

# High-energy tibial plateau fractures: external fixation versus plate fixation

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## Abstract

**Objective** Whether external or plating fixation is more appropriate for high-energy tibial plateau fractures is still being disputed, our aim was to test the hypothesis whether external fixation can provide a fair outcome with fewer complications, when compared to the results with previously reported data of plating fixation for high-energy tibial plateau fractures.

**Methods** An Ovid of Medline, Embase, and Cochrane Library search was conducted for the relevant English orthopedic journals, and eligible studies, including twenty-four case series and one comparative study containing 885 patients associated with 892 fractures, were enrolled.

**Results** The results showed there were a higher proportion of men, open fractures, malunion, knee instability, and posttraumatic arthritis occurred in external fixation group than those in plating group ( $P = 0.007$ ,  $P = 0.000$ ,  $P = 0.024$ ,  $P = 0.006$ ,  $P = 0.000$ , respectively), while valgus deformity happened at a significantly higher rate in plate group ( $P = 0.014$ ). No significant differences were found between the two groups in terms of age, Schatzker type, follow-up, mean time to union, mean range of knee motion, and rate of reoperation. With regard to the functional and radiological outcome assessment, despite what assessment tools were used, most of these studies presented less than 90 % good/excellent results in their high-energy fracture series. Besides, there was a trend for patients in plating group to have a higher risk than those in external

fixation group in terms of heterotopic ossification and local irritation (1.23 vs 0.17 %, 4 vs 1.94 %, accordingly).

**Conclusions** Although lack of good quality randomized control trials, there are rather enough samples supporting the current available results. Meanwhile, future multicentered, randomized, controlled studies should be implemented to test these outcomes.

**Keywords** Tibial plateau fractures · High energy · External fixation · Plating fixation

## Introduction

High-energy tibial plateau fractures (types V and VI, according to the system of Schatzker [1], and types C1, C2, and C3, according to the system of the Orthopaedic Trauma Association [2]) are severe injuries frequently associated with multisystem trauma, ipsilateral skeletal trauma, and multiligamentous injuries. The results of treatment of these injuries have often been poor, with loss of motion, instability, posttraumatic osteoarthritis, wound breakdown, and infection as final outcomes [3–8]. External fixation (EF) is an established method for the treatment of certain types of high-energy tibial plateau fractures because of its ease of application and minimal surgical exposure. Conversely, there has been an increasing trend toward the use of open reduction and internal fixation (ORIF) with plates owing to the potential for direct fracture reduction and earlier postoperative mobilization. Nonetheless, recent systematic reviews of the literature have failed to provide substantial evidence supporting the use of one of the above-mentioned techniques over the other for the management of tibial plateau fractures [9]. We performed case analysis using non-randomized controlled trials that

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compare EF to ORIF with plating for the treatment of high-energy tibial plateau fractures. The purpose of this study was to determine whether the clinical outcomes of patients with bicondylar tibial plateau fractures treated with open reduction and plate fixation (PF) are better than those achieved with external fixation.

## Materials and methods

An Ovid of Medline (1946–2013), Embase (1974–2013), and Cochrane Library search was conducted for relevant publications up to August 2013. The following phrases, respectively, acted as keywords and title through advanced search: High energy/complex/comminuted/severe/Schatzker IV/V tibial plateau fractures, and bibliographies of all retrieved studies were reviewed for relevant articles. This search strategy was performed independently by two co-authors. Inclusive and exclusive criteria are outlined in Table 1. All relevant data from papers that met the initial inclusion criteria were extracted independently by two of the authors. Then, each eligible study was independently reviewed by authors for methodological quality to decrease bias due to the variation in the quality of the published observational studies. Although there are scoring systems available for assessing the methodological quality of randomized controlled trials, we were unable to find any published methodological quality scoring systems to assess non-randomized controlled studies such as case series. Therefore, a methodological scoring system adapted from that of Detsky et al. [10] was used. The scoring system used consisted of answering to the following questions:

1. Were patient characteristics adequately described including at least four details of admission provided? (e.g., age, sex, mobility, fracture type, etc.)

2. Were the treatment methods adequately described?
3. Were inclusion/exclusion criteria well defined?
4. Were the number of patients excluded and reasons for exclusion provided?
5. Were all the outcome measures adequately defined in the text with clarification of any ambiguous terms encountered?
6. Was the timing of outcome measures appropriate? (A minimum of 12 months follow-up for all surviving patients available.)

A clear affirmative answer scored two points, an affirmative answer with incomplete information scored one point, and no information scored zero points. The highest possible score is 12 points; studies with less than 8 points were excluded. Any disagreement in between the 2 reviewers was resolved by means of discussion to achieve consensus. We sought the following summary data from each study: (1) information on general characteristics of participants; (2) clinical and radiological outcomes assessment; (3) postoperative complications (pin-track infection, abnormal union, instability, knee stiffness, etc.); (4) the average range of motion for knee flexion; (5) mean union time; (6) rate of reoperation.

## Data analysis

Statistical analysis was performed with use of the SPSS 18 software. The weighted means of continuous parameters of interest were compared across groups using a two-tailed independent sample *t* test, such as age, knee range of motion, etc. A chi-square test was used for categorical variables between the two groups, such as gender, fracture pattern, etc. A traditional Pearson chi-square test was used when statistical conditions were met. The Fisher exact test was used in case when one or more of the expected variables were less than five. A *P* value of <0.05 was considered to be significant (Tables 2, 3).

## Results

The above methodology identified 263 studies of which 25 studies met the inclusion criteria. One study was a comparative study between locked plating and external fixation [6]; therefore, 16 studies were external fixations and 10 studies were plate fixations. The total number of cases in the included studies was 885 (561 external fixations and 331 plate fixations) associated with 892 tibial plateau fractures. The assessment of study quality was conducted by two authors of this review. The mean study quality score was  $9.69 \pm 1.04$  in the study (Fig. 1).

