COMPARATIVE CLINICAL AND RADIOLOGICAL OUTCOMES OF HYDROXYAPATITE BONE SUBSTITUTE, ANALOGUES ILIAC CREST BONE GRAFT AND NO VOID FILLER IN TIBIAL PLATEAU FRACTURES TREATED WITH OPEN REDUCTION AND INTERNAL FIXATION: A PROSPECTIVE STUDY

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Abstract
Background: Tibial plateau fractures are complex intra-articular injuries that frequently require open reduction and internal fixation (ORIF). Elevation of depressed articular fragments creates metaphyseal bone defects that may be managed using autologous iliac crest bone graft, hydroxyapatite bone substitute, or left unfilled. The optimal method of managing these defects remains controversial.
Aim: To compare the clinical and radiological outcomes of hydroxyapatite bone substitute, autologous iliac crest bone graft, and no void filler in tibial plateau fractures treated with ORIF.
Materials and Methods: This prospective comparative observational study was conducted in the Department of Orthopaedics, Saveetha Institute of Medical Sciences and Hospital, over a period of one year. Forty-eight patients aged 18–56 years with tibial plateau fractures were equally allocated into three groups: Hydroxyapatite bone substitute (n=16), autologous iliac crest bone graft (n=16), and no void filler (n=16). Patients were followed for a mean duration of 12 months. Clinical outcomes were assessed using the Rasmussen Functional Score, while radiological outcomes were evaluated using the Rasmussen Radiological Score. Complications and reoperation rates were also analyzed.
Results: The autologous iliac crest bone graft group demonstrated the earliest fracture union, superior clinical and radiological outcomes, and no reoperations. Hydroxyapatite provided comparable results with the additional advantage of eliminating donor-site morbidity; however, two patients required reoperation. The no void filler group showed delayed union, relatively inferior functional and radiological outcomes, and the highest reoperation rate (four patients).
Conclusion: Autologous iliac crest bone graft remains the gold standard for metaphyseal defect management in tibial plateau fractures. Hydroxyapatite is a safe and effective alternative that avoids donor-site complications, whereas omission of void filling is associated with poorer outcomes and increased reoperation rates.
Keywords: Tibial plateau fracture; Open reduction and internal fixation; Hydroxyapatite; Iliac crest bone graft; Bone graft substitute; Rasmussen functional score; Metaphyseal defect; Radiological outcome.
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Introduction
Tibial plateau fractures are complex intra-articular injuries that account for approximately 1% of all fractures and nearly 8% of fractures occurring in the elderly population. These injuries involve the proximal tibia and frequently result from high-energy trauma such as road traffic accidents in younger individuals or low-energy osteoporotic falls in older adults. Because the tibial plateau forms the weight-bearing articular surface of the knee joint, restoration of joint congruity, mechanical alignment, and stable fixation is essential to preserve knee function and prevent long-term complications such as post-traumatic osteoarthritis, stiffness, malunion, and instability (1, 2).
The management of tibial plateau fractures has evolved considerably over the past few decades with advances in imaging, implant design, minimally invasive surgical techniques, and bone graft substitutes. The primary goals of treatment include anatomical reduction of the articular

surface, restoration of limb alignment, stable fixation to permit early mobilization, and maintenance of reduction until fracture union (3). Open reduction and internal fixation (ORIF) remains the gold standard treatment for displaced tibial plateau fractures, particularly Schatzker type II to VI fractures, where elevation of depressed articular fragments frequently creates a metaphyseal bone void that requires structural support (4).

Following elevation of the depressed articular surface, the residual metaphyseal defect may compromise mechanical stability and predispose to secondary collapse if left unsupported. Traditionally, autologous iliac crest cancellous bone graft has been considered the gold standard for filling these defects because of its unique osteogenic, osteoinductive, and osteoconductive properties (5). Autogenous bone graft contains viable osteoblasts, mesenchymal stem cells, and numerous growth factors that facilitate rapid incorporation and fracture healing. Furthermore, it provides immediate structural support and integrates biologically with the host bone (6).

