Challenges and opportunities in trauma research: study designs and patient-reported outcome measures

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CHAPTER 11

Long-term outcomes after open reduction and internal fixation of bicondylar tibial plateau fractures

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(Injury)

Abstract

Background

To establish normative data, long-term patient-reported outcome measures (PROMs) on function and health-related quality of life (HrQoL) after operative treatment of bicondylar tibial plateau fractures. Secondly, to identify risk factors associated with functional outcome and HrQoL.

Methods

We performed a retrospective cohort study at two Level I trauma centers. All adult patients with AO/OTA 41-C or Schatzker V/ VI tibial plateau fractures treated between 2001 and 2016 (n= 450) by open reduction internal fixation (ORIF). The survey was completed by 214 patients (48%). Primary outcome was patient-reported functional outcome assessed with the PROMIS Physical Function (PROMIS PF). Secondary outcomes were HrQoL measured with the EuroQol 5-Dimensions 3-Levels (EQ-5D-3L), infection rate, and total knee arthroplasty (TKA) rate.

Results

Infection occurred in 26 cases (12%) and TKA was performed in 6 patients (3%). The median PROMIS PF scores was 49.8 (IQR;42-54). The median EQ-5D-3L was 0.83 (IQR;0.78-1.0). %). The multivariable regression model revealed female gender, diabetes, and worse HrQoL were correlated with worse functional outcome. The multivariable regression model revealed smoking, diabetes, and the subsequent need for TKA to be correlated with worse HrQoL.

Conclusion

The PROMIS PF and EQ-5D-3L did not reach a minimum clinically important difference. The PROMIS PF items revealed patients had no difficulty in walking more than a mile or climbing a flight of stairs. However, patients were limited in doing vigorous activities and patients should be counseled about the expected long-term outcomes. This study emphasizes the correlation between injury specific functional PROMs and general health measures.

Introduction

Tibial plateau fractures account for approximately 30% of all tibia fractures, and can be classified according to the Schatzker or AO/OTA classification.[1-4] Bicondylar fractures of the tibial plateau, AO/OTA 41-C or the Schatzker V/VI, are complex and severe injuries.[4,5] These bicondylar fractures account for approximately 18% to 39% of all tibial plateau fractures.[5]

The operative management of bicondylar tibial plateau fractures is challenging due to several aspects that need to be addressed including articular reduction, angular stability, coronal alignment, and soft-tissue injuries.[4,5] However, definitive consensus on the operative fixation of bicondylar tibial plateau fractures has not yet been established. Comparisons of the different treatment modalities remains difficult with no fixation method resulting in superior outcomes or associated with a lower risk of complications.[5] The optimal management should be based on patient- and fracture specific characteristics due to the wide range in fracture complexity, severity, and soft-tissue involvement.[4,5] However, the long-term results and functional outcome after operative treatment of bicondylar tibial plateau fractures have not been widely studied. Contributing to the difficulty in choosing the optimal management for bicondylar tibial plateau fractures is the lack of validated patient-reported outcome measures (PROMs).[5]

The PROMIS PF measures are recently developed PROMs, which have been validated in patient populations with orthopedic disorders, and have shown to be psychometrically superior to legacy measures in several key populations.[6] Although increasingly common, PROMIS scores have not been widely used in the evaluation of bicondylar tibial plateau fractures.

The aim of this study was to establish normative data, long-term patient-reported functional outcome and health-related quality of life (HrQoL) after operative treatment of bicondylar tibial plateau fractures. Secondly, this study sought to identify risk factors associated with functional outcome and HrQoL.

