Trauma mechanism and patient reported outcome in tibial plateau fractures with posterior involvement

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Trauma mechanism and patient reported outcome in tibial plateau fractures with posterior involvement

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ABSTRACT

Introduction: Posterior tibial plateau fractures (PTPF) have a high impact on functional outcome and the optimal treatment strategy is not well established. The goal of this study was to assess the relationship between trauma mechanism, fracture morphology and functional outcome in a large multicenter cohort and define possible strategies to improve the outcome.

Methods: An international retrospective cohort study was conducted in five level-1 trauma centers. All consecutive operatively treated PTPF were evaluated. Preoperative imaging was reviewed to determine the trauma mechanism. Patient reported outcome was scored using the Knee injury and Osteoarthritis Outcome Score (KOOS).

Results: A total of 145 tibial plateau fractures with posterior involvement were selected with a median follow-up of 32.2 months (IQR 24.1–43.2). Nine patients (6%) sustained an isolated posterior fracture. Seventy-two patients (49%) sustained a two-column fracture and three-column fractures were diagnosed in 64 (44%) patients. Varus trauma was associated with poorer outcome on the 'symptoms' ($p = 0.004$) and 'pain' subscales ($p = 0.039$). Delayed-staged surgery was associated with worse outcome scores for all subscales except 'pain'. In total, 27 patients (18%) were treated with posterior plate osteosynthesis without any significant difference in outcome.

Conclusions: Fracture morphology, varus trauma mechanism and delayed-staged surgery (i.e. extensive soft-tissue injury) were identified as important prognostic factors on postoperative outcome in PTPF. In order to assess possible improvement of outcome, future studies with routine preoperative MRI to assess associated ligamentous injury in tibial plateau fractures (especially for varus trauma) are needed.

Abbreviations: PTPF, Posterior tibial plateau fractures; ORIF, open reduction and internal fixation; MPTA, medial proximal tibial angle; PPTA, proximal tibial angle; KOOS, Knee injury and Osteoarthritis Outcome Score; ADL, activities of daily living; ACL, anterior cruciate ligament; LCL, lateral collateral ligament; PLC, posterolateral corner.

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1. Introduction

Posterior tibial plateau fractures (PTPF) account for 28 – 70% of all tibial plateau fractures [1–4]. PTPF and associated sagittal malalignment are important negative prognostic factors with severe impact on functional outcome [3–5]. However, the decision whether or not to perform a posterior surgical approach for open reduction and internal fixation (ORIF) of a PTPF is mainly based on individual morphology of the bone injury [1,3,7]. Although the three-column concept has been proven to be very helpful for the treatment of multiple column fractures and certainly helps to depict PTPF (3, 7), the patient reported outcome scores of PTPF are not necessary better when patients are treated according to the column concept (i.e. successive osteosynthesis of each column fracture) [7].

Fracture morphology is an important factor in the choice whether or not to treat PTPF [7–9]. Subsequently, the implementation of trauma mechanism-based fracture morphology seems to be an important link in order to adopt the column concept and guide surgical decision making with regard to PTPF fixation. Recently, Xie et al. clearly demonstrated six three-dimensional fracture patterns based on injury mechanism. The diagonal nature of these patterns are based on elemental fracture mechanics where a 'compression' side has an associated opposite 'tension' side. These models could help to predict concomitant soft-tissue injuries (i.e. ligamentous and meniscal injury) and forecast clinical outcome [10].

Reported incidence of ligamentous and meniscal injury in tibial plateau fractures using preoperative Magnetic Resonance Imaging (MRI) is rather high, ranging from 47% to 99% [11]. Nevertheless, the diagonal injury pattern of tibial plateau fractures and associated ligamentous injury is not always clear. Particularly with regard to PTPF, considering the trauma mechanism in the column concept to adequately assess associated ligamentous injury, could improve the outcome of these fractures.

The primary aim of this study was to assess trauma mechanism types in PTPF and correlate these with patient reported outcome in a large cohort of PTPF. This could further help to select those patients who may benefit from preoperative MRI investigation, in order to better guide surgical decision making on fracture and soft-tissue injury management, and improve the outcome. The secondary aim was to review the outcome of current posterior plate osteosynthesis in PTPF.