Despite these advantages, harvesting autologous iliac crest bone graft is associated with several disadvantages. Donor-site complications such as postoperative pain, hematoma, infection, nerve injury, cosmetic deformity, prolonged operative time, increased blood loss, and limited graft availability have prompted surgeons to explore alternative bone graft substitutes (7, 8). Persistent donor-site pain has been reported in up to 30% of patients, significantly affecting postoperative recovery and patient satisfaction (9).

The limitations associated with autogenous bone graft have stimulated the development of synthetic bone graft substitutes that can provide structural support without donor-site morbidity. Among these materials, hydroxyapatite (HA) has gained widespread acceptance in orthopedic trauma surgery. Hydroxyapatite is a calcium phosphate ceramic with chemical composition closely resembling the mineral phase of human bone. It exhibits excellent biocompatibility, osteoconductivity, compressive strength, and long-term biological stability (10, 11). Porous hydroxyapatite allows vascular and cellular ingrowth, facilitating gradual incorporation into host bone while maintaining mechanical integrity during fracture healing (12).

Several clinical studies have demonstrated satisfactory outcomes using hydroxyapatite in metaphyseal defects following tibial plateau fracture fixation. The material provides immediate subchondral support, reduces the risk of articular collapse, and eliminates complications associated with autologous bone harvesting (13). Furthermore, advances in biomaterial engineering have resulted in highly porous hydroxyapatite scaffolds with interconnected pore architecture that promotes osteointegration and remodeling. Nevertheless, hydroxyapatite is primarily osteoconductive and lacks intrinsic osteogenic or osteoinductive potential, resulting in slower biological incorporation compared with autologous bone graft (14).

An alternative approach involves leaving the metaphyseal defect unfilled after stable internal fixation, particularly when locking plate technology provides sufficient mechanical stability. Modern locking compression plates function as fixed-angle constructs capable of maintaining reduction even in osteoporotic bone. Some authors have suggested that small metaphyseal voids may heal spontaneously through natural bone regeneration without requiring graft augmentation (15). Avoiding graft or substitute implantation reduces operative time, eliminates graft-related costs, and prevents complications associated with foreign materials or donor-site morbidity. However, concerns remain regarding secondary articular collapse, delayed union, loss of reduction, and inferior functional outcomes when metaphyseal defects are left unsupported, especially in larger depression fractures (16).

The optimal management of metaphyseal bone defects following ORIF of tibial plateau fractures therefore remains controversial. While iliac crest bone graft provides superior biological healing potential, it carries significant donor-site morbidity. Hydroxyapatite offers a readily available synthetic alternative with excellent structural characteristics but slower remodeling. Conversely, no void filler simplifies the procedure but may compromise maintenance of reduction in selected fracture patterns. Existing literature has reported varying outcomes with each strategy, and there is no universal consensus regarding the ideal method of defect management (17).

Clinical outcome following tibial plateau fracture fixation is influenced by multiple factors including fracture pattern, quality of reduction, implant stability, bone quality, rehabilitation, and choice of void filler. Functional assessment is commonly performed using validated scoring systems such as the Rasmussen Functional Score, Knee Society Score, Lysholm Knee Score, and range of motion measurements. Radiological assessment includes evaluation of fracture union, maintenance of reduction, articular depression, condylar widening, alignment, and evidence of secondary collapse using serial radiographs and computed tomography where indicated (18,19).

Comparative studies evaluating hydroxyapatite bone substitute, autologous iliac crest bone graft, and no void filler remain limited, particularly in prospective clinical settings. Most available studies compare only two treatment modalities or include heterogeneous fracture patterns, making interpretation difficult. Direct comparison of these three approaches may provide valuable evidence regarding fracture healing, maintenance of reduction, functional recovery, complication rates, and donor-site morbidity. Such evidence can assist orthopaedic surgeons in selecting the most appropriate strategy for managing metaphyseal defects during ORIF of tibial plateau fractures.

