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# Comparison of Arthroscopic Assisted Reduction and Internal Fixation Versus Open Reduction and Internal Fixation in Tibia Plateau Fracture Treatment: A Prospective Cohort Study With Historical Controls

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**Background:** Orthopedic surgery of tibial plateau fractures has been a challenging procedure for a long duration. However, less-invasive surgical techniques have recently been developed for this condition.

**Objectives:** In an interventional study with a historical control, we evaluated the medium-term functional and radiological outcomes of treatments for tibial plateau fractures using the arthroscopically assisted reduction and internal fixation (ARIF) and open reduction and internal fixation (ORIF) techniques.

**Patients and Methods:** Eleven patients with tibial plateau fractures of Schatzker types I-VI were treated with ARIF, whereas 11 patients were matched historically as the ORIF group. There were no significant differences in gender, age, and fracture types between the groups (P > 0.05). At the last follow-up, range of motion, visual analogue score for pain, Rasmussen functional and radiographic scores, international knee society scoring system (IKSS) score, and the Ahlback radiologic scale score for osteoarthritis were evaluated.

**Results:** All patients achieved union. The ARIF group had a shorter rehabilitation period, as well as a lower rate of midterm osteoarthritis and complications (P < 0.05). There were no significant differences between both groups according to other functional and radiologic assessments.

**Conclusions:** We recommend that the ARIF technique is an acceptable alternative treatment for tibial plateau fractures, with good functional and radiological midterm results and without serious complications.

Keywords: Tibial Fractures; Arthroscopy; Patient Outcome Assessment

# 1. Background

Tibial plateau fractures account for 1% of all fractures, and their management is challenging due to the complexity of injuries and the intra-articular nature of the fracture patterns (1, 2). Different methods have been considered in the treatment of these fractures, and satisfactory results have been reported using both non-surgical and surgical methods (3, 4).

The ultimate goals of intra-articular fracture management should include anatomic reduction, rigid internal fixation, and soft tissue stability, which would permit non-weight bearing rehabilitation protocols in the immediate postoperative period (5, 6). Although open reduction and internal fixation (ORIF) with plates and screws is an established method of treatment for complex tibial plateau fractures, less invasive surgical techniques have been recently developed (7).

Arthroscopic reduction and internal fixation (ARIF) has

been recognized as a minimally invasive method for the treatment of Schatzker type I-III tibial plateau fractures since 1985 (8, 9). Theoretically, it can be used to diagnose and treat associated intra-articular and concomitant soft tissue injuries, visualize the chondral surface reduction, lavage the hematoma and excision of smaller intra-articular loose fragments, decrease soft tissue dissection, reduce the risk of scarring, and promote rapid rehabilitation (10, 11).

Minimally invasive surgical techniques have gained popularity over recent years. Several case series studies on the arthroscopically assisted reduction of tibial plateau fractures have reported good short-term results with few complications (12, 13). However, few studies have assessed the functional and radiological outcomes of arthroscopically assisted reduction of tibial plateau fractures, in comparison with the classic techniques.

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# 2. Objectives

The objective of this interventional study was to assess the medium-term functional and radiological outcomes of the treatment of tibial plateau fractures using the ARIF and ORIF techniques.

# 3. Patients and Methods

### 3.1. Study Design

This multi-centric interventional study, with a historical control, was performed between September 2011 and September 2013 in 4 referral hospitals.

Patients with acute closed tibial plateau fractures, classified as Schatzker type I-VI, were included in the ARIF group. Patients with open fractures, pathological fractures, severe systemic illness, severe osteoarthritis before trauma, and vascular injuries were excluded from this study.

In the ORIF group, patients were chosen retrospectively from patients who were previously treated in the same hospitals, after matching for age, sex, and fracture severity. The indications for operative fixation included fractures with a varus or valgus instability of > 10 degrees, an articular step-off of > 3 mm, or a condylar widening of > 5 mm.