**Table 1** Inclusion and exclusion criteria used

Inclusion criteria	Exclusion criteria
Articles were in English	Non-English studies
Patients included who are skeletally mature	Total knee replacement/arthroplasty
Schatzker V/VI tibial plateau fractures or AO/OTA 41-C tibial plateau fractures	Non-Schatzker V/VI tibial plateau fractures
ORIF or definitive EF	Animal or cadaver studies
Follow-up results included for all surviving patients available (e.g., radiographic and functional evaluation, rates of complications, rates of reoperation, etc.)	Review studies or editorials or letters conference
	Temporary EF
	Secondary salvaged surgery

ORIF open reduction internal fixation, EF external fixation

**Table 2** Summary of basic characteristics of the studies identified in this literature review

Author	Study design	Patients	Gender ratio	Mean age (range)	Fracture pattern	Surgical methods	Quality assessment
Ali et al. [11]	CS	20	n/a	57 (20–90)	V = 4, VI = 16	Sheffield hybrid fixator	10
Babis et al. [14]	CS	33	20 M/ 13F	43.7 (17–86)	V = 16, VI = 17, I = 1, II = 2, IIIa = 2	Hybrid external fixation	10
Catagni et al. [15]	CS	59	40 M/ 19F	43 (23–63)	V = 20, VI = 39, II = 1, III = 4	External circular and limited internal fixation	8
Chin et al. [4]	CS	18	15 M/3F	43.8 (27–68)	V = 14, VI = 4, I = 2, IIIa = 6, IIIb = 2, IIIc = 2	Tensioned fine-wire fixation	10
El Barbary et al. [16]	CS	29	26 M/3F	41.4 (20–76)	VI = 30, II = 3, IIIa = 2, IIIb = 2, IIIc = 2	Ilizarov external fixator with Minimal internal fixation	11
Gaudinez et al. [17]	CS	16	15 M/1F	47 (23–73)	V = 16, II = 8, IIIa = 2	Hybrid external fixation	8
Katsenis et al. [5]	CS	46	36 M/ 10F	43.5 (17–78)	V = 8, VI = 40, I = 6, II = 8, III = 4	Minimally invasive internal and external fixation	11
Katsenis et al. [28]	CS	127	110 M/ 17F	39.5 (17–81)	C1 = 68, C2 = 20, C3 = 41, I = 11, II = 17, IIIa = 9, IIIb = 7, IIIc = 3	Wire fixation and limited internal	11
Mikulak et al. [18]	CS	24	16 M/8F	44.9 (16–70)	VI = 24, IIIa = 5	Wire external fixation and limited internal fixation	9
Stamer et al. [19]	CS	22	18 M/4F	43 (21–66)	VI = 23, II = 2, IIIa = 1, IIIb = 2, IIIc = 1	Hybrid ring external fixation	9
Subasi et al. [13]	CS	15	10 M/5F	41 (22–69)	VI = 13, unclassified 2 cases, I = 3, II = 5, IIIa = 3, IIIb = 2, IIIc = 2	Circular external fixation	10
El-Alfy et al. [20]	CS	28	25 M/3F	35 (22–58)	V = 10, VI = 18, II = 4, III = 4	Hybrid external fixator	9
Krupp et al. [6]	CS	30	9 M/21F	48.8 (28–51)	V = 9, VI = 21 open fracture 5 cases	External fixation	9
Faldini et al. [12]	CS	32	n/a	37.8 (21–64)	VI = 32, I = 4, II = 3, III = 4	Closed reduction and external fixation	10
Kataria et al. [21]	CS	38	32 M/6F	32 (21–60)	V = 16, VI = 22 open fracture 4 cases	Small wire external fixation	10
Dendrinos et al. [22]	CS	24	18 M/6F	39 (18–69)	V = 5, VI = 19 open fracture 11 cases	Ilizarov circular fixator	10
Barei et al. [29]	CS	83	52 M/ 31F	44 (21–88)	C3 = 83, II = 1, IIIa = 7, IIIb = 2, IIIc = 1	ORIF (Dual plating)	9
Egol et al. [7]	CS	36	30 M/6F	47 (19–82)	V = 7, VI = 29, IIIa = 1, IIIb = 1, IIIc = 1	ORIF (LISS plate)	8
Spagnolo et al. [8]	CS	18	15 M/3F	39 (29–49)	VI = 18, I = 1	ORIF(LISS and ZPLT plate)	8
Stannard et al. [30]	CS	37	25 M/ 12F	42 (19–83)	C = 37, IIIa = 8, IIIb = 2	ORIF (LISS plate)	11
Yu et al. [23]	CS	54	33 M/ 21F	45.2 (19–68)	V = 23, VI = 31	ORIF (Dual plating)	11

Table 2 continued

Author	Study design	Patients	Gender ratio	Mean age (range)	Fracture pattern	Surgical methods	Quality assessment
Luo et al. [24]	CS	29	23 M/6F	46.8 (22–62)	V = 9, VI = 20	ORIF (Dual plating)	11
Ehlinger et al. [25]	CS	8	6 M/2F	39 ± 5.6 (20–70)	V = 5, VI = 3, II = 1	ORIF(LCP)	10
Benirschke et al. [26]	CS	13	11 M/2F	42 (17–67)	V = 2, VI = 12, II = 4, IIIa = 7, IIIb = 1, IIIc = 1	ORIF (plating)	9
Chan et al. [27]	CS	18	12 M/6F	35 (23–45)	V = 11, VI = 7 open fracture n/a	AARIF (Dual plating)	11
Krupp et al. [6]	CS	28	14 M/14F	46.6 (22–76)	V = 7, VI = 21 open fracture 4 cases	Locked plating	9

CS = case series; F = female; M = male; I = GustiloI; II = GustiloII; III = GustiloIII; OTA classification: C1 = OTA C1; C2 = OTA C2; C3 = OTA C3; LCP = locking compression plate; ORIF = open reduction internal fixation; n/a = no available; AARIF = arthroscopic-assisted reduction internal fixation

### Demographic variables

The mean age of the patients in these studies included was  $42.38 \pm 4.46$  years (range 17–90 years). Specifically, the mean age of the patients for external fixators was  $41.57 \pm 4.90$  years (range 17–90 years) and for plate fixators was  $43.79 \pm 3.10$  years (range 17–88 years). There was no significant difference between the groups with regard to the ages ( $t = 0.065$ ,  $P = 0.949$ , Fig. 2). These studies included, except gender was not available in two studies [11, 12], reported on 611 males and 222 females. To be specific, there were 390 males and 119 females in the external fixator group and 221 males and 103 females in the plating group; significant difference was detected between the groups with respect to gender ( $\chi^2 = 7.165$ ,  $P = 0.007$ , Fig. 3). In other words, there was a higher male ratio in the external fixator group than plating group.