The present study aims to compare the clinical and radiological outcomes of hydroxyapatite bone substitute, autologous iliac crest bone graft, and no void filler in patients with tibial plateau fractures treated by open reduction and internal fixation. By evaluating fracture union, maintenance of articular reduction, functional outcomes, complications, and overall patient recovery, this study seeks to determine whether hydroxyapatite can provide outcomes comparable to iliac crest bone graft while avoiding donor-site morbidity, and whether omission of void filling is an acceptable alternative in selected patients. The findings may contribute to optimizing treatment protocols and improving patient outcomes in the surgical management of tibial plateau fractures.

Objectives:

To evaluate fracture union, maintenance of articular reduction, and functional outcomes among the three treatment groups using clinical and radiological assessment.

To compare complication rates, including secondary collapse, infection, donor-site morbidity, and need for reoperation, in order to determine the most effective method of managing metaphyseal bone defects following ORIF of tibial plateau fractures.

Materials and Methods

Study Design

This study is a prospective comparative observational study conducted to evaluate the clinical and radiological outcomes of hydroxyapatite bone substitute, autologous iliac crest bone graft, and no void filler in tibial plateau fractures treated with open reduction and internal fixation (ORIF).

Study Setting

The study was conducted in the Department of Orthopedics, Saveetha Institute of Medical Sciences and Hospital, Chennai, Tamil Nadu, India.

Study Duration

The study was carried out over a period of 12 months - Consecutive patients with tibial plateau fractures presenting to our institution were screened for eligibility.

Study Population

Patients presenting with tibial plateau fractures requiring surgical management by open reduction and internal fixation were screened for eligibility and enrolled after obtaining informed written consent.

Sample Size

A total of 48 patients meeting the eligibility criteria during the study period were included as a convenience sample and divided into three equal groups based on the treating surgeon's preference and implant availability at the time of surgery; no a priori power calculation was performed.

Group A (n = 16): Hydroxyapatite bone substitute
Group B (n = 16): Autologous iliac crest bone graft
Group C (n = 16): No void filler

Age Group

Patients aged 18–56 years were included in the study.

Inclusion Criteria

- Patients aged 18–56 years.
- Closed tibial plateau fractures requiring ORIF.
- Schatzker type II–VI tibial plateau fractures.
- Patients willing to provide informed written consent and comply with follow-up.

Exclusion Criteria

- Open tibial plateau fractures.
- Pathological fractures.
- Polytrauma patients with life-threatening injuries.
- Previous surgery involving the affected proximal tibia.
- Active local or systemic infection.
- Patients with severe neurovascular injury requiring vascular reconstruction.
- Patients unwilling or unable to complete follow-up.

Methodology

Following admission, all eligible patients underwent detailed clinical examination and radiological evaluation with plain radiographs, and computed tomography (CT) scan whenever indicated for fracture classification and surgical planning. Routine preoperative investigations and anaesthetic assessment were performed.

All patients underwent open reduction and internal fixation performed by experienced trauma surgeons using anatomically contoured locking compression plates through an approach appropriate to the fracture configuration (anterolateral, posteromedial, or dual-incision where indicated). Articular reduction was achieved under direct visualization and fluoroscopic guidance using reduction clamps and temporary K-wire fixation where necessary. Depressed articular fragments were elevated through a cortical window, and the residual metaphyseal defect was assessed. The decision to use a bone graft, bone substitute, or no void filler was based on a combination of preoperative and intraoperative assessment. Definitive fixation was performed using anatomically contoured proximal tibial locking compression plates with subchondral rafting screws as required. Reduction, implant position, and restoration of alignment were confirmed fluoroscopically before wound closure in layers.

Preoperative considerations included the Schatzker fracture type, degree of articular depression, extent of metaphyseal comminution, estimated metaphyseal bone loss, bone quality, patient age, and CT scan findings.

