Outcomes of Schatzker II Tibial Plateau Fracture Open Reduction Internal Fixation Using Structural Bone Allograft

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Objectives: The purpose of this study is to report the rate of anatomic reduction, articular subsidence, and clinical outcomes for Schatzker II tibial plateau fractures treated with structural bone allografts.

Design: This is a retrospective case series.

Setting: Academic Level I Trauma Center.

Patients/Participants: A trauma registry was used to identify 77 Schatzker II tibial plateau fractures.

Intervention: Schatzker II tibial plateau fracture open reduction internal fixation and structural bone graft using either Plexur P (N = 29) or fibular allograft (N = 48).

Main Outcome Measurement: The primary outcome was articular subsidence. Secondary outcomes included fracture malreduction and clinical outcomes including the Knee Outcome Survey Activities of Daily Living Scale, the Lower Extremity Functional Scale, and the Short Form (SF)-36.

Results: No patients experienced subsidence > 2mm. This rate is significantly lower than published rates for autogenous iliac crest (30.3%, $P < 0.0001$) and calcium phosphate cement (8.7%, $P = 0.0099$). The rate of fracture malreduction was 11.7% (9/77); only 4 had more than 3 mm of residual incongruity. Average outcome scores were the following: Knee Outcome Survey Activities of Daily Living Scale, 81.7; Lower Extremity Functional Scale, 78.5; SF-36 physical component, 48.3; and SF-36 mental component, 53.1. There was no difference between patients treated with Plexur P or fibula with regard to the primary or secondary outcomes.

Conclusions: The use of structural allograft resulted in a high rate of anatomic reduction and negligible rate of articular subsidence and good clinical outcomes in the treatment of this population of Schatzker II tibial plateau fractures. This compares favorably with historical results using nonstructural grafts.

Key Words: tibial plateau, fracture, bone graft, structural, allograft

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

Schatzker II tibial plateau fractures are the most common type of tibial plateau fracture and necessarily involve a metaphyseal split in combination with articular depression. Appropriate open treatment of these injuries involves elevating the displaced articular surface, which inevitably results in a subarticular bone void. Management of these subarticular voids should seek to restore bone stock and, most importantly, prevent future articular subsidence by assisting in maintaining the open reduction. A variety of bone grafts have been used for this purpose, with calcium phosphate cement shown to be the most effective graft to date, in terms of preventing subsidence.[1] At our institution, we have been using a previously developed technique of structural bone graft using allograft to treat the subarticular bone voids in tibial plateau fractures. These structural allografts include fibula cortical allograft and Plexur P (Medtronic, Minneapolis, MN), which is a composite material composed of cortical fibers, extracellular matrix proteins, calcium, phosphate, and trace elements suspended within a resorbable scaffold. These graft materials possess excellent compressive strength, and we have anecdotally found them very effective in maintaining the articular reduction and preventing subsidence. In addition, these structural allografts can be used as a reduction tool to assist in achieving an anatomic reduction during insertion, by virtue of their inherent structural properties, an advantage not conferred with cancellous graft or cement. Although this technique has been used in the past, no study has evaluated the efficacy of these types of structural allografts in this clinical application.

The purpose of this study was to report and compare the radiographic and clinical outcomes of Schatzker II tibial plateau fractures having undergone open reduction internal fixation with the use of a structural bone allograft, either fibula allograft or Plexur P. This includes the frequency of anatomic reduction, the rate of articular subsidence, and the results of patient-based outcomes. We hypothesize that patients undergoing open reduction internal fixation of Schatzker II tibial plateau fractures treated with structural allograft will have a high rate

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of anatomic reduction, a low rate of articular subsidence, and good clinical outcomes.