### Injury characteristics

There were 883 patients who had sustained 890 tibial plateau fractures; the other two were unclassified [13]. Twenty-two studies reported fracture pattern using Schatzker's classification [4–8, 11–27], the other three using the AO/OTA classification [28–30]. From the studies using Schatzker's classification, there were 641 fractures distributed as 28.39 % (182) Type V, and 71.61 % (459) Type VI. For Schatzker type, there was no significant difference between the groups ( $\chi^2 = 1.184$ ,  $P = 0.277$ , Fig. 4). Of the 892 tibial plateau fractures, 214 were open using Gustilo-Anderson's classification, 171 (30.15 %) fractures in the external fixator group while 43 (13.23 %) fractures in the plating group. In terms of open fractures, significant difference was demonstrated between external fixator group and plating group ( $\chi^2 = 32.464$ ,  $P = 0.000$ , Fig. 4).

### Follow-up

Except one study [8], the follow-up was not available. The mean follow-up of the patients in these studies included was  $32.52 \pm 14.30$  months (range 3–112 months). To be specific, the mean follow-up was  $35.42 \pm 15.48$  months (range, 6–112 months) for the external fixation group and  $27.21 \pm 9.85$  months (range, 3–104.2 months) for the plating group. With respect to follow-up, the difference was not as significant between the groups ( $t = 0.358$ ,  $P = 0.724$ , Fig. 5).

### Functional and radiological assessment

With regards to functional and radiological assessment, there existed a significant heterogeneity in intra- and intergroup.

**Table 3** Summary of results in the different studies as identified in this literature

Author	Mean FU (range)	Clinical/functional assessment	Radiological assessment	Mean time to-union (range)	Complications	Rates of reoperation
Ali et al. [11]	30 m (18–51)	Rasmussen: 16 satisfactory ROM n/a	Rasmussen: 85 % satisfactory	n/a	Malunion 2 cases, PTI 5 cases PA 1 case	3/20 (corrective osteotomy 2 cases, total knee replacement 1 case)
Babis et al. [14]	27 m (24–36)	KSCRS: 18 excellent, 10 good, 4 fair, 1 poor, ROM = 115° (75–125°)	n/a (XR)	3.4 m (3–7)	Deep infection 1 case, DVT 1 case, PA 1 case, PTI 3 case, malunion 2 cases, local skin necrosis 1 case	2/33 (ORIF 1 case, skin graft 1 case)
Catagni et al. [15]	21 m (11–60)	ASAMI: 30 excellent, 27 good, 1 fair, 1 poor, ROM = 119° (60–135°)	n/a (XR)	115 d (65–153)	PTI 14 cases, DVT 2 case knee flexion ≤90° 13 cases	2/59(arthrolysis 2 cases, quadricepsplasty 1 case)
Chin et al. [4]	28.2 m (11.5–65.75)	KSCRS: mean 65.9 (6 excellent, 1 good 3 fair, 8 poor), ROM = 103° (25–135°)	Authors own: 13 anatomical reduction, 5 non-anatomical reduction (XR)	14 w (11–22)	Delayed union 3 cases, PTI 12 cases, mediolateral instability 9 cases, anteroposterior instability 2 cases	3/18 (ORIF 1 case, intra-medullary nail 1 case, patella-tendon-bearing cast 1 case)
El Barbary et al. [16]	27 m (16–36)	KSCRS:(18 excellent, 7 good, 1 fair, 2 poor) ROM = 112.5° (0°–170°)	Rasmussen: 17 excellent, 11 good	n/a	Malunion 1 case, PTI = n/a medial–lateral instability 5 cases knee flexion ≤60° 3 cases	n/a
Gaudinez et al. [17]	16.4 m (10–19)	n/a, ROM = 85° (80–110°)	n/a (XR)	18.8 w (14–26)	PTI 4 cases, varus deformity 3 cases PA 15 case	n/a
Katsenis et al. [5]	38 m (28–60)	Honkonen–Jarvinen functional criteria: 34 good and excellent ROM = n/a	Honkonen and Jarvinen radiological criteria : 38 good and excellent	13.5 w (11–18)	PTI 10 cases, DVT 6 cases, Infected nonunion 1 case, knee stiffness 1 case varus deformity 4 case, CPNP 1 case, axis deviation 1 case, PA 26 cases	8/46 (exploration of common peroneal nerve 1 case, arthrolysis 1 case, reconstructive operations 4 case, IM nailing 1 case, closed manipulation 1 case)
Katsenis et al. [28]	60 m (63–112)	Honkonen–Jarvinen functional criteria: 82 good and excellent ROM = n/a	Honkonen and Jarvinen radiological criteria :85 excellent and good	13.7 w (10–20)	Screw fracture 7 cases, Local pin irritation 11 cases, CPNP 2 cases, knee stiffness 1case infected nonunion 1 case, PTI = n/a, deviation 3 cases, varus deformity 4 cases	22/127 (exploration of common peroneal nerve 1 case, IM nailing 1 case, arthrolysis 2 cases, closed manipulation 3 Axis cases, tibia osteotomy 4 cases, wire exchange 11 cases)
Mikulak et al. [18]	25 m (12–48)	KSCRS: (9 excellent, 6 good, 4 fair, 5 poor), ROM = n/a	n/a (XR)	17.7 w (10.7–26)	Osteomyelitis 1 case, CPNP 2 cases, PA 16 cases valgus deformity 1 case, PTI 6 cases, screw infections 2 cases, plantar foot ulcer 2 cases	8/24 (exploration of common peroneal nerve 2 case, fixator site removal 3 case, correcting valgus 1 case, debridement 2 cases)
Stamer et al. [19]	12 m (6–22)	KSCRS:(13 excellent, 3 good, 1 fair, 6 poor), ROM = 107°	n/a (XR)	4.4 m (3–11)	Flexion contracture 4 cases, DWI 3 cases, DVT 1 case, man union 1 case, PTI 1 case	3/23(debridement 3 cases)

