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ORIGINAL ARTICLE

Comparable outcomes with intramedullary nail and plate constructs for Schatzker VI tibial plateau fractures

John Parker Chapman[1] · Matthew R. Patrick[1] · Christopher W. Reb[1] · Kevin A. Hao[1] · Heather K. Vincent[1] · Jennifer E. Hagen[1]

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Abstract

Background Outcomes data of intramedullary nail fixation (IMN) constructs for complex Schatzker VI tibial plateau fractures are scant in the literature. This study compares the clinical and radiographic outcomes of IMN, dual plate, and single plate constructs for Schatzker IV tibial plateau fractures.

Methods Retrospective cohort study of sixty-two patients at a University-based Level 1 trauma center who underwent open reduction internal fixation for Schatzker VI tibial plateau fracture. Constructs evaluated were IMN (with or without raft screws), dual plating, and single plating. Demographic, clinical, and radiographic outcomes were recorded. All fractures were additionally classified based on the OTA classification for sub analyses. Mean follow-up was 13.2 (SD 13.3) months. Predictors of construct selection and outcomes were evaluated with bivariate logistic regression. Outcomes were compared between groups with independent samples t-tests and Chi Square tests.

Results No significant demographic differences were found between IMN, dual plate or single plate construct cohorts. There was a higher proportion of open fractures within the IMN construct group versus the dual plate cohort (21.1% vs 3.6%). No statistically significant differences in radiographic outcomes were observed between cohort groups except for small but statistically significant differences in condylar width (CW) ratio change and tibial slope; when fracture cohorts were sub analyzed by specific OTA classification, there were no significant differences in any radiographic outcomes. There was a significant difference between the ratio of OTA 41C1, C2 and C3 fractures regarding treatment allocation ($p=0.004$), favoring dual plate fixation for OTA 41C3 fractures. There were no significant differences found between treatment cohorts in terms of all cause complications ($p>0.05$). IMN and single plate constructs were utilized when posteromedial condyle fractures were nondisplaced or minimally displaced.

Conclusion Intramedullary nail fixation with or without supplemental raft screws produced similar short-term clinical and radiographic results compared to dual and single plate constructs among patients with Schatzker VI fracture types, regardless of OTA classification.

Level of Evidence

Level III retrospective cohort.

Keywords Tibial plateau fracture · Intramedullary fixation · Outcome study

Introduction

Bicondylar tibial plateau fractures with metadiaphyseal fracture extension require deliberate operative planning. As the zone of injury increases, obtaining and maintaining a stable reduction while limiting iatrogenic soft tissue injury becomes increasingly challenging. Traditional methods of fixation include dual incision bicondylar plating and single column fixation utilizing locked plate technology. However, given biomechanical superiority of intramedullary nail

✉ John Parker Chapman
chapmjp@ortho.ufl.edu

[1] Department of Orthopaedics and Rehabilitation, UF Orthopaedics and Sports Medicine Institute, University of Florida, PO Box 112727, Gainesville, FL 32608, USA

(IMN) fixation of extraarticular proximal tibia fractures, interest in intramedullary fixation constructs for intra-articular fractures is evolving.

IMN fixation of extraarticular proximal tibia fractures has been shown to result in no significant differences in acute infection, malunion, or malreduction compared to proximal tibia plating [1, 2] including in a series with a higher number of open fractures (55% vs. 35% $p=0.18$) in the nail group [1] Furthermore, IMN fixation has been documented to decrease hospital stay, decrease time to weight bearing and to shorten fracture healing time [2].

There is a growing body of evidence to support IMN fixation of tibial plateau fractures. Nork et al. [3] popularized the technique of Plate + nail constructs for unicondylar plateau fractures with diaphyseal extension in 2008. Lasionos et al. [4] compared IMN fixation of bicondylar tibial plateau fractures with supplemental subarticular raft screws to dual and single plate constructs in a sawbones model and found the IMN construct resisted loss of articular alignment as well as dual column plating and better than single column plating. IMN fixation exhibited construct stiffness comparable to single plate fixation but with higher load to failure. The authors concluded that the load sharing by the IMN construct may promote better bone healing than the dual plate construct.

The purpose of this retrospective study was to compare the clinical and radiographical outcomes of Schatzker VI tibial plateau fractures treated with IMN fixation versus plate constructs. We hypothesized there would be no differences in outcomes based on treatment modality.