Methods

Study design

A retrospective cohort study with follow-up by questionnaire was performed using data from two American College of Surgeons (ACS) level I trauma centers. All adult patients with bicondylar tibial plateau fractures who were treated with ORIF between January 2001 and December 2016

were eligible for inclusion. Eligible patients were identified by searching for Current Procedure Terminology (CPT) codes and International Classification of Diseases (ICD) codes in the institution's Research Patient Data Registry (RPDR). Inclusion criteria were: (1) age 18 years or older, (2) bicondylar tibial plateau fracture (AO/OTA 41-C or Schatzker V/VI), (3) treatment with ORIF, and (4) minimum of 12 months follow-up. Exclusion criteria were: (1) treatment for fracture at an outside facility, (2) pathologic fracture, (3) cognitive impairment, or (4) language other than English. Data collection was performed by reviewing electronic medical records, operative reports, and radiology reports. Eligible patients were invited to participate by a recruitment letter. Questionnaires were administered through telephone interviews or collected online and managed using REDCap (Research Electronic Data Capture). REDCap is a secure, web-based application designed to support data collection for clinical research studies.[7] Informed consent was obtained from all subjects and approval was granted by the Institutional Review Board.

Outcome measures and explanatory variables

Electronic medical records were reviewed to collect baseline demographic characteristics, body mass index (BMI), smoking status, diabetes, Charlson Comorbidity Index (CCI), trauma date, trauma mechanism, time from injury to surgery, fracture and treatment characteristics. BMI was considered if reported within a range of six months prior to or after ORIF. Smoking status was considered positive if the patient was a smoker at the time of fixation. The CCI is a method of categorizing and indexing multiple comorbidities.[8] Injury mechanisms were subdivided into low-energy or high-energy and classified according to the Advanced Trauma Life Support guidelines. High-energy trauma (HET) mechanisms were defined as falls from height, crush injuries, motor vehicle and motorcycle accidents.[9,10] AO/OTA 41-C or Schatzker V/ VI tibial plateau fracture classification was confirmed by two orthopedic surgeons.

The primary outcome measure, patient-reported functional outcome, was assessed at least 12 months following ORIF using the PROMIS Physical Function (PROMIS PF). PROMIS was created to standardize the measurement and reporting of health outcomes to improve patient-reported outcome assessment for research and clinical practice. The PROMIS PF short-form-10 questionnaire consists of ten questions with five response options, assessing limitation and difficulty with certain physical activities, with higher scores representing higher physical function.

The PROMIS PF questionnaire measures the domain of physical functioning, with a mean score of 50 being representative of the general population of the United States.[11,12]

Secondary outcomes were HrQoL measured with the EuroQol 5-Dimensions 3-Levels (EQ-5D-3L) questionnaire, infection rate, and total knee arthroplasty (TKA) rate. The EQ-5D-3L is a five-item questionnaire that measures general health status, with a higher score representing a better quality of life. The EQ-5D-3L includes five dimensions, mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. The EQ-5D-3L scores were calculated using a scoring algorithm, with a mean score of 0.88 being representative of the general population of North-American.[13-15] Infections were subdivided in superficial or deep wound infection. Superficial infection was defined as surgical site infection that was treated with antibiotics alone. If surgical irrigation and debridement was required, it was considered a deep infection.

Statistical analysis

Descriptive results are presented as mean values with standard deviations and range (SD, range), median values with interquartile range (IQR) or absolute numbers and percentages (%). Distribution of continuous explanatory and outcome variables were assessed using the Shapiro-Wilk test. Differences in baseline characteristics between responders and non-responders were compared. Continuous variables were evaluated using an independent sample t-test or Mann–Whitney U test. Categorical variables were compared using the Pearson's chi-squared test. The correlations between the PROMIS PF and EQ-5D-3 L outcome measures was assessed using Pearson's correlation coefficient. PROMIS PF and EQ-5D-3 L scores of the study population were compared with the norms for a general North-American population using the independent sample t-test.[12,15] The association between individual predictors and the outcomes measures were determined by bivariate linear regression analyses. Multivariable linear regression analyses were performed to identify factors associated with the outcome measures. To avoid overfitting, the final multivariable linear regression models were selected by forward stepwise regression. In this approach, individual predictors associated with the outcome measure with a p-value <0.1 in the bivariate analyses were included one by one in the multivariable regression model. Predictors no longer significantly associated with the outcome were omitted, only if doing so did not increase the deviance of the model. In the last step, individual predictors initially excluded after bivariate analyses were reincorporated in the multivariable regression model, only if doing so reduced the

overall deviance of the model.[16] The significance level was defined as a p value <0.05. All statistical analyses were performed using STATA® 13.1 (StataCorp LP, TX, USA).