Intraoperatively, the final decision was guided by the size of the residual metaphyseal void after elevation of the depressed articular surface, adequacy of subchondral support, cortical integrity, stability of fracture reduction and fixation, and the anticipated risk of secondary articular collapse. Bone grafting was performed when additional structural support was considered necessary to maintain reduction and facilitate healing. Following reduction, patients in Group A received hydroxyapatite bone substitute, those in Group B received autologous cancellous iliac crest bone graft harvested during the same procedure, and those in Group C underwent fixation without the use of a void filler.

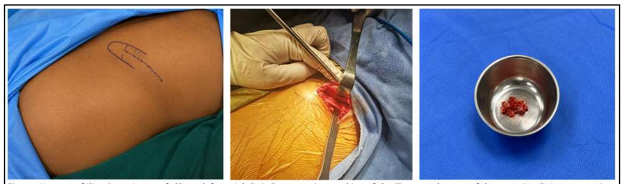


Figure. Harvest of Iliac Crest Autograft (From left to right): A. Preoperative marking of the iliac crest bone graft harvest site, B. Intraoperative harvesting of the iliac crest autograft, C. Harvested cancellous iliac crest bone graft collected in a sterile surgical bowl

A standardized postoperative rehabilitation protocol including early knee range-of-motion exercises, progressive weight-bearing based on fracture healing, and regular clinical follow-up was followed for all patients.

Outcome Measures

Primary Outcome

- Clinical outcome assessed using the Rasmussen Functional Knee Score.
- Radiological outcome assessed using the Rasmussen Radiological Score.

Clinical outcomes were assessed by an independent Orthopaedic surgeon who was not involved in the index procedure and was blinded to the type of void filler used. Radiological outcomes were assessed by the same independent surgeon; complete blinding could not be guaranteed for radiological assessment, as the radiographic appearance of hydroxyapatite and the presence or absence of bone graft were often discernible on plain films.

Secondary Outcomes

- Time to radiological union.
- Maintenance of articular reduction.
- Secondary articular collapse.
- Knee range of motion.
- Postoperative complications (infection, implant failure, donor-site morbidity, loss of reduction, delayed union, non-union, and need for reoperation).

Follow-up: Patients were evaluated clinically and radiologically at 6 weeks, 3 months, 6 months, and 12 months following surgery.

Statistical Analysis

The collected data was entered into Microsoft Excel and analyzed using SPSS software (Version 26.0 or later). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Comparison among the three groups was performed using one-way ANOVA for continuous variables and Chi-square test or Fisher's exact test for categorical variables. A p-value < 0.05 was considered statistically significant.

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of Saveetha Institute of Medical Sciences and Hospital. Written informed consent was obtained from all participants prior to enrolment, and confidentiality of patient information was maintained throughout the study.

Results

A total of 48 patients with tibial plateau fractures treated by ORIF were included in the study. Patients were equally distributed into three groups: Hydroxyapatite bone substitute (n=16), Autologous Iliac Crest Bone Graft (n=16), and No Void Filler (n=16). The mean follow-up period was 12 months.

Table 1. Age Distribution

Age Group (years)	Hydroxyapatite (n=16)	Autograft (n=16)	No Void Filler (n=16)	Total
18–30	5	4	5	14
31–40	6	7	5	18
41–50	3	3	4	10
51–56	2	2	2	6
Total	16	16	16	48

Most patients (37.5%) were between 31 and 40 years of age, indicating that tibial plateau fractures predominantly affected young and middle-aged adults.

Table 2. Gender Distribution

Gender	Hydroxyapatite	Autograft	No Void Filler	Total (%)
Male	12	13	12	37 (77.1)
Female	4	3	4	11 (22.9)

Males constituted the majority (77.1%) of the study population, reflecting the higher incidence of high-energy trauma among males.

