



Lateral Locked Plating or Dual Plating: A Comparison of Two Methods in Simple Bicondylar Tibial Plateau Fractures

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Background: In this study, our aim was to compare the results of the dual locking plate fixation technique and lateral locking plate fixation technique for tibial bicondylar plateau fractures without posteromedial fragment.

Methods: We evaluated 20 patients who underwent surgical treatment due to bicondylar tibial plateau fracture between 2010 and 2015. Ten patients were included in group 1, in which a dual locking plate was employed, whereas 10 patients were included in group 2, in which a lateral locking plate was used. In both groups, functional and clinical outcomes after treatment were rated according to the Knee Society Knee Scoring System, Rasmussen functional score, and Rasmussen radiological score.

Results: The mean follow-up time was 24 months. There were no significant differences between the groups with respect to functional and radiographic outcomes at the final follow-up.

Conclusions: In bicondylar tibial plateau fractures without posteromedial fragment, the lateral locking plate fixation technique showed the similar clinical and radiological outcomes as the dual locking plate fixation technique.

Keywords: *Bicondylar tibial plateau, Fracture, Locking plate fixation, Dual plate, Single plate*

Treatment of complex tibial plateau fractures is technically difficult and controversial.¹⁻⁴⁾ Serious intra-articular damage and soft tissue injury or inappropriate treatment can lead to postoperative complications such as infection, skin necrosis, nonunion, deformity, and arthrosis in tibial plateau fractures.^{1,5,6)} The goal in the treatment of tibial plateau fractures is to provide anatomic reduction of intra-articular fracture fragments while providing stability.¹⁻⁴⁾ Many different techniques of internal and external fixation are used to treat these fractures.²⁻⁸⁾

The bilateral open reduction and internal fixation technique have been favored by the Association for Osteosynthesis/Association for the Study of Internal Fixation.³⁾ However, bilateral plating may require excessive dissection through the injured soft tissue, leading to wound complications or compromised osteosynthesis.^{1,3,5,8)} A minimally invasive surgical approach is desirable for reducing the additional soft tissue trauma.^{1,3)} Some authors claimed bicondylar tibial plateau fractures can be stabilized with unilateral locked plating technique while avoiding medial soft tissue dissection.^{1,3,9-13)} This reduces complications associated with bilateral plate fixation, but it is unclear whether it will maintain the acquired articular reduction compared to bilateral plate fixation.^{3,9-13)} Dual locking plate fixation technique and lateral locking plate fixation technique used for tibial bicondylar plateau fractures as cited in the literature are shown in Table 1.^{9,11,14,15)}

In a biomechanical study, it was reported that

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Table 1. Studies Available in the Literature on the Comparison of Bicondylar Plateau Fractures with Unilateral Locked Plating and Dual Plating (2000–2017)

Study	No. of patients		Mean age (yr)		Follow-up (mo)	Type of fracture (AO classification)		Plate type		Union rate (%)		Complication (infection, deep venous thrombosis, failure of fixation, nonunion; %)		Knee score	
	SP	DP	SP	DP		SP	DP	SP	DP	SP	DP	SP	DP	SP	DP
Jiang et al. (2008) ⁽¹⁾	41	43	41	43	24	C1, 8; C2, 19; C3, 16	C1, 5; C2, 16; C3, 22	LISS	M, buttress plate; L, LC-DCP	100	97.7	63.4	48.8	HSS, 83	HSS, 83
Lee et al. (2014) ⁽⁴⁾	15	19	49	53	18	S (V/VI), 8/7	CDP: S (V/VI), 13/6; HDP: S (V/VI), 4/7	LCP	CDP: M and L, buttress plate; HDP: L, LCP; M, buttress plate	86	CDP, 78; HDP, 90	40	CDP, 47; HDP, 27	WOMAC, 36	WOMAC, 34; WOMAC, 32
Yao et al. (2015) ⁽⁹⁾	41	44	43	45	12–36	C1, 26; C2, 10; C3, 5	C1, 24; C2, 13; C3, 7	LCP	M and L, buttress plate	100	100	4.8	27.2	HSS, 81	HSS, 79
Neogi et al. (2015) ⁽⁵⁾	29	32	41	37	12–24	C1, 10; C2, 11; C3, 8	C1, 11; C2, 13; C3, 8	LCP	M, RP/DCP/DRP; L, LCP	100	100	65.5	50	HSS, 79	HSS, 80