2. Patients and methods

2.1. Patients

A multicenter retrospective cohort study was conducted in five level 1 trauma centers (*names blinded for revision*). All consecutive operatively treated patients sustaining a tibial plateau fracture between January 2014 and December 2016 were evaluated for eligibility. Preoperative CT imaging was mandatory to classify all fractures according to the revised three-column classification [6]. All tibial plateau fractures involving at least a posterior column fracture (Fig. 1, yellow marked zone) were selected. Exclusion criteria were: age < 18 years, deceased patients, no preoperative CT imaging available, bilateral fractures, pathological fractures, refractures and language incompatibility with the questionnaires. This study was completed in compliance with national legislation and the ethical guidelines of all separate institutions.

2.2. Study variables

All patient data was retrieved from the electronic medical file databases of the respective institutions. Relevant demographic and clinical variables were assessed. Cardiovascular risk factors include current cardiovascular diseases (e.g., cerebrovascular accident, myocardial infarction, peripheral artery disease), diabetes, obesity, smoking, dyslipidemia,

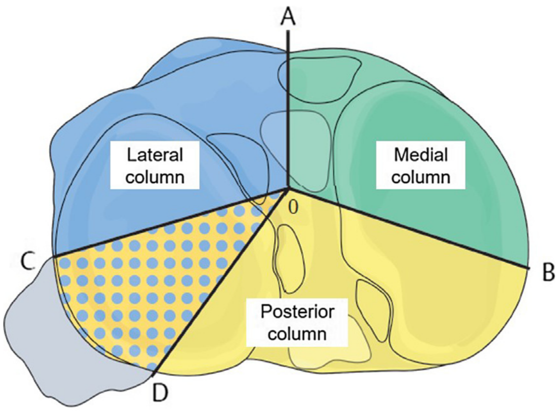

Fig. 1. The revised three-column classification. The revised three-column classification (rTCC) according to Hoekstra et al. [6], depicting the posterior column (0BC), which should be treated via a posterior approach. Lateral column (0AC) fractures that extend into the posterolateral corner (dotted area) are defined as extended lateral column fractures (0AD).

Fig. 2. Measurement of MPTA and PPTA. Measurement of MPTA and PPTA depicted on antero-posterior and lateral view, respectively.

hypercholesterolemia, hypertension, alcohol use, and rheumatoid arthritis). Medication associated with impaired wound healing (e.g., corticosteroids, adrenergic beta-agonists, and chemotherapeutic agents) was recorded. External fixation included all fractures treated by using an external fixator in a staged surgical protocol. No patients were treated with an external fixation as definite treatment. Complications were categorized as fracture-related infection, nonunion and other tibia related complications (i.e., wound related problems, implant related complaints, compartment syndrome, excessive pain, quadriceps muscle atrophy, deep vein thrombosis and neuropraxia). Fracture-related infection was defined according to the recent consensus definition [12]. Furthermore, nonunion was assessed by using follow-up radiographs and defined according to the US Food and Drug Administration guidelines as a not completely healed fracture within 9 months of injury and without progression toward healing over the past three consecutive months. Postoperative X-rays and CT-imaging were evaluated to assess the quality of the reduction. Medial proximal tibial angle (MPTA, coronal alignment, 87 ± 5°), posterior proximal tibial angle (PPTA, sagittal alignment, 9 ± 5°) and condylar width (0–5 mm, inclusive) were calculated (Fig. 2). Furthermore, postoperative reduction was assessed and marked as failed if the articular congruence (gap and/or step) exceeded 2 mm. The reintervention rate was defined as either implant removal, revision or total knee arthroplasty. Revision was defined as any intervention for loss of reduction, hardware failure or intra-articular hardware penetration.

2.3. Trauma mechanism

Preoperative X-rays and CT images were retrospectively reviewed to determine the trauma mechanism according to the updated Three-Column Concept. Varus trauma was defined as a decrease of MPTA on antero-posterior X-rays and coronal

