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The use of a new grafting material (b.Bone™) for the management of severely depressed tibial plateau fractures: Preliminary report of three cases.

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ABSTRACT

Tibial plateau fractures are often complex injuries that result from high-energy trauma affecting the articular congruity of the knee. Managing tibial plateau fractures can be challenging because of severe depression of the subchondral cancellous bone and concomitant cartilage injury. Bone substitutes are commonly used to fill such defects as part of the surgical treatment of tibial plateau fractures. We describe three cases of tibial plateau fractures managed with a synthetic bone substitute (b.Bone™, GreenBone ORTHO S.p.A Faenza, Italy) with a highly interconnected and porous 3D structure to mimic the hierarchical architecture and morphology of natural human bone.

Introduction

Fractures of the tibial plateau usually involve articular and meta-epiphyseal segments of the proximal tibia [1]. These complex injuries can result from both high-or low-energy trauma, affecting either young adults or the "third-age" population [3]. They occur due to medial, lateral, or axial compression and pose significant morbidity to patients when the articular congruity of the knee is compromised [2]. Tibial plateau fractures are usually associated with soft tissue injuries and might require a staged treatment approach [3].

The main treatment goals are limb alignment and articular surface restoration to allow early knee motion and avoid long-term degenerative changes [3]. ORIF (open reduction and internal fixation) is the gold standard for treating these fractures [3]. Frequently, the depressed articular fragments have to be elevated back toward the knee, followed by fixation with a plate and screws, and sometimes supplemented with a bone graft to fill any cancellous bone voids left beneath the joint surface after fracture reduction [2]. Bone substitutes of calcium phosphate (CaPs) are commonly used to fill such defects resulting from compacted cancellous bone as part of the surgical treatment of tibial plateau fractures [1]. Tibial plateau fractures have a high incidence of reduction loss when fixed without bone graft support [2]. A loss of reduction of more than 2 mm is considered clinically relevant and plays an essential role in the development of osteoarthritis [1]. In addition, good clinical outcomes are directly related to the degree of anatomic reduction of tibial plateau fractures [2]. In contrast to autografts, synthetic bone substitutes avoid the risk of significant comorbidities such as donor site complications [4]. b.Bone is a ceramic resorbable scaffold composed of hydroxyapatite and beta-tricalcium phosphate in a unique, highly interconnected, and porous 3D structure to reproduce the hierarchical architecture and morphology of natural human bone.

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The authors present the successful management of three cases of traumatic tibial plateau fractures where b.Bone was used to addressing bone defects and restore the articular congruity.

Case report 1

The first patient was an 18-year-old woman who slipped and fell while skiing. She could not walk, and a tibial plateau fracture was diagnosed in a local hospital. After transfer to a hospital close to her home, there was sustained knee joint swelling, suggesting severe hematoma formation. Radiographs and CT scans confirmed a severely impressed Schatzker III fracture, suggesting the need for bone grafting (Fig. 1). No associated injuries to the periarticular region were observed.

An anterolateral hockey stick approach was made to approach the fracture. The underlying soft tissues and muscular compartments were gently dissected. The knee joint was opened underneath the meniscus and approximately 500 mL of hematoma were evacuated. Inspection of the joint line confirmed a sustained impression of a single block, as seen in the preoperative CT scan. The anterolateral osseous border was gently elevated to visualize the depth of the impression. The block was then mobilized and elevated as a single fragment. The correct reduction was assessed by direct visualization and fluoroscopic control. This maneuver left a significant bone defect of about 2×2 cm, which was then filled by b.Bone, a synthetic bone substitute. A block configuration was cut and shaped to fit the gap. Thus, b.Bone created the required support to adequately maintain fracture reduction (Fig. 2).

A 4.5 mm lateral angular stable plate was then applied to stabilize the bone (Fig. 3). The soft tissues and the skin were closed without tension. The patient was mobilized with partial weight bearing at the first postoperative day.

Follow-up after 2 weeks showed uneventful wound healing. The first X-ray control after 3 weeks demonstrated adequate positioning of the plate and the synthetic bone substitute. The patient was able to start full weight bearing when the X-ray control after 8 weeks confirmed progressive bone union without fracture displacement.