### 3.2. Patients

There were 11 patients (8 men and 3 women) in the ARIF group, with a mean age of 36.6 years (range, 24 - 48 years). The injuries were related to a traffic accident in 10 cases and due to falling in 1 case. The fractures were classified as Schatzker types II and III in 5 and 4 patients, respectively; the fractures were classified as Schatzker types V and VI in 1 patient each.

The ORIF group comprised 11 patients (8 men and 3 women), with a mean age of 38.6 years (range, 24 - 52 years). The injuries were related to a traffic accident in 8 cases and due to falling in 3 cases. The fractures were classified as Schatzker types II and III in 6 and 2 patients, respectively; the fractures were classified as Schatzker types IV, V, and VI in 1 patient each.

Bone lesions were assessed using standard anteroposterior and lateral radiographs in the emergency department as well as computed tomography (CT) images. The delay between the occurrence of trauma and time to surgery ranged from 3 to 5 days, according to the severity of soft tissue swelling and the patient's general condition. Our institutional review board (IRB) approved this study. Informed consent was obtained from the patients after they were provided with explanations of the available treatment options prior to surgery.

# 3.3. Surgical Technique

In the ARIF group, the first diagnostic arthroscopy was performed through standard portals, and associated injuries to the menisci, ligaments, and chondral surfaces were assessed. We did not use an arthroscopic pump, and the inflow was regulated via gravity. The blood clots were excluded and loose bodies were removed. In cases of depressed articular fracture, after the fracture pattern in the joint surface and the depressed area were determined, an ACL guide was placed over the depressed area and a guide pin was passed through the contralateral tibial metaphyseal window (primarily involving the anteromedial metaphysis, as most fractures were lateral plateau fractures). A 11-mm reamer was used to ream the metaphysis over the guide pin to a point just below the subchondral bone at the depressed area. Under fluoroscopic guidance, an impactor was used to elevate the articular surface through the metaphyseal tunnel. After confirmation of reduction under arthroscopy view and fluoroscopy, two cannulated size 4 mm screws were placed as a raft under the articular surface and supported it. The metaphyseal void was then filled with allograftcorticocancellous bone chips. In more complex fracture patterns, after reduction and fixation of the articular fracture, supplementary metaphyseal fixation was performed with a buttress plate or screws, if the fracture lines involved the medial and/or lateral metaphyseal cortices (Figure 1).

In the ORIF group, the classic approach for plateau intra-articular fracture, involving submeniscal arthrotomy for articular surface reduction as well as internal fixation with plate and screw, was performed.

#### 3.4. Post-Operative Considerations

Intravenous antibiotic prophylaxis was administered for 24 hours, and was initiated before anesthesia was induced. The Knee range of motion exercises was started on the 1st postoperative day. A hinged knee brace was used for 6 weeks to protect the knee. Weight bearing was restricted until 3 months postoperatively.

# 3.5. Clinical and Radiographic Evaluations

The patients were examined during post-operative visits at 6-week intervals until 3 months, after which they were evaluated at 12-week intervals until full recovery and complete union were observed. From among the functional parameters, physical examination findings, and radiography findings, the following functional and radiologic scores were assessed at the last visit: visual analogue score (VAS) for pain, Rasmussen functional, score (0-30, according to pain, walking capacity, extension lag, range of motion, and stability), International knee society scoring system (IKSS) score, and Rasmussen radiologic score (0 - 18, based on depression, condylar widening, and angulation). The Ahlback radiological scale (0 - 5, according to joint space narrowing and bone attrition) for osteoarthritis was also evaluated at the final follow-up.

# 3.6. Statistical Analysis

Statistical analysis was performed using the SPSS soft-

ware, version 18.0 (Statistical Product and Service Solutions, SPSS Inc. Chicago, IL, USA). The data are presented as the mean  $\pm$  standard deviation and median (range). The test for normality was performed using the Kolmogorov-Smirnov test. The Wilcoxon and Mann-Whitney U tests were used to compare the continuous variables. The paired t-test was used to compare the quantitative variables before and after the surgery. A P value of < 0.05 was considered statistically significant.