Methods

Study design

This was an IRB approved retrospective cohort study of patients at a University-based Level 1 trauma center.

Patients

An administrative claims database search identified 240 patients aged 19–90 years old admitted to the Orthopedic Trauma service with a diagnosis of a tibia plateau fracture between January 1, 2010, and December 31, 2017. Exclusion criteria included incorrect diagnosis ($N=5$), bilateral tibia plateau fractures ($N=2$), primary treatment with total knee arthroplasty ($N=7$), additional ipsilateral fractures within the knee joint (femur or patella), ipsilateral tibial shaft or distal tibia fractures ($N=2$), and loss to follow-up after hospitalization ($N=32$). Of the 192 remaining, 62 patients had a Schatzker classification type VI fracture (age range 22–83) and were included. The mean follow-up for this group was 13.2 (SD 13.3) months.

Chart review

Demographic data recorded included age, gender, body mass index (BMI), race, insurance coverage, and comorbidities. Injury-related data included whether the tibia plateau fracture was open, if compartment syndrome was present prior to osteosynthesis, or if the fracture was in a polytrauma patient. Treatment-related data included treating surgeon, surgical time (hours), length of index hospital admission (days), if a staged approach to osteosynthesis was taken, and what definitive fixation construction was used for the tibial plateau fracture—dual plating, intramedullary nail (with or without raft screw fixation), or single plating. Complications assessed included the number and type of complications (including wound complication, deep infection, nonunion/malunion, removal of hardware) and whether the patient returned to the emergency department or was readmitted to the hospital for reasons directly related to their surgery. Deep infection was defined as purulence involving the hardware requiring operative debridement.

Surgical intervention

Surgical fixation constructs were defined as dual plate—two separate surgical approaches for placement of bicondylar plating, single plate—one surgical approach for medial or lateral single plate, and intramedullary nail—construct involving intramedullary nail as the primary construct with or without additional percutaneous raft screws for additional plateau stabilization. All surgeries were performed by or under the direct supervision of fellowship trained orthopedic traumatologists at our institution. Surgical technique and approach(es) were decided based on surgeon preference; factors routinely considered included bone quality, degree of metaphyseal comminution, diaphyseal extension, soft tissue condition, and patient comorbidities.

Radiographic analysis

Injury radiographs were used to assess each tibia plateau fracture. The Schatzker classification system and OTA classification systems were utilized for classification based on substantial agreement in regards to intra- and inter-rater reliability, based on the Landis And Koch criteria [5], and wide acceptance among traumatologists for communicating fracture characteristics [6]. This study specifically investigated the Schatzker VI plateau fractures and OTA 41C fractures. Tibial plateau angle (TPA), tibial slope (TS), and femur/tibia condylar width (CW) were measured on all immediate postoperative radiographs and follow-up radiographs at least 6 months or at the latest follow-up visit. Measurements were made by an orthopedic surgery resident and associate

professor of clinical research (JPC, HKV). Inter-rater consistency was assessed by intraclass correlation (ICC) using a two-way mixed model comparing exact measures. The sample comprised approximately 30% of all subjects (192). Observer consistency for radiographic parameters was assessed by intraclass correlation and found to be 0.744, demonstrating good ICC reliability. This level of ICC was demonstrated in a study of pre and postoperative measurements of the distal femur and proximal tibia in patients undergoing total knee arthroplasty in short tibia plain radiographic films; one of the measurements taken was medial proximal tibial angle (MPTA), akin to the TPA using short film radiographs. The ICC for MPTA was 0.66 for preoperative (native proximal tibia) radiographs [7].

Statistical analyses

Continuous measures were expressed as mean ± standard deviation (SD). Categorical measures were expressed as % (N). Regression models were calculated using demographic and clinical factors as predictors of radiographic and clinical outcomes. Welch's unpaired t-test and one-way analysis of variance tests were used to assess for statistically significant differences in continuous measures where appropriate. Fisher's exact test and chi-square tests were used to compare proportions. Post hoc pairwise comparisons were made with Tukey correction. Post hoc power analyses were performed to determine the achieved statistical power to identify differences between treatment groups for the primary clinical and radiographic outcomes. To identify independent predictors of clinical and radiographic outcomes, multivariate linear and logistic regression was performed for continuous and dichotomous outcomes, respectively. All statistical analyses were performed in R Software (version 3.6.3; R Core Team, Vienna, Austria). Post hoc power analyses were performed in G*Power [8]. The level of significance was established at $P < 0.05$ for all statistical tests á priori.