SP: single lateral locking plate, DP: dual plate, LISS: Less Invasive Stabilization System, M: medial side, L: lateral side, LC-DCP: limited-contact dynamic compression plate, HSS: Hospital for Special Surgery score, CDP: classic dual plate, HDP: hybrid dual plate, S: Schatzker classification, LCP: locking compression plate, WOMAC: The Western Ontario and McMaster Universities Osteoarthritis Index, RP: reconstruction plate, DRP: distal end radius plate.

unilateral buttress plate fixation in a bicondylar fracture model resulted in a greater reduction loss in the medial plateau than axial loading than double plate fixation did.¹⁶⁾ This may lead to pain and osteoarthritic changes in later processes. On the other hand, in other bicondylar fracture modeled biomechanical studies, there was no difference between the two methods.^{3,10,13,17)}

The hypothesis of this study was that, in selected tibial plateau fractures, lateral locking plating technique would yield clinical and radiological results comparable to those of dual locking plating technique. Therefore, in this study, our aim was to compare the results of dual locking plate fixation technique and lateral locking plate fixation technique for tibial bicondylar plateau fractures without posteromedial fragment.

METHODS

Clinical Data

We retrospectively evaluated 20 patients who underwent surgical treatment due to bicondylar tibial plateau fracture between 2010 and 2015. Ten patients (seven males and three females; five right knees and five left knees; mean age, 51.3 years; range, 34 to 73 years) were included in group 1, in which a dual locking plate was employed, whereas 10 patients (eight males and two females; five right knees and five left knees; mean age, 51.2 years; range, 25 to 83 years) were included in group 2, in which a lateral locking-plate was used (Figs. 1 and 2).

Inclusion and Exclusion Criteria

Inclusion criteria were the presence of a bicondylar tibial plateau fracture (Schatzker V–VI) without posteromedial fragment. Pathologic, pediatric, extra-articular proximal tibial fractures, and serious open fractures (Gustilo grade III) were all excluded.

Operative Procedure

All operations were performed under spinal anesthesia by using pneumatic tourniquet. In dual plating group, antero-lateral and anteromedial incisions were made. After soft tissue dissection, under longitudinal traction, the joint line congruity was checked with C-arm fluoroscopy. If there was need for arthrotomy, it was performed through the lateral incision to gain anatomic reduction via submeniscal view. By using locking screws and plate, definitive fixation was obtained. The medial plate was placed in the epiphyseal-metaphyseal region or metaphyseal-diaphyseal region depending on the fracture pattern. In single lateral plating group, we just made an anterolateral incision. The