METHODS

Patient and Data Acquisition

This was a retrospective study performed at a level I trauma center. Institutional review board's approval was obtained. The institution's orthopaedic trauma registry was used to identify tibial plateau fractures having undergone open reduction internal fixation by 2 surgeons (D.L.H. and D.G.L.) between 2006 and 2011. From this roster, the final study population was identified. Inclusion criteria consisted of the following: unicondylar split depression type tibial plateau fracture (Schatzker II, AO/OTA 41-B3.1) with greater than 2 mm displacement (Fig. 1), ORIF within 30 days from injury, minimum 1-year clinical and 6-month radiographic follow-up, documented compliance in weight bearing recommendations, and use of a structural bone graft (either fibula allograft or Plexur P) to fill a subarticular void. Vulnerable patients (minors and prisoners) were excluded. Each patient's medical record was reviewed to identify and record patient demographics, medical comorbidities, injury details, operative data (including type of bone graft and fixation used), and information regarding clinical follow-up. Final clinical follow-up required an examination documenting weight bearing status and knee range of motion (ROM) at 1 year. In addition, patients were instructed to complete several patient-based questionnaires including the Knee Outcome Survey Activities of Daily Living Scale (KOSADLS), the Lower Extremity Functional Scale (LEFS), and the Short Form (SF)-36. The KOSADLS is a validated questionnaire that serves to measure knee function specifically.[2] The LEFS is a validated patient outcome measure that assesses the general function of the affected lower extremity as it impacts daily life, whereas the SF-36 provides insight into patient outcome from a global perspective.[3] Three independent reviewers, all senior level orthopaedic residents (M.B.B., M.T.M.L., and P.C.S.) examined all injury, immediate postoperative, and final postoperative radiographs for each patient to confirm the fracture pattern, assessed the quality of the immediate postoperative articular reduction, and recorded the amount of articular subsidence present at minimum 6-month follow-up. Minimum radiographic follow-up was set at 6 months as the literature has shown that subsidence is most likely to occur between 3 and 6 months postoperatively.[1] The fracture was considered anatomically reduced if both the medial proximal tibial angle was within 87 $\pm$ 5 degrees and the maximum amount of articular stepoff on the anteroposterior or lateral radiograph of the knee was less than 2 mm. Articular subsidence was measured according to the method described by Boraiah et al[4]; this involved drawing a horizontal line at the level of the area of maximal joint depression on the involved (lateral) condyle and then drawing a horizontal line at the level of the nondepressed (medial) condyle's articular surface. The difference in height (measured by the midline perpendicular) was recorded for the immediate postoperative x-ray and for the final follow-up x-ray. The difference between these values was considered the amount of articular subsidence. Magnification was corrected for each image by using the longest screw with a known length as a calibration tool. Measurements were made on the hospital's digital image archiving system.

Surgical Technique and Postoperative Management

The structural properties and compressive strength of these bone grafts allow them to be used in a unique and useful fashion

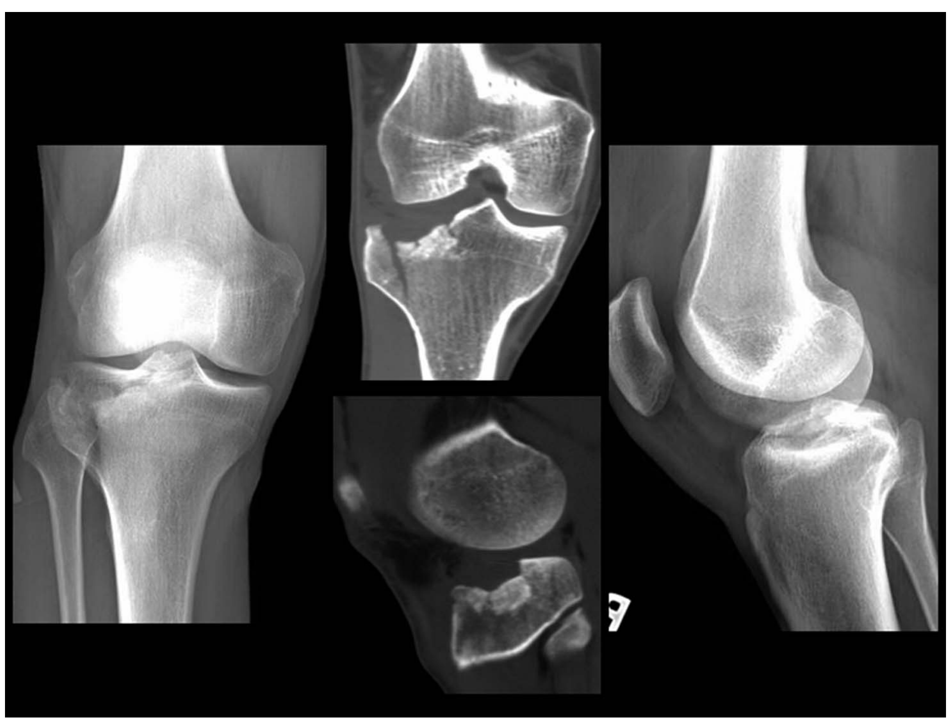

FIGURE 1. Anteroposterior and lateral radiographs and coronal and sagittal computed tomography images demonstrating Schatzker II tibial plateau fracture, which comprised this study population.

