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ORIGINAL ARTICLE

Bicondylar tibial plateau fracture treated by open reduction and fixation with unilateral locked plating

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Abstract The management of bicondylar tibial plateau fractures is challenging. A lateral locking plate offers an alternative method to traditional dual plating to avoid further stripping of soft tissue. Nevertheless, the rate of malreduction and fixation loss remains high. From 2007 to 2009, we performed open reduction and fixation with unilateral locked plating to directly reduce the fracture in 15 patients with bicondylar plateau fracture. The average follow-up duration was 16.2 months (range: 12–30 months), and the average age of the patients was 43 years (range: 19–64 years). All fractures were Orthopaedic Trauma Association type 41-C. Postoperative radiographic alignment was evaluated immediately and at 2–4 weeks, 8–12 weeks, 5–7 months, and 11–13 months. Both Oxford knee score and Hospital for Special Surgery knee score were used to evaluate functional outcomes. The average duration within which union was achieved was 4.8 months (range: 2–10 months). One patient incurred wound dehiscence; however, there was no case of deep infection. Malreduction occurred in one patient (6.7%) while fixation loss occurred in three patients (20%) with subsidence of the posteromedial fragment and varus malalignment. Despite the malreduction rate being lower in our study than in previous studies involving unilateral locked plating, a high rate of fixation loss was recorded. Per our limited experience, we believe that unilateral locked plating may have limitations in patients with selective patterns of bicondylar tibial plateau fractures.

Introduction

Bicondylar tibial plateau fractures usually occur in a bimodal age distribution. In young patients, high-energy trauma results in comminuted fractures and severe soft tissue damage,

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whereas in older patients, comminution and soft tissue injury arise mainly from poor bone quality and thin skin. Surgical fixation of bicondylar tibial plateau fractures is challenging because of geographic complexity and compromise of the soft tissue envelope. Treatment goals include preservation of soft tissues, restoration of articular congruity, and correction of anatomic alignment in the lower extremities.

Adequate fixation and early achievement of postoperative range of motion are important for a good prognosis and adequate postoperative functioning. Buttressing of both the medial and lateral compartments with conventional double plating is the gold standard for managing bicondylar fractures because this may provide sufficiently rigid fixation to prevent medial collapse and subsequent varus deformity. However, this may require excessive dissection through injured soft tissue, leading to wound complications or compromised osteosynthesis [1–3]. Nonlocked unilateral buttress plating with lag screw fixation has the advantage of less stripping of soft tissue. However, poor bony purchase by lag screws due to comminution and the natural characteristics of cancellous bone lead to further widening of the joint surface and displacement of fragments.

Introduction of advanced instrumentation, such as locking plate systems, and techniques for internal fixation, such as minimally invasive plate osteosynthesis (MIPO), have changed the nature of treatment for these fractures over the last decade [4]. MIPO, with its key benefit of preserving the intact soft tissue envelope, is the representative biological plate technique. The less invasive stabilization system (LISS) developed by Synthes is representative of locking plates that offer multiple points of fixed-angle contact between the plate and screws, aiming to decrease the tendency toward angular deformity. A lateral locking plate can provide adequate stability for comminuted or osteoporotic plateau fractures and may offer an alternative to additional medial buttressing, thus avoiding further stripping of soft tissue [5–8]. Nevertheless, these series revealed a higher rate of malreduction and fixation with unilateral locked plating using the LISS technique than with conventional double plating.

In this study, we used open reduction and fixation with unilateral locked screw plating to treat bicondylar tibial plateau fractures and evaluated the rates of malreduction, fixation loss, and other complications. Comparing the findings of our study with those of previous studies on LISS may further address the clinical effectiveness of unilateral locked plating in the management of bicondylar tibial plateau fractures.

Materials and methods

From 2007 to 2009, 65 patients with 65 tibial plateau fractures were operated on at Kaohsiung Medical University Hospital. Of these, the records of 15 patients [15 fractures (7 males and 8 females); mean age: 43 years (range: 19–64 years)] were retrospectively reviewed after applying the following inclusion criteria: the presence of an acute high-energy bicondylar tibial plateau fracture classified as Schatzker V or VI, age >18 years, use of a unilateral locking plate, and completion of a minimum 1-year follow-up. Patients with a history of prior tibial infection were excluded.