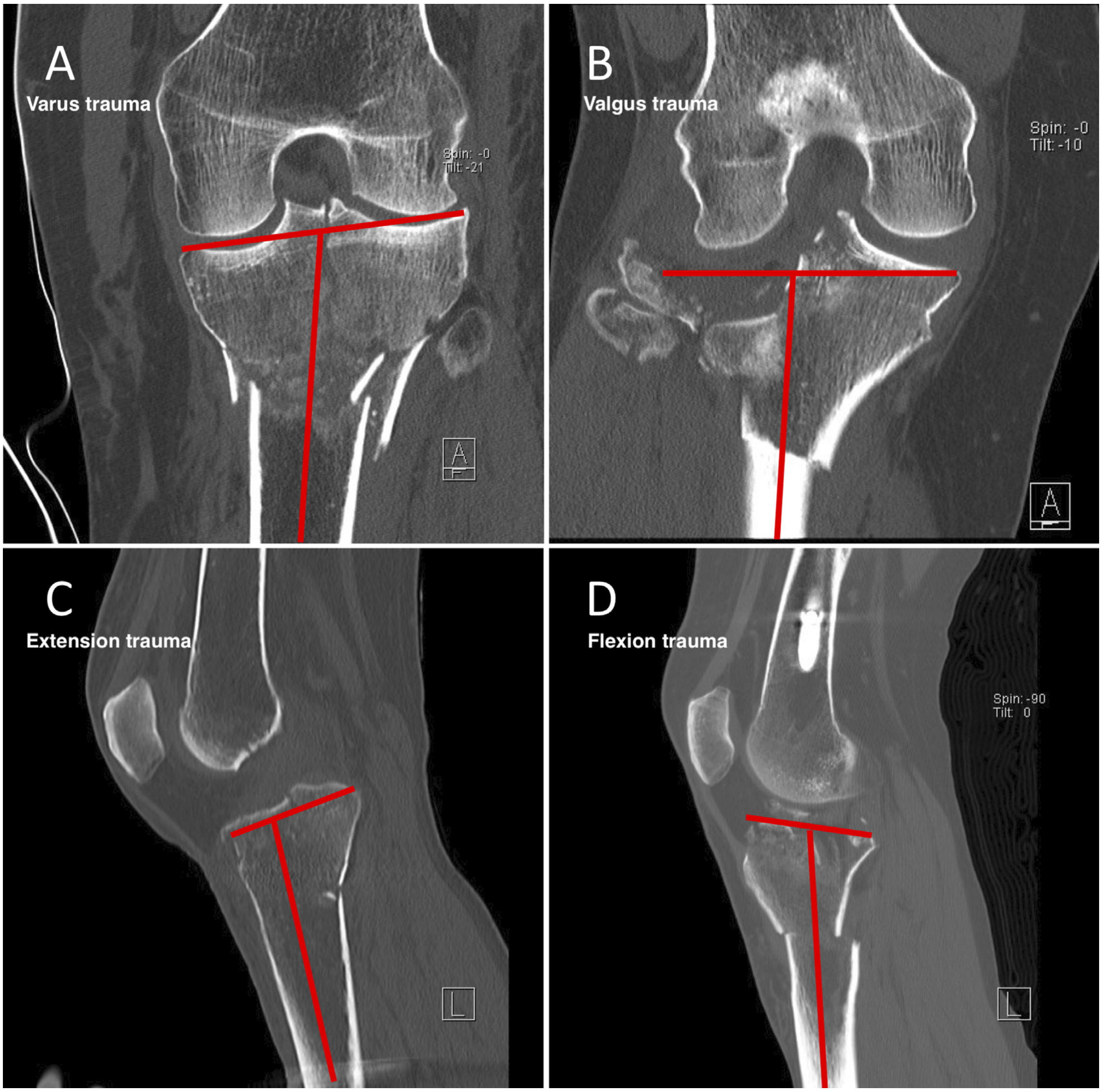

Fig. 3. Radiological determination of trauma mechanism. Varus or valgus trauma is determined by reviewing the respective decrease or increase of MPTA on antero-posterior X-rays and coronal CT-imaging (A, B). Extension and flexion trauma were determined by reviewing the respective decrease or increase of PPTA on lateral X-rays and sagittal CT-imaging (C, D).

CT-imaging. Valgus trauma was defined as an increase of MPTA on antero-posterior X-rays and coronal CT-imaging. Extension trauma was defined as a decrease of PPTA on lateral X-rays and sagittal CT-imaging. Flexion trauma was defined as an increase of PPTA on lateral X-rays and sagittal CT-imaging. Furthermore, zones of greater comminution were taken into account in deciding on definitive trauma mechanism [3,10]. Case examples are shown in Fig. 3.

2.4. Outcome measures

All selected patients received the standardized Knee injury and Osteoarthritis Outcome Score (KOOS) questionnaire to investigate functional outcome and general health status [13]. Patients were contacted by telephone if no response was obtained after four weeks. The KOOS questionnaire is validated for the Dutch, French and German language and consists of five subscales; symptoms, pain, activities of daily living (ADL), function in sport and recreation and knee related quality of life. Each subscale is presented as a normalized score (100 indicating no symptoms, 0 indicating extremely severe symptoms).

