Injury, Int. J. Care Injured 46 (2015) 2243–2247

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

How much articular displacement can be detected using fluoroscopy for tibial plateau fractures?

Justin M. Haller [a], Robert O'Toole [b], Matthew Graves [c], David Barei [d], Michael Gardner [e], Erik Kubiak [a], Jason Nascone [b], Sean Nork [d], Angela P. Presson [a,f], Thomas F. Higgins [a,*]

[a] Department of Orthopaedic Surgery, University of Utah, 590 Wakara Way, Salt Lake City, UT 84108, United States
[b] R Adams Cowley Shock Trauma Center, Department of Orthopaedic Surgery, University of Maryland School of Medicine, 22 S Greene Street, Baltimore, MD 21201, United States
[c] Department of Orthopaedic Surgery and Rehabilitation, University of Mississippi Medical Center, 2500 North State Street, Jackson, MS 39216, United States
[d] Department of Orthopaedic Surgery, Harborview Medical Center, 325 9th Avenue, Seattle, WA 98014, United States
[e] Department of Orthopaedic Surgery, Washington University School of Medicine, 660 South Euclid Avenue, St. Louis, MO 63110, United States
[f] Division of Epidemiology, Department of Internal Medicine, University of Utah, Salt Lake City, UT, United States

ARTICLE INFO

Article history:
Accepted 30 June 2015

Keywords:
Reduction
Proximal tibia fracture
Anatomic reduction
Articular fracture
Malreduction

ABSTRACT

Introduction: While there is conflicting evidence regarding the importance of anatomic reduction for tibial plateau fractures, there are currently no studies that analyse our ability to grade reduction based on fluoroscopic imaging. The purpose of this study was to determine the accuracy of fluoroscopy in judging tibial plateau articular reduction.
Methods: Ten embalmed human cadavers were selected. The lateral plateau was sagitally sectioned, and the joint was reduced under direct visualization. Lateral, anterior-posterior (AP), and joint line fluoroscopic views were obtained. The same fluoroscopic views were obtained with 2 mm displacement and 5 mm displacement. The images were randomised, and eight orthopaedic traumatologists were asked whether the plateau was reduced. Within each pair of conditions (view and displacement from 0 mm to 5 mm) sensitivity, specificity, and intraclass correlations (ICC) were evaluated.
Results: The AP-lateral view with 5 mm displacement yielded the highest accuracy for detecting reduction at 90% (95% CI: 83–94%). For the other conditions, accuracy ranged from (37–83%). Sensitivity was highest for the reduced lateral view (79%, 95% CI: 57–91%). Specificity was highest in the AP-lateral view 98% (95% CI: 93–99%) for 5 mm step-off. ICC was perfect for the AP-lateral view with 5 mm displacement, but otherwise agreement ranged from poor to moderate at ICC = 0.09–0.46. Finally, there was no additional benefit to including the joint-line view with the AP and lateral views.
Conclusion: Using both AP and lateral views for 5 mm displacement had the highest accuracy, specificity, and ICC. Outside of this scenario, agreement was poor to moderate and accuracy was low. Applying this clinically, direct visualization of the articular surface may be necessary to ensure malreduction less than 5 mm.

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Introduction

Orthopaedic surgeons use fluoroscopy and radiographs to assist with decision-making during the management of tibial plateau fractures, particularly in regard to the adequacy of articular congruity. There is various types of evidence regarding the importance of anatomic reduction for preventing post-traumatic osteoarthritis (PTOA) and improving patient outcomes following tibial plateau fractures [1–6].

Despite the potential importance of reduction accuracy in the management of tibial plateau fractures, there are few studies that

* Corresponding author. Tel.: +1 801 587 5440; fax: +1 801 587 5411.
E-mail addresses: Justin.haller@hsc.utah.edu (J.M. Haller), rvo3@yahoo.com (R. O'Toole), mattgraves1@gmail.com (M. Graves), barei@uw.edu (D. Barei), gardnerm@wudosis.wustl.edu (M. Gardner), erik.kubiak@hsc.utah.edu (E. Kubiak), Jnascone@umoa.umm.edu (J. Nascone), nork@uw.edu (S. Nork), angela.presson@hsc.utah.edu (A.P. Presson), thomas.higgins@hsc.utah.edu (T.F. Higgins).

http://dx.doi.org/10.1016/j.injury.2015.06.043
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analyse the ability of a surgeon to grade reduction based on radiographic or fluoroscopic imaging. In a study by Martin et al., the authors reported the tolerance limits for tibial plateau articular depression is ±12 mm. This result would suggest that 95% of the articular incongruity measurements made by 90% of observers are within 12 mm of each other [7]. In the context of tibial plateau congruity, these tolerance limits are fairly wide. Prior data would suggest that the difference between a good outcome and a poor one lies well within that range between 0 and 12 mm of articular step-off [4]. This would certainly question our ability to assess reduction on plain radiographs. Previous examination of the tibial plafond demonstrated a poor ability by surgeons to assess articular congruity on lateral projections of that joint [8]. The accuracy of acetabular reduction on fluoroscopy has been critically examined [9]. The instrument used most commonly to used on assess accuracy and adequacy of reduction intraoperatively is fluoroscopy, and we have no data to critically evaluate the precision of this technology in assessing articular reduction of the tibial plateau fracture.