All fractures were Orthopaedic Trauma Association type 41-C. Four patients had open fractures (26.7%), including three Gustilo type IIIC fractures and one Gustilo type IIIB fracture. Four patients had multiple fractures. The demographic data of the patients are presented in Table 1.

Open reduction and definite fixation was performed within 12 hours of injury or after soft tissue swelling had subsided. A tourniquet (300 mmHg pressure) was used. The

Table 1 Preoperative data of the included patients.

Case	Age (y)	Gender	BMI	Smoking	Multiple trauma	Gustilo class	Schatzker class	OTA class	Follow-up (mo)	Pre-OP stay (d)	Combine injury
1	27	M	22.2	Y	Y	IIIB	6	41-C2	21	15	Subdural hemorrhage, left facial palsy
2	61	F	26.6	N	N	Closed	6	41-C3	30	0	Lateral meniscus tear
3	62	F	21.4	N	N	IIIC	6	41-C2	14	0	Nil
4	42	F	24.46	N	N	Closed	5	41-C1	30	0	Nil
5	32	M	18.9	N	N	IIIC	6	41-C2	12	12	Compartment syndrome
6	23	M	17.3	N	Y	IIIC	6	41-C2	18	16	Right deep peroneal nerve injury
7	46	M	22.5	N	N	Closed	6	41-C3	13	7	Compartment syndrome
8	59	M	26	N	Y	Closed	6	41-C3	15	6	Compartment syndrome
9	64	F	23	N	N	Closed	5	41-C1	12	3	Nil
10	19	M	21.7	N	N	Closed	6	41-C3	16	5	Nil
11	20	F	22.4	N	N	Closed	6	41-C2	15	3	Nil
12	38	M	24.45	Y	N	Closed	6	41-C3	12	7	Nil
13	47	F	30	N	N	Closed	6	41-C1	15	6	Nil
14	62	F	25.84	N	N	Closed	6	41-C2	12	0	Nil
15	44	F	18.9	N	N	Closed	6	41-C1	12	0	Nil
Average/ percentage	43		23.04	13.3%	20%				16.47	5.3	

BMI = body mass index; OP = operation; OTA = Orthopaedic Trauma Association.

Table 2 Intraoperative and postoperative data of the included patients.

Case	Lag screw(s)	Bone graft	OP duration	Blood loss (mL)	Hospital stay (d)	Post-OP MPTA	Post-OP PPTA	Union time (mo)	Range of motion (extension to flexion)	Oxford score	HSS	Complication(s)
1	0	Allograft	02:50	80	22	85.7	11.1	6	3—135	43	94	N
2	3	N	02:30	50	7	88.3	4.9	5	5—130	36	86	N
3	0	N	02:20	50	12	86.8	6.2	3	8—135	36	88	N
4	1	Allograft	02:35	200	8	83.3	5.2	6	3—140	41	92	N
5	0	Allograft	02:30	150	20	85.4	5.7	4	5—145	44	94	N
6	1	N	06:35	550	30	85.9	10.3	6	0—145	42	94	N
7	3	N	03:30	525	19	94	16.1	4	10—130	34	78	N
8	2	Allograft	04:10	70	17	91.5	7	10	8—125	35	84	N
9	0	Allograft	03:05	40	13	90.9	7.7	3	5—135	35	78	N
10	4	Allograft	02:35	50	12	92	7.2	4	0—140	46	96	N
11	0	Allograft	03:50	100	12	84	6.9	6	0—135	44	96	Poor wound healing
12	0	N	02:35	50	13	84.2	7.4	4	0—140	40	92	N
13	0	Artificial graft	04:20	200	13	85.3	9.2	4	3—140	36	88	N
14	0	Allograft	03:40	50	9	87.4	8.3	4	5—135	41	94	N
15	0	N	01:50	10	7	84.2	7.7	2	3—135	40	90	N
Average/ percentage	40%	60%	03:15	145	14	87.3	8.1	4.7 (4.4)[a]	3.9—136.3	39.5	89.6	6.7%

HSS = Hospital for Special Surgery; MPTA = medial proximal tibial angle; OP = operation; PPTA = posterior proximal tibial angle.
[a] Average union time except for the delayed-union case.