During the 6-month follow-up (Fig. 4), all implant and osseous structures were in normal position, and the bone appeared completely healed. The X-ray demonstrated a healed fracture, no radiolucency in the area of the plate, and an unchanged bone replacement. The patient felt well and requested to go back to sports activities. Her gait was normal by then and showed no signs of lateralization despite a minimal difference in the circumference in the quadriceps muscle area.

Case report 2

The second case report describes the treatment of a 23-year-old polytrauma patient who sustained a Schatzker II fracture (AO/OTA 41B3) of the right tibia. The patient also suffered an ipsilateral fracture of the femoral neck and bilateral fractures of the tibial pilon. Preoperative CT images show the severely depressed joint line with a substantial bone defect with dimensions of 2.7 cm from medial to lateral, 2.5 cm from anterior to posterior and 2 cm from superior to posterior (Fig. 5).

In this case, the block configuration of b.Bone was used to fill the defect. The block was trimmed in smaller pieces to snuggly fit the subchondral defect. The block was soaked into blood before insertion and then impacted to restore the impressed joint line. A 4.5 LCP Proximal Lateral Tibial Plate (DePuy Synthes) was used for the osteosynthesis of the fracture. Two 2.7 mm rafting screws were inserted in addition to the plate to support the subchondral bone. The reduction and the fixation were confirmed with intraoperative fluoroscopic images. The immediate postoperative images showed restoration of the joint line and acceptable containment and alignment of the tibial plateau (Fig. 6).

Postoperatively, the patient was placed in a back slab for 7 days. Thereafter, controlled active assisted and passive range of motion was instructed. Non weight bearing was exercised for 8 weeks and the patient achieved full weight bearing at 10 weeks after the surgery. At the 6 month follow-up the patient was fully weight bearing without pain. The radiological images showed full bone consolidation, whereas the synthetic bone substitute was not yet completely resorbed (Fig. 7).

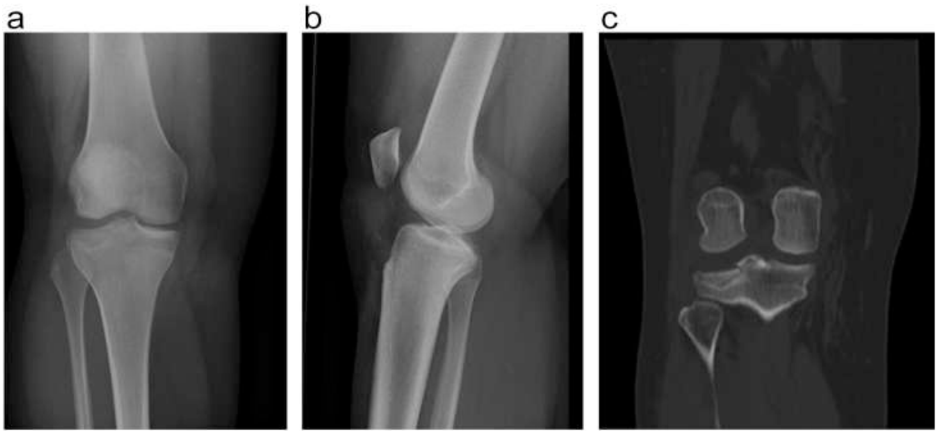

Fig. 1. Preoperative AP (A) and lateral (B) radiological images and AP CT scan (C) of a Schatzker III fracture.