The purpose of this study was to determine if malreduction of the lateral tibial plateau could be detected with the use of fluoroscopy. The authors chose to use fluoroscopy, as opposed to radiographs, as this represents the clinical scenario where the surgeon has the ability to makes changes intra-operatively if reduction is deemed to be unsatisfactory. Specifically, we posed the following questions: (1) Can a 2-mm and a 5-mm malreduction of the lateral tibial plateau can be detected on anterior-posterior (AP) and lateral views using fluoroscopy?; (2) Does the inclusion of a joint-line view improve our ability to detect malreduction?; and, (3) What are the sensitivity, specificity, and interobserver agreement in assessing articular reduction in a tibial plateau fracture model using fluoroscopy?

Materials and methods

Ten formalin-fixed human cadaveric specimens (five male and five female) with an average age of 65.7 (range, 32–79 years) were selected. After gross examination of the specimens, the lower extremity (six left and four right) of each cadaver was sectioned in the diaphysis of the femur and the diaphysis of the tibia. The extremities were fixed with an external fixator frame (Synthes large external fixator, West Chester, PA) with two 5.0-mm half-pins in the femur and two half-pins in the tibia. The positions of the bar to the clamps was measured and recorded. The frame was then removed and the surrounding soft tissues were removed. The patella tendon was released from the tibial tubercle, and the anterior cruciate ligament, lateral collateral ligament, posterior cruciate ligament, and posterior capsule were all released. Both menisci were removed. The lateral tibial plateau was sagitally sectioned into 7-mm slices using a band saw (0.25 mm blade thickness) (Grizzly Industrial, Bellingham, WA). Several sections were made to simulate a comminuted, lateral split-depression tibial plateau fracture. A handheld sagittal saw (Stryker, Kalamazoo, MI) was used to make the transverse cut 20 mm below the articular surface. The joint was reduced under direct visualization and held with a reduction clamp. The external fixator was placed in the same position as before the soft tissue releases, using the previously recorded measurements.

Lateral, AP, and joint-line (AP 10° cephalic to caudad) fluoroscopic views were obtained with C-arm (GE OEC 9600 series, Fairfield, CT) and saved (Fig. 1) [10]. The fixator was removed, and 2 mm of metaphyseal bone was measured with a caliper (Mitutoyo, Aurora, IL) and removed from one of the lateral plateau articular segments. The articular segment was depressed 2 mm and the bone was re-clamped. The same fluoroscopic views were then obtained and saved. This process was repeated with resecting an additional 3 mm of bone, creating 5 mm of displacement. No computed

Fig. 1. Fluoroscopy image demonstrating 7 mm sagittal cuts in the lateral tibial plateau.

tomography images were obtained for this study. All fluoroscopic images were collected in a 90-slide Powerpoint (Microsoft Office 2011, Redmond, WA) presentation in random order. Thirty slides had only laterals, 30 slides featured an AP and lateral, and 30 slides featured the AP, lateral, and joint line view (Fig. 2a–c). Randomization was done using a random sequence generator [11].

Eight blinded, fellowship-trained orthopaedic traumatologists (years in practice ranged 7–15 years) participated in the study. The surgeons practice at five different academic medical centres. Each surgeon was asked to independently grade whether the plateau was reduced (yes/no) on each slide. Reduced was defined as anatomical alignment of the subchondral bone visualised on the fluoroscopy image. All surgeons were unaware of the step-off scenarios. There were three views (lateral, AP-lateral, AP-lateral-joint line) and three step-off conditions (0 mm-reduced, 2 mm, 5 mm) for a total of nine experimental conditions. All analyses were conducted within, rather than across, these nine conditions because otherwise results would not be representative of evaluating a random sample of subjects. Sensitivity, specificity and accuracy of judging reduction was evaluated using logistic mixed effects regression models, where accuracy was predicted from view and step-off, and random effects were included for both subjects and surgeons. Sensitivity was evaluated for observations where reduction was present, and specificity was estimated from observations where reduction was absent. Statistical analyses were conducted in R (v.2.15.3, http://cran.us.r-project.org/) using the lme4 and lsmeans packages. Interobserver agreement was evaluated using a two-way random effects model ICC(2,1) that assumed random samples of both surgeons and subjects using the psych package in R. An ICC = 0–0.2 was considered poor agreement, 0.21–0.40 was considered fair and 0.41–0.60 was considered moderate agreement [12]. Ninety-five percent confidence intervals were included for all estimates and significance was also evaluated using a 0.05 level.

Results

Accuracy was 37% (95% CI: 26–50%) using only the lateral view for a reduced tibial plateau (Table 1). Accuracy improved to 61% (95% CI: 48–73%) and 63% (95% CI: 50–75%) using only the lateral

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