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ORIGINAL PAPER

# Functional outcome of intra-articular tibial plateau fractures: the impact of posterior column fractures

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**Abastract**
*Introduction* Although regularly ignored, there is growing evidence that posterior tibial plateau fractures affect the functional outcome. The goal of this study was to assess the incidence of posterior column fractures and its impact on functional outcome and general health status. We aimed to identify all clinical variables that influence the outcome and improve insights in the treatment strategies.
*Methods* A retrospective cohort study including 218 intra-articular tibial plateau fractures was conducted. All fractures were reclassified and applied treatment was assessed according to the updated three-column concept. Relevant demographic and clinical variables were studied. The patient reported outcome was assessed using the Knee injury and Osteoarthritis Outcome Score (KOOS).
*Results* Median follow-up was 45.5 (IQR 24.9-66.2) months. Significant outcome differences between operatively and non-operatively treated patients were found for all KOOS subscales. The incidence of posterior column fractures was 61.9%. Posterior column fractures, sagittal malalignment and an increased complication rate were associated with poor outcome. Patients treated according to the updated three-column concept, showed significantly better outcome scores than those patients who were not. We could not demonstrate the advantage of posterior column fracture fixation, due to a limited patient size.
*Conclusion* Our data indicates that implementation of the updated three-column classification concept may improve the surgical outcome of tibial plateau fractures. Failure to recognize posterior column fractures may lead to inappropriate utilization of treatment techniques. The current concept allows us to further substantiate the importance of reduction and fixation of posterior column fractures with restoration of the sagittal alignment.
*Level of Evidence: 3*

**Keywords** Tibial plateau fractures · Functional outcome · Three-column classification · Posterior column

**Abbreviations**

| | |
|---|---|
| TCC | Three-column classification |
| uTCC | Updated three-column concept |
| PCF | Posterior column fractures |
| KOOS | Knee injury and Osteoarthritis Outcome Score |
| OA | Osteoarthritis |
| TKA | Total knee arthroplasty |
| AO/ OTA | Arbeitzgemeinschaft fur Osteosynthesefragen/ Orthopedic Trauma Association |
| ASA-score | American Society of Anesthesiologists physical status score |
| ADL | Activities of daily living |
| QoL | Knee related quality of life |

## Introduction

The outcome of tibial plateau fractures is rather moderate [1, 2]. Factors influencing functional outcome and general

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health status are not well defined in literature, due to heterogeneity in study populations, fracture types and osteosynthesis techniques. Moreover, variable follow-up time is reported and different measurement tools are used to assess outcome in tibial plateau fractures [1–4]. Recent studies suggest that involvement of the posterior surface of the tibial plateau has more impact on outcome than previously appreciated [5, 6]. The reported incidence of posterior tibial plateau fractures ranges from 28.8% to 70.7% [6–8]. However, fractures of the posterior tibial plateau are not adequately depicted according to the widely used Schatzker and AO/OTA classification systems [7].

In contrast, the three-column classification (TCC) approach, introduced by Luo et al. in 2010 [9] has proven very useful and reliable for the pre-operative planning and treatment of tibial plateau fractures, in particular posterior tibial fractures [8–10]. According to the TCC approach, tibial plateau fractures are classified as either one, two or three column fractures (combined articular depression and cortical fracture) and need to be stabilized successively. Subsequently, with the updated three column concept (uTCC) they support the surgical approach and implant choice for the treatment of multiple column fractures on the basis of the mechanism of injury and fracture pattern [8, 11]. Limited articular depression without cortical fractures (i.e., zero column fractures) can be treated non-operatively with rather good results [12].

In this study, we retrospectively assessed the incidence of posterior column fractures (PCF) and its impact on patient functional outcome and general health status in a large consecutive patient cohort with intra-articular tibial plateau fractures. Therefore, all intra-articular tibial plateau fractures were reclassified according to the TCC approach and the treatment type was assessed, subsequently. We aimed to identify all clinical variables that influence the patient reported outcome and improve insight in the treatment strategies of intra-articular tibial plateau fractures.

## Patients and methods

### Patients

Between January 2009 and December 2014, a total of 218 consecutive patients were included in this study. Patient selection method and exclusion criteria are displayed in Fig. 1. All patients were treated in a single level 1 trauma center for intra-articular tibial plateau fractures. Follow-up was until March 14th 2016, resulting in a minimal follow-up time of 14.5 months. This study was completed in compliance with national legislation and the guidelines of the ethics committee of the University Hospitals Leuven.