Table 3 continued

Author	Mean FU (range)	Clinical/functional assessment	Radiological assessment	Mean time to-union (range)	Complications	Rates of reoperation
Subasi et al. [13]	32 m (24–54)	KSCRS: mean 77(3 excellent, 7 good 1 fair, 4 poor)	Authors own: 5 anatomical good, 3 fair, 1 poor (XR)	22.8 w (16–44)	popliteal vein injury 1 case, PTI 8 case, malunion 4 cases, septic arthritis 1 case, osteomyelitis 1 case, flexion contractures 2 cases, PA 11 cases	2/15(debridement 2 cases)
El-Alfy et al. [20]	27 M (16–42)	Rasmussen:(5 excellent, 18 good 4 fair, 1 poor), ROM = 110° (0°–140°)	n/a (XR)	3.2 m (2–4.5)	PTI 12 cases , extension lag 2 cases, PA 2 cases ) varus deformity 1 case, DWI 1 case	1/28 (debridement 1 case)
Krupp et al. [6]	16.4 M (6–53)	n/a, ROM = 103.8° (80°–135°)	n/a (XR)	7 m (3–15)	Nonunion 4 cases, malunion 13 cases, delayed union 11 cases, knee stiffness 4 cases, DWI 2 cases, PA 6 cases, cellulitis 2 cases, HO 1 case, painful hardware 3 cases, knee instability 1 case, gastrocnoleus equines 1 case	10/30 (additional procedures)
Faldini et al. [12]	48 M (38–57)	KSCRS: mean 89, (25 excellent 4 good, 2 fair, 1 poor, ROM = 105° (75°–125°)	n/a (XR)	24 w (18–29)	Varus deformity 1 case, valgus deformity 1 case, nonunion 1 case	3/32(tibial osteotomy 2 cases, secondary ORIF 1 case)
Kataria et al. [21]	32 M (24–41)	Rasmussen: mean 26 (19 excellent, 17 good, 2 fair), ROM = 134° (90°–140°)	Rasmussen: mean 14, (6 excellent, 26 good, 6 fair)	3.7 m (3.3–5.2)	PTI 3 cases, superficial infection 2case, peroneal nerve palsy 4 cases	No
Dendrinios et al. [22]	36.5 M (24–53)	Honkonen–Jarvinen functional criteria: 17 good and excellent ROM = n/a	Honkonen and Järinen radiological criteria: 17 good and excellent	14.4 w	Delayed union 1 case, DVT 8 cases, pulmonary embolism 4 case	3/24 (fasciotomy 3 cases)
Barej et al. [29]	36.3 ± 35.4 m (3–104.2)	n/a	Authors own: 36 satisfactory, 19 unsatisfactory, 3 malreduction	n/a	Nonunion 1 case, HO 2 cases, DVT 16 cases equines contracture 1 case, DWI 7 cases, varus malalignment 4 case, valgus malalignment 1 case	15/83 (bone grafting 1 case, resecting heterotopic ossification 2 cases, improving knee motion 4 cases, tendo-Achilles lengthening 1 case, debridements 7 cases)
Egol et al. [7]	17 m (8–39)	n/a, ROM = 109.3° (60°–135°)	n/a (XR)	4 m	Delayed unions 2 cases, knee stiffness 5 cases PA 2 cases	3/36 (bone grafting 2 cases, quadricepsplasty 1 case)
Spagnolo et al. [8]	n/a (24–60)	n/a	n/a (XR)	17.2 w	Superficial infection 2 cases, Hardware irritation 3 cases, nonunion/delayed union 2 cases	5/18 (DCP plate 1 case, IM nailing 1 case, Hardware removal 3 cases)
Stannard et al. [30]	21 m (12–38)	SF-36: mean PCS 40, mean MCS 52, Lysholm knee scores: mean 90	n/a (XR)	15.6 w (6–28)	Superficial infection 2 cases, malpositioned screw 1 case, hardware problems 6 cases, soft tissue irritation 2 cases, pain 4 cases	10/39 (revision 1 case, implant removal 8 cases, debridement 1 case)

