The influence of arthroscopy on the classification and treatment of tibial plateau fractures

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ABSTRACT

Introduction: Arthroscopically-assisted reduction and percutaneous fixation of tibial plateau fractures is associated with fewer adverse events, better knee motion, and better Rasmussen functional scores compared to open reduction internal fixation in a number of non-randomized studies. The purpose of this study was to measure the influence of arthroscopy on the interobserver reliability in classification, treatment, and evaluation of intra-articular pathology and fracture reduction for fractures of the tibial plateau.

Methods: Surgeons were invited to participate in this online survey study. Surgeons were randomized at a 1:1 ratio to review eight cases of patients with tibial plateau fractures with either 1) knee radiographs alone or 2) radiographs and arthroscopic images. Multirater kappa was used to assess chance-corrected interobserver agreement.

Results: There was no difference in interobserver agreement between groups for classification, treatment choice, determination of intra-articular pathology, or evaluation of fracture reduction.

Conclusions: Arthroscopy may not influence classification, treatment choice, diagnosis of intra-articular pathology, or quality of fracture reduction. Future studies will be necessary to determine if arthroscopic-assisted fixation of tibial plateau fractures is generalizable to surgeons of different training backgrounds.

1. Introduction

Goals for the treatment of tibial plateau fractures include restoration of articular congruity, joint stability, alignment, and range of motion while limiting complications. The influence of tibial articular incongruity on symptoms and limitations varies, and its importance relative to alignment, stability, and motion are unclear. Open reduction internal fixation (ORIF) of tibial plateau fractures involves incisions that allow for reduction maneuvers and placement of instrumentation. Fracture reduction is assessed with the use of fluoroscopy and direct visualization. Arthroscopic-assisted fixation (AAF) of tibial plateau fractures is typically performed with percutaneous reduction and fixation methods, and evaluation of fracture reduction relies on fluoroscopic and arthroscopic images.

The post-operative articular reduction has been evaluated for different techniques described for achieving and maintaining reduction in tibial plateau fractures. In one prospective cohort study, patients with

tibial plateau fractures treated with ORIF underwent postoperative computed tomography (CT) which identified an articular step off or gap greater than 2 millimeters (mm) in 21 of 65 patients with fractures (32%).¹ Treatment was further divided into reduction based on fluoroscopy alone or the addition of a submeniscal arthrotomy, and rates of an articular 2 mm gap or step off were reported to be 41% and 16% respectively.¹ A smaller retrospective study found that patients treated with AAF had a mean articular step off of 1 mm (range 0–3 mm) based on post-operative radiographs.² Due to the lack of post-operative CT evaluation of patients treated with AAF as well as no randomized studies that include both techniques, the difference in the radiographic outcome of articular congruity between techniques is currently unknown.

AAF of tibial plateau fractures has the theoretical potential to improve articular visualization and reduction while minimizing comorbidity with preservation of the blood supply to soft tissues and bone. A number of retrospective studies have compared AAF to ORIF for the treatment of tibial plateau fractures. The studies found AAF was

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associated with fewer complications, better knee range of motion, and better Rasmussen functional scores.^{3–9} The conclusions of these studies are limited due to the lack of randomization and inclusion of only single-center trials. Although there may be benefit to AAF, there remains a need for a prospective, randomized controlled trial that is multi-center in nature to confirm these findings.

The purpose of this study was to measure the influence of arthroscopy on the interobserver reliability in classification, treatment choice, determination of intra-articular pathology, and quality of fracture reduction for fractures of the tibial plateau.

2. Methods

Our institutional review board approved the use of deidentified radiographs and arthroscopic images of tibial plateau fractures. Members of the Science Of Variation Group (SOVG) and Orthopaedic Trauma Association (OTA) were invited to participate in this online study. Participation is voluntary and participants are aware that completing the survey indicates informed consent. After initial invitations were sent, three reminder emails followed over the course of one month in case they did not respond.