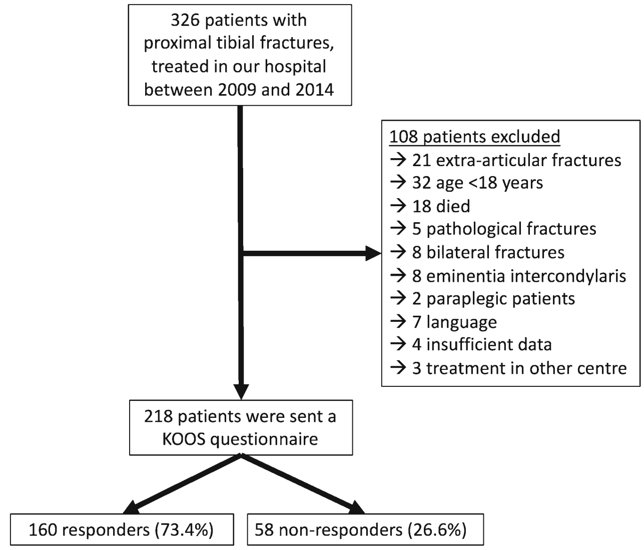


**Fig. 1** Patient inclusion and exclusion criteria

### Demographics and clinical characteristics

A total of 18 demographic and clinical variables were studied. All data was retrieved from the University Hospitals Leuven electronic medical file database. Cardiovascular risk factors include current cardiovascular diseases (e.g., CVA, MI, peripheral artery disease), diabetes, obesity, smoking, dyslipidemia, hypercholesterolemia, hypertension, alcohol use, and rheumatoid arthritis. Medication associated with impaired wound healing (e.g., corticosteroids, adrenergic beta-agonists, and chemotherapeutic agents) was recorded. All fractures were classified according to the Schatzker and AO/OTA classification systems using X-rays and CT-images if available. In addition, all fractures and applied treatment were CT based reclassified according to the TCC approach and uTCC, respectively [8, 9]. Type of treatment represents either a surgical or non-operative approach. External fixation includes all fractures treated with an external fixator in a staged surgical protocol or as definite treatment. Complications were categorized as surgical site infection, nonunion and other tibia related complications (i.e., wound related problems, implant related complaints, compartment syndrome, excessive pain, drop foot, quadriceps muscle atrophy, and deep vein thrombosis). In turn, surgical site infection was classified as either superficial or deep infection according to Center for Disease Control guidelines for surgical site infections. Furthermore, nonunion was assessed using follow-up radiographs and defined according to the US Food and Drug Administration guidelines as a not completely healed fracture within 9