2.5. Statistical analysis

Statistical evaluation of all data was performed using IBM SPSS 25.0 (SPSS Inc. Chicago, IL). Nominal variables were compared using Chi-Square statistics (Fisher's Exact test) and nonparametric variables using the Mann-Whitney U test. For correlation testing the Pearson correlation test was used for continuous variables and the Spearman correlation test for nominal variables. A significance level of <0.05 was accepted for all tests. A multivariate analysis was conducted on all significant variables using a linear logistic regression analysis with a stepwise approach.

3. Results

3.1. Patient cohort

After exclusion, a total of 145 patients with a posterior tibial plateau fracture were included with a minimum of 14 months and a median of 32.2 months (IQR 24.1–43.2) of follow-up. A total of 92 patients (63%) responded to the questionnaires. Responders were compared to non-responders with regard to all demographic and treatment related variables. Non-responders were likely to have longer follow-up (38.9 months (IQR 26.4–50.5) versus 31.8 months (IQR 23.4–41.2), p = 0.020) and have more cardiovascular risk factors (37.7% versus 19.6%, p = 0.030). Descriptives are presented in Table 1. Open fractures were classified according to the Gustilo-Anderson classification, with 6 type I fractures, 5 type II fractures and 1 type IIIa fracture. Other complications were present in 24 (16%) patients. These included, 6 patients with wound dehiscence, 6 implant related complaints, 4 cases of compartment syndrome, 1 case with excessive clinical pain, 2 cases with deep venous thrombosis, and 5 cases with neurapraxia.

Table 1
Descriptives (n = 145).

Age (years)	50.8 (39.7–61.0)
Gender	
Male	53 (36.6%)
Female	92 (63.4%)
ASA-score	
1	64 (44.1%)
2	67 (46.2%)
3	14 (9.7%)
CVRF	
BMI (kg/m^2)	25.1 (22.3–27.7)
Smoking	34 (23.4%)
Medication	32 (22.1%)
DM	10 (6.9%)
Other CVRF	38 (26.2%)
Side	
Left	85 (58.6%)
Right	60 (41.4%)
Open fracture	12 (8.3%)
External fixation	27 (18.6%)
Delayed(-staged) surgery	
Direct (<24 h)	37 (25.1%)
Delayed (>24 h)	107 (73.8%)
Time to surgery (days)	4 (1–8.8)
Complication rate	
FRI	21 (14.5%)
Nonunion	4 (2.8%)
Other complications	24 (16.6%)
Reintervention rate	60 (41.4%)
Implant removal	38 (26.2%)
Revision	20 (13.8%)
TKA	5 (3.4%)

Continuous parameters are expressed as median values with their respective interquartile range. Categorical variables are expressed as numbers and percentages of the total number of included patients (n = 145). *Abbreviations:* ASA, American Society of Anesthesiologists; CVRF, cardiovascular risk factors; BMI, body mass index; DM, diabetes mellitus; FRI, fracture related infection; TKA, total knee arthroplasty.

3.2. Fracture classification and trauma mechanism

Classification according to the revised three-column classification resulted in 9 (6%) isolated posterior column fractures. Seventy-two patients (49%) sustained a two-column fracture, with 55 (37%) combined posterior and lateral column fractures and 17 (11%) combined posterior and medial column fractures. Three-column fractures were diagnosed in 64 (44%) patients, 27 patients sustaining a varus trauma, compared to 37 patients with valgus trauma. Considering all patients, valgus trauma was noted in 99 (68%) patients, either with extension or flexion in 42 (29%) and 57 (39) patients respectively. In 46 (31%) patients varus trauma was noted, combined with extension and flexion in 16 (11%) and 30 (20%) patients, respectively. Overall, varus trauma was associated with higher number of columns fractured (p = 0.011).

3.3. Outcome

Median KOOS scores for the five subscales are 60.7 (IQR 35.7–82.1) for 'symptoms', 63.9 (IQR 47.2–83.3) for 'pain', 69.1 (IQR 51.5–89.7) for 'activities of daily life', 30.0 (IQR 10.0–62.5) for 'sports and recreation' and 37.5 (IQR 25.0–56.3) for 'knee related quality of life'. With 17 (18%) patients reporting frequent or continuous swelling of the knee. Inability to perform full extension and flexion was reported in 31 (33%) and 28 (30%) patients, respectively. Patients reported suffering from pain in the affected knee on a daily basis in 31 cases (33%) and continuous pain in 6 cases (6%). Median KOOS scores are displayed in Fig. 4 in comparison to a population-based reference cohort and a cohort operatively treated tibial plateau fractures [7,14]. Twenty-seven patients (18.6%) were treated with initial external fixation before definitive surgery, with 2-column and 3-column fractures in 8 and 19 patients respectively.