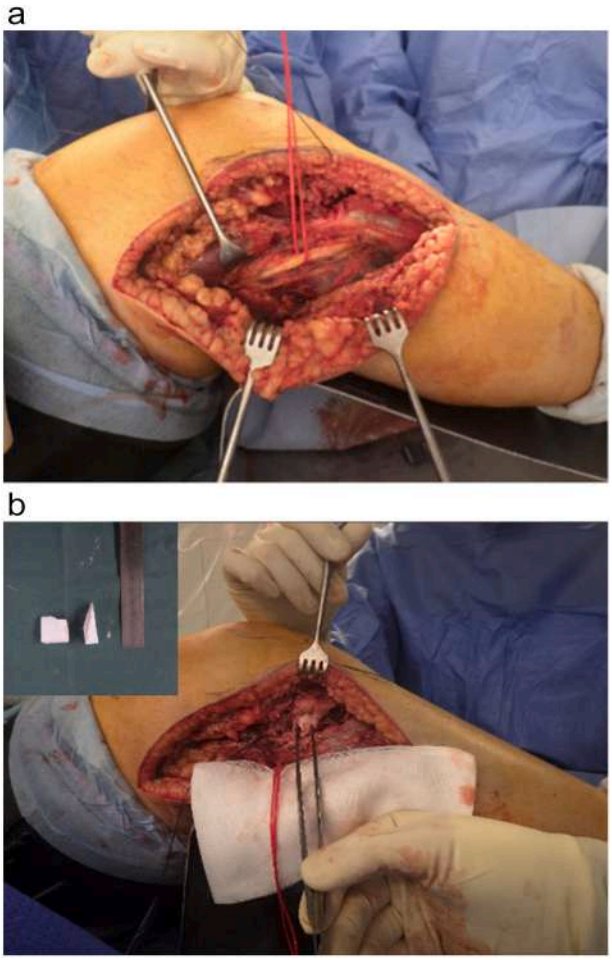

Fig. 2. Intraoperative images. Access to the fracture via an anterolateral hockey stick approach and preservation of the common peroneal nerve (A). The block configuration of b.Bone was cut and shaped to the appropriate size and inserted to fill the bone gap and to support fracture reduction (B).

The first radiological signs of resorption of the synthetic bone substitute were observed after 12 months (Fig. 8). Meanwhile, the patient regained full range of motion, and did not observe any complications or adverse effects.

Case report 3

The third case details the management of a 75-year-old female patient who sustained a ground level fall with subsequent isolated Schatzker II fracture (AO/OTA 41B3) of the left tibial plateau. Preoperative radiographs and CT images demonstrated a severely depressed joint line with a substantial bone defect of 3 cm from medial to lateral, 2.5 cm from anterior to posterior and 1.5 cm from superior to posterior (Figs. 9 and 10).

The subchondral bone defect was filled with a b.Bone block that was trimmed to its edges. Adequate fracture reduction was observed intraoperatively with sufficient subchondral bone reduction and containment/alignment of the proximal tibia. The fracture was stabilized with the use of a 4.5 LCP Proximal Lateral Tibial Plate (DePuy Synthes) without the use of additional rafting screws. Immediate postoperative radiographs showed acceptable reduction (Fig. 11).

Postoperatively, a posterior knee back slab was applied for 7 days, controlled active and passive range of motion was started immediately thereafter and the patient was kept non weight bearing for 8 weeks. Full weight bearing was achieved at 10 weeks postoperatively. The patient had an uneventful recovery.

The patient had painless full range of motion of the knee and returned to her everyday activities without difficulties 3 months after surgery. The radiographs at that point in time showed no secondary subsidence of the articular surface. No resorption of the grafting material was apparent (Fig. 12).

At 6 month clinical and radiological follow-up, the patient reported no complaints, no complications and no adverse effects were observed, while full radiographic consolidation of the fracture was evident (Fig. 13). The b.Bone graft was not fully resorbed yet. Nevertheless, signs of ongoing resorption are evident.