**Table 1** Demography and fracture classification

| | Total (n= 218) | Operative (n=148) | Non-operative (n=70) |
|---|---|---|---|
| Age (years) | 51.4 (36.5 – 63.7) | 52.3 (41.0 – 63.3) | 46.2 (31.7 – 66.6) |
| Gender | | | |
| Male | 103 (47.2%) | 67 (45.3%) | 36 (51.4%) |
| Female | 115 (52.8%) | 81 (54.7%) | 34 (48.6%) |
| ASA-score | | | |
| 1 | 71 (32.6%) | 59 (39.9%) | 12 (17.1%) |
| 2 | 96 (44.0%) | 73 (49.3%) | 23 (32.9%) |
| 3 | 19 (8.7%) | 14 (9.5%) | 5 (7.1%) |
| 4 | 1 (0.5%) | 1 (0.7%) | 0 |
| Unknown | 31 (14.2%) | 1 (0.7%) | 30 (42.9%) |
| BMI (kg/m$^2$) | 25.3 (22.3 – 28.5) | 25.5 (22.5 – 28.8) | 24.4 (21.1 – 27.0) |
| Smoking | 50 (22.9%) | 37 (25.0%) | 13 (18.6%) |
| Medication | 37 (17.0%) | 30 (20.2%) | 7 (10.0%) |
| DM | 16 (7.3%) | 11 (7.4%) | 5 (7.1%) |
| Other CVRF | 102 (46.8%) | 72 (48.6%) | 30 (42.9%) |
| Side | | | |
| Left | 131 (60.1%) | 89 (60.1%) | 42 (60.0%) |
| Right | 87 (39.9%) | 59 (39.9%) | 28 (40.0%) |
| Open fracture | 9 (4.1%) | 8 (5.4%) | 1 (1.4%) |
| Fracture classification | | | |
| AO/OTA type 41 | | | |
| B1 | 17 (7.8%) | 9 (6.1%) | 8 (11.4%) |
| B2 | 55 (25.2%) | 16 (10.8%) | 39 (55.7%) |
| B3 | 78 (35.8%) | 61 (41.2%) | 17 (24.3%) |
| C1 | 6 (2.8%) | 5 (3.4%) | 1 (1.4%) |
| C2 | 2 (0.9%) | 1 (0.7%) | 1 (1.4%) |
| C3 | 60 (27.5%) | 56 (37.8%) | 4 (5.7%) |
| Schatzker | | | |
| 1 | 4 (1.8%) | 3 (2.0%) | 1 (1.4%) |
| 2 | 57 (26.1%) | 51 (34.5%) | 6 (8.6%) |
| 3 | 82 (37.6%) | 27 (18.2%) | 55 (78.6) |
| 4 | 68 (31.2%) | 60 (40.5%) | 8 (11.4%) |
| 5 | 1 (0.5%) | 1 (0.7%) | 0 |
| 6 | 6 (2.8%) | 6 (4.1%) | 0 |
| TCC | | | |
| 0 column | 13 (6.0%) | 0 | 13 (18.6%) |
| 1 column | 56 (25.7%) | 28 (18.9%) | 28 (40.0%) |
| 2 column | 79 (36.2%) | 68 (45.9%) | 11 (15.7%) |
| 3 column | 42 (19.3%) | 41 (27.7%) | 1 (1.4%) |
| missing CT | 28 (12.8%) | 11 (7.4%) | 17 (24.3%) |

Continuous parameters are expressed as median values with their respective interquartile range. *Abbreviations:* CVRF, cardiovascular risk factors; BMI, body mass index; DM, diabetes mellitus; ASA, American Society of Anesthesiologists; AO/OTA, Arbeitsgemeinschaft fur Osteosynthesefragen/Orthopedic Trauma Association; TCC, three column classification; CT, computer tomography

months of injury and without progression toward healing over the past three consecutive months. The re-intervention rate was defined as either implant removal or revision for screw loosening, loss of reduction, intra-articular hardware, and total knee arthroplasty (TKA).

## Outcome measures

Functional outcome and general health status were evaluated using the standardized and validated version of the Knee injury and Osteoarthritis Outcome Scale (KOOS) questionnaire for the Dutch language [13]. All eligible patients were sent questionnaires and contacted by telephone if no response was obtained after one month. The KOOS consists of five subscales; pain, symptoms, activities of daily living (ADL), function in sport and recreation (sport), and knee related quality of life (QoL). A normalized score (100 indicating no symptoms and 0 indicating extreme symptoms) was calculated for each subscale. A summarized scale of the KOOS score can not be calculated due to heterogeneity of the subscales.

The radiological outcome was evaluated by a single specialized emergency radiologist (E.G.) based on RX-alignment and location and grade of intra-articular congruence. Moreover, available images were evaluated to assess for coronal alignment (medial proximal tibial angle 87±5°) and sagittal alignment (posterior proximal tibial angle 9±5°) and condylar width (0-5 mm, inclusive). Furthermore, post-operative reduction was assessed and marked as failed reduction in the presence of articular incongruence (gap and/or step >2 mm) [14, 15].

**Table 2** Operative characteristics (n=148)

| | |
|---|---|
| External fixation | 14 (9.4%) |
| Delayed (-staged) surgery | |
| Direct (<24 hrs) | 31 (20.9%) |
| Delayed (>24 hrs) | 117 (79.1%) |
| Time to surgery (days) | 3 (2 – 6) |
| Complication rate | 40 (27.0%) |
| Superficial infection | 3 (2.0%) |
| Deep infection | 6 (4.1%) |
| Nonunion | 3 (2.0%) |
| Other complications | 36 (24.3%) |
| Re-intervention rate | 55 (37.2%) |
| Implant removal | 48 (32.4%) |
| Revision | 18 (12.2%) |
| TKA | 9 (6.1%) |
| Treatment according to uTCC | |
| Medial column (n=65) | 39 (60.0%) |
| Lateral column (n=140) | 100 (71.4%) |
| Posterior column (n=135) | 14 (10.4%) |

Continuous parameters are expressed as median values with their respective interquartile range. Percentage displayed is according to total operatively treated fractures unless otherwise stated. *Abbreviations:* DVT, deep vein thrombosis; TKA, total knee arthroplasty; uTCC, updated three column classification

## Statistical analysis

Statistical evaluation of all data was performed using IBM SPSS 23.0 (SPSS Inc. Chicago, IL). Nominal variables were compared using Chi-square statistics 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.