Results

In total, 450 patients met the inclusion criteria. However, 236 patients could not be contacted or refused participation. This resulted in the inclusion of 214 patients (48%) for analysis. The responders were significantly older; 53 years compared with 49 years in the non-responder group (p = 0.004). The responders consisted of less males (50% versus 69%) (p= <0.001), less active smokers (17% versus 28%) (p = 0.005), and more patients with diabetes (11% versus 3%) (p = 0.002) compared with the non-responders. There was no statistical difference in the year of injury between responders 2010 (IQR; 2006–2013) and non-responders 2009 (IQR; 2006–2013) (p = 0.188). The baseline responder characteristics are shown in Table 1.

Table 1. Baseline characteristics (n= 214)

	Mean	**SD**
Age (years)	53	13
BMI (n= 198)*	27	(24-30)
	N	%
Gender		
Male	107	50
Female	107	50
Smoking (n= 210)		
Yes	36	17
No	178	83
Diabetes		
Yes	24	11
No	190	89
CCI		
0	76	36
1	56	26
2	44	21
3	17	8
≥ 4	21	10
Fracture side		
Left	111	52
Right	103	48
Open fracture		
Yes	17	8
No	197	78
Mechanism		
Fall - low energy	79	37
Fall - high energy	34	16
Motor vehicle crash	40	19
Motorcycle crash	25	12
Bicycle accident	2	1
Sports-related	19	9
Other	15	7
HET		
Yes	110	51
No	104	49

* Median (IQR); BMI, Body Mass Index; CCI, Charlson Comorbidity Index; HET, High-Energy Trauma; Percentages may not add up to 100 due to rounding

Table 2. Treatment and outcome measures (n=214)

	Median	IQR
Time injury to ORIF (days)	3	1-7
Time external fixation to ORIF (days)	5	4-11
Time injury to infection (days)	15	13-23
Time ORIF to TKA (months)	23	13-29
Time to questionnaire (months)	86	48-134
PROMIS PF	49.8	42-54
EQ-5D-3L	0.83	0.78-1.0
	N	**%**
Time to questionnaire distribution (months)		
12-24	19	9
24-48	35	16
48-72	40	19
>72	120	56
Approaches		
Anterior	48	22
Lateral	115	54
Medial	33	15
Posterior	4	2
Posteromedial	14	7
External fixation		
Yes	61	29
No	153	72
Infection		
No	188	88
Superficial	6	3
Deep	20	9
TKA		
Yes	6	3
No	208	97

ORIF, Open reduction internal fixation; TKA, Total knee arthroplasty; PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function; EQ-5D-3L, EuroQol 5-Dimensions 3-Levels; Percentages may not add up to 100 due to rounding.

The mean age at injury for the population of responders was 53 years (SD 13, range 24–89) and 107 patients (50%) were male. Open fractures were sustained by 17 patients (8%). The mechanism of injury was a low-energy fall for 79 patients (37%), with 110 patients (51%) involved in high-energy trauma mechanisms. Treatment and outcome measures are shown in Table 2. The median time from injury to fixation was 3 days (IQR; 1–7) and 61 fractures (29%) were treated with temporizing external fixation. Infection occurred in 26 cases (12%), with 6 superficial infections (3%) and 20 deep infections (9%). TKA was performed in 6 patients (3%) after a median duration of 23 months following ORIF (IQR; 13–29).