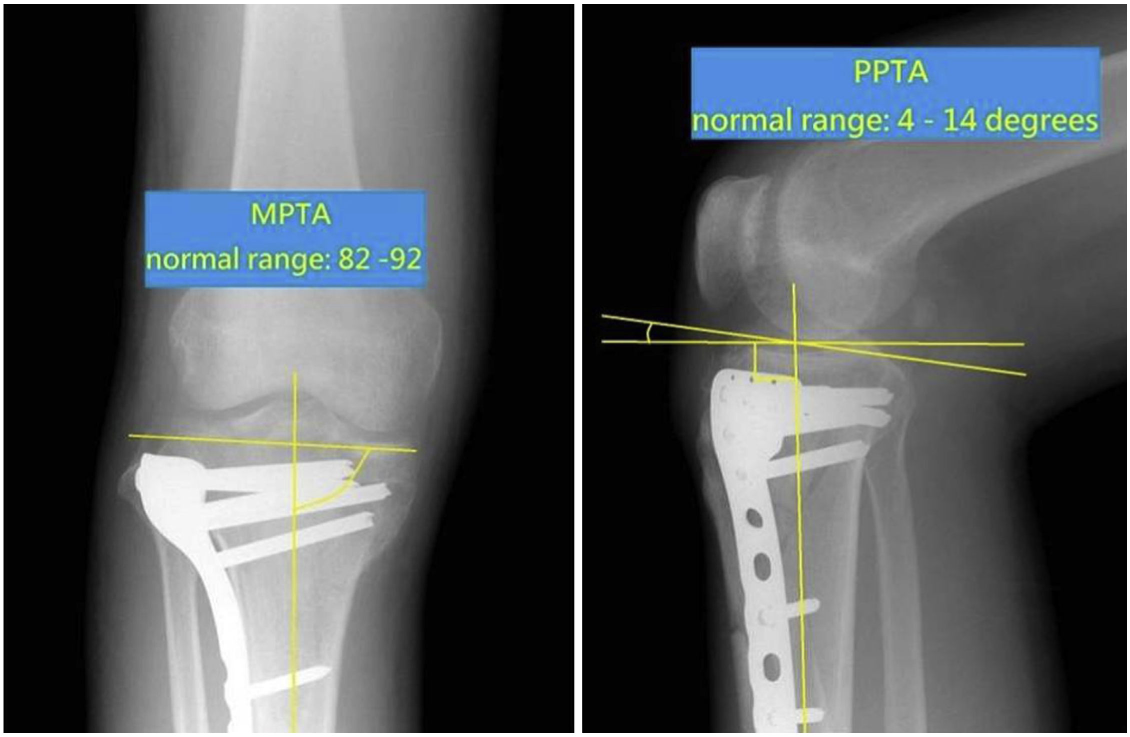

Figure 1. The method of radiographic measurement on the anteroposterior and lateral X-rays of the knee. MPTA = medial proximal tibia angle; PPTA = posterior proximal tibia angle.

unilateral anterolateral approach was employed for all patients. Reduction of the lateral articular surface was directly assessed by elevating the lateral meniscus from the anterior horn. Intraoperative fluoroscopy was used for assessment of the medial joint surface and alignment of the reduction throughout surgery. Depression of the joint surface was addressed by impacting subchondral bone through the created bony window or fracture gap. Temporary pin fixation was applied to maintain the joint surface, and this acted as a guide for plate placement. Bone defects were filled with allogenous cancellous bone graft or graft substitute. A unilateral locking plate was placed over the lateral aspect of the tibia for fixation. Additional lag screws for fixation or buttressing at the medial condyle were placed for large medial fragments via small incisions. Medial buttress plating was not used in order to prevent excessive stripping of soft tissue. The surgical details are shown in Table 2.

Postoperative long-leg splinting was maintained for 2 weeks. Rehabilitation began during hospitalization using continuous passive motion devices twice daily with temporary removal of the splint. A shift to long-leg casting or hinged-knee bracing was then suggested for knee immobilization in full extension for another 2 weeks. Isometric muscle exercises and ankle pumping were also encouraged. Active range of motion was initiated 4 weeks after surgery. Partial weight-bearing was forbidden until callus formation was radiographically observed (usually 2—3 months after surgery). Radiographs were obtained at each follow-up visit at 2—4 weeks, 8—12 weeks, 5—7 months, and 11—13 months. Wound status was also clinically assessed at each follow-up.