Source of funding

Funding source did not play a role in investigation.

Table 1 Characteristics of included patients

Characteristic	All patients (N = 62)	IMN (N = 19)	Single Plate (N = 15)	Dual Plate (N = 28)	*P* value
Age at surgery (years)	55.1 ± 14.4	55.8 ± 13.1	58.9 ± 14.9	52.6 ± 15	.386
Female sex	45.2% (28)	47.4% (9)	60.0% (9)	35.7% (10)	.295
BMI (kg/m^2)	28.0 ± 7.3	28.4 ± 7.6	28 ± 4.4	27.6 ± 8.5	.701
Caucasian ethnicity	77.4% (48)	68.4% (13)	73.3% (11)	85.7% (24)	.298
Insurance					.423
Commercial	29.0% (18)	15.8% (3)	26.7% (4)	39.3% (11)	–
Medicare	40.3% (25)	47.4% (9)	33.3% (5)	39.3% (11)	–
Medicaid	14.5% (9)	15.8% (3)	26.7% (4)	7.1% (2)	–
Veterans Affairs	3.2% (2)	0.0% (0)	6.7% (1)	3.6% (1)	–
None	12.9% (8)	21.1% (4)	6.7% (1)	10.7% (3)	–
Performed by high volume surgeon [a]	77.4% (48)	89.5% (17)	73.3% (11)	71.4% (20)	.362
Open fracture	14.5% (9)	21.1% (4)	26.7% (4)	3.6% (1)	.057
Polytrauma	45.2% (28)	42.1% (8)	46.7% (7)	46.4% (13)	1
Staged surgery	74.2% (46)	63.2% (12)	53.3% (8)	92.9% (26)	**.006**
Compartment syndrome	9.7% (6)	10.5% (2)	0.0% (0)	14.3% (4)	.462
OTA Classification 41C					**.004**
1	22.6% (14)	42.1% (8)	33.3% (5)	3.6% (1)	
2	17.7% (11)	21.1% (4)	20.0% (3)	14.3% (4)	
3	59.7% (37)	36.8% (7)	46.7% (7)	82.1% (23)	
Posteromedial fragment					**.006**
None	64.5% (40)	84.2% (16)	66.7% (10)	50.0% (14)	
Non-displaced	12.9% (8)	10.5% (2)	26.7% (4)	7.1% (2)	
Displaced	22.6% (14)	5.3% (1)	6.7% (1)	42.9% (12)	

Bolded figures indicate statistical significance (below $p = 0.05$)

BMI body mass index; *IMN* intramedullary nail

[a]Operating surgeon responsible for treating ≥ 10 patients in this series

Results

Sixty-two patients were included (Table 1). The mean age was 55.1 ± 14.4 years and 28 (45%) were female. Of the patients included, 19 were treated with IMN, 15 with a single plate, and 28 with dual plates. Surgery was staged in a greater proportion of patients receiving dual plates compared to a single plate or IMN (93% vs. 53% and 63%, $P = 0.006$). Treatment groups differed based on the OTA-41C classification of the fracture ($P = 0.010$). The disproportionate increased use of dual plates for 41C-3 fractures as well as decreased use for 41C-1 constituted most of the difference on post hoc pairwise analysis ($P = 0.010$ for both). Similarly, treatment groups differed in the presence and displacement of a posteromedial fragment ($P = 0.006$); specifically, a displaced posteromedial fragment was more common in the treatment group receiving a dual plate ($P = 0.005$).

Clinical outcomes

On univariate analysis, patients receiving a dual plate had longer surgical times compared to patients receiving an IMN or single plate (7.6 ± 2.6 vs. 5.2 ± 2.9 and 5.5 ± 2.7 h, $P = 0.013$) (Table 2) [surgical time corresponds to time of incision until procedure end—includes dressing application]. On multivariate analysis, independent predictors of increased surgical time included operation performed by a low-volume surgeon ($P = 0.029$), single-stage surgery ($P = 0.003$), and absence of compartment syndrome ($P = 0.016$) (Table 3). Predictors of increased length of stay included a preoperative diagnosis of an open fracture ($P = 0.009$) and presence of a displaced fragment ($P = 0.041$). No predictors of readmission or surgical complications were identified on multiple logistic regression analysis.