PROMs

The questionnaires were completed after a median duration of 86 months from injury (IQR; 48–134) (Table 2). The questionnaires were completed by 120 patients (56%) after more than 72 months following injury, 40 patients (19%) between 48 and 72 months, 35 patients (16%) between 24 and 48 months, and 19 patients (9%) between 12 and 24 months. The mean PROMIS PF score was 47.7 (SD 9.5), significantly lower compared with the mean score of 50 for

Table 3. PROMIS PF items targeting walking or mobility. (n=214)

	Median	IQR
Does your health now limit you in doing vigorous activities, such as running, lifting heavy objects, participating in strenuous sports?	3	2-4
Does your health now limit you in walking more than a mile?	5	3-5
Does your health now limit you in climbing one flight of stairs?	5	4-5
Does your health now limit you in bending, kneeling, or stooping?	4	3-5

PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function; Items scored 1 (Cannot do), 2 (Quite a lot), 3 (Somewhat), 4 (Very little), and 5 (Not at all), with higher scores representing higher physical function

Table 4. Multivariable regression analyses

	β regression coefficient	95% CI	p-value
PROMIS PF			
Age	-0.080	-0.168 – 0.006	0.068
Sex			
Male	Ref	–	–
Female	-2.857	-5.034 – -0.680	0.010
BMI	-0.135	-0.310 – -0.039	0.128
Smoking	-0.063	-2.605 – -2.478	0.961
Diabetes	-3.635	-6.576 – -0.694	0.016
Infection	-0.676	-3.568 – 2.216	0.645
TKA	-1.691	-7.168 – 3.785	0.542
EQ-5D-3L	30.910	25.893 – 35.927	<0.001
EQ-5D-3L			
Age	-0.001	-0.003 – 0.000	0.211
Sex			
Male	Ref	–	–
Female	-0.048	-0.104 – 0.007	0.091
Smoking	-0.093	-0.160 – -0.026	0.006
Diabetes Mellitus	-0.086	-0.167 – -0.004	0.038
Infection	-0.057	-0.134 – 0.018	0.139
TKA	-0.212	-0.361 – -0.063	0.005

PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function; EQ-5D-3L, EuroQol 5-Dimensions 3-Levels; BMI, Body Mass Index; TKA, Total knee arthroplasty

the reference population score (P= <0.001). The median scores of different items of the PROMIS PF targeting walking or lower extremity mobility are shown in Table 3. The mean EQ-5D-3L was 0.82 (SD 0.2), significantly lower compared with the mean score of 0.88 for the reference population score (p= <0.001). The PROMIS PF and EQ-5D-3L outcome measures were correlated (correlation coefficient = 0.75, p= <0.001). In the bivariate linear regression analyses age, BMI, female gender, diabetes, CCI, time to questionnaire, and TKA were found to be independently associated with worse physical function measured with the PROMIS PF (Supplementary Table 1). Factors associated with lower HrQoL measured by the EQ-5D-3 L score in the bivariate linear regression analyses were age, BMI, female gender, active smoking status, diabetes, CCI, time to questionnaire, and TKA (Supplementary Table 1).

In multivariable regression analyses, female gender (regression coefficient (β) −2.857; 95% Confidence Interval (CI) −5.034 to −0.680; p = 0.010), diabetes (β –3.635; 95% CI −6.576 to −0.694; p = 0.016), and lower HrQoL assessed using the EQ-5D-3L (β 30.910; 95% CI 25.893 –

35.927; p= <0.001) were found to be independently associated with worse physical function measured with the PROMIS PF (Table 4). Factors associated with lower EQ-5D-3 L score in the multivariable regression model were active smoking status (β −0.093; 95% CI −0.160 −0.026; p = 0.006), diabetes (β −0.089; 95% CI −0.167 to −0.004; p = 0.038), and TKA (β −0.212; 95% CI −0.361 to −0.063; p = 0.005).

Discussion

To our knowledge, with the inclusion of 214 patients, this study is the largest cohort to establish normative data and evaluate long-term patient-reported physical function outcome and HrQoL after ORIF of bicondylar tibial plateau fractures. Infection occurred in 26 cases (12%), with 6 superficial infections (3%) and 20 deep infections (9%). TKA following initial ORIF was performed in 6 patients (3%). Both patient-reported physical function and HrQoL were significantly lower compared with the age-by-gender norms for a general North American population. The multivariable regression model revealed female gender, diabetes, and worse HrQoL were correlated with worse functional outcome. The multivariable regression model revealed smoking, diabetes, and the subsequent need for TKA to be correlated with worse HrQoL.