# Results

## Descriptives

Patient demography, fracture classification, and operative characteristics are displayed in Tables 1 and 2, respectively. The median follow-up in the study was 45.5 months (IQR 24.9–66.2). 160/218 patients returned the questionnaire resulting in a response rate of 73.4%. Age was not distributed equally between responders (median 53.8, IQR 42.2-64.9) and nonresponders (median 41.0, IQR 29.4-60.2). Moreover, responding patients were more likely female (58.1%), non-smoking (73.8%), and more often received operative treatment (73.8%). Besides infection and nonunion, 36 operatively treated patients suffered from other tibia related complications (11 wound related problems, eight implant related complaints, five compartment syndrome, five excessive pain, four drop foot, two quadriceps muscle atrophy and one deep vein thrombosis). One superficial infection was recorded in an open tibial plateau fracture after nonoperative treatment. During the follow-up period nine patients (4.1%) received a TKA, all after osteosynthesis as primary treatment, representing 6.1% of all operatively treated patients (n=148). The median time to TKA was 17 months (IQR 16-34). The incidence of patients with medial column fracures, lateral column fractures, and PCF was 29.8%, 64.2%, and 61.9%, respectively.

## Outcome

Reference values for the KOOS questionnaire were compared to the study population and presented in Fig. 2 with regard to both operatively and non-operatively treated patients [16]. Fifteen (10.1%) operatively patients lost their ability to participate in sporst activities. Regarding pain perception, 41 (27.7%) operatively treated patients reported experiencing pain on a daily basis. Nine (4.7%) patients were identified with continuous pain perception. The radiological failure rate

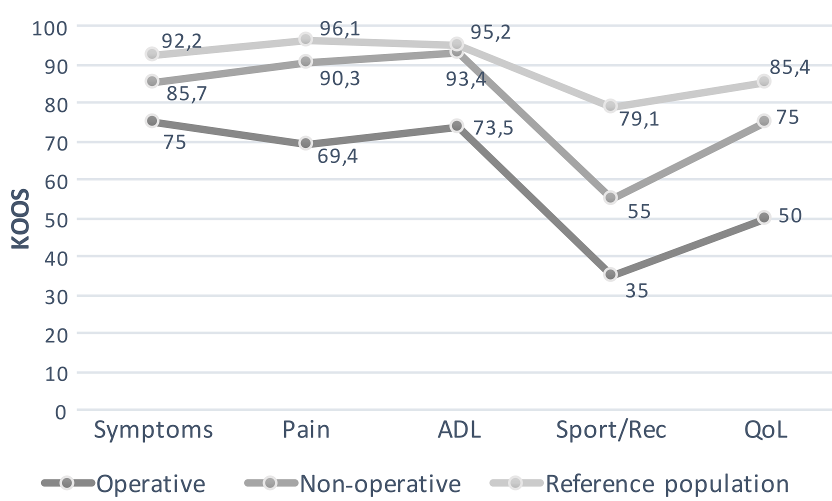


**Fig. 2** The KOOS subscales are displayed for 118 (73.8%) operatively treated patients, 42 (26.2%) nonoperatively treated patients, and a general population [16]. Abbreviations: KOOS, Knee injury and Osteoarthritis Outcome Score; ADL, activities of daily living; Sport/Rec, function in sport and recreation; QoL, knee related quality of life

was 42.2% (n=92), including 44 patients (20.2%) with coronal malalignment, 47 patients (21.6%) with sagittal malalignment, 35 patients (16.1%) with abnormal condylar width, and 35 patients (16.1%) with post-operative articular incongruence. Good, moderate, and poor functional outcome cases are illustrated in Figs. 3, 4, and 5, respectively.