Radiographic outcomes

On univariate analysis, there was a statistically significant difference in the change in the tib/femur width ratio and the postoperative slope between treatment groups ($P = 0.043$ and $P = 0.003$, respectively) (Table 2). On post hoc pairwise analysis, patients receiving a dual plate had a significantly greater change in the tib/femur width ratio (0.023 ± 0.034 vs. − 0.003 ± 0.034, $P = 0.028$) and a lower postoperative slope (8.8 ± 4.3 vs. 14.1 ± 4.9°, $P = 0.003$) compared to patients receiving an IMN. No statistically significant differences in radiographic outcomes were found when stratifying treatment groups by OTA 41-C classification (Table 4); however, a nonsignificant trend toward greater postoperative slope and change in slope were noted in the IMN group.

On multivariate analysis, independent predictors of a greater postoperative tib/femur width ratio included increased age ($P = 0.023$) and use of a dual plate over an IMN ($P = 0.016$), whereas only the use of a dual plating over IMN predicted an increase in the change in the tib/femur width ratio ($P = 0.006$) (Table 5). The only independent predictor of a greater postoperative TPA angle was presence of a displaced posteromedial fragment ($P = 0.032$), whereas predictors of change in the TPA angle included both younger age ($P = 0.042$) and treatment with a single plate rather than a dual plate ($P = 0.020$). Predictors of a greater postoperative slope included male sex ($P = 0.036$), treatment with a dual plate rather than IMN ($P < 0.001$), and presence of a displaced posteromedial fragment ($P = 0.009$). In contrast, only preoperative diagnosis of compartment syndrome predicted increased change in slope ($P = 0.048$).

Table 2 Univariate analysis comparing clinical and radiographic outcomes between treatment groups

Outcomes	Achieved power[a]	IMN (N = 19)	Single plate (N = 15)	Dual plate (N = 28)	*P* value
Surgical time (hours)	83%	5.2 ± 2.9	5.5 ± 2.7	7.6 ± 2.6	**.013**
LOS (days)	7%	11.4 ± 6.2	11.5 ± 8.6	12.3 ± 6.3	.874
Readmission	11%	31.6% (6)	33.3% (5)	32.1% (9)	1
Complications	85%	21.1% (4)	20.0% (3)	25.0% (7)	1
CW ratio	23%	1.087 ± 0.047	1.106 ± 0.046	1.105 ± 0.063	.421
CW ratio change	68%	− 0.003 ± 0.034	0.007 ± 0.032	0.023 ± 0.034	**.043**
TPA (°)	16%	86.5 ± 4.1	87.6 ± 3.4	86.4 ± 3.8	.551
TPA change (°)	86%	− 1.6 ± 2.1	0.8 ± 3.2	− 1.0 ± 3.0	.059
TS (°)	96%	14.1 ± 4.9	10.8 ± 6.8	8.8 ± 4.3	**.003**
TS change (°)	49%	1.3 ± 3.3	0.1 ± 4.7	− 0.9 ± 3.6	.130

Bolded figures indicate statistical significance (below $p = 0.05$)

CW condylar width; *IMN* intramedullary nail; *LOS* length of stay; *TPA* tibial plateau angle; *TS* tibial slope

[a]Post hoc power analyses performed in G*Power assuming $\alpha = 0.05$

Table 3 Multivariate analysis assessing patient and surgical predictors of clinical outcomes