Previous studies have reported impaired functional outcome and HrQoL after bicondylar tibial plateau fractures. Jansen et al.[17] reported the medium-term results of 22 patients with 23 AO/OTA type C fractures of the tibial plateau. They concluded that complex articular tibial plateau fractures continue to have a severe impact on function in the injured knee, with an average Lysholm score of 66.2 and an average KOOS score of 67.84. Timmers et al.[18] presented the results after a mean of 6 years of 82 patients after ORIF of tibial plateau fractures, 46 with Schatzker I–IV and 17 with Schatzker V–VI fractures. They evaluated functional outcome with the KOOS questionnaire and HrQoL using the EuroQol-6D questionnaire. Their overall cohort had a "Fair" functional knee outcome and HrQoL was lower in comparison to the general Dutch population.[18] Rohra et al.[19] presented the functional results of 34 Schatzker type V and VI tibial plateau fractures using The Knee Society Score after treatment with dual plates after a minimum of 3 years. They reported 24 patients (71%) with an Excellent, 8 patients (24%) with Good, 1 patient (3%) with Fair, and 1 patient (3%) with Poor functional Knee Society Scores. Cavallero et al.[20] compared outcomes between locking (n = 29) and nonlocking constructs (n = 27) for the treatment of bicondylar tibial fractures and they reported a PROMIS PF score of 39 and 41,

respectively. Virkus et al.[21] reported a mean PROMIS PF scores of 40, for both 1-stage definitive fixation (n = 28) and 2-stage fixation (n = 24) after initial spanning external fixation for bicondylar tibial fractures.

In the current study, both the PROMIS PF (47 vs. 50) and EQ-5D-3L (0.82 vs. 0.88) were significantly lower compared with the age-by-gender norms for a general North American population. However, these lower scores are likely not clinically significant, as the minimum clinically important difference of the EQ-5D-5 L in patients with hip or knee osteoarthritis among surgical patients has been shown to be 0.32.[22] The PROMIS PF has been shown to have a minimum clinically important difference of 15.98 for patients with knee injuries.[23] In the current study, the PROMIS PF items targeting walking or mobility showed patients had no difficulty in walking more than a mile or climbing flight of stairs. However, patients were limited in doing vigorous activities. Unfortunately, comparison of literature remains difficult due a wide variety of functional outcome scores and the lack of validated patient-centered outcome measures. Further research is needed to focus on specific fracture types to optimize patient-reported outcomes.[5]

The impaired long-term functional outcome and HrQoL in previous studies could be the result of the complexity and severity of bicondylar tibial fractures.[4,5] Bicondylar tibial plateau fractures are usually caused by high-energy trauma mechanisms as a result of motor vehicle collisions, falls from height, motorcycle collisions, and pedestrians being struck by vehicles.[5] These fractures are associated with substantial soft-tissue injuries, and 8% to 43% of bicondylar tibial plateau injuries are presented as open fractures.[5] In our study, open fractures were sustained by only 17 patients (8%), and 110 patients (51%) were involved in high-energy trauma mechanisms. Our results for open fractures and energy of trauma mechanisms showed no association in the bivariate linear regression analyses with long-term physical function or HrQoL.