All participants were asked demographic questions regarding gender, years in independent practice, supervising trainees in the operating room, completion of an orthopaedic fellowship training, specialization, geographic practice location, setting of practice, and utilization of arthroscopy in practice and in treatment of a tibial plateau fracture. Surgeons were randomized at a 1:1 ratio to review eight cases of patients with either 1) anteroposterior and lateral knee radiographs alone or 2) radiographs and arthroscopic images. We used Survey-Monkey® (San Mateo, CA, USA)¹⁰ to develop the survey and allocate randomization. For each patient scenario, surgeons were asked: (1) How would you classify this injury based on the Schatzker classification?¹¹ (2) Would you recommend surgery? (3) Do you suspect any intra-articular pathology (meniscal or cruciate ligament injuries) that would benefit from surgery? And (4) based on the intraoperative images provided, do you find this reduction acceptable? Pre-reduction imaging was provided for questions 1, 2, and 3. Imaging after reduction maneuvers were applied was provided for question 4 (Fig. 1). The patients presented in the survey had tibial plateau fractures that were treated with arthroscopic-assisted fixation (AAF) at an outpatient surgery center from 2016 to 2018. All eight patients were active individuals that were younger than 50 years old.

2.1. Surgeon characteristics

One hundred six surgeons completed the survey of which ninety-seven were men. The most commonly reported subspecialty was orthopaedic trauma, and most participants have been in practice for greater than 10 years. Less than half (42%) of participants utilize arthroscopy in their practice, and a similar proportion (43%) reported the use of arthroscopy in treating tibial plateau fractures (Table 1).

2.2. Statistical analysis

The distributions of continuous variables and assumptions concerning normality were assessed to determine the appropriateness of the statistical tests. Continuous variables are presented as median (interquartile range; IQR) and discrete data as proportions. Multirater kappa (κ ; with bootstrapping using 1000 repetitions) was used to assess chance-corrected interobserver agreement. The κ values were interpreted using the guidelines proposed by Landis and Koch¹²; a value of 0.01–0.20 indicates slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; and 0.81–0.99, almost perfect agreement. Zero indicates no agreement beyond that expected because of chance alone; –1.0, total disagreement; and +1.0, perfect agreement. We calculated the proportion of

Fig. 1. Anteroposterior and lateral knee radiographs demonstrating a depressed lateral plateau fracture in a patient with a previous anterior collateral ligament (ACL) reconstruction. a) Imaging provided to surgeons in the control group for questions 1, 2, and 3. b) Arthroscopic images of the same patient demonstrating the fracture displacement, lateral meniscus, and ACL graft. Imaging included with Fig. 1a to surgeons randomized to the intervention group for questions 1, 2, and 3. c) Anteroposterior and lateral knee radiographs after a reduction maneuver. Imaging provided to the control group for question 4. d) Arthroscopic imaging demonstrating fracture line after reduction maneuver. Imaging included with Fig. 1c to intervention group for question 4.

recommending surgery for the cases. We used Kruskal-Wallis tests and Mann-Whitney U tests to assess differences between continuous variables. We created a multivariable linear regression model to assess factors independently associated with recommending surgery. We included all variables with $P < 0.10$ on bivariate analysis in the final model (Appendix 1) and also included if surgeons reviewed radiographs alone or with arthroscopic images. The regression coefficient (β) indicates the change in the value of a dependent variable corresponding to the unit change in the independent variable. The higher the absolute value of the coefficient, the stronger the effect of the relationship. There are no fixed cut off scores. Adjusted R^2 values indicate the amount of variability in the dependent variable that the model accounts for. Semipartial R^2 expresses the specific variability of a given independent variable in the model. We considered nonoverlapping confidence intervals (CIs) as a significant difference for interobserver agreement and $P < 0.05$ as a significant difference for bivariate and multivariable tests.

An a priori power calculation indicated that we needed 73 raters to find a difference in κ of 0.20 between surgeon demographics and a

Table 1
Surgeon characteristics.