Predictive factors	Surgical time (hours)			LOS (days)			Readmission			Complication		
	β	SE	*P* value	β	SE	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Intercept	9.49	2.29	**< .001**	18.41	5.57	**.001**	NA	NA	NA	NA	NA	NA
Age at surgery (years)	− 0.03	0.03	.277	− 0.09	0.07	.198	0.99	0.94 – 1.05	.805	0.97	0.88 – 1.05	.430
Female sex	− 0.16	0.75	.829	− 1.03	1.81	.572	1.01	0.24 – 4.25	.985	0.56	0.07 – 4.35	.576
BMI (kg/m^2)	0.00	0.04	.940	0.05	0.11	.620	1.00	0.91 – 1.09	.956	0.99	0.90 – 1.10	.910
Caucasian ethnicity	− 0.60	0.87	.491	− 1.18	2.10	.578	1.34	0.26 – 6.80	.726	0.36	0.02 – 5.57	.467
High volume surgeon[a]	− 1.89	0.84	**.029**	− 2.17	2.03	.290	0.63	0.12 – 3.37	.587	0.25	0.03 – 2.21	.211
Open fracture	− 0.44	1.08	.683	7.20	2.62	**.009**	0.27	0.04 – 2.03	.205	0.05	0.00 – 1.34	.075
Polytrauma	− 0.36	0.71	.618	0.74	1.71	.668	0.61	0.16 – 2.39	.479	0.24	0.03 – 1.68	.151
Staged surgery	− 2.64	0.85	**.003**	− 3.91	2.07	.064	0.34	0.06 – 1.84	.213	0.26	0.03 – 2.62	.251
Compartment syndrome	− 3.03	1.21	**.016**	− 1.97	2.94	.507	0.60	0.06 – 5.65	.653	0.71	0.04 – 12.31	.811
Surgical treatment												
Single plate versus IMN	0.44	1.00	.666	− 1.56	2.43	.523	0.40	0.06 – 2.71	.348	0.13	0.01 – 2.68	.188
Dual plate versus IMN	0.25	0.90	.778	− 0.68	2.18	.756	0.88	0.15 – 5.20	.889	0.20	0.01 – 3.23	.257
OTA Classification 41C												
2 versus 1	1.78	1.22	.152	− 0.60	2.97	.839	0.42	0.04 – 4.27	.462	NA	NA	NA
3 versus 1	1.19	1.02	.246	− 1.13	2.46	.649	0.39	0.05 – 2.91	.360	NA	NA	NA
Posteromedial fragment												
Non – displaced versus no fragment	1.42	1.08	.196	− 3.47	2.62	.192	0.58	0.08 – 4.44	.600	0.38	0.02 – 6.59	.509
Displaced versus no fragment	1.78	0.91	.057	4.65	2.21	**.041**	2.83	0.46 – 17.42	.261	4.00	0.49 – 32.76	.196

BMI body mass index; *IMN* intramedullary nail; *LOS*, length of stay. Multiple linear and logistic regression performed for ontinuous and dichotomous outcomes, respectively

[a]Operating surgeon responsible for treating ≥ 10 patients in this series

Complications

The all-cause complication rate ranged from 16 to 21% depending on treatment type (Table 6). While the most common complication in patients receiving dual plates was painful hardware necessitating removal (11% [3]), infection was the most common in patients receiving an IMN or a single plate (11% [2] and 13% [2]), however, there was no statistical difference in incidence of infection between groups.

Discussion

The results of this study demonstrate that IMN constructs yielded similar short-term radiographic and clinical results compared to plate fixation constructs, which affirms the null hypothesis. There were no statistically significant differences in postoperative tibial plateau angle or tibial plateau angle change between cohorts that was maintained in the sub analysis grouped by OTA classification. Overall few comparisons between groups reached or approached statistically significant differences (Table 2, 4 and 5). A statistically significant difference in operative time was observed between cohorts with a mean of approximately two additional hours of surgical time in the dual plating cohort. Mean differences in Tib/femur width ratio change range from 1 to 2.6%; such small percentage changes in CW, despite being of statistical significance, is highly unlikely to be clinically significant. The largest statistically significant mean difference in radiographic measurements involved postoperative tibial slope between IMN and dual plate groups (5.3 degrees). This statistical difference between plate and nail cohorts may reflect an increase in difficulty restoring native slope based on an indirect reduction technique with intramedullary device placement compared to direct visualization with plate osteosynthesis. Procurvatum, or apex anterior malalignment, which would indirectly increase tibial slope, is a known complication of intramedullary nail fixation of extraarticular proximal tibia fractures [1, 9, 10] and tends to occur more frequently than plate osteosynthesis [1, 10]. The use of posterior poller blocking screws has been shown to help prevent apex anterior malalignment in extraarticular proximal tibia fractures [11–13] and potentially may have addressed this difference in tibial slope seen between IMN cohort and plate construct cohorts. It is also possible that this difference is not clinically important based on the known variability of physiologic tibial slope in the general population [14, 15]. It is also important to note that despite the significant difference in immediate postoperative tibial slope measurements