**Table 3** continued

Author	Mean FU (range)	Clinical/functional assessment	Radiological assessment	Mean time to-union (range)	Complications	Rates of reoperation
Yu et al. [23]	23.7 m (12–48)	HSS score: mean 77.3, Lysholm score: mean 79.5, KSCRS = 70.3, ROM = 107.6° (85°–130°)	Authors own: 49 excellent and satisfactory	15.4 w (12–30)	Knee stiffness 9 case, varus abnormality 3 cases, valgus abnormality 2 cases, delayed union 1 case, DWI 2 cases, PA 1 cases	2/54 (debridement and external fixation 2 cases)
Luo et al. [24]	27.3 m (24–36)	SF-36 score: mean 89(80–98); HSS score: mean 90(84–98) ; LEM score : mean 87 (80–95), ROM = 123.4°	n/a (XR)	13.1 w (11–16)	Varus deformity 1 case, valgus deformity 1 case, screw loosening 2 cases	No
Ehlinger et al. [25]	37.6 ± 5.1 m (19–54)	HSS score: mean 91.9 (74–99), Lysholm score: mean 91.4(73–100), ROM = 131.9° (120°–140°)	n/a (XR)	10.7 w (8–12)	DVT 1 case, superficial infection 1 case	No
Benirschke et al. [26]	31 m (6–60)	HSS functional score: mean 81.5 HSS knee score: mean 84.6	Authors own: 10 excellent, 2 satisfactory, 2 poor	14 w (10–20)	Valgus deformity 1 case	n/a
Chan et al. [27]	48 m (36–49)	Rasmussen: 4 excellent, 12 good, 2 fair, ROM = 130°(113°–140°)	Rasmussen: 5 excellent, 11 good, 2 fair	12 w (11–15)	Wound dehiscence 1 case, valgus abnormality 2 cases, joint collapse 3 cases, lateral calf paresthesia 2 cases, PA 3 cases	No
Krupp et al. [6]	10.2 M (6–24)	n/a, ROM = 109° (75°–150°)	n/a (XR)	6 m (3–14)	Nonunion 3 cases, malunion 4 cases, delayed union 7 cases, knee stiffness 1 case, DWI 1 case, cellulitis 1 case, HO 2 cases, painful hardware 2 cases, knee instability 1 case, PA 5 cases	7/28 (additional procedures)

PTI = pin tract infection; PA = posttraumatic arthritis; ORIF = open reduction internal fixation; HO = heterotopic ossification; DVT = deep venous thromboses; DWI = deep wound infections; ASAMI = association for the study and application of the method of Ilizarov; KSCRS = knee society clinical rating score; CPNP = common peroneal nerve paresis; DWI = deep wound infection; PCS = physical component scores; MCS = mental component scores; HSS = hospital for special surgery; lower-extremity measure = surgery score; n/a = no available; IM = intramedullary

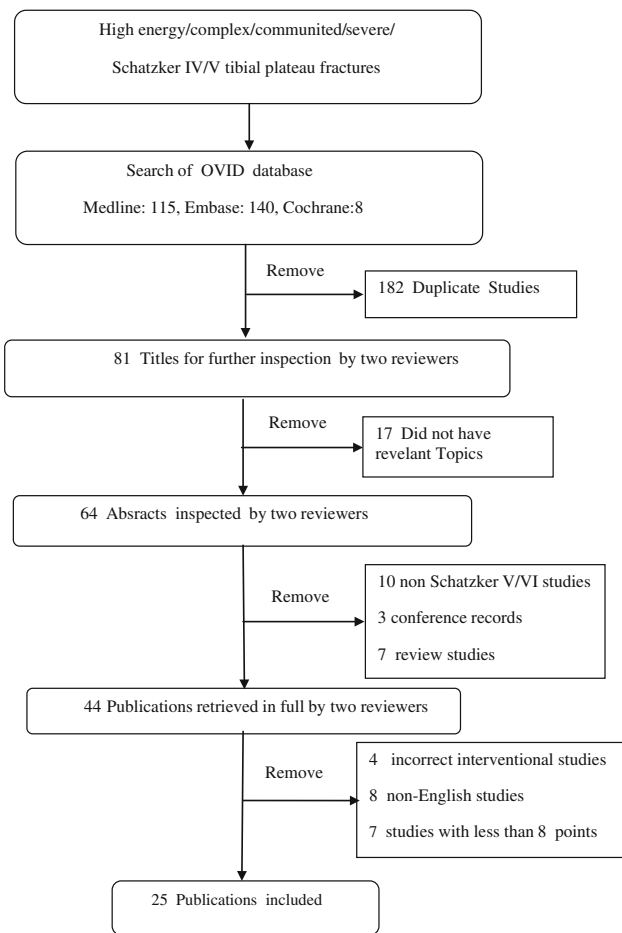


Fig. 1 Flow chart of study selection process

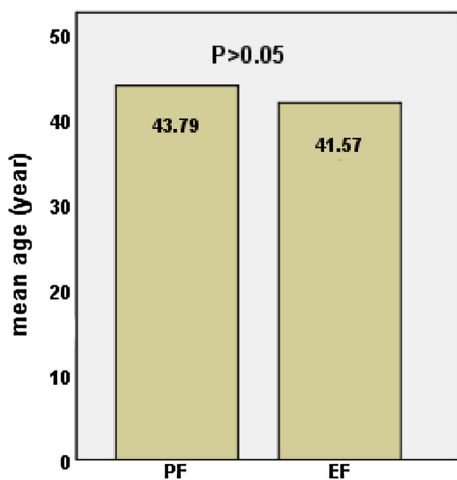


Fig. 2 Age between two groups is not statistically different

All but four [6–8, 17] of the studies report the functional outcome following plateau reconstruction. Four studies [11, 20, 21, 27] used Rasmussen’s score [31], three of the studies [11, 20, 21] in the external fixation group and the