Variables	N = 106
Sex	
Women	9 (8.5)
Men	97 (92)
Years in independent practice	
0–5	11 (10)
6–10	16 (15)
>10	79 (75)
Supervising trainees in operating room ¹	80 (92)
Completed an orthopaedic fellowship training	99 (93)
Specialization	
Orthopaedic traumatology	87 (82)
General orthopaedics	9 (8.5)
Resident	4 (3.8)
General orthopaedics & hand and wrist	2 (1.9)
Geographic practice location	
USA	46 (43)
Europe	37 (35)
South America	9 (8.5)
UK	6 (5.7)
North America (other than USA)	5 (4.7)
Australia	2 (1.9)
Asia	1 (0.94)
Setting of practice	
Academic	61 (58)
Non-academic	45 (42)
Utilizing arthroscopy in practice	44 (42)
Utilizing arthroscopy in treatment of a tibial plateau fracture	46 (43)
Randomized to survey version	
Radiographs alone	54 (51)
Radiographs and arthroscopic images	52 (49)

Continuous variables as mean $\pm$ standard deviation (range); Discrete variables as number (percentage)¹; 19 missing.

hypothesized overall κ of 0.50, with alpha set at 0.05.

3. Results

3.1. Interobserver agreement

There was no difference in interobserver agreement between groups for classification, treatment choice (recommending surgery or not), determination of intra-articular pathology, or evaluation of fracture reduction (overlapping confidence intervals for all; [Table 2](#)). There was slight interobserver agreement for Schatzker classification (κ 0.13). There was fair agreement for classification of Schatzker IV injuries (κ 0.36), and agreement was higher (moderate agreement) for this classification in the group of surgeons receiving radiographs alone (κ 0.47 versus κ 0.26; [Table 2](#)).

3.2. Factors associated with recommending surgery

Accounting for potential interaction of variables using multivariable analysis, surgeons that supervise trainees independently recommended more surgery for patients with tibial plateau fractures (β 0.20, 95% CI 0.08–0.32, $P = 0.002$; [Table 3](#)). The regression coefficient indicates that a surgeon supervising trainees is 20% more likely to recommend operative treatment compared to surgeons not supervising trainees. Reviewing arthroscopic images in addition to radiographs or radiographs alone was not associated with recommending surgery.

4. Discussion

Prior studies have demonstrated that there may be benefit to AAF in the treatment of tibial plateau fractures, but no previous studies have evaluated the reliability of interpretation of arthroscopic images

Table 2
Interobserver agreement.

Variables	Survey versions combined	Radiographs alone	Radiographs and arthroscopic images
	Kappa (95% CI)		
Schatzker classification	0.13 (0.02–0.25)	0.17 (0.01–0.33)	0.12 (0.04–0.21)
Schatzker I	0.08	0.07	0.10
Schatzker II	0.12	0.16	0.12
Schatzker III	0.08	0.09	0.09
Schatzker IV	0.36	0.47	0.26
Schatzker V	0.06	0.08	0.03
Schatzker VI	0.00	0.00	–
"Would you recommend surgery?" (yes/no)	0.08 (0.03–0.15)	0.11 (0.01–0.20)	0.07 (0.03–0.12)
"Do you suspect any intra-articular pathology (meniscal or cruciate ligament injuries) that would benefit from surgery?" (yes/no)	0.12 (0.04–0.20)	0.14 (0.03–0.25)	0.10 (0.02–0.18)
"Based on these intra-operative images do you find this reduction is acceptable?" (yes/no)	0.25 (0.00–0.49)	0.30 (–0.01 to 0.62)	0.23 (0.04–0.41)

CI: Confidence interval.

amongst orthopaedic surgeons treating tibial plateau fractures. The purpose of this study was to measure the influence of arthroscopic images on the interobserver reliability in classification, treatment choice, and evaluation of intra-articular pathology and fracture reduction for tibial plateau fractures.

A number of limitations of the study need to be taken into consideration. We cannot calculate a response rate because we do not know if all email addresses are active or how many of the invited participants treat tibial plateau fractures. However, because we randomize the response rate it is less important and only affects the generalizability of the findings with respect to the comparison. In addition, participants may have been influenced to recommend surgery based on the presence of surgical implants on radiographs in the survey. Although only injury radiographs accompanied questions related to surgical treatment, the surgeon could have returned to previous questions and changed answers if later radiographs demonstrated the presence of surgical implants. In addition, the relatively low rate of utilization of arthroscopy amongst surgeons surveyed may contribute to detection bias. This effect should have been similar between both groups and should not have affected our comparison of the two groups.