during the surgical procedure. First, the depressed articular surface is accessed through the preexisting fracture line exiting through the anterior cortex of the proximal tibia. This gap is exploited with the use of osteotomes to gain full visualization of the displaced articular surface (with the assistance of a submeniscal arthrotomy). The depressed articular surface is then disimpacted and initially reduced with the assistance of an elevator. After this step, the structural allograft of choice is crafted such that it is slightly oversized relative to the resulting bone void. The graft is then malletted into place beneath the articular fragments with the assistance of a bone tamp. This maneuver serves to elevate all involved articular fragments as a unit, until the oversized graft has created a stable wedge within the void and reduced the joint surface. Anatomic reduction is confirmed in 2 ways: first, by means of visualizing the articular surface directly through a submeniscal arthrotomy. Second, the appropriate amount of varus of the proximal tibia (3 degrees) is restored by elevating the lateral plateau to a position just proximal to the level of the medial plateau. This is assessed and confirmed radiographically by using the central axis of the proximal tibial metaphysis as a reference. The fracture gap in the anterior cortex is then closed and fixation provided with a buttress plate and screw construct. Care is taken to ensure that 1 or more screws passing through the plate purchase the structural graft. This crucial step locks in the position of the allograft, forming a composite fixation construct that will buttress the subchondral bone and articular cartilage and effectively secure the reduction and resist subsidence. Because the medial tibial plateau and medial cortex were intact in all of these Schatzker II fractures, fixation was sufficiently appropriate using either locking or nonlocking plate and screw construct. The choice of implant was at the discretion of the treating surgeon.

All patients were treated with a standardized postoperative rehabilitation protocol. Active and passive ROM is initiated immediately, with the assistance of continuous passive motion. Patients are kept nonweight bearing until 3 months postoperatively to allow for a sufficient period of joint unloading to facilitating healing of the chondral injury and then progressed to weight bearing as tolerated.

Outcomes

The primary outcome in this study was the presence of articular subsidence. The secondary outcomes included the rate of anatomic reduction and clinical measures including the KOSADLS, LEFS, SF-36, knee ROM, and rate of complications (infection, wound complications, and nonunion). These outcomes were first compared between the group treated with fibula allograft and the group treated with Plexur P to detect differences between these 2 types of structural grafts. In addition, the results for both fibula and Plexur were pooled together and compared with quoted rates of subsidence in the literature using nonstructural bone grafts.[1] Comparisons were made between groups using a *t* test or Fisher exact test where appropriate.

No sources of external funding were used for the purposes of this investigation. All implants used in this investigation were FDA approved.

RESULTS

From an original roster of 209 tibial plateau fractures treated during the study time period, 77 met all inclusion and exclusion criteria for analysis: 29 treated with Plexur P and 48 with fibula allograft. The average duration of follow-up was 24 months (range, 12–56 months). 44% (34/77) patients were men, with the average age 50.9 years (range, 25–87 years). Forty-four percent (34/77) patients sustained their fracture as a result of a fall from standing height; the remainder experienced a high-energy mechanism (most frequently pedestrian struck or motor vehicle accident). There were no open fractures.

None of the 77 (0%) patients experienced subsidence greater than 2 mm. The average amount of measured subsidence for the entire cohort was 0.13 mm; 88.3% (68/77) patients obtained an anatomic reduction. Figure 2 provides an illustration of a case treated with fibula allograft with an excellent reduction and no subsidence. Considering only the 9 malreductions, 5 had between 2 and 3 mm stepoff and 4 had greater than 3 mm of stepoff; the maximum amount of residual displacement was 5.5 mm. There were no nonunions and a single case of surgical site infection (1/77, 1.3%), successfully managed with antibiotics alone. Five secondary procedures were performed, including 2 manipulations under anesthesia and 3 knee arthroscopies, all to address postoperative stiffness. Average knee ROM was 130 degrees at final follow-up. Complete minimum 1-year clinical questionnaire data were available for 59 of 77 (77%) patients (21 Plexur P and 38 fibular allograft). Among these patients, the average KOSADLS score was 81.7, the average LEFS was 78.5, and the average SF-36 physical and mental component scores were 48.3 and 53.1, respectively.