### Which factors influence the outcome?

Bivariate analysis on the KOOS subscales was performed in regard to all demographic variables, fracture classifications, treatment parameters, and radiological outcome. All results are presented in Table 3. Further investigation into influencing factors on KOOS subscales was achieved by analyzing bivariate significant results in a linear logistic regression model. Regarding the 'symptoms' subscale, PCF (p=0.030), sagittal malalignment (p=0.039), and an increased complication ratio (p<0.001) were all associated with worse outcome scores. Regarding the 'pain' subscale, PCF (p=0.035) and an increased complication ratio (p=0.002) were associated with more pain. For the 'ADL' subscale, PCF (p=0.004), sagittal malalignment (p=0.029), and an increased complication ratio were also identified as significant influencing factors. Poorer scores on the 'sport' subscale were associated with multiple

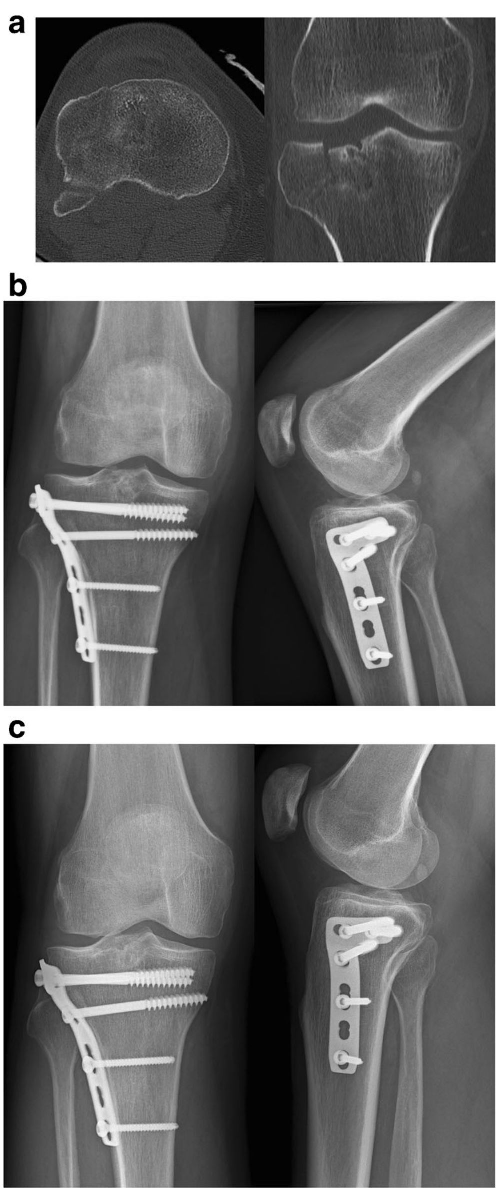


**Fig. 3** Demonstrative case with good functional outcome. **a** Pre-operative CT-images showing a lateral column fracture with a depressed central fragment. **b** Post-operative coronal and sagittal X-rays after anterolateral plating.**c** Coronal and sagittal X-rays at 2 years follow-up