3.4. Did posterior plate osteosynthesis improve the outcome?

In total, 27 patients (18%) were treated with posterior plate osteosynthesis. Eighteen of them returned the questionnaires (19% of all responders). Posterior plate osteosynthesis was performed in 4/9 patients (44%) with a single posterior column fracture, 9/72 patients (12%) with a two-column fracture and 14/64 patients (21%) with a three-column fracture. Comparing patients with and without posterior plate osteosynthesis did not show significant differences in any of the KOOS subscales ('Symptoms' p = 0.510, 'Pain' p = 0.076, 'ADL' p = 0.746, 'Sports/Rec' p = 0.947, 'QoL' p = 0.869).

3.5. Which factors determined the outcome?

Bivariate analysis was performed on all KOOS subscales with regard to all demographic and treatment related variables, the results are presented in (Table 2). All bivariate significant factors were evaluated for independence using a linear logistic regression analysis. Regarding the 'symptoms' subscale, varus trauma (p = 0.004) and delayed-staged surgery (p = 0.005) were associated with worse outcome. Varus trauma was also associated with higher 'pain' scores (p = 0.039). Regarding the 'ADL' subscale, delayed-staged surgery (p = 0.002) and number of columns fractured (p = 0.026) were determining factors for worse outcome. Lower scores on the 'Sports and recreation' were seen in association with delayed-staged surgery

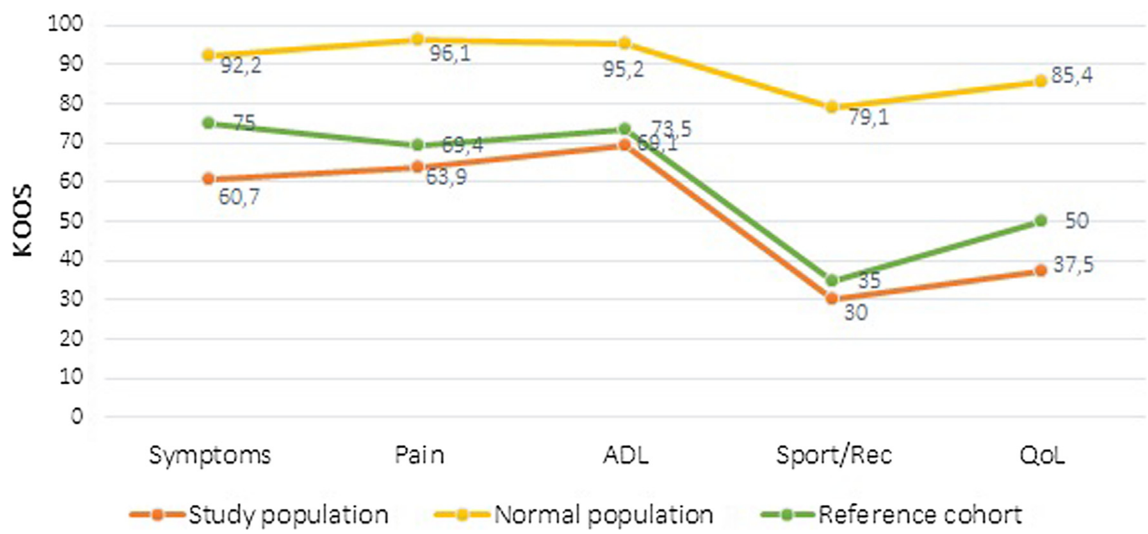

Fig. 4. KOOS outcome scores. KOOS subscale outcome scores of the study cohort, compared to a population-based reference cohort and a reference cohort of operatively treated tibial plateau fractures [7,14].

Table 2
Bivariate correlation analysis.