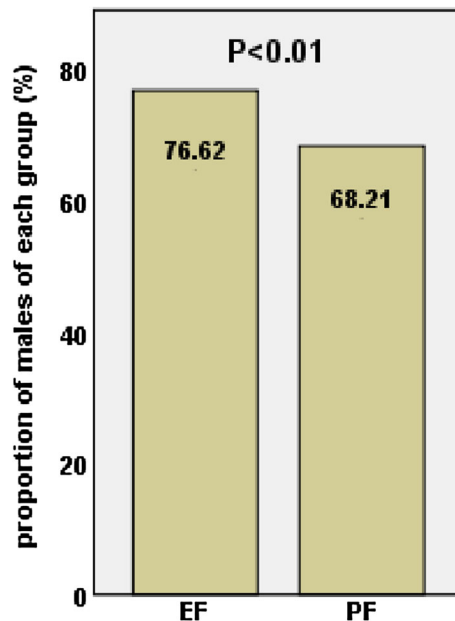


Fig. 3 Gender ratio difference between two groups is statistically different

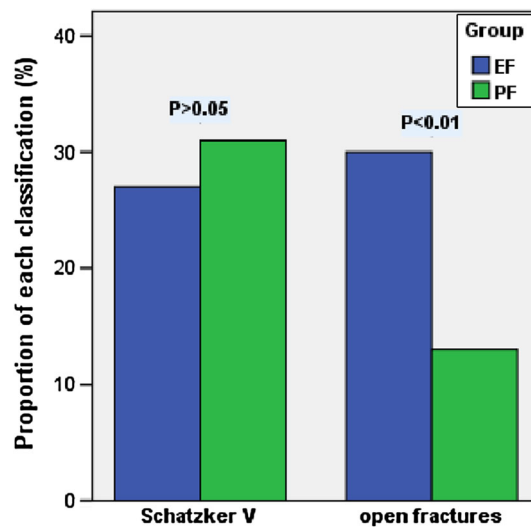


Fig. 4 Injury characteristics: P values between groups are shown

remaining one [27] in plating group, the former reporting on 86 tibial plateau fractures and have recorded good-to-excellent results in over 87 % of their cases at over 16 months of follow-up and the latter recording on 18 tibial plateau fractures. Of the cases, 88 % have scored good-to-excellent results at over 36 months of follow-up. Eight studies [4, 12–14, 16, 18, 19, 23] were evaluated according to the Knee Society Clinical Rating System criteria [32], one study [23] in plating group reported 54 tibial plateau fractures, and the mean Knee Society Clinical Rating Score was 70.3 at over a year of follow-up. The remaining seven



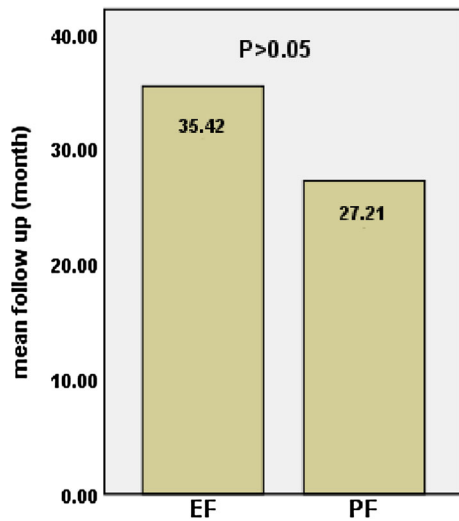


Fig. 5 Follow-up between two groups is not statistically different

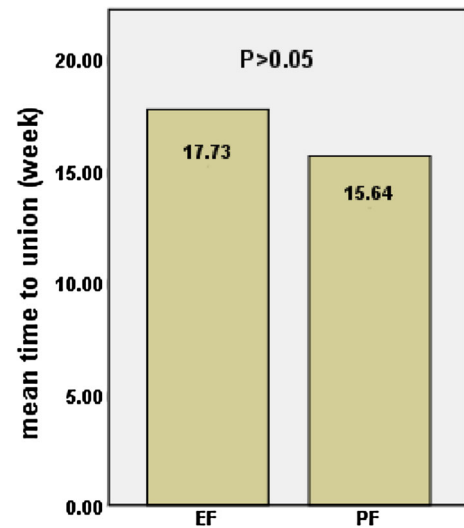


Fig. 7 Mean time to union between two groups is not statistically different

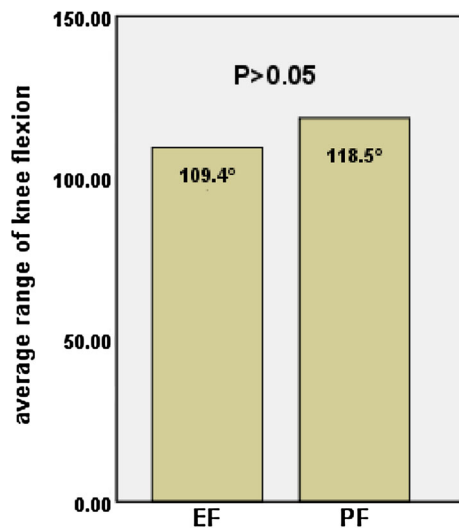


Fig. 6 Average range of knee flexion: significance of differences between groups is not shown

studies in external fixator group recorded 173 tibial plateau fractures, 80.9 % of the cases have achieved good-to-excellent results at over 6 months of follow-up. For external fixator group, one study [15] using ASAMI’s (Association for the Study and Application of the Method of Ilizarov) scoring system, 96 % of the cases have achieved good-to-excellent results at over 11 months of follow-up; three studies [5, 22, 28], using the Honkonen–Jarvinen functional criteria [33], attained good-to-excellent results in 66 % of their cases at over 24 months of follow-up. For plating group, SF-36 (Short Form-36) patient health assessments were implemented in two studies [24, 30], the mean physical component scores and mental component scores were, respectively, 40 and 52 in one study [30], and