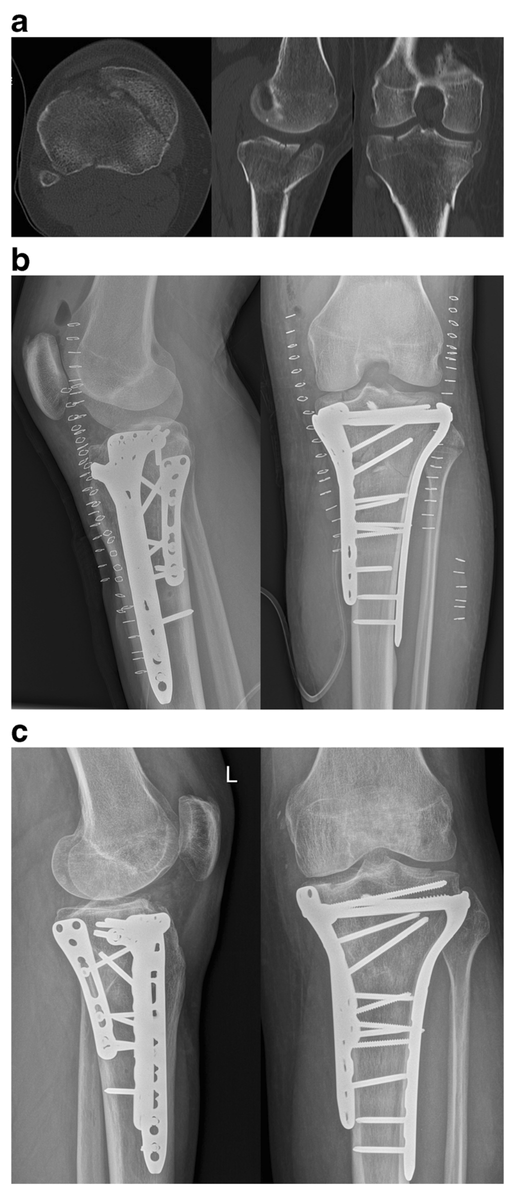


**Fig. 4** Demonstrative case with moderate functional outcome. **a** Pre-operative CT-images showing a three-column tibial plateau fracture. **b** Post-operative coronal and sagittal X-rays after combined lateral, anteromedial and posteromedial plating. **c** Coronal and sagittal X-rays at 1 year follow-up

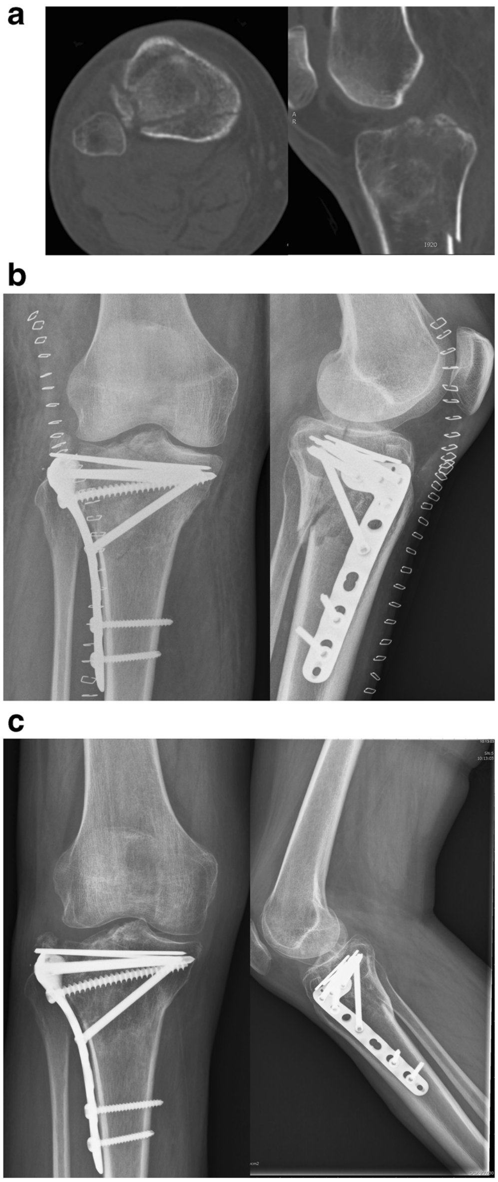


**Fig. 5** Demonstrative case with poor functional outcome. **a** Pre-operative CT-images showing a three-column tibial plateau fracture. **b** Post-operative coronal and sagittal X-rays after anterolateral plating and the use of additional K-wires. **c** Coronal and sagittal X-rays at 10 months follow-up

column fractures (p=0.013), the need for external fixation (p=0.037) and an increased complication ratio (p=0.006). Regarding the 'QoL' subscale, PCF (p=0.018), sagittal malalignment (p=0.001), and an increased complication ratio (p<0.001) were associated with poorer outcome scores.

### Relation between the uTCC, PCF fixation, and outcome

187/340 Column fractures (55.0%) were not treated according to the uTCC (Table 2); it concerned mainly PCF (n=121). In order to determine the value of the uTCC and importance of PCF fixation, a comparison between uTCC-based patient clusters was peformed. 147/218 Patients (67.4%) were not treated according to uTCC; it concerned 109/160 responding patients (68.1%), which showed significantly lower outcome scores on every subscale except for 'symptoms', as compared to patients treated according to uTCC ('symptoms' p= 0.061, 'pain' p= 0.012, 'ADL' p= 0.002, 'sport' p< 0.001, 'QoL' p= 0.001). Subanalysis for PCF however, revealed no significant differences for any KOOS subscale between those patients with (n=9, 8.8%) and without fixation of PCF (n=93, 91.2%).

## Discussion

The primary aim of this study was to determine the incidence and impact of PCF on functional outcome and general health status. For that purpose, both operatively and non-operatively treated intra-articular tibial plateau fractures were reclassified and the treatment modalities were assessed according to the (u)TCC. In order to improve the insight in treatment strategies, all variables affecting the patient reported outcome were identified.