Table 3. Side of Injury

Side	Hydroxyapatite	Autograft	No Void Filler	Total
Right	10	9	11	30
Left	6	7	5	18

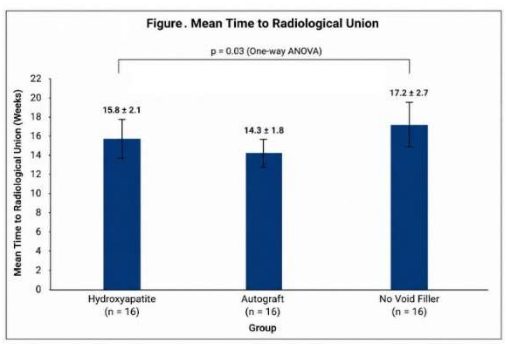
Right-sided tibial plateau fractures were more common (62.5%) than left-sided injuries.

Table 4. Schatzker Fracture Type Distribution

Schatzker Type	Hydroxyapatite (n=16)	Autograft (n=16)	No Void Filler (n=16)	Total
II	5	4	6	15
III	2	3	2	7
IV	2	1	2	5
V	4	5	3	12
VI	3	3	3	9
Total	16	16	16	48

Fracture severity, as assessed by Schatzker classification, comparable across the three groups (p = 0.99), suggesting that the non-randomized treatment allocation based on intraoperative and clinical judgment did not introduce a significant imbalance in baseline fracture complexity.

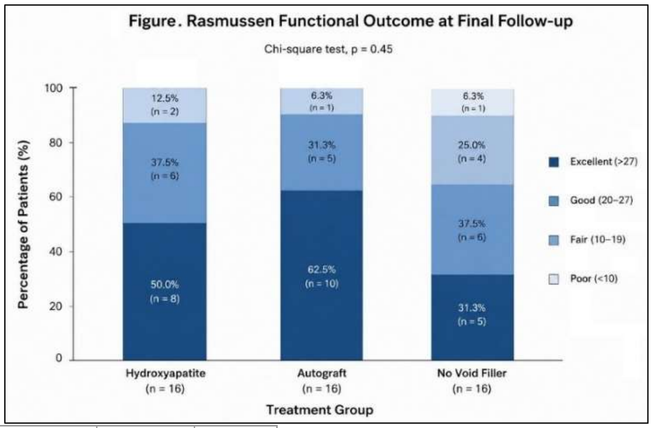
Table 5. Mean Time to Radiological Union



Group	Mean ± SD (Weeks)
Hydroxyapatite	15.8 ± 2.1
Autograft	14.3 ± 1.8
No Void Filler	17.2 ± 2.7
p-value	0.03

The autograft group demonstrated the earliest radiological union, whereas the no void filler group had the longest time to union. The overall difference among the three groups was statistically significant (one-way ANOVA, p = 0.03).

Table 6. Rasmussen Functional Score at Final Follow-up



Outcome	Hydroxyapatite (n)	Autograft (n)	No Void Filler (n)
Excellent	8	10	5
Good	6	5	6
Fair	2	1	4
Poor	0	0	1
p-value (chi-square)	0.45		

Functional outcomes showed a numerical trend favoring the autograft group, followed by the hydroxyapatite group, while the no void filler group had a higher proportion of fair and poor outcomes. However, the difference among the three groups was not statistically significant (chi-square test, p = 0.45).

Table 7. Rasmussen Radiological Score

Outcome	Hydroxyapatite	Autograft	No Void Filler
Excellent	9	11	5
Good	5	4	7
Fair	2	1	3
Poor	0	0	1
p-value (chi-square)	0.41		

Radiological outcomes demonstrated a numerical trend favoring the autograft group, with comparable results in the hydroxyapatite group and relatively poorer outcomes in the no void filler group. However, this difference was not statistically significant (chi-square test, p = 0.41).