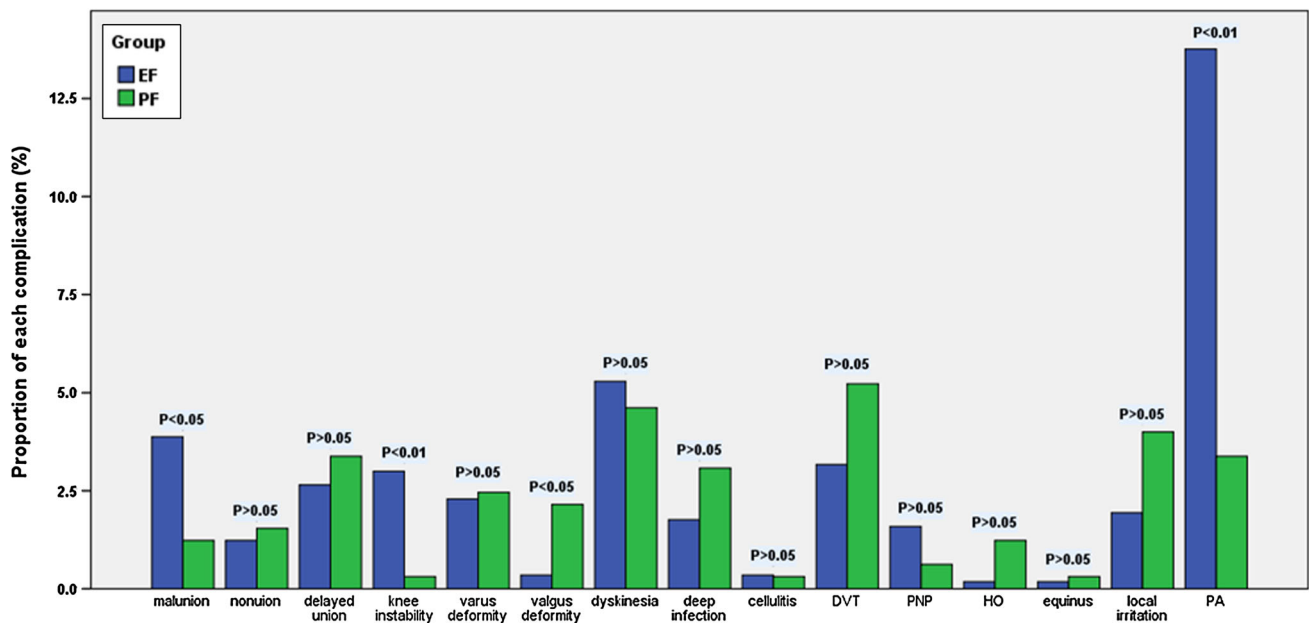
Table 4 Results of statistical analysis for complications between the two groups

Parameter	External fixator group (N = 567)	Plate fixator group (N = 325)	P value
Malunion	22	4	0.024
Nonunion	7	5	0.766 <sup>a</sup>
Delayed union	15	11	0.528
Knee instability	17	1	0.006
Varus deformity	13	8	0.873
Valgus deformity	2	7	0.014 <sup>a</sup>
Dyskinesia	30	15	0.657
Deep infection	10	10	0.202
Cellulitis	2	1	1.000 <sup>a</sup>
Deep venous thromboses	18	17	0.128
Peroneal nerve paresthesia	9	2	0.345 <sup>a</sup>
Heterotopic ossification	1	4	0.062 <sup>a</sup>
Equinus	1	1	1.000 <sup>a</sup>
Local pin/hardware irritation	11	13	0.067
Posttraumatic arthritis	78	11	0.000

<sup>a</sup> Fisher exact test

the others were 89 with regard to the mean SF-36 health assessments. Four studies [23–26] used the Hospital for Special Surgery (HSS) knee score; the mean of HSS score was 82.87 ± 6.10. Lysholm knee scores were obtained in three studies [23, 25, 30], the average value of which was 84.35 ± 5.35.

Fifteen studies [4, 6, 7, 12, 14–17, 19–21, 23–25, 27] reporting the average range of knee flexion. Therefore, the



**Fig. 8** Respective complication rates associated with external fixation and plating fixation: *P* values between groups are shown (*DVT* deep venous thromboses, *PNP* peroneal nerve paresis, *HO* heterotopic ossification, *PA* posttraumatic arthritis)

average value of knee flexion was  $109.4^\circ \pm 12.6^\circ$  (range,  $0^\circ$ – $170^\circ$ ) in external fixation group [4, 6, 12, 14–17, 19–21] and  $118.5^\circ \pm 11.2^\circ$  (range,  $60^\circ$ – $150^\circ$ ) in plating group [6, 7, 23–25, 27]; no significant difference was demonstrated between the groups ( $t = 1.453$ ,  $P = 0.168$ , Fig. 6).

The radiological assessment of outcome was reported by twelve [4, 5, 11, 13, 16, 21–23, 26–29] of the twenty-five studies. Four studies [11, 16, 21, 27] used the Rasmussen's score recording 106 tibial plateau fractures, to be specific, there were 88 tibial plateau fractures in the external fixation group [11, 16, 21] and 18 in plating group [27], the former have recorded good-to-excellent results in over 87 % of their cases at over 16 months of follow-up, the latter reporting good-to-excellent results in over 88 % of their cases at over 36 months of follow-up. Besides, three studies [5, 22, 28] were estimated according to Honkonen and Jarvinen radiological criteria; 69 % of the results achieved good-to-excellent results at over 2 years of follow-up. Six others [4, 13, 23, 26, 28, 29] reporting 313 fractures used the author's own assessment tools and have recorded good-to-excellent results in over 65 % of their cases at over 3 months of follow-up.

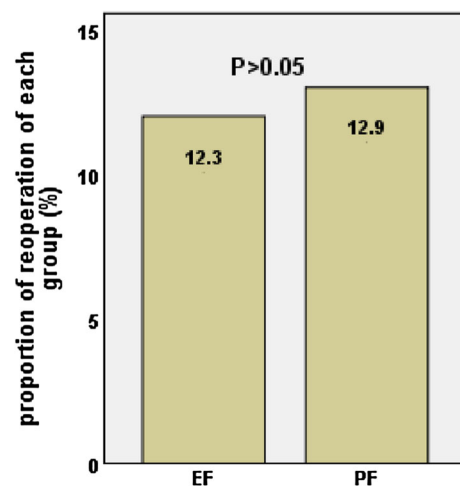
#### Mean time to union

Fracture healing was recorded in 22 of the reviewed studies [4–8, 12–15, 17–28, 30] with 759 tibial plateau fractures. The average time to union in the external fixation group was  $17.73 \pm 4.87$  weeks (range, 8.5–64.2 weeks) versus  $15.64 \pm 4.36$  weeks (range, 6–60 weeks) with plating

group. There was no difference between the groups with respect to the mean time to union ( $t = 1.041$ ,  $P = 0.310$ , Fig. 7).