Although comparing outcome between different studies is difficult due to differences in demographics, fracture patterns and study design, our patient reported outcome scores were markedly lower compared to the general population, with operatively treated patients scoring significantly lower (Fig. 2) [16]. Our operatively treated patients also reported notably lower KOOS as compared to a recent retrospective study including 96 patients by Van Dreumel et al. [1], whereas our findings were rather in line with Timmers et al. [2]. Since differences between operative and non-operative treatment are inherently biased by fracture severity, demonstrated by fewer complications and a lower response rate in non-operatively treated patients, further comparison between the two groups was not conducted. On the contrary, all fractures were reclassified and the treatment modalities were assessed according to the (u)TCC. Both PCF and sagittal malalignment were found to negatively influence the functional outcome of intra-articular tibial plateau fractures. In addition, the occurence of post-operative complications was associated with poor outcome as well.

Patients who were treated according to the uTCC compared to those who were not, showed significantly better outcome scores on all subscales except for 'symptoms'. The 'symptoms' subscale showed a clear tendency toward significance though. In parallel, the presence of PCF was significantly associated with lower scores on 'symptoms', 'pain', 'ADL', and 'QoL'. This indicates that implementation of the (u)TCC may improve the outcome. Of all patients with a PCF, only 10.4% were treated according to the uTCC. Therefore, failure to recognize PCF may lead to inappropriate utilization of treatment techniques resulting in worse outcome as also shown by other

**Table 3** Correlation analysis

| | Symptoms | Pain | ADL | Sport/Rec | QoL |
|---|---|---|---|---|---|
| Demographics | | | | | |
| Age[a] | .778 | .961 | .076 | .061 | .550 |
| Gender | .917 | .677 | .474 | .218 | .604 |
| ASA Score | .663 | .768 | .653 | .645 | .668 |
| BMI[a] | .202 | .394 | .481 | .702 | .720 |
| Smoking | .815 | .878 | .991 | .816 | .489 |
| Medication | .424 | .380 | .488 | .571 | .880 |
| DM | .106 | .341 | .896 | .769 | .197 |
| Other CVRF | .183 | .314 | .873 | .680 | .465 |
| Follow-up time[a] | .643 | .948 | .272 | .062 | .952 |
| Side | .218 | .650 | .732 | .403 | .620 |
| Open fracture | .012* | .032* | .038* | .201 | .078 |
| Fracture classification | | | | | |
| AO/OTA | .002* | .004* | .001* | .002* | <.001* |
| Schatzker | .038* | .013* | .010* | .026* | .031* |
| Three-column | .001* | <.001* | <.001* | <.001* | <.001* |
| Medial column | .100 | .039* | .028* | .195 | .076 |
| Lateral column | .399 | .882 | .216 | .025* | .116 |
| Posterior column | .005* | <.001* | <.001* | .001* | <.001* |
| Treatment parameters | | | | | |
| Type of treatment | .007* | .008* | .014* | .004* | <.001* |
| External fixation | .019* | .055 | .024* | .002* | .030* |
| Delayed (-staged) surgery | .595 | .218 | .371 | .967 | .096 |
| Time to definite surgery[a] | .367 | .699 | .852 | .348 | .482 |
| Complication rate | <.001* | <.001* | <.001* | <.001* | <.001* |
| Superficial infection | .062 | .442 | .243 | .659 | .180 |
| Deep infection | .073 | .185 | .115 | .061 | .181 |
| Nonunion | .087 | .439 | .502 | .314 | .344 |
| Other complications | .213 | .570 | .566 | .771 | .991 |
| Re-intervention rate | .097 | .197 | .138 | .015* | .109 |
| Implant removal | .165 | .309 | .291 | .046* | .499 |
| Revision | .024* | .168 | .107 | .048* | .052 |
| TKA | .414 | .083 | .045* | .162 | .233 |
| Radiological outcome | | | | | |
| Failure rate | .060 | .057 | .025* | .093 | .010* |
| Coronal malalignment | .670 | .988 | .879 | .208 | .582 |
| Sagittal malalignment | .042* | .073 | .033* | .076 | .004* |
| Condylar width | .046* | .035* | .020* | .166 | .096 |
| Gap/Step | .240 | .066 | .068 | .091 | .137 |

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]. *Abbreviations*: ASA, American Society of Anesthesiologists; BMI, body mass index; DM, diabetes mellitus; CVRF, cardiovascular risk factor; AO/OTA, Arbeitsgemeinschaft fur Osteosynthesefragen/Orthopedic Trauma Association; TKA, total knee arthroplasty; ADL, activities in daily living; Sport/rec, function in sport and recreation; QoL, knee related quality of life.

authors in recent years [11, 17]. Nevertheless, no significant differences were observed for any KOOS subscale between those patients with and without fixation of PCF. The limited number of responding patients, with PCF treated according to uTCC (n=9), may explain this.