When comparing the Plexur P and fibular allograft groups against each other, these 2 populations were similar with regard to demographic and injury variables (Table 1). Furthermore, there was no difference in the rate of subsidence $>$ 2mm, the rate of anatomic reduction, knee ROM, the rate of complications including infection, wound complications, and nonunion (Table 2). There was also no difference between groups with regard to the KOSADLS, LEFS, or SF-36 results (Table 3). When pooling the results of these 2 groups together and comparing them with historical data published by Russell and Leighton,[1] the rate of articular subsidence $>$ 2 mm using structural bone graft (0%) was significantly better than autogenous iliac crest (30.3%, $P < 0.0001$) and calcium phosphate cement (8.7%, $P = 0.0099$).

DISCUSSION

The purpose of this investigation was to report the radiographic and clinical results of tibial plateau fractures treated with structural bone allografts including Plexur P and fibula allograft. Seventy-seven tibial plateau fractures with bone voids were treated with these structural grafts: 29 with Plexur P and 48 with fibular allograft. No cases experienced articular subsidence greater than 2 mm. The rate of anatomic reduction was 88.3%. SF-36 results were comparable with age-matched controls for the physical component score (49.6 vs. 48.3 in this study) and slightly above average for the mental component score (50.5 vs. 53.1 in this study). KOSADLS and

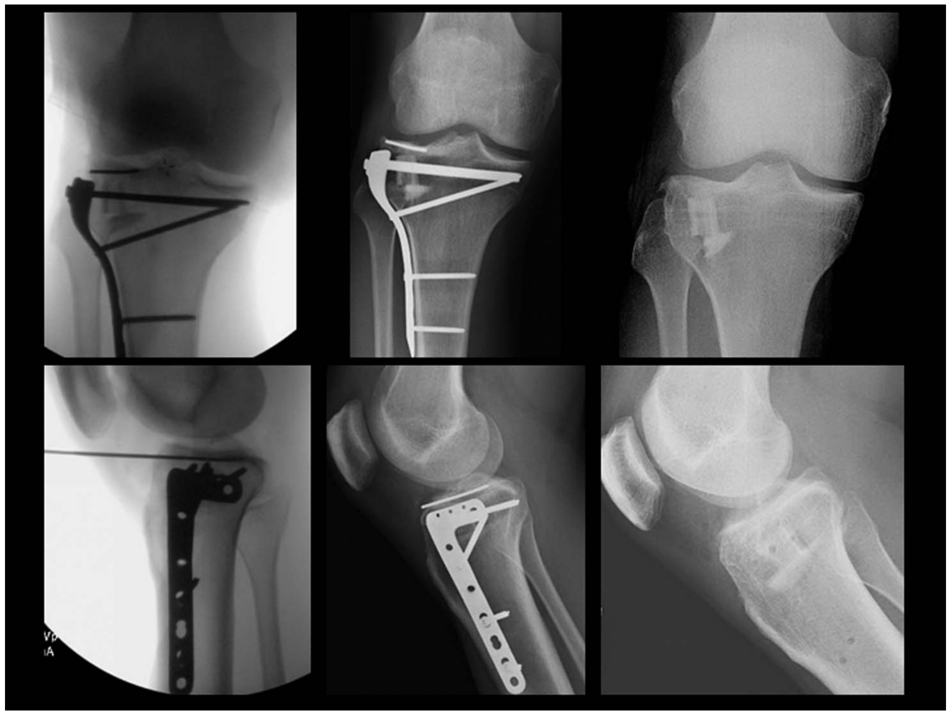

FIGURE 2. Intraoperative, immediate postoperative and final follow-up radiographs following open reduction internal fixation with structural bone graft, in the form of fibula allograft. Injury films for this fracture can be viewed in Figure 1. Note the anatomic reduction and maintenance of reduction with no evidence of subsidence.

LEFS outcomes compared favorably with the reported scores for other treated pathologic conditions reported for the knee and lower extremity in the literature.[5,6] When comparing these 2 types of structural grafts against each other, there was no differences detected between the primary and secondary outcomes. The rate of articular subsidence greater than 2 mm observed among this cohort of patients compares favorably with the rates of subsidence reported in the literature for tibial plateau fractures treated with either autogenous iliac crest bone graft or calcium phosphate cement.