Operative treatment of bicondylar tibial plateau fracture has been associated with complications such as deep infection, non-union and the need of revision surgery, with an overall high complication rate varying from 28% to 39%.[5] Khatri et al.[24] evaluated 65 patients with Schatzker type V and type VI tibial plateau fractures treated by ORIF. They reported superficial wound infections in 9.2% of patients and 4.6% with deep wound infections. In the current cohort, in accordance with previous literature, infection occurred in 26 cases (12%), with 6 superficial infections (3%) and 20 deep infections (9%). The need for subsequent arthroplasty surgery also

low, with in 6 patients (3%) needing TKA following initial ORIF. However, our study demonstrates that the development of infection and the need for TKA, while suboptimal in the treatment course and recovery, were not associated with worse long-term functional outcome in the multivariable regression model. However, TKA was associated with worse HrQoL in the multivariable regression model. Comparison of literature still remains difficult, with different reports of infection rates, due to the use of different surgical techniques and a variety of approaches.[5]

In the current study, female gender, diabetes, and HrQoL were correlated with worse knee function in the multivariable regression model. To our knowledge, this study is the first to evaluate factors associated with patient-reported functional outcome. In our study, HrQoL was correlated with functional outcome, emphasizing the importance of obtaining both general global health measures and injury specific measures when evaluating outcomes after injuries. A previous study has shown strong correlation between global health measures and injury specific functional scores.[25] Different fracture characteristics of bicondylar tibial plateau fractures contribute to the potential for poor outcome such as associated soft-tissue injury and concomitant injuries. By adjusting injury specific functional outcome measures for general health measures, functional outcome scores might be assessed in the right context when evaluating treatment. This could be important for the evaluating of injuries that occur in the context of high-energy trauma mechanisms, concomitant injuries, and heterogeneous patient populations.

This study has several limitations. First, the study is limited by the retrospective nature. This study did not include prospective collection of functional and radiological measures during standardized follow-up times, which would increase the understanding of the impact treatment and recovery have on patient-reported functional outcome and HrQoL. Second, we were not able to account for all variables that could potentially influence the outcome measures. Therefore, the factors identified to be correlated with our outcome measures should not be considered as the only factors effecting patient-reported functional outcome and HrQoL after ORIF of bicondylar tibial plateau fractures. Third, due to the relative long interval between treatment and follow-up, 91% of patients had a follow up of >24 months, functional outcome scores could be influenced by other conditions, events, or patient factors. Although time to questionnaire was associated with both the PROMIS PF and EQ-5D-3L in the bivariate analyses, there was no association with worse outcome in the multivariable regression model. Fourth, the response rate

was relatively low (48%). However, to our knowledge, with the inclusion of 214 patients, this study is the largest cohort to establish normative data and evaluate long-term outcome of bicondylar tibial plateau fractures focusing on AO/OTA 41-C or Schatzker V/ VI. Fifth, there were several differences in baseline characteristics between the responders and non-responders. The responders consisted of significantly less males, less active smokers, and more patients with diabetes, compared with the non-responders. Therefore, the effect of diabetes on functional outcome and HrQoL might be an overestimation and may not be generalized to all tibial plateau fracture patients. However, the effect of smoking on HrQoL might be an underestimation of the true impact of tobacco use.

Unfortunately, comparison of literature remains difficult due to a wide variety of AO fracture types, operative treatments, approaches, PROMs, and duration to follow-up, indicating a substantial need for further research. We suggest future research to focus on factors that might contribute to the potential for poor outcome such as associated soft-tissue injury and concomitant injuries (poly-trauma). Furthermore, we suggest the prospective collection of functional and radiological measures during standardized follow-up times, which would increase the understanding of the impact treatment and recovery have on patient-reported functional outcome and HrQoL.

Conclusion

Both the PROMIS PF and EQ-5D-3L were lower compared with the age-by-gender norms for a general North American population, however, did not reach a minimum clinically important difference. The PROMIS PF items revealed patients had no difficulty in walking more than a mile or climbing a flight of stairs. However, patients were limited in doing vigorous activities and patients should be counseled about the expected long-term outcomes. Factors that may influence worse functional outcome following ORIF of bicondylar tibia fractures are female gender, diabetes, and patients with lower HrQoL. This study emphasizes the correlation between injury specific functional outcome measures and general health measures. By adjusting injury specific functional outcome measures for general health measures, functional outcome scores might be assessed in the right context.