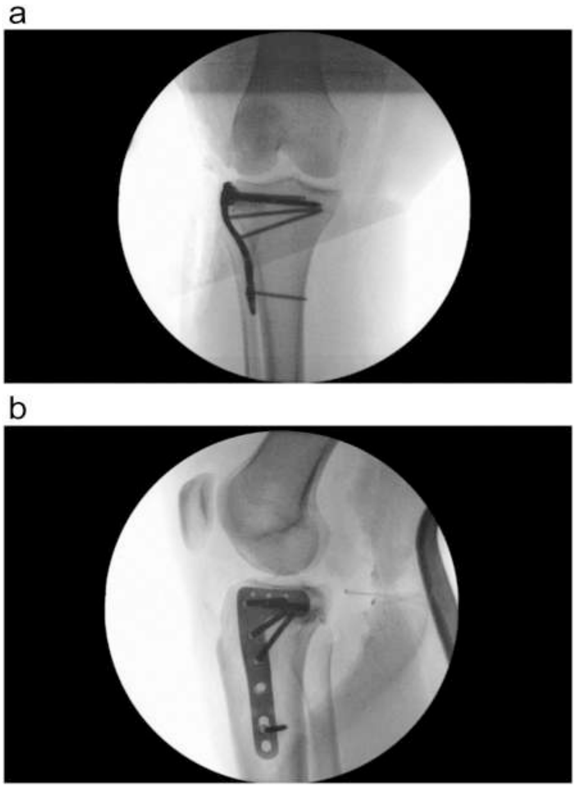

Fig. 3. Intraoperative AP (A) and lateral (B) radiological images after fracture reduction and insertion of a 4.5 mm angular stable plate.

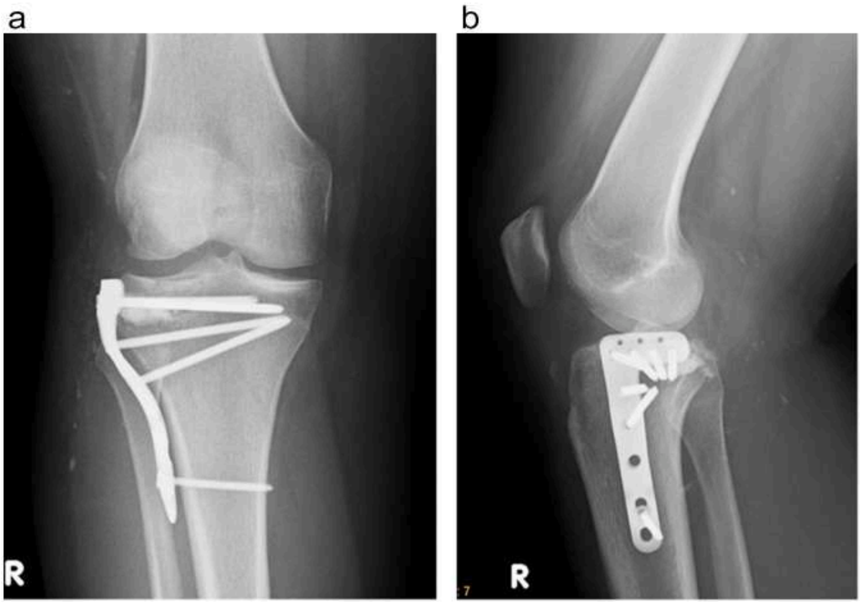

Fig. 4. AP (A) and lateral (B) radiological images 6 months after surgery confirm adequate fracture reduction and restoration of the joint line.

Discussion

Major considerations of bone defect management, in general, include: 1) the ability of the surrounding tissue to provide the biological background for healing; 2) the biomechanical stability to enable the biological reactions to promote ingrowth, and 3) the

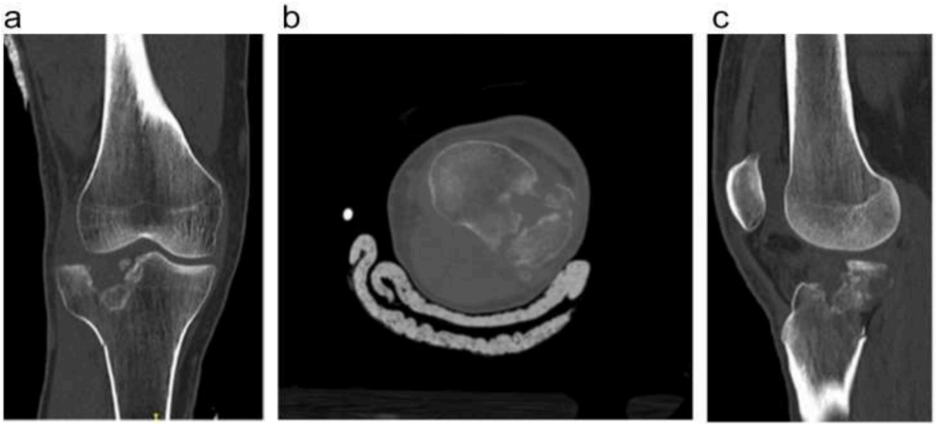

Fig. 5. Frontal (A), axial (B) and sagittal (C) preoperative CT scans of a Schatzker II fracture with a significant bone defect and a severely depressed joint line.