There are limitations to this study. There was no standardized protocol in place during the treatment period to determine which patients were treated with structural allografts and which type was chosen. This decision was at the discretion of the 2 attending surgeons, made at the time of treatment. This investigation is simply a retrospective evaluation of the results of this cohort of patients. Second, there were 2 treating surgeons involved in this study. Although this may make the results more widely applicable, it also allows for treatment bias especially because, in general, each surgeon used a different type of structural allograft. However, the surgical techniques and postoperative rehabilitation protocols used by these 2 surgeons are similar. The lack of complete follow-up also limits the conclusions of this study. Third, there are a number of cases treated with structural grafts, which had incomplete clinical and/or radiographic follow-up, and the results of these cases cannot be known. Fourth, there was no power analysis calculation performed. It is the belief of the treating surgeons that the use of fibula or Plexur P would have equally good outcomes. Thus, a massive

TABLE 1. Injury and Demographic Data for the Entire Cohort and for the Plexur and Fibula Allograft Groups

Variable	Overall (n = 77)	Plexur (n = 29)	Fibula (n = 48)	*P*
Age (y)	50.9; SD: 14.7 (25–87)	49.8; SD: 14.05	51.7; SD: 15.2	0.5863*
Sex (% male)	34/84 (44)	11/29 (38)	23/48 (48)	0.4799†
Tobacco, n (%)	4/77 (5.2)	3/29 (10.3)	1/48 (2.1)	0.1472†
Associated LE injury, n (%)	8/77 (9.5)	2/29 (6.9)	6/48 (12.5)	0.7027†
Open Fx, n (%)	0 (0)	0 (0)	0 (0)	1†
% Low E Mech, n (%)	34/77 (44.1)	15/29 (51.7)	19/48 (39.6)	0.3483†
Compartment syndrome, n (%)	1/77 (1.3)	0 (0)	1/48 (2.1)	1†
Days to ORIF	6.1; SD: 4.5	8.1; SD: 4.8	4.9; SD: 3.9	0.002‡
Average x-ray follow-up (d)	347; SD: 204.5	365; SD: 251.7	336; SD: 171.9	0.55‡
Days to WBAT	91; SD: 17.2	86.2; SD: 17.5	93.2; SD: 16.7	0.0841‡

*Unpaired test.
†Fisher exact test.
‡*t* test.

TABLE 2. Radiographic Outcomes, Complications, and ROM for the Entire Cohort and for the Plexur and Fibula Allograft Groups

Variable	Overall (n = 77)	Plexur (n = 29)	Fibula (n = 48)	P
Malreduction, n (%)	9/77 (11.7)	5/29 (17.2)	4/48 (8.3)	0.2846*
Average subsidence (mm)	0.13; SD: 0.71	0.27; SD: 0.43	0.05; SD: 0.83	0.1711†
Subsidence > 2mm, n (%)	0/77 (0)	0 (0)	0 (0)	1*
Revision ORIF, n (%)	0 (0)	0 (0)	0 (0)	1*
Nonunion, n (%)	0 (0)	0 (0)	0 (0)	1*
ROM	129.6; SD: 12.9	126.6; SD: 12.8	131.4; SD: 12.7	0.1133†
Wound complications, n (%)	5/77 (6.5)	1/29 (3.4)	4/48 (8.3)	0.6446*
Surgical site infections, n (%)	1/77 (1.3)	0 (0)	1/48 (1.89)	1*

*Fisher exact test.
†*t* test.

number of patients would have to be included to detect any clinically meaningful and statistically significant difference, which is not realistic for this study. Finally, there was no true control group in this investigation, such as fractures treated without graft or iliac crest or calcium phosphate cement. We are limited to comparing our results using structural grafts with other rates reported in the literature, which is not as scientifically robust as a direct comparison group.