References:

1. Schatzker J, McBroom R, Bruce D. The tibial plateau fracture. The Toronto experience 1968--1975. *Clinical orthopaedics and related research.* 1979(138):94-104.
2. Kellam JF, Meinberg EG, Agel J, Karam MD, Roberts CS. Introduction: Fracture and Dislocation Classification Compendium-2018: International Comprehensive Classification of Fractures and Dislocations Committee. *Journal of orthopaedic trauma.* 2018;32 Suppl 1:S1-S10.
3. Millar SC, Arnold JB, Thewlis D, Fraysse F, Solomon LB. A systematic literature review of tibial plateau fractures: What classifications are used and how reliable and useful are they? *Injury.* 2018;49(3):473-490.
4. Mthethwa J, Chikate A. A review of the management of tibial plateau fractures. *Musculoskeletal surgery.* 2018;102(2):119-127.
5. Lee AK, Cooper SA, Collinge C. Bicondylar Tibial Plateau Fractures: A Critical Analysis Review. *JBJS reviews.* 2018;6(2):e4-e4.
6. Brodke DJ, Saltzman CL, Brodke DS. PROMIS for Orthopaedic Outcomes Measurement. *The Journal of the American Academy of Orthopaedic Surgeons.* 2016;24(11):744-749.
7. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of biomedical informatics.* 2009;42(2):377-381.
8. Quan H, Li B, Couris CM, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *American journal of epidemiology.* 2011;173(6):676-682.
9. Advanced trauma life support (ATLS(R)): the ninth edition. *The journal of trauma and acute care surgery.* 2013;74(5):1363-1366.
10. Linder F, Mani K, Juhlin C, Eklöf H. Routine whole body CT of high energy trauma patients leads to excessive radiation exposure. *Scandinavian journal of trauma, resuscitation and emergency medicine.* 2016;24:7.
11. Cella D, Yount S, Rothrock N, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS): progress of an NIH Roadmap cooperative group during its first two years. *Medical care.* 2007;45(5 Suppl 1):S3-S11.
12. Cella D, Riley W, Stone A, et al. The patient-reported outcomes measurement information system (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005-2008. *Journal of Clinical Epidemiology.* 2010;63(11):1179-1194.
13. Rabin R, de Charro F. EQ-5D: a measure of health status from the EuroQol Group. *Annals of medicine.* 2001;33(5):337-343.
14. Shaw JW, Johnson JA, Coons SJ. US valuation of the EQ-5D health states: development and testing of the D1 valuation model. *Medical care.* 2005;43(3):203-220.
15. Fryback DG, Dunham NC, Palta M, et al. US norms for six generic health-related quality-of-life indexes from the National Health Measurement study. *Medical care.* 2007;45(12):1162-1170.
16. Shankaran V, Jolly S, Blough D, Ramsey SD. Risk factors for financial hardship in patients receiving adjuvant chemotherapy for colon cancer: a population-based exploratory analysis. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology.* 2012;30(14):1608-1614.
17. Jansen H, Frey SP, Doht S, Fehske K, Meffert RH. Medium-term results after complex intra-articular fractures of the tibial plateau. *Journal of orthopaedic science : official journal of the Japanese Orthopaedic Association.* 2013;18(4):569-577.
18. Timmers TK, van der Ven DJC, de Vries LS, van Olden GDJ. Functional outcome after tibial plateau fracture osteosynthesis: a mean follow-up of 6 years. *The Knee.* 2014;21(6):1210-1215.
19. Rohra N, Suri HS, Gangrade K. Functional and Radiological Outcome of Schatzker type V and VI Tibial Plateau Fracture Treatment with Dual Plates with Minimum 3 years follow-up: A Prospective Study. *Journal of clinical and diagnostic research : JCDR.* 2016;10(5):RC05-10.
20. Cavallero M, Rosales R, Caballero J, Virkus WW, Kempton LB, Gaski GE. Locking Plate Fixation in a Series of Bicondylar Tibial Plateau Fractures Raises Treatment Costs Without Clinical Benefit. *Journal of orthopaedic trauma.* 2018;32(7):333-337.
21. Virkus WW, Caballero J, Kempton LB, Cavallero M, Rosales R, Gaski GE. Costs and Complications of Single-Stage Fixation Versus 2-Stage Treatment of Select Bicondylar Tibial Plateau Fractures. *Journal of orthopaedic trauma.* 2018;32(7):327-332.
22. Bilbao A, Garcia-Perez L, Arenaza JC, et al. Psychometric properties of the EQ-5D-5L in patients with hip or knee osteoarthritis: reliability, validity and responsiveness. *Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation.* 2018;27(11):2897-2908.
23. Hung M, Bounsanga J, Voss MW, Saltzman CL. Establishing minimum clinically important difference values for the Patient-Reported Outcomes Measurement Information System Physical Function, hip disability and osteoarthritis outcome score for joint reconstruction, and knee injury and osteoarthritis ou. *World journal of orthopedics.* 2018;9(3):41-49.
24. Khatri K, Lakhotia D, Sharma V, Kiran Kumar GN, Sharma G, Farooque K. Functional Evaluation in High Energy (Schatzker Type V and Type VI) Tibial Plateau Fractures Treated by Open Reduction and Internal Fixation. *International scholarly research notices.* 2014;2014:589538-589538.
25. Turchin DC, Schemitsch EH, McKee MD, Waddell JP. Do foot injuries significantly affect the functional outcome of multiply injured patients? *Journal of orthopaedic trauma.* 1999;13(1):1-4.