Table 4 Univariate analysis comparing clinical and radiographic outcomes between treatment groups stratified by OTA 41C classification

Outcomes	IMN	Single plate	Dual plate	*P* value*
OTA 41 – C1 (N)	8	5	1	–
CW ratio	1.086 ± 0.055	1.125 ± 0.024	1.036	.115
CW ratio change	0.004 ± 0.036	0.015 ± 0.028	0.004	.532
TPA (°)	87.1 ± 4.5	89.0 ± 1.8	85.0	.309
TPA change (°)	− 0.6 ± 1.9	1.0 ± 3.0	− 0.6	.337
TS (°)	14.4 ± 5.0	11.0 ± 4.5	5.2	.235
TS change (°)	1.1 ± 3.9	2.5 ± 2.2	− 2.8	.405
OTA 41 – C2 (N)	4	3	4	–
CW ratio	1.082 ± 0.016	1.130 ± 0.067	1.090 ± 0.05	.577
CW ratio change	− 0.015 ± 0.022	0.010 ± 0.016	0.031 ± 0.031	.144
TPA (°)	85.7 ± 3.6	86.5 ± 1.7	87.3 ± 2.3	.741
TPA change (°)	− 2.9 ± 2.3	0.4 ± 3.4	0.0 ± 2.1	.270
TS (°)	12.2 ± 3.8	14.1 ± 11.0	10.6 ± 8.3	.908
TS change (°)	− 0.7 ± 2.6	− 3.6 ± 2.9	− 1.2 ± 5.0	.478
OTA 41 – C3 (N)	7	7	23	–
CW ratio	1.090 ± 0.054	1.082 ± 0.042	1.110 ± 0.066	.425
CW ratio change	− 0.003 ± 0.040	0.001 ± 0.04	0.023 ± 0.036	.235
TPA (°)	86.4 ± 4.3	87.1 ± 4.5	86.3 ± 4.1	.922
TPA change (°)	− 2.0 ± 1.8	0.7 ± 3.6	− 1.1 ± 3.2	.226
TS (°)	14.7 ± 5.8	9.2 ± 6.8	8.7 ± 3.5	.084
TS change (°)	2.6 ± 2.6	− 0.1 ± 5.8	− 0.7 ± 3.5	.065

CW condylar width; *IMN* intramedullary nail; *OTA* orthopedic trauma association; *TPA* tibial plateau angle; *TS* tibial slope

*In the OTA-41C1 group, comparisons were made between IMN and single plate only using a two-sample unpaired t-test given the lack of patients receiving a dual plate in this patient cohort

between IMN and plate constructs, there was no significant difference in change in slope comparing follow-up plain radiographs to immediate postoperative imaging.

This study also identified that the presence of a posteromedial fragment was a significant predictor of treatment allocation (Table1, $p = 0.006$). At this institution, IMN constructs were utilized largely for fractures with articular fragments that were classified as simple articular—12 of 19 patients within the IMN cohort were classified as OTA 41C1 or 41C2. However, greater than a third in the IMN cohort were classified as fragmentary or multifragmentary joint line and metaphyseal segments (41C3). Of the nineteen Schatzker VI plateau fractures treated with an intramedullary construct, two had non-displaced or minimally displaced posteromedial fragments that were either large enough to accommodate compression/raft screws, or small enough that it did not compromise fracture alignment after fixation of the remainder of the larger medial plateau fragment. These were amenable to percutaneous fixation using either the proximal interlocking screws through the nail or separate rafting screws.

The present study provides comparative outcomes lacking in prior studies. Nork and colleagues included three cases of Schatzker VI fractures among 33 proximal tibia fractures treated by IMN. Overall, the outcomes were very good but the Schatzker VI subgroup was not separately reported [3]. Garvanos et al. [16] reported the prospectively observed 2-year clinical outcomes of eight patients with tibial plateau fracture treated with IMN supplemented by raft screws. The inclusion criteria were strict and included age greater than 60 years, no articular depression, and no neurovascular compromise. The clinical results included recovery of excellent knee range of motion and no cases of infection or nonunion. However, fracture alignment and maintenance was not reported.