#### 4. Results

We treated 12 cases in the ARIF group. Among these cases, 11 patients participated in the mid-term follow-up study. The mean follow-up time was  $21 \pm 9$  months. These 11 patients were matched with the patients in the ORIF group, who had a mean follow-up time of  $24 \pm 10$  months. All fractures achieved union. The details are presented in

#### 4.1. Clinical and Functional Assessments

In the ARIF group, all patients achieved knee ROM of  $\geq$  120 degrees at the final visit. In the ORIF group, 1 patient underwent knee arthrodesis. Another patient achieved a maximum ROM of 90 degrees, whereas the remaining 9 patients achieved complete ROM. The median ROM was not significantly different between the 2 groups (P = 0.8). The mean interval between surgery and the achievement of maximum ROM in the ARIF and ORIF groups was 4 months (range, 3 - 6 months) and 5 months (range, 4 - 8 months), respectively. The differences between the 2 groups were significant (P = 0.002).

The median VAS score was 1 for both groups, with no significant differences (P = 0.7). The general satisfaction with the surgical results was 91% in the ARIF group and 82% in the ORIF group.

In the ARIF group, the median Rasmussen functional score was 29 (range, 23 - 30). Excellent and good scores were obtained in 9 and 2 patients, respectively. None of the patients reported fair or poor results. In the ORIF

group, 8 and 2 patients obtained excellent and fair results, respectively. One patient achieved a poor result, and the median score was 29 (range, 9 - 30). There were no significant differences between the 2 groups in terms of the rasmussen functional score (P = 0.5).

The median IKSS scores in the ARIF and ORIF groups were 93 (range, 83 - 100) and 90 (range, 30 - 100), respectively, and no significant difference was noted between the groups (P = 0.8).

### 4.2. Radiographic Assessments

All patients in both groups had achieved complete union at the last follow-up visit. The Rasmussen radiologic score was used to assess reduction quality. The median Rasmussen radiologic scores in the ARIF and ORIF groups were 18 (range, 14 - 18) and 18 (range, 12 - 18), respectively. There was no significant difference in the Rasmussen radiologic score between the groups (P = 0.5). The median Ahlback score, which was used to reflect the osteoarthritis changes, was 0 (range, 0 - 1) in the ARIF group and 0.5 (range, 0 - 2) in the ORIF group. The difference in the median Ahlback score was significant between the groups (P = 0.03).

#### 4.3. Complications

There was no evidence of local or deep infection in ARIF patients. One of the patients could not actively extend the knee after surgery, and no response to aggressive physiotherapy was obtained. However, a passive knee ROM of 120 degrees was obtained, and no femoral nerve lesions were noted in this case. Nevertheless, after 10 months, quadriceps reefing was performed, and active knee extension was reported.

In the 3 patients in the ORIF group, discharge or wound dehiscence was noted early after surgery, which required reoperation. In one of the patients, resistant infection, and osteomyelitis were noted, which eventually required knee arthrodesis using an Illizarov external fixator. Two other patients recovered, with a minimal degree of joint arthritis (Table 1).

#### Figure 1. Pre-Operative, Intraoperative, and Post-Operative Imaging of a Tibial Plateaue Fracture









A, coronal computed tomography (CT) view of a Schatzker type 2 tibial plateau fracture. B, arthroscopic view of the depressed joint surface with a guide pin in place. C, arthroscopic view following arthroscopically assisted reduction. D, post-reduction fluoroscopic view after screws were used as a raft to support the articular surface.