All radiographic images were reviewed and analyzed by the picture archiving and communication system. Anteroposterior radiographs were used to measure the medial proximal tibial angle (MPTA) in the coronal plane (normal range: 82°—92°). In the sagittal plane, we measured the posterior proximal tibial angle (PPTA; normal range: 4°—14°) using a lateral view of the knee. These angles were measured according to Freedman and Johnson (Fig. 1) [9]. Malreduction was defined as postoperative alignment that exceeded the normal range of MPTA or PPTA. An increase in malalignment of more than 5° from the malalignment observed on initial postoperative radiographs was defined as fixation loss.

We used the new Oxford knee scoring system [10,11] and the Hospital for Special Surgery knee score (HSS score) [12] to evaluate functional outcome at 1 year after surgery.

Results

The average predefined surgery stay was 5.3 days (range: 0—16 days). Three patients (20%) had compartment syndrome and required urgent fasciotomy. The average delay in definite fixation after fasciotomy was 8.3 days (range: 6—12 days). Four patients with open fracture were initially managed with debridement. The average delay in definite surgery was 10.8 days (range: 0—16 days) for these patients so that open wounds could be managed until infection was brought under control. One patient had subdural hemorrhage and underwent preoperative intensive care, followed by observation for 15 days until vital signs were stable.

During surgery, the bone defects were filled with allogenous bone graft in eight patients (53.3%) and artificial bone graft in one patient (6.7%). Lag screws were used in six patients (40%). The average surgical duration was 3.3 hours (range: 1.8—6.6 hours). The average intraoperative blood loss was 145 mL, mainly from hematoma around the fracture site. Malreduction occurred in only one patient (#7; 6.7%); MPTA and PPTA were outside the normal range in this patient because of inadequate reduction of the posteromedial fragment (Fig. 2).

After follow-up for an average of 16.2 months (range: 12—30 months), it was observed that all patients had achieved union within an average duration of 4.8 months (range: 2—10 months). One patient (#8) achieved radiographic union only at the 10th month, albeit without secondary procedures. If this patient was excluded, the average union time was 4.4 months. One patient (#11) incurred the complication of wound dehiscence that required secondary closure; however, deep infection was not recorded in any patients. The mean knee extension was 3.9° (range: 0°—10°), whereas the mean knee flexion was 136.3° (range: 125°—145°) at the most recent follow-up. According to Oxford knee scoring, five patients (33.3%) were classified as excellent (>41) while the remaining 10 (66.7%) were classified as good (34—41). The average HSS score was 89.6 (range: 78—96; Table 2).

During follow-up, fixation loss was observed in three patients (#1, 8, 11; 20%; Table 3) with an average age of 35.3 years and an average time to union of 7.3 months (range: 6—10 months). Most deformed alignments were found at 8—12 weeks after surgery when partial weight-bearing commenced. Fixation loss was mainly due to

Figure 2. (A) Preoperative radiographic presentation of patient #7. (B) Postoperative anteroposterior and lateral X-rays of the knee revealed malalignment. MPTA = medial proximal tibia angle; PPTA = posterior proximal tibia angle.

Table 3 Cases with loss of reduction.

	Coronal plane	Sagittal plane	Displaced fragment
Case 1	Varus	Posterior slope↑	Medial metaphyseal comminution
Case 8	Varus	—	Posteromedial fragment
Case 11	Varus	Posterior slope↑	Medial metaphyseal comminution

subsidence of the posteromedial fragment or varus alignment as a result of comminution of the medial metaphysis. Two patients (#1 and #11) had a larger posterior plateau slope (Figs. 3—5).

Discussion

The rationale for using a unilateral locking plate for bicondylar tibial plateau fractures includes prevention of

Figure 3. (A) Preoperative radiographic presentation of patient #1. (B) Postoperative anteroposterior and lateral X-rays of follow-up revealed loss of fixation with increased medial proximal tibia angle and posterior proximal tibia angle.

Figure 4. (A) Preoperative radiographic presentation of patient #8. (B) Postoperative anteroposterior and lateral X-rays of follow-up revealed loss of fixation with varus alignment.

a second incision wound, reduced stripping of the medial periosteum, and provision of sufficient stability for certain fracture patterns. Although Egol et al. proposed in a biomechanical study that the LISS plating system can provide stability equal to that of double plating [5], the rate of malreduction and fixation loss in a clinical series was still high (Table 4) [6,13–15]. We assumed that high malreduction rates may result from difficulties in gross evaluation of alignment and the articular surface under intraoperative fluoroscopy or from inexperience in using the reduction technique with LISS.