The dual plate group served as a reference group. Acceptable postoperative alignment has been reported ranging 91–95% with dual plating [17–21] for Schatzker VI fractures. While requiring less soft tissue stripping than the historical midline incision, incisional necrosis along the medial and lateral approaches, deep infection (range 8.6–23.6%) and nonunion (0–10%) remain the most common complications [17–25] The present clinical and radiographic findings were consistent with these results including > 92% acceptable alignment maintained for a mean 13 months of follow-up and infection rate of 7.1% for the dual plating group.

Table 5 Multivariate linear regression analysis assessing patient and surgical predictors of radiographic outcomes

Predictive factors	CW ratio			CW change			TPA (°)			TPA change			TS (°)			TS change		
	β	SE	*P* value	β	SE	*P* value	β	SE	*P* value	β	SE	*P* value	β	SE	*P* value	β	SE	*P* value
Intercept	0.99	0.05	**<.001**	−0.05	0.03	.108	92.39	3.81	**<.001**	4.06	2.84	.160	17.77	4.90	**.001**	−1.32	3.51	.707
Age at surgery (years)	0.00	0.00	**.023**	0.00	0.00	.525	−0.07	0.05	.153	−0.07	0.03	**.042**	0.03	0.06	.563	0.06	0.04	.138
Female sex	0.02	0.02	.167	0.01	0.01	.205	1.81	1.24	.151	0.55	0.92	.554	−3.43	1.59	**.036**	0.18	1.14	.874
BMI (kg/m^2)	0.00	0.00	.334	0.00	0.00	.430	−0.10	0.07	.182	−0.04	0.06	.501	−0.04	0.10	.706	−0.01	0.07	.908
Caucasian ethnicity	−0.02	0.02	.352	0.02	0.01	.081	0.83	1.44	.567	−0.10	1.07	.923	0.00	1.85	.999	0.43	1.32	.747
High volume surgeon[a]	0.00	0.02	.824	0.00	0.01	.807	−0.47	1.39	.736	0.18	1.04	.861	−1.12	1.78	.532	−1.08	1.28	.400
Open fracture	0.03	0.02	.231	0.01	0.02	.468	0.72	1.79	.689	−0.46	1.34	.732	−3.34	2.31	.154	3.19	1.65	.060
Polytrauma	−0.02	0.02	.224	−0.01	0.01	.539	−0.76	1.17	.519	−0.25	0.88	.774	−0.38	1.51	.800	−2.09	1.08	.059
Staged surgery	0.01	0.02	.715	0.01	0.01	.240	−0.23	1.41	.872	−1.10	1.06	.303	−2.21	1.82	.231	1.87	1.30	.157
Compartment syndrome	−0.01	0.03	.722	0.02	0.02	.357	−0.85	2.01	.673	−0.47	1.50	.755	−1.18	2.59	.651	3.76	1.85	**.048**
Surgical treatment																		
Single plate vs. IMN	0.02	0.02	.355	0.01	0.01	.284	0.73	1.49	.627	2.69	1.12	**.020**	−3.17	1.92	.106	−1.50	1.37	.282
Dual plate vs. IMN	0.05	0.02	**.016**	0.04	0.01	**.006**	−1.47	1.59	.362	−0.01	1.19	.994	−7.77	2.05	**<.001**	−0.60	1.47	.683
OTA Classification 41C																		
2 vs. 1	−0.02	0.03	.377	−0.01	0.02	.620	0.39	2.03	.850	−0.21	1.52	.889	0.67	2.61	.798	−3.07	1.87	.107
3 vs. 1	−0.02	0.02	.501	−0.01	0.01	.581	−0.36	1.69	.830	−0.74	1.26	.561	−2.31	2.17	.293	−0.94	1.55	.549
Posteromedial fragment																		
Non − displaced vs. no fragment	−0.02	0.02	.332	−0.03	0.02	.069	−0.92	1.79	.612	−0.56	1.34	.679	2.60	2.31	.265	0.33	1.65	.841
Displaced vs. no fragment	−0.03	0.02	.186	−0.01	0.01	.269	3.35	1.51	**.032**	1.09	1.13	.338	5.30	1.95	**.009**	−0.78	1.39	.578

Bolded figures indicate statistical significance (below $p = 0.05$)

