

# Application of cortical bone plate allografts combined with LISS plates for fixation of comminuted distal femur fractures

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## Research article

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1       **Application of cortical bone plate allografts combined with LISS**  
2                   **plates for fixation of comminuted distal femur fractures**

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1 **Abstract**

2 *Background:* At present, the management of comminuted distal femur fractures  
3 remains challenging for orthopedic surgeons. The aim of this study is to report a  
4 surgical treatment for comminuted distal femur fractures using supplementary medial  
5 cortical bone plate allografts in conjunction with the lateral less invasive stabilization  
6 system (LISS) plates, and to discuss the therapeutic effects of this treatment after  
7 long-term follow-up with patients.

8 *Patients and methods:* From January 2009 to January 2014, the records of thirty-three  
9 patients who underwent supplementary medial cortical bone plate allografts combined  
10 with lateral LISS plate fixation were reviewed. Twenty-nine patients suffered from  
11 closed fractures and four had open fractures. Clinical and radiographic data were  
12 collected during regular post-operative follow-up visits. Functional outcomes were  
13 determined according to the special surgery knee rating scale (HSS) used at the  
14 hospital.

15 *Results:* Thirty patients were followed for 13 to 73 months after surgery, with an  
16 average follow-up time of 31.3 months. The mean time to bone union was 5.4 months  
17 (range of 3-12 months) and the mean range of knee flexion was 105.6° (range of  
18 80°-130°). Of the remaining patients, 10 had a score of “Excellent” while 10 had a  
19 score of “Good” (the proportion of “Excellent” and “Good” scores was 67.7%). Three  
20 patients had superficial or deep infections, one patient had nonunion that required  
21 bone grafting and one patient had post-traumatic knee arthritis. No loosening of  
22 fixation or refracture had occurred in any patient at the time of the last follow-up

1 appointment.

2 *Conclusions:* Based on these promising results, we propose that supplementary medial  
3 cortical bone plate allografts combined with lateral LISS plates fixation may be a  
4 good treatment option for comminuted distal femur fractures. This treatment choice  
5 not only resulted in markedly improved stability on the medial side of the femur, but  
6 also satisfactory outcomes for distal femoral fractures.

7 **Key words:** Cortical bone plate allograft; Comminuted fracture; Distal femoral;  
8 Implant failure; LISS

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## 1 **Introduction**

2 Distal femoral fractures comprise approximately 3%–6% of all femoral fractures [1].  
3 Till now, effective treatment of comminuted distal femur fractures remains difficult  
4 for orthopedic surgeons. These fractures are often unstable and comminuted, typically  
5 resulting either from falls in female patients older than 75 years or as a result of the  
6 high energy activities common amongst adolescent boys and men aged 15 to 24 years  
7 [2]. Classification of distal femur fractures was first described by Müller et al. and  
8 expanded in the AO/OTA classification [3,4]. These classifications are based on  
9 fracture location and pattern and are useful in determining treatment and prognosis.  
10 With the development of improved internal fixation devices, operative treatment can  
11 now produce better results than nonoperative treatment. This is especially true for  
12 comminuted supracondylar and intercondylar femur fractures [5].

13 Surgical treatment of comminuted distal femur fractures demands experience and  
14 surgical skill. A complete set of instruments and familiarity with their use are required  
15 for this method of fixation. Condylar buttress plates, dynamic condylar screws,  
16 intramedullary nailing, LISS plates, and external fixation were introduced to facilitate  
17 the treatment of these types of fractures [6-9]. However, the spectrum of injuries is so  
18 great that no single implant has been found to be suitable for every case. Moreover,  
19 patient outcomes with these types of fractures are generally unsatisfactory due to the  
20 proximity of the fracture to the knee joint [10], meaning that regaining full knee  
21 motion and function may be difficult. In addition, internal fixation above such  
22 fractures is disadvantageous since a lengthy non-weight bearing period is required

1 following surgery, and significant complications such as malunion, nonunion,  
2 infection, and implant failure occur at relatively high rates in many reports [11-14].

3 Given these challenges, this study sought to investigate a novel surgical  
4 treatment strategy for comminuted distal femur fractures. The fractures included in  
5 this study were in accordance with AO/OTA classification, consisting of patients with  
6 either type A3 fractures involving distal shaft comminution, type C2 fractures  
7 involving metaphyseal comminution, or type C3 fractures characterized by  
8 metaphyseal and intra-articular comminution. The approach described here features  
9 the use of a supplementary medial cortical bone plate allograft in conjunction with a  
10 lateral LISS plate. Therapeutic effects were assessed in patients, with an average  
11 follow-up time of 31.3 months.