#### Complications

There were 567 tibial plateau fractures in external fixation group and 325 in plating group. One of the most common complications in the former was pin tract infection, eleven studies [4, 5, 11, 13–15, 17–21] reported on pin tract infection in 78 cases, the rate of pin tract infection was



**Fig. 9** Reoperation rate between groups; difference is not statistically different

13.75 %, while superficial infection in the latter was 5 (1.53 %) cases, and the other common complications are detailedly listed in Table 4. To make full use and analyze these data, knee stiffness, knee flexion  $<90^\circ$ , flexion contracture, and extension lag were categorized into dyskinesia (Table 4). Likewise, deep wound infection, osteomyelitis, and septic arthritis were defined as deep infection. Besides, there existed rare complications in external fixator group, such as intraoperative popliteal vein injury 1 case [13] and pulmonary embolism four case [22]. When the data analysis focused on differences between the groups, it was evident that complications of malunion, knee instability, and posttraumatic arthritis occurred at a significantly higher rate in external fixator group ( $P = 0.024$ ,  $P = 0.006$ ,  $P = 0.000$ , respectively, Fig. 8) while valgus deformity in plating group ( $P = 0.014$ , Fig. 8). Nevertheless, with regards to heterotopic ossification and local irritation, there was a higher trend in plating group compared with external fixator group (1.23 vs 0.17 %, 4 vs 1.94 %, accordingly).

### Reoperation

Procedures done secondary to the definitive intervention were considered a reoperation or a complication. 70 (12.3 %) fractures had external fixators required secondary surgeries, whereas 42 (12.9 %) fractures managed with plating fixations required additional surgeries ( $\chi^2 = 0.063$ ,  $P = 0.802$ , Fig. 9). Due to some information was not available, it was unclear that what complication leads to the most common secondary revisional surgery.

### Discussion

High-energy tibial plateau fractures, which are notoriously difficult fractures associated with severe bone and soft tissue injury that lead to high complication rates and poor clinical outcomes [4, 13, 16, 22, 23, 26]. Different methods for treating these complex injuries have been proposed, including arthroscopic-assisted reduction with internal fixation [27], open reduction and internal fixation [7, 8, 23–26, 29, 30] and indirect reduction, and application of a hybrid [11, 14, 17, 19, 20] or a circular external fixation device [13, 15]. In the herein study, our aim was to test the hypothesis whether external fixation can provide a fair outcome with less complications, when compared to the results with previously reported data of plating fixation for types V and VI high-energy tibial plateau fractures.

In terms of demographic variables and injured features, Hall et al. [34] and Krupp et al. [6], in their compared clinical trial of high-energy tibial plateau fractures treated with internal or external fixation, reported no significant

differences between external fixation and plating fixation. However, our study showed there were a higher proportion of men and open fractures in the external fixator group than those in plating group. Our findings were consistent with those of Bugler et al. [35] who found 69.1 % of open fractures occurred in males with an average age of 40.8 years and 30.9 % occurred in females with an average age of 56.0 years; it is the males who tend to sustain open fractures as a result of sport, falls from a height, road traffic accidents, and direct blows or assaults.

This paper initially planned to focus on the outcome of the clinical and radiological evaluation. However, such an analysis was not possible due to the amalgamation of the different clinical and radiological results in the papers. No matter what questionnaires were used, as far as the functional outcome be concerned, except one study [15] in the external fixation group, 96 % of the cases have achieved good-to-excellent results at over 11 months of follow-up, most of these studies presented less than 90 % good/excellent results in their type V and VI fracture series [4, 5, 11–14, 16, 18–21, 23, 25, 28, 30].

Our study was supported by the results of the previous work Hall et al. [34], who reported that the mean HSS score was 75 in the circular fixator group while 68 in the open reduction and internal fixation group 2 years after the injury. The same was to radiological outcome assessment. Besides, the mean knee flexion was  $109^\circ$  in the circular fixator group compared with  $118^\circ$  in plating group in this review, the difference was not significant, which was similar to previous reported results [6, 34].

Fracture healing, in theory, was superior in external fixation due to the principles of biological osteosynthesis and minimally invasive surgery for the treatment of comminuted tibial plateau fractures. Although Hall et al. [34] in their randomized, controlled clinical trial had reported that patients in the circular fixator group were more likely to have returned to the preinjury level of activity than those in the open reduction and internal fixation group at the 6-month evaluation, this paper demonstrated no significant difference between external fixation group and plating group (17 vs 15 weeks, respectively). What's more, Krupp et al. [6] in their comparative study found that the average time to union was shorter in locked plating group than external fixator group (5.9 vs 7.4 months); the improved healing rate may potentially be related to the fixation characteristics of the locking plates, increased use of bone grafting, and/or a more adequate reduction.

The rate of complications, especially deep infection, is often a variable that orthopedic surgeons have cited in favor of external fixation over ORIF. The results of our study were different from this theory; the groups were not significantly different with respect to deep infection. On the contrary, there was a higher complication rate in the

external fixation group, in particular, complications of malunion, posttraumatic arthritis, and knee instability as compared to plating group; these findings are supported in studies by Krupp et al. [6] and Hall et al. [34], and plates provide improved healing rates, restoration of the articular surface, a straight leg, a stable knee, and decreased complications. With regards to heterotopic ossification and local hardware irritation, there was a higher proportion in plating group. In addition, in term of reoperation, there was no difference between the groups in our study, but Hall et al. [34] recorded that there was a lower reoperation rate in the circular fixator group when compared to plating group.

Although the small population size, the lack of control groups, and the various functional assessment tools in the majority of these publications limited the strength of any recommendations that could be made regarding the optimal options of surgical method, the systematic analysis of the accumulated data contributed to increasing relatively high level of evidence.

## Conclusion

Although lack of enough quality randomized control trials and there exists some bias in the study, this paper shows rather enough samples supporting the current available results, and our study could offer some useful information for orthopedists in the management of complex tibial plateau fractures to help patients with these severe injuries to obtain optimal outcomes. Meanwhile, future multicentered, randomized, controlled studies should be implemented to test these outcomes.

**Conflict of interest** All the authors declared that there is no conflict of interest.

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