Our finding that arthroscopic images did not improve the reliability of fracture classification suggests that disagreement about classification may relate more to heuristics (mental short cuts) than images. Several previous studies have reported mean kappa values for inter-observer reliability of classification of tibial plateau fractures using radiographs alone, and values ranged from 0.38 to 0.47.^{13–15} Our overall lower reliability (mean kappa 0.17) compared to prior studies is common with SOVG studies, perhaps because each surgeon is less prepared for the specific study than one involving just a few raters, perhaps because of the more controlled study methods, and perhaps subjects go through the images more rapidly and with less care when doing an internet survey. It is impossible to know the relative influence of these conjectures.

The observation that recommendation for surgery was not associated with arthroscopy, but was associated with surgeons supervising trainees in the operating room, suggests that personal factors such as practice setting are important influences on variation in treatment. The use of surgical procedures varies across geographical regions.¹⁶ Attitudes and beliefs about the surgeon's indications for surgery as well as surgeon personality influence surgical variation.^{17–19}

The observation that the agreement on adequate fracture reduction

Table 3

Multivariable linear regression of factors associated with recommending surgery.

Dependent variable	Retained variables	Regression coefficient (95% Confidence interval)	Standard error	P value	Semipartial R ²	Adjusted R ²
Recommending surgery	Supervising trainees in operating room	0.20 (0.08–0.32)	0.06	0.002	0.11	0.12
	Survey with radiographs alone	0.06 (–0.01–0.12)	0.03	0.102		

R²: R-squared; Only the semipartial R² of significant variables is displayed.

was not improved by arthroscopic images, suggests that radiographs alone provide adequate assessment of the articular surface. The fact that agreement was only fair for both groups indicates that any benefit to arthroscopy can only be realized by developing new surgeon heuristics, perhaps using specific training methods.

From a clinical perspective, the use of arthroscopy would potentially assist with intraoperative decision-making by providing direct visualization of all aspects of the tibial plateau and articular fracture alignment. However, the lack of improvement in interobserver agreement with the addition of arthroscopic images in our study may relate to the challenge of interpretation of arthroscopic images. The interpretation of arthroscopic images involving a fracture, similar to the interpretation of radiographs, is likely an important aspect of clinical experience that develops and improves over time. A first step to determining the influence of arthroscopy on the surgical treatment and outcomes of tibial plateau fractures is reliable assessment of fracture characteristics. Previously reported benefits of AAF, including lower rates of complications and better functional outcomes,^{3–9} may be related to the surgeon expertise with the technique, evaluator bias, less soft tissue dissection with the use of associated percutaneous fixation, or bias towards using arthroscopic assistance with relatively simple fractures. Future studies will be necessary to determine if AAF of tibial plateau fractures is generalizable to surgeons of different training backgrounds. Future randomized controlled trials should be designed to include multiple centers with surgeons of varying training background and number of years in practice.

Declaration of competing interest

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Appendix A

Appendix 1

Bivariate analyses of factors associated with recommending surgery.

Variables	Proportion of recommending surgery	P value
Sex		
Women	0.94 ± 0.09	0.609
Men	0.91 ± 0.16	
Years in independent practice		
≤10	0.91 ± 0.20	0.412
>10	0.91 ± 0.14	
Supervising trainees in operating room ¹		
No	0.71 ± 0.36	0.041
Yes	0.92 ± 0.13	
Completed an orthopaedic fellowship training		
No	0.95 ± 0.07	0.845
Yes	0.91 ± 0.16	
Geographic practice location		
USA	0.91 ± 0.13	0.154
Europe	0.88 ± 0.20	
Other	0.98 ± 0.05	
Setting of practice		
Academic	0.91 ± 0.13	0.562

(continued on next page)

Appendix 1 (continued)

Variables	Proportion of recommending surgery	P value
Non-academic	0.91 ± 0.19	
Utilizing arthroscopy in practice		
No	0.91 ± 0.13	0.595
Yes	0.91 ± 0.19	
Utilizing arthroscopy in treatment of a tibial plateau fracture		
No	0.92 ± 0.13	0.962
Yes	0.90 ± 0.19	
Randomized to survey version		
Radiographs alone	0.89 ± 0.18	0.236
Radiographs and arthroscopic images	0.93 ± 0.12	

Continuous variables as mean ± standard deviation[†]; 19 missing.

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