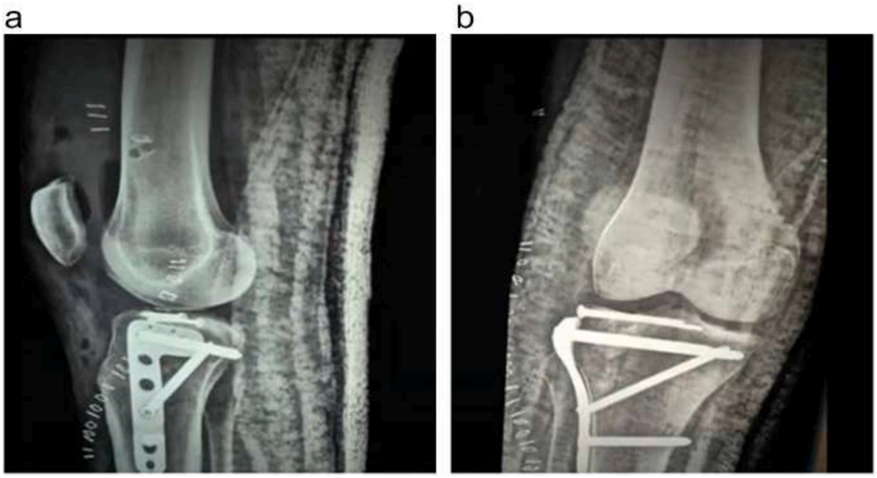

Fig. 6. Postoperative AP (A) and lateral (B) radiographs demonstrating adequate fracture reduction and alignment/containment of the tibial plateau with a lateral tibial plate, two rafting screws, and the b.Bone synthetic bone graft.

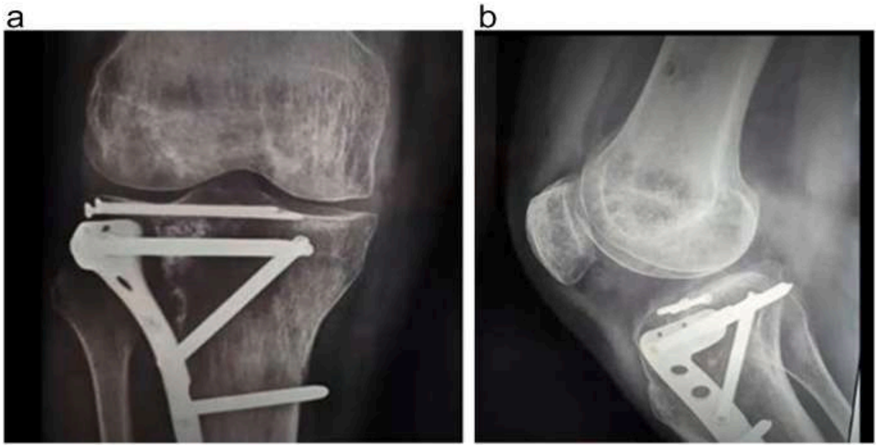

Fig. 7. Radiological follow-up after 6 months confirmed no signs of joint line depression and maintained fracture reduction. The synthetic bone substitute is not yet resorbed.

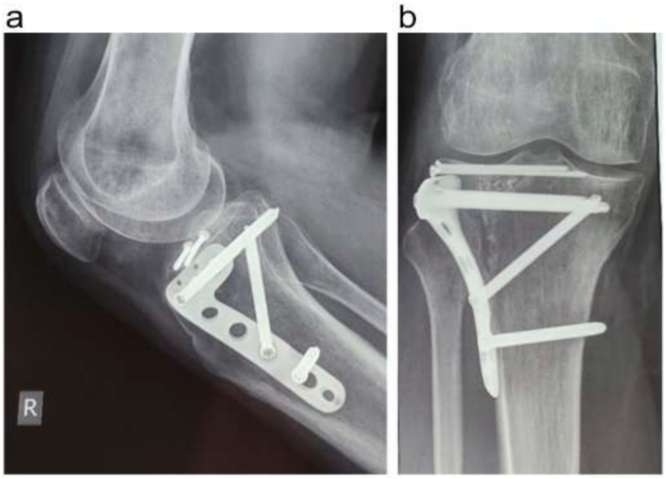

Fig. 8. AP (A) and lateral (B) radiographs at 12 months confirmed the first signs of resorption of the synthetic bone substitute.