KOOS subscale	Symptoms	Pain	ADL	Sports/rec	QoL
Age[a]	0.061	0.152	0.576	0.557	0.142
Gender	0.249	0.903	0.244	0.920	0.863
ASA-score	0.513	0.948	0.102	0.210	0.277
BMI[a]	0.357	0.622	0.416	0.770	0.059
Smoking	0.507	0.463	0.409	0.707	0.764
Medication	0.714	0.523	0.541	0.883	0.195
DM	0.616	0.314	0.531	0.754	0.223
Other CVRF	0.134	0.342	0.881	0.422	0.952
Side	0.484	0.380	0.570	0.544	0.471
Open fracture	0.921	0.169	0.130	0.121	0.113
External fixation	0.005*	0.053	0.006*	0.002*	0.021*
Delayed (-staged) surgery	0.009*	0.529	0.196	0.380	0.163
Time to surgery[a]	0.093	0.633	0.360	0.493	0.958
Complication rate	0.361	0.299	0.373	0.845	0.092
FRI	0.652	0.813	0.633	0.400	0.682
Nonunion	0.083	0.129	0.047*	0.858	0.047*
Other complications	0.259	0.240	0.155	0.036*	0.036*
Reintervention rate	0.277	0.246	0.538	0.902	0.532
Implant removal	0.932	0.358	0.989	0.341	0.802
Revision	0.055	0.114	0.152	0.278	0.147
TKA	0.224	0.288	0.165	0.106	0.165
rTCC classification	0.038*	0.179	0.003*	0.028*	0.023*
Follow-up[a]	0.413	0.432	0.621	0.553	0.671
Radiological failure rate	0.253	0.031*	0.123	0.120	0.081
Coronal malalignment	0.774	0.682	0.464	0.667	0.460
Sagittal malalignment	0.544	0.940	0.557	0.704	0.413
Condylar width	0.207	0.040*	0.314	0.308	0.026*
Articular incongruence	0.184	0.088	0.070	0.309	0.141
Valgus/Varus	0.004*	0.040*	0.044*	0.102	0.052
Extension/Flexion	0.441	0.578	0.224	0.454	0.814

Bivariate analysis was performed using Mann-Whitney U test and Pearson correlation. Results are displayed as p-value and marked (*) if $p < 0.05$. Continuous variables are marked with[a]. Follow-up is the time interval between time of trauma and KOOS evaluation in months. Radiological failure rate was defined as presence of either malalignment, excessive condylar width or articular incongruence. *Abbreviations:* KOOS, Knee injury and osteoarthritis outcome score; ADL, activities of daily living; Sports/Rec, Sports and recreation; QoL, quality of life, ASA, American Society of Anesthesiologists; BMI, body mass index; DM, diabetes mellitus; CVRF, cardiovascular risk factors; FRI, fracture related infection; TKA, total knee arthroplasty; rTCC, revised three-column classification.

($p = 0.002$). Regarding the 'quality of life' subscale, nonunion ($p = 0.033$) and delayed-staged surgery ($p = 0.008$) were associated with poorer outcome scores.

3.6. Relation between trauma mechanism and outcome

A comparison between outcome in valgus and varus trauma is presented in Tables 3 and 4. Subgroup analysis was performed for both groups respectively for flexion and extension. For all varus trauma patients, no statistical significant differences were observed in KOOS subscales between flexion and extension. Patients with valgus trauma reported lower outcome scores when associated with extension compared to flexion trauma for the 'ADL' ($p = 0.020$) and 'Sports and recreation' ($p = 0.040$) subscales.

Table 3
Trauma mechanism versus KOOS (n = 145).

	Valgus trauma (n = 99)	Varus trauma (n = 46)	P-value
KOOS			
Symptoms	67.9 (42.9–85.7)	46.4 (32.1–64.3)	0.004*
Pain	72.2 (50.0–94.4)	59.7 (44.4–75.0)	0.041*
ADL	73.5 (57.4–95.6)	61.8 (51.5–75.0)	0.045*
Sports/Rec	35.0 (10.0–67.5)	20.0 (5.0–43.8)	0.102
QoL	43.8 (31.3–62.5)	32.3 (12.5–50.0)	0.053

Continuous parameters are expressed as median values with their respective interquartile range. Percentage displayed is according to the respective trauma mechanism. The respective P-values are calculated between treatment groups using Mann-Whitney U test for continuous variables. *Abbreviations:* KOOS, Knee injury and osteoarthritis outcome score; ADL, activities of daily living; Sports/Rec, Sports and recreation; QoL, quality of life.

Table 4
Trauma mechanism (n = 145).