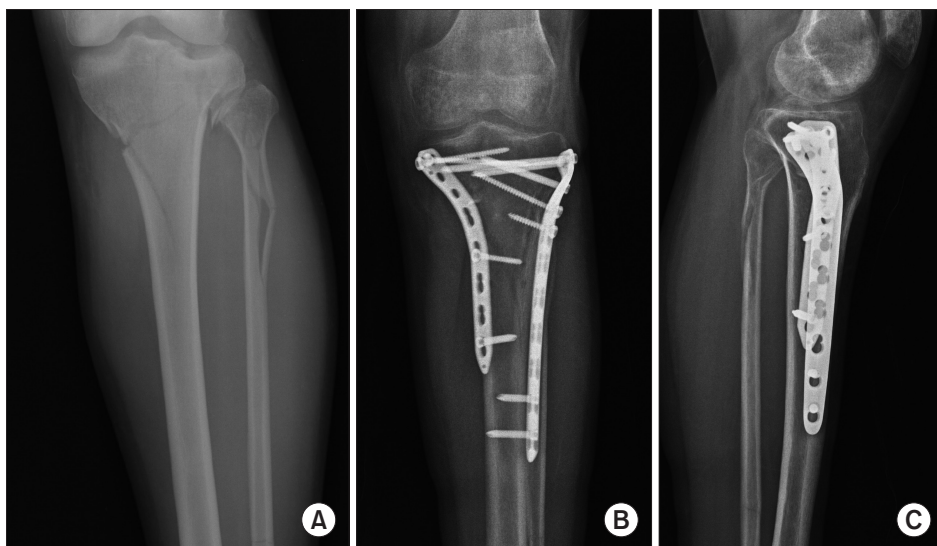


Fig. 1. (A) Preoperative radiograph showing left tibial plateau fracture in a 36-year-old male patient. (B, C) Radiographs taken 21 months after dual locking plate fixation.

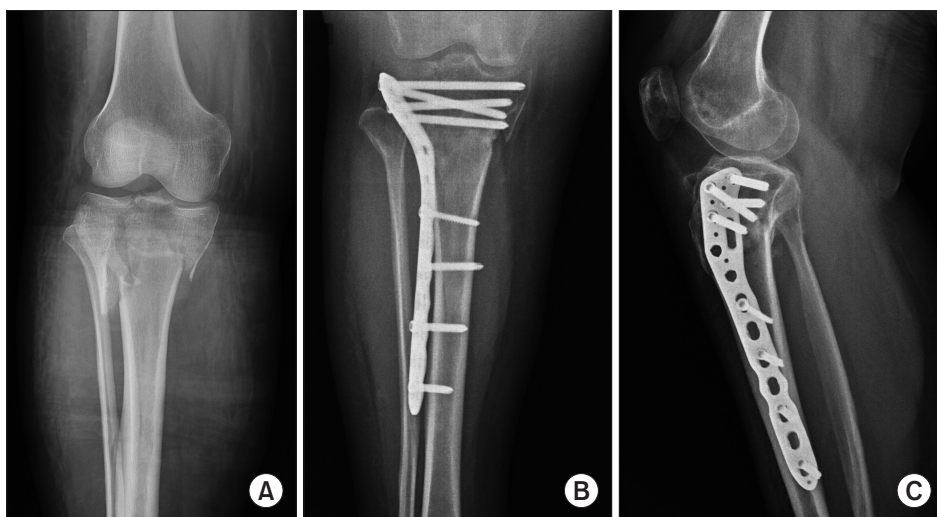


Fig. 2. (A) Preoperative radiograph showing right tibial plateau fracture in a 36-year-old female patient. (B, C) Radiographs taken 14 months after lateral locking plate fixation.

next steps were the same as in dual plating group. In this group, we used the subchondral screws as long as possible to secure medial part of the tibia. The choice of fixation technique (either dual plate fixation [HGK] or lateral plate fixation [CK]) was based on surgeon's preference.

First-generation cephalosporin for antibiotic prophylaxis and low molecular weight heparin for venous thromboembolism were used 24 hours and 3 weeks, respectively. All patients were encouraged to perform active and passive range of motion exercises in the 2nd postoperative week after suture removal at the outpatient clinic under the supervision by a physiotherapist.

Clinical and Radiographic Evaluation

In both groups, functional and clinical outcomes after treatment were rated according to the Knee Society Knee

Scoring System (KSS), Rasmussen functional score (RFS), Rasmussen radiological score (RRS).^{18,19} Radiographic healing was defined as callus bridging of three of four cortices on anteroposterior and lateral radiographs as well as painless weight bearing on the affected extremity.²⁰ Radiological assessments were performed in a comparative manner with the contralateral side.

Radiographic examination included coronal alignment of the proximal tibia, medial proximal tibial angle (MPTA), tibiofemoral anatomic angle (TFAA), sagittal alignment, and proximal posterior tibial angle (PPTA). Radiological measurements were carried out from immediately postoperatively to the last visit at the outpatient clinic with 3-month intervals. The last clinical and radiological evaluations were performed at final follow-up.