Fig. 9. AP (A) and lateral (B) radiographs showing the Schatzker Type II fracture of the left tibial plateau.

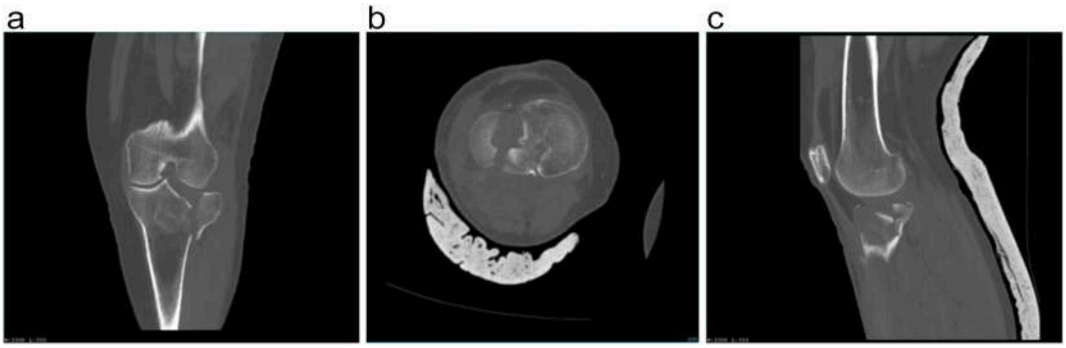

Fig. 10. Frontal (A), axial (B) and sagittal (C) CT scan images depicting the severely depressed tibial plateau fracture.

Fig. 11. Postoperative AP (A) and lateral (B) radiographs showing acceptable reduction and stabilization of the fracture.

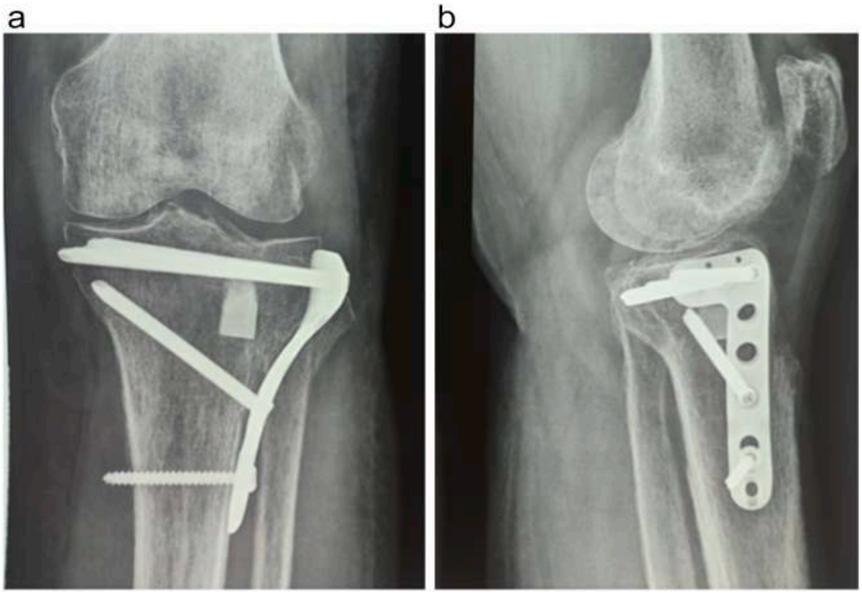

Fig. 12. Three-month radiographs showing the maintenance of the reduction. The grafting material shows no signs of resorption.

decision on whether a one- or two-stage approach should be performed when 1) and 2) are applicable.