For the past several decades, orthopaedic surgeons have recognized the problems that subarticular bone voids create when dealing with depressed tibial plateau fractures. A variety of bone grafts and substances have been used to help manage these voids in an effort to preserve the fracture reduction and prevent postoperative subsidence. Cancellous autograft, cancellous allograft, calcium phosphate cement, and even trabecular metal have been described in this application.[7–10] Cancellous autograft was long considered the standard of care for the management of these subchondral bone voids,[11,12] and relatively good results were reported with its use.[7,8] However, after the development of injectable calcium phosphate cement, surgeons almost immediately realized the possible benefits of this bone graft substitute with regard to tibial plateau fractures. Lobenhoffer et al[10] published the first substantial case series using this product in 26 tibial plateau fractures and reported promising results. Biomechanical data also helped support the use of calcium phosphate cement, as multiple animal and cadaver studies have shown that cement offers superior stiffness and resistance to subsidence compared with cancellous bone graft.[13–16] Perhaps the most compelling evidence establishing injectable calcium phosphate cement as the standard of care was demonstrated in a large randomized, controlled trial comparing calcium phosphate cement with autogenous iliac crest bone graft. The cement group experienced a significantly lower rate of postoperative articular subsidence greater than 2 mm compared with the bone graft group.[1]

Although structural grafts have been previously used by surgeons in managing bone voids of the tibial plateau, to date, no investigation has formally reported the surgical technique or results using structural allografts in this application. We have been performing this technique at our institution for over 3 years, because we believe it offers several advantages over other bone grafts or bone graft substitutes. First, it avoids the possibility of complications related to donor site morbidity, as would be expected with the use of autogenous bone graft. Second, these bone grafts have an innate shape and structure before being placed within the bone void, unlike calcium phosphate cement or cancellous graft. We believe this offers several advantages; first, the graft can actually be used as a reduction tool. The Plexur or fibula allograft is malleted into place below the articular surface, which assists in disimpacting metaphyseal bone and elevating the articular surface as a unit to its anatomical bed. This maneuver is impossible with cement or cancellous graft. Second, these structural grafts offer screw purchase. Once placed appropriately within the proximal tibia, this graft can be drilled and have screws passed through it, thus enhancing the fixation. In essence, the graft acts as an internal cortex for screw purchase. This coupled with the innate compressive strength of these structural grafts help to minimize postoperative articular subsidence.

The results obtained in this investigation using structural allograft are promising. All fractures healed, 88% were anatomically reduced, negligible subsidence was encountered, and good subjective outcome scores were observed. This

TABLE 3. Patient-Based Questionnaire Results for the Entire Cohort and for the Plexur and Fibula Allograft Groups

Variable	Overall (N = 59)	Plexur (N = 21)	Fibula (N = 38)	P
Average clinical follow-up (mo)	24.3; SD: 13.7	25.3; SD: 8.7	23.7; SD: 15.8	0.6699*
KOSADLS	81.7; SD: 16.6	82.1; SD: 19.6	81.5; SD: 15	0.8957*
LEFS	78.5; SD: 20.6	82.4; SD: 19.1	76.3; SD: 21.3	0.2797*
SF-36, physical component	48.3; SD: 10	48.1; SD: 10.8	48.5; SD: 9.6	0.884*
SF-36, mental component	53.1; SD: 9.3	53.3; SD: 8.4	52.9; SD: 9.9	0.8762*

**t* test.

compares favorably with outcomes reported in the literature using cancellous bone graft and perhaps even calcium phosphate cement. Rates of articular subsidence reported in clinical studies using cancellous bone graft range anywhere between 12.5% and 61.5%.[1,7,17] Calcium phosphate cement seems to offer improved performance, with subsidence rates reported between 7.8% and 23%.[1,10,17] The most scientifically robust study in this area was performed by Russell and Leighton; this was a randomized control trial comparing autogenous iliac crest bone graft with calcium phosphate cement. The bone graft group experienced a 30% subsidence rate, and the cement group reported a 9% subsidence rate. The 0% subsidence rate seen with structural bone grafts in this study is significantly better than both of these groups. Although these data should be interpreted cautiously owing to the fact that these are not direct comparison groups, it do provide compelling evidence in support of the use of structural bone grafts for this application. We did not detect a difference in radiographic or clinical outcome between the Plexur and fibula allograft groups in this, although none was necessarily expected based on clinical experience.

In conclusion, structural allograft present an attractive alternative to nonstructural grafts such as calcium phosphate cement or cancellous bone graft for the management of tibial plateau fracture bone voids. Structural bone allografts yielded a minimal rate of articular subsidence in the treatment of this population of tibial plateau fractures, especially when compared with historical rates for nonstructural grafts. In addition, both Plexur P and fibula allograft helped achieve low rates of malreduction and good clinical outcomes. Future studies directly comparing the efficacy of these structural grafts with nonstructural grafts, including calcium phosphate cement, are warranted.

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