Table 8. Complications

Complication	Hydroxyapatite	Autograft	No Void Filler
Superficial infection	1	1	2
Secondary collapse	1	0	3
Delayed union	2	1	3
Donor-site pain	0	3	0

Donor-site pain was observed only in the autograft group, whereas secondary articular collapse and delayed union occurred more frequently in the no void filler group. Owing to the low frequency of complications, statistical comparison between the groups was not performed.

Table 9. Reoperations

Group	Reoperations	Percentage
Hydroxyapatite	2	12.5%
Autograft	0	0%
No Void Filler	4	25.0%
Total	6	12.5%
p-value (chi-square)	0.10	—

Reoperation was required in two patients (12.5%) in the hydroxyapatite group and four patients (25.0%) in the no void filler group, whereas no patient in the autograft group underwent reoperation. This difference was not statistically significant (chi-square test, p = 0.10).

Discussion

The present study compared the clinical and radiological outcomes of hydroxyapatite bone substitute, autologous iliac crest bone graft, and no void filler in patients with tibial plateau fractures treated with open reduction and internal fixation (ORIF). Restoration of the articular surface and adequate metaphyseal support are fundamental to achieving stable fixation and satisfactory functional recovery following tibial plateau fractures. Bone defects created after elevation of depressed articular fragments have traditionally been managed with autologous iliac crest bone graft; however, synthetic bone substitutes such as hydroxyapatite have gained increasing acceptance because they eliminate donor-site morbidity while providing structural support.(5-7) The findings of the present study suggest that all three treatment strategies resulted in fracture union. Autologous iliac crest bone graft was associated with the earliest radiological union and demonstrated a trend toward superior clinical and radiological outcomes, followed closely by hydroxyapatite, whereas the no void filler group showed comparatively less favourable results.

The study population consisted predominantly of males (77.1%), with most patients belonging to the third and fourth decades of life. This demographic distribution is consistent with the epidemiology of tibial plateau fractures reported by Court-Brown and Caesar, who observed that these injuries predominantly affect economically active males because of high-energy mechanisms such as road traffic accidents (1). Similar observations have also been reported in several clinical studies where young males constituted the majority of surgically treated tibial plateau fractures (3, 17). The predominance of right-sided injuries in the present study is also comparable with previous reports, although laterality has not been consistently associated with clinical outcome.

The mean follow-up duration in the present study was 12 months, which was sufficient to evaluate fracture union, maintenance of reduction, functional recovery, and early postoperative complications. Among the three groups, patients treated with autologous iliac crest bone graft achieved the shortest mean time to radiological union. This finding may be attributed to the presence of viable osteogenic cells, osteoinductive growth factors, and an osteoconductive scaffold within cancellous autograft, all of which facilitate bone regeneration and incorporation. Younger and Chapman described autologous iliac crest bone graft as the gold standard for the management of bone defects because of its unique combination of osteogenic, osteoinductive, and osteoconductive properties, which remain unmatched by currently available synthetic bone substitutes (5).

Hydroxyapatite bone substitute also demonstrated satisfactory radiological union and functional recovery. Although the mean time to union was slightly longer than that observed with autologous bone graft, maintenance of articular reduction was satisfactory throughout follow-up. Hydroxyapatite provides excellent compressive strength and serves as an osteoconductive scaffold, facilitating gradual vascular invasion and bone remodeling while providing structural support to metaphyseal defects (10–12). These findings are consistent with those of Bucholz et al., who reported that hydroxyapatite effectively maintains metaphyseal reduction until fracture healing is achieved (13). Likewise, Fillingham and Jacobs concluded that calcium phosphate-based bone substitutes provide reliable structural support and represent effective alternatives when autologous bone graft harvest is contraindicated or undesirable (14).

