Analysis of Post-Traumatic Osteoarthritis Development and Clinical Outcomes in Post-Operative Tibial Pilon Fracture Patients: A Multivariate Analysis

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INTRODUCTION: Patients suffering from tibial pilon fractures are known to have significant long-term post-operative sequela, including post-traumatic osteoarthritis (PTOA) [1]. Since its advent, an increasing number of studies are utilizing weight bearing CT (WBCT) to visualize ankle 3D alignment [2]. However, few studies have investigated the many variables that may contribute to PTOA progression along the post-operative course. This study aims to utilize patient demographics, 3D models generated from WBCT, PTOA grades, and other variables to identify the effect that many factors may have on the development of PTOA. Thus, a multivariate analysis was designed to estimate the contributions of clinically significant variables to tibiotalar PTOA progression.

METHODS: 15 patients surgically treated for pilon fractures at a Level-I trauma center who received WBCT scans at 6-, 12-, and 18-months post-operative were included in this study. WBCT scans were automatically segmented and used to develop digitally reconstructed radiographs (DRRs) via DISIOR Bonelogic 2. Clinical measures of bony alignment were automatically calculated from the DRRs, and included Saltzman 20 degree hindfoot alignment (Saltzman_20), medial distal tibial angle, coronal (MDTAC), medial talar articular surface angle, coronal (MTSAC), talar tilt angle, coronal (TTA), and tibial lateral surface angle, sagittal (TLSAS). PROMIS scores included physical function (PF) and pain, as well as Foot and Ankle Ability (FAAM) Sport and activities of daily living (ADL). Radiographic evaluation of OA in the subtalar (ST), tibiotalar (TT), and tibiofibular (TF) joints was performed by a musculoskeletal radiologist via the Richter grading scale [3]. A linear mixed model fit by REML ['lmerMod'] in R Statistical Software (R Core Team 2023) incorporating OA gradings at the TF and ST joints, months post-op, patient age, fracture type, bony alignment measures, and patient-reported outcome scores (PROMIS and FAAM) to estimate their fixed effects contributing to TT OA progression. For each variable, the program calculated the estimated contribution to the model (Estimate), spread of the data (Std. Error) and the significance of its contribution (as represented by the estimate divided by the standard error: the t value).

RESULTS: PTOA grading showed worsening severity in TT OA from time of injury (average OA score of 0.2) to 18-months postop (average OA score of 2.0). The TT joint was the most affected joint in terms of PTOA severity. The multivariate analysis identified significant predictive contribution to TT OA from TF OA (Estimate = 0.50, t = 2.32) but not ST PTOA (Estimate = -0.01, t = -0.02). Each post-operative time point showed significant contribution to TT OA (6 month Estimate = 0.77, t = 2.66; 12 month Estimate = 0.75, t = 2.16; 18 month Estimate = 1.32, t = 3.33). PROMIS scores, FAAM scores, fracture type, age, and DRR measurements did not have significant contributions to the model.

FIXED EFFECTS:	ESTIMATE	STD. ERROR	T VALUE
(INTERCEPT)	-2.87	8.60	-0.33
TF OA	0.50	0.22	2.32*
ST OA	-0.01	0.46	-0.02
6 MONTHS POSTOP	0.77	0.29	2.66*
12 MONTHS POSTOP	0.75	0.35	2.16*
18 MONTHS POSTOP	1.32	0.40	3.33*
PATIENT AGE	0.01	0.03	0.24
FRACTURE TYPE 43C	0.76	0.87	0.88
SALTZMAN_20	-0.03	0.03	-1.13
MDTAC	43.24	43.03	1.01
MTSAC	-43.26	43.05	-1.01
TTA	-43.25	44.03	-1.01
TLSAS	-0.02	0.02	-1.21
PROMIS PF	0.05	0.08	0.67
PROMIS PAIN SCORE	0.03	0.07	0.40
FAAM SPORT	-0.03	0.03	-1.13
FAAM ADL	0.04	0.03	1.14

Table 1: The mixed linear model's fit to the data is described in the table above. The column titled estimate shows the estimated numerical effect on the TT OA Richter Score given the fixed effect. The t value indicates the level of statistical significance, with values great than 2.0 roughly translating to significance at p<0.05. Significant values marked by an asterisk.

DISCUSSION: PTOA is a well-known sequela in patients suffering from pilon fractures [1]. There are a multitude of variables that may contribute to PTOA development in these patients, and gaining a better understanding of the most significant contributors may provide insight for improvement of both surgical technique and post-operative rehabilitation. Regardless of worsening PTOA severity up to 18-months following pilon fracture repair, DRR ankle alignment measures do not show significant effect on TT arthritis progression. Further, in post-operative pilon fracture patients, arthritis in the ST joint does not show a significant effect on TT arthritis progression. In this model, TF OA demonstrated a significant contribution to development of TT OA. As tends to be true with degenerative diseases, time after injury was also a significant contributor to TT OA throughout the measured post-operative period. Addressing the progression of TF PTOA may be an important factor for both surgical considerations and post-operative rehabilitation to improve overall ankle PTOA in this patient population.

SIGNIFICANCE/CLINICAL RELEVANCE: Progression of ankle PTOA can happen quickly and be severely debilitating in patients following surgical repair of pilon fractures. Understanding how a multitude of variables interact with each other and influence progression of PTOA is integral to improving surgical repair as well as post-operative rehabilitation in patients suffering from pilon fractures.

REFERENCES: [1] S. Jo et al. *J Am Acad Orthop Surg,* 2022, [2] A. Bernasconi *et al. Foot Ankle Surg,* 2020, [3] Richter M. et al. *Foot Ankle Clin* 2022