Supplementary materials to Chapter 11

Table S1. Bivariate linear regression analyses

	PROMIS PF			EQ-5D-3L		
	β	**95% CI**	**p-value**	**β**	**95% CI**	**p-value**
Age	-0.191	-0.284 – -0.098	<0.001	-0.002	-0.004 – -0.001	0.007
BMI	-0.440	-0.692 – -0.187	0.001	-0.005	-0.011 – -0.001	0.039
Sex Female	-4.955	-7.427 – -2.482	<0.001	-0.061	-0.113 – -0.0098	0.020
Smoking	-2.975	-6.388 – 0.437	0.087	-0.09	-0.160 – -0.023	0.009
Diabetes	-7.306	-11.313 – -3.300	<0.001	-0.102	-0.185 – -0.019	0.016
CCI	-2.072	-3.021 – -1.124	<0.001	-0.023	-0.043 – -0.003	0.024
Open fracture	0.586	-4.140 – 5.3124	0.807	0.061	-0.034 – 0.156	0.209
HET	2.138	-0.407 – 4.684	0.099	0.031	-0.020 – 0.083	0.236
Time injury to ORIF (days)	0.015	-0.046 – 0.077	0.632	0.001	-0.001 – 0.001	0.455
Time ex-fix to ORIF (days)	0.079	-0.304 – 0.463	0.680	0.001	-0.006 – 0.009	0.695
Time injury to infection (days)	0.031	-0.033 – 0.096	0.287	0.001	-0.001 – 0.002	0.318
Time ORIF to TKA (months)	-0.005	-0.337 – 0.326	0.964	-0.001	-0.009 – 0.007	0.818
Time to questionnaire (months)	0.001	0.001 – 0.001	0.004	0.001	0.001– 0.001	0.023
Approach	0.012	-0.764 – 0.789	0.975	0.002	-0.013 – 0.017	0.792
Ex-fix	-2.385	-5.215 – 0.443	0.098	-0.029	-0.087 – 0.028	0.317
TKA	-10.252	-17.868 – -2.635	0.009	-0.227	-0.381 – -0.073	0.004
Infection	-3.099	-6.990 – 0.096	0.287	-0.076	-0.155 – 0.002	0.058

PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function; EQ-5D-3L, EuroQol 5-Dimensions 3-Levels; BMI, Body Mass Index; CCI, Charlson Comorbidity Index; HET, High-Energy Trauma; ORIF, Open reduction internal fixation; Ex-fix externa fixation; TKA, Total knee arthroplasty; β regression coefficient