Statistical Analysis

Statistical analysis was performed using IBM SPSS ver. 22.0 (IBM Corp., Armonk, NY, USA). Fisher's exact test and Pearson chi-square test were used to compare categorical data between groups. Mann-Whitney *U*-test and Wilcoxon signed-rank test were used to compare continuous data. A $p < 0.05$ was considered statistically significant.

Ethical Approval

This study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki and informed written consent was obtained from all the patients. The protocol was reviewed and approved by the Institutional Review Board of Izmir Bozyaka Education and Research Hospital (No. 29.12.2015-5).

RESULTS

Patient characteristics are presented in Table 2. The mean follow-up time was 24 months (range, 13 to 56 months) in group 1 and 27.8 months (range, 15 to 54 months) in group 2 ($p = 0.761$). The most common cause of injury was a traffic accident in 11 patients (55%), fall from height in five patients (25%), simple fall in three patients (15%) and crush injury in one patient (5%). No significant difference was detected between group 1 and group 2 in terms of patient age, sex, fracture type, fracture side, time from

injury to operation ($p > 0.05$) (Table 2). Three of these fractures were open: two were Gustilo grade I and one was Gustilo grade II. Open fractures were initially managed with debridement and temporary fixation. The average delay in definitive surgery was 7.3 days (range, 6 to 9 days) in these patients. The bone defects were filled with allogeneous bone graft in one patient (10%) in group 2.

There were no significant difference between the groups with regard to KSS, RFS, RRS, VAS, and ROM at the final follow-up (Table 3). According to the KSS, we found four unsatisfactory results (two in group 1 and two in group 2, 20%); the remaining 16 cases were graded as good or excellent. Similarly, there were no significant intergroup differences in TFAA, MPTA, and PPTA at the final follow-up. However, there was a significant side-to-side difference in TFAA of group 2 ($p = 0.046$). Furthermore, we detected significant side-to-side difference in PPTA of group 1 ($p = 0.035$). We attributed this difference to intraoperative malreduction measured on immediate postoperative X-rays (Table 4).

All fractures were healed. There were no late or malunion cases. Partial and full weight-bearing were initiated 8 weeks and 12 weeks, respectively. The average time to radiological union was 14 weeks (range, 9 to 16 weeks). Late postoperative complications detected in group 1 were as follows: arthrosis in six patients (60%; Kellgren-Lawrence grade 1–3); flexion contracture in two patients (20%; 10° and 15°); extension contracture in one patients (10%; 10°), which occurred at the 5 mm tibial medial metaphyseal depression and a total knee arthroplasty was performed at 15 months postoperatively; and superficial incision site infection in one patient (10%), which was resolved with antibiotic therapy and wound care. Late complications detected in group 2 include arthrosis in four patients (40%; grade 1–3), flexion contracture in five patients (50%; range, 10°

Table 2. Demographic Characteristics

Variable	Group 1 (n = 10)	Group 2 (n = 10)	p-value
Age (yr)	51.3 (34–73)	51.2 (25–83)	0.880
Sex			1.000
Female	3	2	
Male	7	8	
AO classification			0.303
C1	4	1	
C2	6	9	
Side of involvement			1.000
Right	5	5	
Left	5	5	
Follow-up (mo)	24 (13–56)	27.8 (15–54)	0.761
Time from injury to surgery (day)	7.8 (3–15)	8.5 (4–15)	0.542

Values are presented as mean (range) or number.
Group 1: dual locking plate group, Group 2: lateral locking plate group.

Table 3. Functional Outcomes of Two Techniques

Variable	Group 1 (n = 10)	Group 2 (n = 10)	p-value
KSS	79.1 (49–100)	72.9 (30–94)	0.496
RFS	24.3 (16–30)	22.9 (17–28)	0.238
RRS	15.8 (10–18)	15.2 (6–18)	0.903
VAS	4.5 (0–9)	5.5 (2–9)	0.517
ROM (°)	120 (100–130)	119 (110–130)	0.430

Values are presented as mean (range).
Group 1: dual locking plate group, Group 2: lateral locking plate group, KSS: Knee Society Knee Scoring System, RFS: Rasmussen functional score, RRS: Rasmussen radiological score, VAS: visual analog scale, ROM: range of motion.