Figure. Hydroxyapatite bone substitute in sterile surgical bowl used as bone graft in Open reduction internal fixation with plate osteosynthesis in Proximal tibia fractures

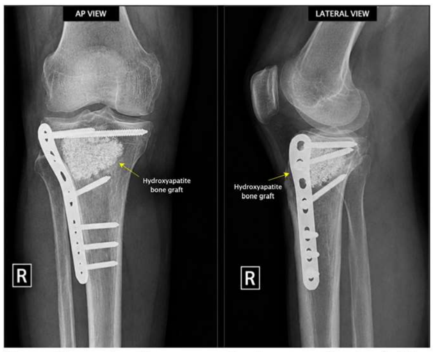


Figure. 12 months old postoperative X-ray post Proximal Tibia ORIF + PO with Hydroxyapatite bone graft

Although autologous iliac crest bone graft demonstrated numerically better functional and radiological outcomes than hydroxyapatite, these differences were not statistically significant. The trend toward earlier healing with autologous bone graft is biologically plausible because hydroxyapatite lacks viable osteogenic cells and osteoinductive proteins, relying primarily on host bone for incorporation (10, 14). Previous studies have similarly reported that hydroxyapatite provides excellent mechanical support but undergoes slower biological remodeling than autologous cancellous bone (11, 12). Nevertheless, the overall clinical and radiological outcomes of the two groups were comparable, suggesting that hydroxyapatite represents a reasonable alternative for metaphyseal defect augmentation, particularly when avoidance of donor-site morbidity is desirable.

Figure: (A) Right closed Tibial plateau fracture; (B) Immediate postoperative radiograph following ORIF with plate osteosynthesis with autologous iliac crest bone graft; (C) Three-month postoperative radiograph; (D) Twelve-month postoperative radiograph showing fracture union *(Left to right, top to bottom)*

Patients managed without metaphyseal void filling demonstrated less favourable radiological and functional outcomes than those treated with autologous bone graft or hydroxyapatite. Although fracture union was achieved in all patients, the no void filler group exhibited the longest mean time to radiological union, along with a higher frequency of secondary articular collapse. These findings suggest that augmentation of metaphyseal defects following elevation of depressed articular fragments may help provide structural support and maintain reduction during fracture healing (4, 15). Higgins et al. demonstrated biomechanically that metaphyseal defect augmentation improves construct stability and reduces the risk of articular subsidence, particularly in osteoporotic bone (15). Similarly, Yu et al. reported better maintenance of reduction in patients receiving graft augmentation compared with fixation alone (16).

Figure: (A) Left closed Schatzker type V tibial plateau fracture; (B) Immediate postoperative radiograph following ORIF with bicondylar plating without bone void filler; (C) Six-month postoperative radiograph showing fracture union *(Left to right, top to bottom)*

An important observation in the present study was the difference in reoperation rates among the three treatment groups. No patient in the autologous iliac crest bone graft group required reoperation, compared with two patients in the hydroxyapatite group and four patients in the no void filler group. Although this difference did not reach statistical significance, the findings suggest a trend toward fewer revision procedures with autologous bone graft. The higher reoperation rates observed in the hydroxyapatite and no void filler groups may be related to differences in structural support and biological incorporation, although the relatively small number of events precludes definitive conclusions. Nevertheless, the greater frequency of reoperations in the no void filler group reinforces the potential importance of adequate metaphyseal defect augmentation during ORIF of tibial plateau fractures.

Donor-site morbidity remains the principal limitation of autologous iliac crest bone graft. Although no patient in the autograft group required reoperation, postoperative donor-site discomfort was observed following iliac crest harvest. Previous studies by Arrington et al. and Banwart et al. have reported donor-site complications including pain, hematoma, infection, sensory disturbances, and cosmetic concerns after iliac crest bone graft harvesting (7,8). Persistent donor-site pain has been reported in up to 30% of patients, making synthetic bone substitutes increasingly attractive despite their comparatively slower biological incorporation (9). As expected, no donor-site complications were observed in the hydroxyapatite group, highlighting an important clinical advantage of this treatment option.