In order to assess articular step-off easily, we used the open reduction method to achieve adequate exposure of the fragments and articular surface. A portable radiological unit was used to recheck gross alignment during surgery, and we believe that the use of this device and the open method were helpful in lowering the incidence of malreduction. To the best of our knowledge, no series has investigated the efficiency of open reduction with unilateral locked plating for bicondylar tibial plateau fractures. Compared with previous studies using minimally invasive techniques, we successfully decreased the rate of postoperative malalignment, as observed on postoperative radiographs (Table 4). Although the open reduction method may involve a larger incision wound, more intraoperative dissection, and greater blood loss, we recorded only one patient with superficial wound infection and one patient with delayed union. The open reduction method appeared to result in a low rate of wound complications or nonunion in our study. In addition, postoperative functional outcome

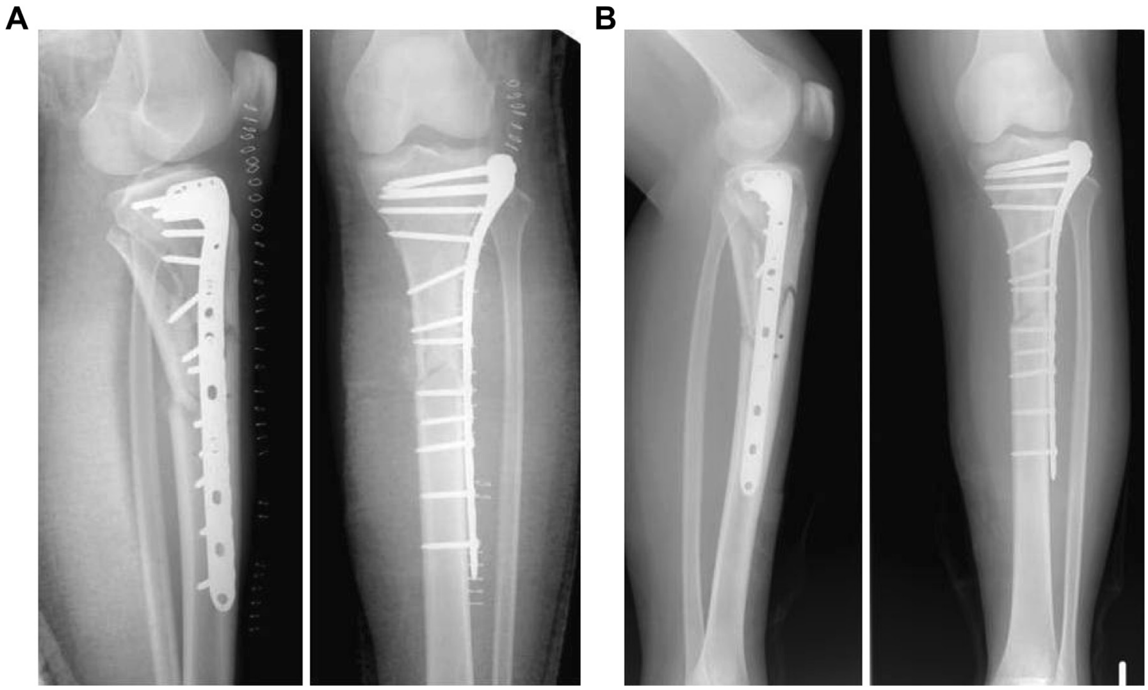

Figure 5. (A) Immediate postoperative radiographic presentation of patient #11.(B) Follow-up lateral (right) and anteroposterior (left) X-rays revealed loss of fixation with increased medial proximal tibia angle and posterior proximal tibia angle.

was good-to-excellent according to the Oxford scores. In spite of reviewing only 15 patients in this study, we can infer that the results of open reduction and fixation are clinically and functionally comparable with those of the minimally invasive method.