Table 1. Detail	led Charact	teristics o	f the Study	Popul	ation <sup>a</sup>								
Patient	Age, y	Gender	Mechanism of Trauma	Type (Schatzker)	Follow-Up, mo	VAS Score	ROM (Degree)	Time to Final ROM, min	Rasmussen Functional Score	Knee Society Score	Rasmussen Radiologic Score	Ahlback Score	Satisfaction
N. ARIF													
1	37	Male	mva	6	20	1	130	4	28	87	16	1	Yes
2	31	Male	mva	3	36	0	130	3	29	95	18	0	Yes
3	47	Male	mva	3	30	0	140	4	30	100	18	0	Yes
4	22	Male	falling	5	13	4	140	3	28	83	16	0	Yes
5	44	Male	mva	3	26	1	140	4	30	93	18	0	Yes
6	31	Male	mva	2	13	1	140	3	29	88	18	0	Yes
7	24	Female	mva	2	26	1	140	3	29	95	18	0	Yes
8	28	Male	mva	2	20	0	140	4	30	100	18	0	Yes
9	60	Female	mva	2	32	2	120	4	23	87	18	0	Yes
10	29	Female	mva	3	12	5	120	6	23	85	14	0	No
11	50	Male	mva	2	10	1	140	3	29	95	18	0	Yes
Median	36	-	-	-	21	1	140	4	29	93	18	0	-
Range	24 - 48	-	-	-	10 - 36	1-5	120 - 140	3-6	23-30	83 - 100	14 - 18	0 - 1	-
N. ORIF													
1	27	Male	mva	2	12	0	140	5	30	100	18	0	Yes
2	60	Male	falling	5	24	7	90	-	16	33	16	2	No
3	35	Male	mva	6	36	2	140	8	29	70	12	2	Yes
4	33	Female	mva	2	38	1	140	4	28	90	16	1	Yes
5	45	Male	mva	2	20	5	140	5	28	65	18	1	Yes
6	26	Male	mva	2	26	1	140	5	16	100	18	1	Yes
7	39	Male	mva	4	14	1	140	6	29	95	16	0	Yes
8	73	Female	Falling	2	36	4	0	-	9	30	-	arthrodesis	No
9	33	Male	mva	2	30	0	140	5	30	100	18	0	Yes
10	29	Female	Falling	3	26	0	140	5	30	100	18	0	yes
11	25	Male	mva	3	10	1	140	6	29	90	18	0	Yes
Median	38	-	-	-	24	1	140	5	29	90	18	5	-
Range	25 - 73	-	-	-	10 - 38	1-5	0 - 140	4 - 8	9-30	30-100	12 - 18	0 - 2	-

<sup>a</sup> Abbreviations: ARIF, arthroscopic reduction and internal fixation; mva, motor vehicle accident; ORIF, open reduction and internal fixation; ROM, range of motion; VAS, visual analogue score.

# 5. Discussion

Compared to other intra-articular fractures, the treatment of tibial plateau fractures remains challenging for orthopedic surgeons. Tscherne defined the main goals in the treatment of these fractures as appropriate articular surface reduction, rigid fixation for early ROM, and management of associated injuries (14). Other studies indicated that joint line congruity and stability were the main predictors of outcome in plateau fracture management (1, 15).

Although ORIF is the classically acceptable method for the treatment of plateau fractures, several other methods have also been introduced. However, arthrotomy and open

<b>Table 2.</b> Summary of the Different Studies Reporting the Outcomes of Arthroscopically Assisted Fixation of Tiblal Plateau Fractures										
Study	Gill 2001	Kieffer 2001	Asik 2002	Levy 2008	Kayali 2008	Rossi 2008	Siegler 2011	Current Study		
No. of patients	25	29	48	16	21	46	21	11		
Mean age, y	45.2	47.4	39	44.8	41	48	43	36.6		
Mean follow-up, mo	24	25.1	36	41	38	60	59.5	21		
Post-operative complications	0	6.9	4.2	0	0	3.5	0	9		
IKSS objective score	-	-	-	-	-	93.2	85.2	93		
Rasmussen clinical score	27.5	-	-	29.2	-	28.2	25.5	29		
Rasmussen radiologic score	-	-	-	16.8	-	-	-	18		

Table 2. Summary of the Different Studies Reporting the Outcomes of Arthroscopically Assisted Fixation of Tibial Plateau Fractures

reduction of the articular surface increases the risk of prolonged stiffness, and is associated with increased pain and wound complications (16). In the present study, 3 cases of surgical site infections were noted in the ORIF group, whereas no infections were noted in the ARIF group.