Table 4. Comparison of the Radiological Outcomes between Group 1 and Group 2 and between the Injured Side and the Uninjured Side in Each Group

Variable	Group 1 (n = 10)	p-value*	Group 2 (n = 10)	p-value*	p-value [†]
TFAA (°)		0.799		0.046	0.399
Fracture side, early postoperative	3.9 (2–6)		5.4 (2–13)		
Fracture side, last visit	3.9 (2–6)		5.6 (2–15)		
Normal side	4.0 (2–6)		3.3 (1–7)		
MPTA (°)		0.221		0.779	0.545
Fracture side, early postoperative	86.1 (82–89)		86 (81–90)		
Fracture side, last visit	86.8 (84–89)		86.3 (82–91)		
Normal side	87.2 (85–88)		86.1 (83–88)		
PPTA (°)		0.035		1.000	0.903
Fracture side, early postoperative	5.3 (2–7)		5.4 (4–9)		
Fracture side, last visit	5.4 (3–7)		5.5 (4–9)		
Normal side	6.3 (5–8)		5.4 (4–6)		

Values are presented as mean (range).

Group 1: dual locking plate group, Group 2: lateral locking plate group, TFAA: tibiofemoral anatomic angle, MPTA: medial proximal tibial angle, PPTA: proximal posterior tibial angle.

*Statistical comparison of the last visit values between the fracture side and the normal side. [†]Statistical comparison of the last visit values in the fracture side between group 1 and group 2.

to 15°) and extension contracture in two patients (20%; 5° and 10°). There was no significant difference in terms of late complications between the groups ($p = 0.582$).

DISCUSSION

In this study, we compared the dual locking plate fixation technique and unilateral locking plate fixation technique in tibial bicondylar plateau fractures without posteromedial fragment. We did not observe significant differences in functional and clinical results between the groups, whereas the TFAA values of group 2 and the PPTA values of group 1 in the operated extremity showed significant difference when compared to those in the contralateral extremity.

The goals of operative treatment for the tibial plateau fractures include anatomic reduction with restoration of articular congruity and rigid fixation for recovery of previous range of motion.^{1-4,7} There are many different surgical techniques that have been advocated for the management of bicondylar tibial plateau fractures such as dual buttress plate fixation, locking plate fixation, external fixation, and a combination of internal and external fixation.^{2-4,7,8,21-23}

The advantages of dual plate technique are visual reduction and maintenance of proximal tibial alignment,

but soft tissue complications and damage to the periosteal blood supply are major concerns in this method of internal fixation.^{17,23} Some authors claimed a single lateral locking plate can decrease the risk of soft tissue damage and wound infection, but it cannot provide sufficient stability for multipart fractures.^{3,9-13} The posteromedial fracture fragment has been reported to have a frequency of 33% in bicondylar tibial plateau fractures.²⁴ A single lateral locking plate fixation may not allow adequate stability in all bicondylar tibial plateau fractures.

Biomechanical and cadaver studies have shown that the dual locking plate fixation technique in bicondylar tibial plateau fractures allows less collapse when compared with the lateral locking plate fixation technique.^{25,26} Weaver et al.¹² reported that fractures with medial coronal fracture lines had a higher rate of plateau collapse and loss of reduction in lateral locking plate fixations. They came to the conclusion that such fractures can be treated better with double plates. For this reason, complex fractures with posteromedial fragment were excluded from the current study; because of their different treatment strategy.

Different scoring systems have been recommended to evaluate functional results of tibial plateau fractures. We used KSS and RFS in this study. With regard to these

systems, there were no difference between dual and single plating groups. In addition, in the literature, other series have reported good/excellent scores in 65%–89% of subjects.^{2,11)} Our results are comparable with those of other published studies with 80% satisfaction rates.