It was unfortunate that the incidence rate of fixation loss was still high in our study (20%), despite the relatively low initial malreduction rate. We suggest several possible reasons. First, unilateral locked plating may not allow sufficient stability in all bicondylar tibial plateau fractures. Locking plates are designed as fixed-angle internal fixation constructs, and their limited ability to alter the angle of the screw makes it difficult to fix fragments with certain geographic variations. With regard to fracture morphology in our patients with fixation loss, the medial component or posteromedial fragment was the most commonly displaced fragment with varus alignment (Table 3). The significance of posteromedial fragments in bicondylar tibial plateau fractures was recently addressed in the literature although both incidence and subsequent displacement are usually underestimated. Barei et al. and Higgins et al. reported that the incidence rate of posteromedial fragments in patients with bicondylar tibial plateau fractures was 28.8—59% [16,17]. The presentation of posteromedial fragments makes reduction and fixation of complex plateau fractures more difficult, especially when a single fixed-angle plate is used. Some biomechanical studies have proved that the stability of fixation of a posteromedial fragment with a lateral locking plate is weaker than that with conventional lateral plating with a posteromedial buttress plate [18,19]. Some authors have proposed different approaches and reduction methods to treat posteromedial fragments in complex plateau fractures, specifically for more secure fixation [20—23]. Evidence of the incidence of fixation loss encountered in our study may further address the weakness of the lateral locking plate system in treating bicondylar tibial plateau fractures with posteromedial fragments. Second, delayed fracture union may increase the incidence of fixation loss and implant failure. Patients with reduction loss had a much longer union time (7.3 months) than those without (4.1 months) in our study. Soft tissue damage, a comminuted fracture pattern, poor bone quality, and the timing of weight-bearing may all play key roles.

Before definite fixation, patient #1 underwent debridement for a Gustilo type II open fracture and

Table 4 Comparison of related series of bicondylar plateau fractures with unilateral locked plating.

Study	Case number	Malreduction	Nonunion/delayed union	Loss of fixation	Wound problem
Cole et al (2003) [13]	77	13 (17%)	2 (3%)	2 (3%)	3 (4%)
Stannard et al (2004) [6]	34	2 (5.8%)	0	No record	2 (5.8%)
Gosling et al (2005) [7]	62	16 (25.8%)	1 (1.6%)	9 (14.5%)	4 (6.5%)
Phisitkul et al (2007) [15]	37	7 (22%)	0	3 (8%)	7 (22%)
This study	15	1 (6.67%)	1 (6.67%)	3 (20%)	1 (6.67%)

patient #8 underwent fasciotomy for compartment syndrome. Case #11 had a postoperative wound complication that required secondary closure. All the three patients had suffered considerable damage to their soft tissues. Initial severe soft tissue damage or intraoperative overstripping may result in a loss of vascular supply and increase the rates of infection or poor healing. Careful and staged management of plateau fractures with soft tissue damage is of great importance. In our series, staged treatment was arranged to observe and manage the condition of the soft tissues. Although there was no deep infection in the patients with fixation loss, delayed union still occurred.

A comminuted fracture pattern and bony defects are key factors in delayed union. Bone graft substitutes are commonly used to augment bone healing and reconstruct skeletal defects. We used allografts in the patients with fixation loss to decrease the gap between fragments. Although the use of allografts can avoid donor-site morbidity, the use of autogenous cancellous bone grafts remains the gold standard because of the latter's ability to induce osteogenesis, osteoinduction, and osteoconduction. The use of autografts may accelerate the process of bone healing and prevent delayed union and fixation loss.

The timing of weight-bearing after surgical fixation of fractures may also affect the maintenance of reduction. Per our protocol, weight-bearing is not permitted until radiographic proof of callus formation is obtained. However, patient noncompliance and incorrect radiographic interpretation can lead to inappropriate loading before the fracture is adequately healed. We believe that prolonged nonweight-bearing may be necessary for patients whose fracture gap exists with a comminuted pattern or patients whose soft tissue status is unfavorable.

The limitation of this study was that the number of patients was insufficient to demonstrate statistical significance. Because of the inferior results obtained for unilateral locked plating in patients with bicondylar tibial plateau fractures, we no longer use this method.

Conclusion

Although the minimally invasive method of locked plating has become popular for managing osteopenic, comminuted, or periarticular fractures, limitations still exist. The LISS technique may decrease the amount of stripping of the soft tissue envelope, but there is a learning curve involved in the use of this technique to reduce fractures with limited fragment exposure. In our series, we used the open reduction method to keep the malreduction rate to the minimum, and functional outcome was comparable with that of LISS. However, the incidence of fixation loss remained high, especially in patients with posteromedial fragments. According to our experience with the limited number of patients in this study, we consider that locked plating has its limitations with regard to certain patterns of bicondylar tibial plateau fracture, especially in the presence of medial metaphyseal comminution of the posteromedial fragment. Supplementary medial buttress plating may be necessary in such cases.

Acknowledgments

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