The philosophy underlying ARIF, initially recommended by Caspari and Jennings in 1985, is to prevent additional surgical trauma to the knee joint by using a minimally invasive approach (8, 10). The advantages of ARIF include better visualization of joint surface reduction, shorter hospital stay, and faster postoperative rehabilitation; moreover, ARIF enables lavage and removal of hematoma and loose bodies, and treatment of concomitant ligamentous and menisci injuries (17). However, the ARIF technique is complex, and it may lead to compartment syndrome due to fluid extravasation during arthroscopy (18, 19).

Several reports support the arthroscopic management of tibial plateau fractures and have reported acceptable short-term outcomes; however, these findings are difficult to compare due to the heterogeneity in the assessment methods (20). Fowble and colleagues reported that the anatomic reduction in ARIF is superior to that in ORIF, with lower complication rates and a shorter delay to full weight bearing, consistent with our results (21). Ohdera and colleagues found no significant differences in the duration of surgery, ROM, and clinical results between the ARIF and ORIF methods (22). At the medium-term follow-up, Cassard et al. reported a mean IKSS knee and functional score of 94.1 and 94.7, respectively, in a series of 26 patients. In a 5-year follow-up study of 46 patients (23), Rossi et al. reported a mean IKSS knee and functional score of 93.2 and 94.8, respectively, and a mean Rasmussen clinical score of 28.2 (12).

Since articular reduction with the aid of arthroscopy was first recommended for the treatment of Schatzker type I-III tibial plateau fractures by Caspari and Jennings, it has become very popular. With recent developments in the techniques and increased surgeon experience, more complex fracture patterns involving both chondyles can be managed with the arthroscopic technique and buttress plating (9, 24). In the present study, 1 patient each had Schatzker type V and VI fractures that were treated with the arthroscopic method, wand good functional and radiological results were obtained.

From a technical point of view, the metaphyseal window for reduction is established at the same side of the fracture in most of the surgical techniques described in the literature. However, we suggest approaching the articular depression through the contralateral intact cortex. We agree with Rossi et al. that this approach may not further weaken the fractured metaphysis and compromise the vascular supply (25).

The main complication of proximal tibial fractures is osteoarthritis, which is related to either joint surface incongruency or instability due to varus/valgus deformity. We reported a significant reduction in radiographic osteoarthritis, as measured by the Ahlback score, in the ARIF group as compared to the ORIF group, consistent with previous reports (2).

In this study we have used different scoring system for comparison with similar studies. Based on our results, the patients undergoing ARIF exhibited acceptable midterm functional results, consistent with that noted in other studies (Table 2). However, statistical analysis between the findings of different studies was not possible. The main limitation of the current study is the insufficient number of patients. As a result, the findings with actual significant differences may be masked due to the lack of statistical power. In addition, it would be interesting to review the patients with a longer follow-up.

Arthroscopically assisted surgery for tibial plateau fractures requires advanced techniques and greater surgeon experience, and is associated with a deeper learning curve as compared to the open technique. In the present study, we compared the results of arthroscopic and open techniques from several tertiary hospitals. We recommend the use of arthroscopic techniques as an alternative method for the treatment of a wide spectrum of intra-articular tibial plateau fractures to obtain good functional and radiologic midterm results, without serious complications, and as a method of training for orthopedic surgeons.

## **Authors' Contributions**

Mohammad Hossein Nabian: conception and design,

acquisition of data, analysis and interpretation of data, drafting the article, and revising the article critically. Mohammad Naghi Tahmasebi: conception and design, acquisition of data, revising the article critically, and final approval of the version to be submitted. Sohrab Keyhani: acquisition of data and revising the article. Seyed Mohammad Javad Mortazavi: acquisition of data and revising the article critically. Mohammad Reza Sobhan: acquisition of data, revising the article. Leila Oryadi Zanjani: analysis and interpretation of data, drafting the article, and revising the article.

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