	Valgus trauma (n = 99)	Varus trauma (n = 46)	P-value
Age (years)	53.0 (42.2–63.3)	47.6 (37.3–58.4)	0.196
Gender			0.418
Male	34 (34.3%)	19 (41.3%)	
Female	65 (65.7%)	27 (58.7%)	
ASA-score			0.684
1	43 (43.4%)	21 (45.7%)	
2	45 (45.5%)	22 (47.8%)	
3	11 (11.1%)	3 (6.5%)	
CVRF			
BMI (kg/m^2)	24.8 (21.9–27.4)	26.1 (22.5–28.0)	0.188
Smoking	24 (24.2%)	10 (21.7%)	0.741
Medication	22 (22.2%)	10 (21.7%)	0.947
DM	8 (8.1%)	2 (4.3%)	0.409
Other CVRF	30 (30.3%)	8 (17.4%)	0.114
Side			0.012*
Left	65 (65.7%)	20 (43.5%)	
Right	34 (34.3%)	26 (56.5%)	
Open fracture	8 (8.1%)	4 (8.7%)	0.900
Delayed (-staged) surgery			0.081
Direct (<24 h)	21 (21.2%)	16 (34.8)	
Delayed (>24 h)	78 (78.8%)	30 (65.2)	
Time to surgery (days)	4 (2–9)	4 (1–7)	0.157
Complication rate	17 (17.2%)	20 (43.5%)	0.001*
FRI	11 (11.1%)	10 (21.7%)	0.096
Nonunion	1 (1.0%)	3 (6.5%)	0.059
Other complications	11 (11.1%)	13 (28.3%)	0.015*
Reintervention rate	40 (40.4%)	20 (43.5%)	0.726
Implant removal	28 (28.3%)	10 (21.7%)	0.404
Revision	10 (10.1%)	10 (21.7%)	0.059
TKA	4 (4.0%)	1 (2.2%)	0.566
Follow up (months)	31.9 (24.2–45.3)	33.4 (23.9–41.6)	0.827
Radiological failure rate	61 (61.6%)	33 (71.7%)	0.266
Coronal malalignment	11 (11.1%)	11 (23.9%)	0.080
Sagittal malalignment	21 (21.2%)	12 (26.1%)	0.527
Condylar width	18 (18.2%)	7 (15.2%)	0.814
Articular incongruence	40 (40.4%)	24 (52.2%)	0.211

Comparison between demographics treatment related variables of patients with valgus and varus trauma. Continuous parameters are expressed as median values with their respective interquartile range. Percentage displayed is according to the respective treatment category. The respective P-values for all variables are calculated between treatment groups using Chi-Square testing for binominal, ANOVA for multinominal and Mann-Whitney U test for continuous variables. *Abbreviations:* ASA, American Society of Anesthesiologists; CVRF, Cardiovascular Risk Factors; BMI, Body Mass Index; DM, Diabetes Mellitus; FRI, fracture related infection; TKA, total knee arthroplasty.

4. Discussion

The goal of this study was to assess the impact of trauma mechanism on patient reported outcome and to evaluate the outcome of current posterior plate osteosynthesis in a large multicenter cohort of PTPF. Since soft-tissue injuries are frequent in tibial plateau fractures, our results could potentially identify those patients who are at risk for poor outcome and require preoperative soft-tissue investigation using MRI [9–11,15,16].

Our results showed that the majority of PTPF resulted from valgus trauma (68%), which is in line with previous studies showing frequent lateral column involvement in tibial plateau fractures [4,10,17]. In contrast, varus trauma, although less frequent, results in medial column fractures and is associated with posterolateral corner injury and other ligamentous injuries in the lateral compartment of the knee as shown by Porrino et al. [18] Patients who sustained a varus trauma showed significantly lower outcome scores for symptoms and pain compared to valgus trauma. However, no statistical significant differences in radiological postoperative outcome (gap/step, condylar width, MPTA and PPTA) between varus and valgus trauma were observed (Table 4). Although varus trauma more frequently resulted in three-column fractures, varus type trauma mechanism was multivariately found to be an independent factor for worse outcome. Moreover, a significantly higher complication rate was found after varus trauma. Varus trauma and medial column fractures have been associated with anterior cruciate ligament (ACL) ruptures, lateral collateral ligament (LCL) tears and posterolateral corner (PLC) injury [10,11,19]. ACL tears combined with PLC injury can lead to rotational instability and subsequent osteoarthritis. The value of preoperative MRI and the implications of ligamentous injury and repair need to be further addressed. Routine assessment of soft-tissue injury and joint stability perioperatively as well as during the follow-up is essential to identify patients in need for secondary intervention. In the present study, meniscal injuries were not specifically investigated. However, in current literature regarding meniscal tears, surgical repair is advised during primary ORIF in all visualized lesions. Remarkably, Forman et al. showed that primary repair in lateral meniscal tears had similar outcome as patients without meniscal tears [15].

