventing femoral shortening. Because the medial cortex is distal to the lateral cortex in the proximal femoral segment after the first cut, the femur can be lengthened by pushing the distal femoral segment. In this study, the LLD improved at the latest follow-up in comparison to the preoperative measurements ($p<0.001$). The other advantage of this technique is that the resected bone can be used as bone graft and packed in the defects of the osteotomy site to eliminate the gap.

When malunion in the supracondylar region of the femur occurs, the marrow cavity in this region may be unavoidably obliterated. Recanalization to restore the endosteal vascularity is critical for fracture healing.[31,32] Retrograde locked nailing can reestablish the endosteal vascularity and provide fragment stability for axial compression and bending.[33,34] Nevertheless, the torsional stability provided by retrograde dynamic locked nailing (three-point fixation principle) may be insufficient.[35] Because the marrow cavity of the proximal femoral segment around the osteotomy site is normally obliterated in plate fixation, a complete reduction of the proximal and distal segments may not be possible.[36] In this study, a humeral buttress or dynamic compression plate was sometimes added to reinforce the torsional stability and was highly successful.[13] However, tissue adhesion around the osteotomy site is largely prominent and rotating the fragments to realign the axis for retrograde nail insertion can achieve a sufficient torsional stability. Plate augmentation is not always necessary.

In this study, a traditional femoral locked nail was used to replace a standard supracondylar nail. A standard supracondylar nail is typically short and insertion of the upper locked screws requires no image intensifier[37] and is normally used in a static mode. The most serious disadvantage of this device is that it creates a stress riser on the contact surface of the nail end and the anterior femoral cortex. A second fracture may occur before the first fracture heals. It has been recommended that the nail end reaches the level of the lesser trochanter.[38] Thus, insertion of the upper locked screws becomes much more complex and an image intensifier must be used. In addition, the standard supracondylar nail is costly. In this study, a traditional femoral locked nail with short plate augmentation has achieved a high success rate.

Articles reporting the treatment of femoral supracondylar malunions are few and none report the use of retrograde locked nailing to treat femoral supracondylar malunion.[16] Therefore, the present study cannot be comprehensively compared in terms of its superiority among various surgical techniques. Retrograde locked nails are biomechanically considered superior to CBPs and angled blade plates but comparable to dynamic condylar screws and locking plates for unstable supracondylar fractures.[7,33,34,39] As described above, the techniques of plate application are more complex than those of retrograde locked nails in supracondylar malunion.[1,13,27] In this study, the osteotomy technique was further simplified and a high success rate was achieved.

The limitations of this study include the fact that the small sample size was not suitable for a prospective randomized or cohort comparison of various techniques. Therefore, the conclusions may be non-objective. However, based on clinical and theoretical considerations, this technique should be feasible for achieving a high success rate. Additionally, it was not clear whether this technique can be applied to varus malunion of femoral supracondylar fractures after treatment by other devices. Theoretically, the answer should be positive, but clinical trials are still necessary.

In conclusion, retrograde locked intramedullary nailing may be an excellent alternative for treatment of varus malunion of femoral supracondylar fractures after CBP treatment. The technique is not complex and the satisfaction rate is high.

Conflicts of Interest: No conflicts declared.

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