In tibial plateau fractures with unilateral involvement alone, a lateral plate is usually sufficient for the ingrowth of synthetic bone substitutes. Nonunions and secondary bone defects after grafting procedures can be a major cause of reoperation due to disturbed bone healing [5]. These situations can also have a significant socioeconomic aspect, as they are associated with a prolonged total hospital stay and an increase in surgical procedures. Besides increasing direct and indirect costs, the outpatient treatment and rehabilitation period is prolonged, and thus a reduction in the quality of life might result. Several factors have been identified as unfavorable to the bone healing process, including the severity of trauma, patient-related factors, and in-hospital complications [6,7].

The three patients described herein represent the early experience of the implantation of the new scaffold b.Bone for the treatment of metaphyseal defects. These early results show that the patients did benefit from using a synthetic bone substitute to manage bone defects and restore joint line congruity. All patients were able to start full weight bearing quickly and regained their full range of motion. Postoperative radiographic controls confirmed complete bone healing, maintenance of fracture reduction, and first signs of resorption of b.Bone. Whereas tibial plateau fractures have a high incidence of reduction loss when fixed without bone graft support [2], bone defect management with b.Bone provided excellent outcomes for both the granules and block configuration in the

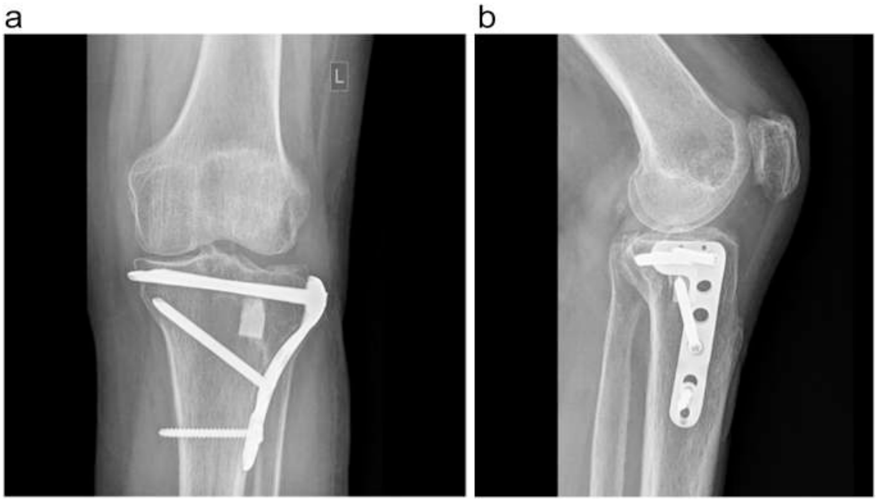

Fig. 13. AP (A) and lateral (B) radiographs at 6 months showing acceptable reduction. There is no secondary collapse of the articular surface. The block of graft shows evidence of ongoing resorption.

management of tibial plateau fractures with depressed joint lines.

Synthetic bone substitutes have also been developed to overcome the drawbacks of autologous bone grafts [1,8,9]. CaP-based materials, including hydroxyapatite and beta-tricalcium phosphate, are the most common synthetic bone grafts due to their osteoconductive properties and structural support [1,10–12]. Cortical bone has a compressive strength of 130–290 MPa and a tensile strength of 90–190 MPa [1]. In contrast, cancellous bone only has a compressive strength of 2–38 MPa, while CaPs bear compressive strengths in the range of 10–100 MPa, with low tensile strengths of 1–10 MPa [1]. This property makes CaP an ideal candidate for augmenting compacted cancellous bone in tibial plateau fractures with the potential of reducing the risk for loss of reduction compared to iliac crest grafts [1]. No significant joint line depression was reported in the three cases described here. Limitations of this study include the small number of cases reported and the short term follow up.

Overall, b.Bone provided a suitable option to restore bone defects in tibial plateau fractures, maintain the fracture reduction and restoration of the joint congruity, and thus contributed to good clinical and radiological outcomes.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Both authors are paid consultants for GreenBone ORTHO S.p.A Faenza, Italy.

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