Secondary surgical treatment for soft-tissue injury in our cohort was reported in only 4 patients (n = 1 medial collateral ligament repair and n = 3 arthroscopic meniscal repair). Obviously, due to the retrospective nature of the study and possible loss to follow-up, these numbers could be an underestimation. Since both PTPF and ligamentous injury are associated with high-energy trauma, frequent involvement of these ligamentous and meniscal injuries is expected in this fracture type. Gardner et al. presented a prospective cohort of 103 consecutive patients sustaining a tibial plateau fracture, who all underwent a preoperative MRI. They showed that almost everyone (99% of patients) suffered from concomitant ligamentous injury, indicating not only the high frequency of these injuries but also implicating that not all diagnosed lesions need specific treatment [19]. Currently, studies presenting the incidence of ligamentous injury selectively for PTPF are lacking. Nevertheless, MRI is not routinely performed in the standard preoperative workup for tibial plateau fractures mainly due to lacking availability and costs. Thorough knee examination (under general anesthesia) after ORIF could contribute to early diagnosis of residual ligamentous instability. Since tension contralateral to the compression side of the fracture can lead to ligamentous injury, this might further substantiate the understanding of the trauma mechanism. Understanding the relation between position of the knee during trauma and the applied force vector (and rotation) ultimately leads to more precise understanding of associated ligamentous injury, similar to the Lauge-Hansen classification for ankle fractures, where this relation has undoubtedly proven helpful in guiding treatment and prognosis (i.e. a classification based on fracture morphology, ligamentous injury and trauma mechanism).

Delayed-staged surgery using an external fixation device was shown to be a significant indicator for worse outcome on all KOOS outcome subscales except for pain. A delayed-staged surgery protocol is primarily reserved for fracture dislocations and extensive soft-tissue injury [20,21]. Although delayed-staged surgery was associated with open fractures, the need for revision surgery and multiple column fractures, linear regression analysis clearly revealed that delayed-staged surgery is an independent factor influencing outcome. The authors conclude this substantiates the possible impact of soft-tissue injury on postoperative outcome in our cohort, meaning not only ligamentous and meniscal injury but all peri-articular tissue injury. However, grading of preoperative soft-tissue injury is highly influenced by the time of evaluation and was not standardized between participating centers.

Indication for posterior plate osteosynthesis remains a highly debated topic [1,3,7]. In our study, posterior plate osteosynthesis was performed in 18% of patients. Although differences in incidence were observed compared to one, two or three columns fractured (44%, 12% and 21% respectively), no statistical significant difference was found ($p = 0.932$). No significant impact on any of the KOOS subscales was noted regarding application of posterior plate osteosynthesis. However, these results should be viewed with caution since only 18/92 responding patients were treated with posterior plating and due to heterogeneity in treatment protocols between participating centers. Recently, some authors have implicated posterior ORIF indications using the three-column concept, but this concept alone has shown insufficient to guide surgical decision making here [2,3,7]. Hence, the question remains who will benefit from plate osteosynthesis of PTPF alone and who qualify for additional treatment.

The current study has some limitations. This study presents a large multicenter cohort of posterior tibial plateau fractures in which the relationships between fracture morphology, injury mechanisms and functional outcome have been assessed. Therefore, the inherent limitations of any retrospective cohort study apply. Information regarding ligamentous injury and clinical appreciation and decision-making can therefore not be completely ascertained. Secondly, possible selection bias as a result of difference in length of follow up between responders and non-responders cannot be excluded. Thirdly, due to heterogeneity in length of follow-up, no standardized scoring of radiological outcome and osteoarthritis could be performed.

In conclusion, the presence of PTPF have been shown to severely reduce patient reported outcome after surgical treatment of tibial plateau fractures. Besides fracture morphology, varus trauma mechanism and delayed-staged surgery (i.e. extensive soft-tissue injury) were identified as important prognostic factors on postoperative outcome. Future (prospective) studies with preoperative MRI are needed to investigate associated ligamentous injury patterns in PTPF and correlate with peri- and postoperative clinical findings to guide treatment protocols and improve outcome.

Ethical approval

This study was completed in compliance with national legislation and the guidelines of the ethics committees of all participating centers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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