Sagittal malalignment was found to have a negative impact on 'symptoms', 'ADL' and 'QoL', whereas coronal malalignment did not have consequential impact on the outcome. Sagittal malalignment can lead to biomechanical and functional problems [18]. Various authors have already demonstrated the importance of reduction and fixation of posterior tibial plateau fractures and prevention of malalignment [5, 19, 20]. These observations, together with our findings regarding the outcome, underscore the need for reduction of PCF and restoration of the posterior proximal tibial angle within reasonable limits. Using buttress techniques in an adequate manner as described before [8, 10, 11], may help to choose the optimal approaches and reduction methods. In contrast, articular incongruence does not necessarily have a negative impact on the functional outcome as previously reported by different authors [14, 21]. Furthermore, according to concurrent studies by Van Dreumel et al. [1] and Siegler et al. [22], the radiological characteristics of OA are not related with lower functional outcomes in the mid- to long-term. These findings are consistent with our data on postoperative articular incongruence. Neither the AO/OTA nor Schatzker classification was significantly associated with the outcome, probably due to its heterogeneity. In contrast, multiple column fractures (TCC approach) negatively influenced function in sports and recreation.

For all KOOS subscales, an increased complication ratio was a predictor for worse outcome. Although the category of complications was heterogeneous (e.g., infections, compartment syndrome, implant related), the occurrence of any of these complications seems to have a relevant impact on outcome. Except for one superficial infection in an open fracture, all complications were registered in operatively treated patients. Compared to the literature our overall observed complication rate in the operatively treated group was relatively low (27.0%). Jansen et al. [23] reported an overall complication rate of up to 39.1% with high infection rates and local wound problems. In contrast, our total infection rate was remarkably lower (4.6%) than in most other studies [15, 24]. Secondary OA is a late complication of tibial plateau fractures often resulting in the need for a TKA, but the incidence rates of both OA and TKA vary in the literature [21, 25]. For TKA, incidence ranges from 4% after a mean follow-up of 20 months to 22% after a mean follow-up of six years. [1, 2]. Wasserstein et al. defined the risk for TKA in a large cohort at 5.3% and 7.3% after five and ten years, respectively [25]. Since our study has a median follow-up of 45.5 months, the incidence rate for TKA of 6.1% was in line with the literature.

This study has some limitations. Firstly, the limitations inherent to any retrospective study. Secondly, the fact that outcome was reported at a single point in time rather than at a certain point in follow-up time may limits the strength of the evidence. Furthermore, concurrent soft tissue injury was not evaluated in this study which could potentially influence outcome results.

In conclusion, our outcome scores after both operative and non-operative treatment of intra-articular tibial plateau fractures were markedly lower compared to the reference population. The incidence of patients with PCF (61.9%) was rather high. This may be explained by the frequent involvement of the posterolateral corner in lateral column fractures, the so-called extended lateral column fractures [10]. Subsequently, PCF and associated sagittal malalignment were identified as negative prognostic factors toward the outcome; patients treated according to the uTCC showed significantly higher outcome scores than patients who were not. This indicates that implementation of the uTCC may improve the outcome. Failure to recognize and treat PCF and sagittal malalignment may lead to inappropriate utilization of treatment techniques resulting in worse outcome (Fig. 5). Nevertheless, we could not demonstrate the benefit of PCF fixation compared to non PCF fixation due to limited patient numbers. Moreover, the occurrence of complications of various aetiology in operatively treated patients had significant effects on the overall outcome as well. This retrospective comparative study was only possible by the fact that posterior tibial plateau fractures were often ignored in our clinical practice. However, since 2014 all tibial plateau fractures in our center are treated according to the (u)TCC principles. Therefore, consistent treatment will allow us in the future to further substantiate the importance of reduction and fixation of PCF with restoration of the sagittal alignment.

**Compliance with ethical standards**

**Conflict of Interest** The authors declare that they have no conflict of interest.

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**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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