BMI body mass index; *CW* condylar width; *IMN* intramedullary nail; *LOS*, length of stay; *OTA* orthopedic trauma association; *SE* standard error; *TPA* tibial plateu angle; *TS* tibial slope

[a]Operating surgeon responsible for treating ≥ 10 patients in this series

Table 6 Incidence of complications

Complication	IMN	Single plate	Dual plate
All cause complications	21.1% (4)	20.0% (3)	21.4% (6)
Infection	10.5% (2)	13.3% (2)	7.1% (2)
Soft tissue breakdown	5.3% (1)	0.0% (0)	0.0% (0)
Nonunion	0.0% (0)	0.0% (0)	3.6% (1)
Painful hardware—removed	5.3% (1)	6.7% (1)	10.7% (3)

Single plate fixation was also found to be similar to dual plate fixation regarding short-term radiographic and clinical outcomes. Current literature suggests that limited incision single column locked plating produces similar results compared to dual plating for Schatzker VI and OTA 41C tibial plateau fractures [26]. There is a lower incidence of incisional necrosis and comparable overall infection rates [18, 19, 26, 27]. In this study, there were a higher proportion of open fractures in the single plate group compared to the dual plate group with other factors being equal. Therefore, the lack of significant difference in postoperative complications is clinically important. Additionally, the single plate construct was not associated with loss of medial column or sagittal plane alignment, which has been demonstrated in clinical and biomechanical studies before [4, 18, 19, 26–28]. It is important to note that there was a predilection to treat fractures that had the presence of a displaced posteromedial fragment and were classified as OTA 41C3 with dual plate fixation over single plate constructs (42.9% versus 6.7% and 82.1% versus 46.7%, respectively).

Current studies have demonstrated no significant difference in infection and nonunion between plate and nail fixation of proximal extraarticular tibia fractures [1, 2]. This study demonstrated no significant difference in all cause complications between dual plating and IMN fixation (Table 6). There was almost five times the incidence of open fractures in the IMN group and single plate cohorts compared to the dual plate cohort (21.1% vs. 3.6% and 26.7% vs. 3.6%, respectively). Similar to the higher percentage of IMN constructs selected for treatment of open fractures observed in the study performed by Lindvall et al. [1], there was a higher proclivity for surgeons in this study to select less invasive constructs for open fracture, suggesting compromised tissue quality plays an important role in construct selection.

There were several limitations of this study. Firstly, the study faces the same well-documented limitations intrinsic to a retrospective cohort study such as lack of randomization, non-blinded analysis, and selection bias. A follow-up prospective cohort evaluating similar radiographic parameters would be a useful corollary to the findings of this study. Another limitation involved measurement error. While inter-rater reliability was good (indicative of substantial agreement based on Landis and Koch guidelines [5]), the study could have benefited from additional observers to strengthen the inter-observer reliability. Additionally, having the same observer repeat measurements to assess baseline intra-observer reliability would strengthen the measurement accuracy. While this study contained a relatively large cohort of Schatzker VI tibial plateau fractures, it is still possible that the study was underpowered to detect significance in variables approaching significance. Based on the results of the post hoc analysis, the sample size is insufficient to assess differences in some of our clinical and radiographic outcomes between treatment groups (Table 2). However, our data may allow future investigators to determine the necessary sample size a priori to detect smaller yet clinically relevant differences in these outcomes between treatment groups.

The patients in this cohort were followed for mean 13.2 months. Longer follow-up including clinical outcomes would strengthen these analyses. The limited follow-up is a frequently sighted issue in orthopedic trauma studies and can be owed to the complex social dynamics of the trauma patient population. Lastly, the study would additionally benefit from clinical outcomes measures as a corollary to the radiographic outcomes; further investigation with a prospective cohort would likely be contributory to the better understanding of complexity of Schatzker VI tibial plateau fractures and treatment modalities.

Conclusions

Intramedullary nail fixation with or without supplemental raft screws produced similar short-term clinical and radiographic results compared to dual and single plate constructs among patients with Schatzker VI fracture types.

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Declarations

Conflict of interest Authors have no financial or competing interests to disclose.

Ethical approval This study was performed in line with the principles of the University of Florida International Review Board (IRB).

Informed consent Consent to participate and consent to publish was not applicable for this study.

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