Overall, functional outcomes were favorable across all three treatment groups, with most patients achieving excellent or good Rasmussen functional scores. Although numerical differences were observed between the groups, these did not reach statistical significance, suggesting that successful functional recovery depends not only on graft selection but also on accurate fracture reduction, stable fixation, and structured postoperative rehabilitation. Rasmussen emphasized that restoration of joint congruity and early mobilization are critical determinants of long-term knee function following tibial plateau fractures (18). Advances in locking plate fixation have further improved the ability to maintain reduction, even in complex fracture patterns and osteoporotic bone (3, 15). Therefore, bone grafts and bone substitutes should be considered adjuncts that complement meticulous surgical technique rather than the primary determinants of clinical outcome.

Radiological outcomes were satisfactory across all three treatment groups, with the autologous bone graft and hydroxyapatite groups demonstrating numerically better maintenance of reduction than the no void filler group. Although these differences did not reach statistical significance, the findings are consistent with previous studies suggesting that adequate metaphyseal support helps maintain articular reduction and minimizes postoperative collapse (13, 16). Preservation of joint congruity is particularly important, as residual articular incongruity has been identified as a major risk factor for the development of post-traumatic osteoarthritis and poorer long-term functional outcomes (2, 18).

The present study has several strengths. Inclusion of three comparable treatment groups enabled direct evaluation of hydroxyapatite bone substitute, autologous iliac crest bone graft, and no void filler under similar surgical conditions. Furthermore, clinical and radiological outcomes were assessed prospectively using standardized evaluation methods, thereby improving the consistency and reliability of outcome assessment. Nevertheless, several limitations should be acknowledged. The relatively small sample size may have limited the ability to detect significant differences in infrequent outcomes such as complications and reoperations, and no post-hoc pairwise comparisons or power calculations were performed for the statistically significant difference in time to union; the non-significant findings for functional score, radiological score, and reoperation rate should therefore be interpreted with caution given the risk of type II error, and Fisher's exact test rather than chi-square may have been more appropriate for outcome categories with small expected cell counts (Tables 6 and 7). Treatment allocation was based on preoperative and intraoperative clinical assessment rather than randomization, introducing the possibility of selection bias; in particular, intraoperative metaphyseal defect size, a key determinant of graft selection, was not systematically compared between groups despite comparable Schatzker classification distributions. In addition, the follow-up period of 12 months was insufficient to evaluate long-term outcomes, including post-traumatic osteoarthritis, and the single-center design may limit the generalizability of the findings. Larger multicenter randomized controlled trials with longer follow-up are warranted to further evaluate the comparative effectiveness and long-term outcomes of these treatment strategies.

Overall, the findings of the present study suggest that autologous iliac crest bone graft remains an effective option for the management of metaphyseal defects in tibial plateau fractures, demonstrating the earliest radiological union and favorable clinical and radiological outcomes. Hydroxyapatite bone substitute produced comparable short-term functional and radiological results while eliminating donor-site morbidity, making it a practical alternative when autologous bone graft harvesting is contraindicated or undesirable. In contrast, patients managed without metaphyseal void filling demonstrated a longer time to radiological union, a greater frequency of secondary articular collapse, and higher reoperation rates. These findings highlight the importance of appropriate metaphyseal defect augmentation during ORIF of tibial plateau fractures (4, 15, 16), while suggesting that hydroxyapatite provides a reasonable balance between structural support and reduced surgical morbidity (10–14).

Conclusion

Autologous iliac crest bone graft was associated with the earliest radiological union and demonstrated favorable clinical and radiological outcomes, although donor-site morbidity remained an important limitation.

Hydroxyapatite bone substitute produced comparable short-term functional and radiological outcomes while eliminating donor-site complications, making it a practical alternative for metaphyseal defect management. In contrast, the no void filler group demonstrated a longer time to radiological union, a greater frequency of secondary articular collapse, and higher reoperation rates. These findings suggest that appropriate metaphyseal defect augmentation is an important component of successful ORIF for tibial plateau fractures, with hydroxyapatite representing a reasonable alternative when autologous bone graft harvesting is contraindicated or undesirable.

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