Jiang et al.¹¹⁾ reported a higher incidence of postoperative malalignment of the proximal tibia in the lateral Less Invasive Stabilization System group than in the dual plate group. Therefore, they suggested that the lateral locking plate cannot replace the conventional double plate technique in bicondylar tibial plateau fractures.¹¹⁾ Similarly, another biomechanical study using the cadaveric model of the bicondylar tibial plateau fracture revealed that the double plate fixation resulted in less collapse in cyclic loading than isolated lateral locking plates did. This suggests that the lateral locking plate is not sufficient for bicondylar tibial plateau fractures.²⁵⁾

In a biomechanical study by Mueller et al.,¹⁰⁾ stability in a tibial plateau fracture model was compared between the unilateral locking plate fixation and the dual locking plate fixation. The results were similar to those in the study of Yao et al.⁹⁾ who suggested that the shape of the medial condyle fracture plays a key role in single or double plate application. They reported there was no significant difference in the incidence of early postoperative malalignment and malreduction between dual plates and lateral locking plates used to treat bicondylar tibial plateau fractures in patients with a relatively intact medial condyle.

Similarly, in our study, radiological parameters including TFAA, PPTA, and MPTA showed no significant difference between the groups. Two significant differences were noted only in the comparison with the uninjured extremities in each group. In the lateral plating group, the mean TFAA was changed from 5.6° to 3.3°. In the dual plating group, the mean PPTA was changed from 5.4° to 6.3°. These differences were attributed to intraoperative malreduction.

Soft tissue complications are a major concern in the treatment of bicondylar tibial plateau fractures with plates and the incidence is reported to range from 5% to 88%.²⁷⁻²⁹⁾ Optimal timing for surgery, surgical time, soft tissue protection, and prevention of infection in tibial plateau fractures are important factors.⁹⁾ With the use of a single incision and less soft tissue damage, fracture healing may be improved as in the lateral locking plate fixation technique.^{7,9,13)}

Deep infection with plates has been reported to occur in up to 22% in tibia plateau fractures.^{1,2,27,29)} In our study, we

had no deep infection cases. Superficial tissue infection developed in one patient in the dual plate group (10%), which was treated by oral antibiotics and wound care. In the lateral plating group, there was no sign of infection.

Studies have demonstrated that articular incongruity and joint instability can lead to early posttraumatic joint degeneration.^{2,30)} The incidence of osteoarthritis following tibial plateau fractures is 17%–83%.²⁾ Since the follow-up period in this study was relatively short, the incidence of posttraumatic arthritis was not as high as that reported in other studies. In total, 10 cases had signs of arthrosis (grade I–III) when compared to the uninjured side (50%). We though our results are comparable to those in other published studies.

Nonunion of bicondylar tibial plateau fractures has an incidence of approximately 4%.^{3,7,13)} Nutrient vascular injury, bone defect, and lack of adequate fixation can cause this complication.^{3,7,9,13,29)} There was no nonunion in our study, which is related to the preservation of blood circulation of tissues during surgery. A spongy bone defect can easily occur in the tibial plateau fractures. The bone graft does protect the mechanical support and prevent late collapse.^{3,9,29,30)} In this study, a bone graft was used in one patient in group 2.

One of the limitations of this study is the relatively small number of patients, for which we could not perform post-hoc analysis. In addition, the duration of follow-up was short, and the study was performed retrospectively. Studies with a larger number of cases performed in a randomized controlled manner with a longer-term follow-up may allow more accurate assessment. However, a major advantage of this study is that we included only patients with bicondylar plateau fractures without posteromedial fracture fragment.

Dual locking plate fixation technique and lateral locking plate fixation technique are effective methods in the treatment of bicondylar tibial plateau fractures when used properly. The lateral locking plate fixation technique may provide comparable clinical and radiological outcomes with dual locking plate fixation technique for the treatment of bicondylar plateau fractures without posteromedial fragment.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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