12

## 13 **Patients and Methods**

### 14 **Clinical data**

15 This study was a retrospective analysis of existing clinical cases and was approved by  
16 the institutional review board. Written informed consent was obtained preoperatively  
17 for all patients. Thirty-three patients (20 males and 13 females) were enrolled in the  
18 study between January 2009 and January 2014. The average age at enrollment was  
19 44.5 years (range was 18-78 years). Follow-up visits were conducted with thirty  
20 patients between 13 and 73 months post-operation, with an average follow-up time of  
21 31.3 months. One patient stopped responding after a 3-month follow-up visit, and two  
22 patients lost connection at 6-month follow-up visit. Twenty-nine patients suffered

1 from closed fractures and 4 had open fractures (1 Gustilo I, 1 Gustilo II, 1 Gustilo  
2 IIIA and 1 Gustilo IIIB). According to the AO/ASIF system, 33 fractures were  
3 classified as the following: A3 (n=10), C2 (n=13), and C3 (n=10). The causes of  
4 injury included: traffic accidents (20 patients, 60.6%), heavy object crush injuries (5  
5 patients, 15.1%), falls from a significant height (6 patients, 18.2%), and implant  
6 failure (2 patients, 6.1%). Two patients had fractures associated with an ipsilateral  
7 tibial fracture (including one popliteal artery injury patient), two with a  
8 hemopneumothorax, two with a traumatic brain injury, two with contralateral tibial  
9 and fibula fractures, and one with an ipsilateral patella fracture. All patients were  
10 diagnosed according to clinical presentation, X-ray, and computer tomography (CT)  
11 scans. Study participants were evaluated post-operatively every 1-2 months in the  
12 outpatient clinic. Detailed clinical patient parameters are shown in Table I.

13

#### 14 **Pre-operative preparation**

15 Proximal tibial skeletal traction was performed immediately after all patients with  
16 closed fractures were admitted to the hospital. Patients with Gustilo I and Gustilo II  
17 open fractures first underwent debridement and suturing, after which they received  
18 proximal tibial skeletal traction. In two patients with a Gustilo III fracture, limited  
19 internal fixation combined with external fixation was implemented following  
20 debridement. All patients with open fractures received postoperative intravenous  
21 antibiotics for 24 to 48 h. X-ray and CT examinations were used to visualize fracture  
22 displacement and the presence of fragments when determining the surgical strategy

1 for each patient. All patients underwent surgical treatment as soon as their condition  
2 had stabilized.

3

#### 4 **Surgical procedure**

5 Prophylactic antibiotics were given 30 min prior to surgery. No tourniquet was used.

6 The patient was placed under either general or spinal anesthesia and then positioned in

7 a supine position with a bolster under the knee to acquire 20°-30° of flexion. This was

8 done in order to relax the deforming force of the gastrocnemius. For type A3 fractures,

9 a 4–5 cm lateral incision was made just proximal to the joint line. A distal femoral

10 LISS plate (AO, Synthes Inc. West Chester, Pennsylvania, USA) was slipped under

11 the vastus lateralis proximally and provisionally fixed distally using K wires. Close

12 reduction was accomplished using traction and external manipulation and confirmed

13 under fluoroscopy. During the procedure, specific attention was paid to limb

14 alignment and length. When the position of the LISS plate was deemed satisfactory,

15 three to six locking screws were inserted in the distal and proximal part of the bone

16 respectively.

17 For type C2 and C3 fractures, an incision made on the lateral condyle of the

18 femur and elongated to the tibial tubercle to fully expose the anterior and lateral

19 aspects of the femoral condyle. Intercondylar fractures were then reduced and fixed

20 with cannulated screws (AO) to form the supracondylar fracture. These fractures were

21 then treated as type A3 fractures. For patients with implant failure after surgery, the

22 lateral parapatellar approach was used to remove the implant. After the fracture was

1 fully exposed, any scar tissue and sclerotic bone was excised and the medullary cavity  
2 was reamed. An appropriate length LISS plate was then used to fix the fracture, and  
3 autologous iliac bone was implanted.

4 A suitable width cortical bone plate allograft (Xin Kang Chen Medical  
5 Technology Development Co., Ltd, Beijing, China) was selected and trimmed with a  
6 wire saw. The sharp edge of the cortical bone plate allograft was filed with a bone file,  
7 and the tip was rounded and obtuse. A 4-5 cm anteromedial incision was made along  
8 the anterior margin of the pes anserinus, following the adductor canal. The fascial  
9 envelope surrounding the vastus medialis along the posterior margin of the muscle  
10 was then incised. Blunt dissection was used to elevate the muscle off the periosteum  
11 and the intermuscular septum from the adductor tubercle to the intact proximal  
12 femoral shaft. Next, a periosteal elevator was used to strip the region between the  
13 periosteum and adductor muscles of the thigh. The prepared cortical bone plate  
14 allograft was implanted via the anteromedial incision and placed on the opposite side  
15 of the LISS plate. The LISS plate and cortical bone plate allograft were fixed in place  
16 with cortical bone screws. At least two screws were used at the distal and proximal  
17 ends of the bone plate. Finally, the open wound was rinsed and the incisions were  
18 closed, with a suction drain at the surgical site.

19

## 20 **Postoperative management**

21 All patients received post-operative intravenous antibiotics for 24 h. Suction drains  
22 were removed on day 2-3. Active and passive range-of-motion exercises were then

1 started. Full weight-bearing activity was allowed after a bridging callus was observed  
2 on radiographs.

3

#### 4 **Outcome assessment**

5 Outcomes after surgery were evaluated according to HSS scores, which rely on a  
6 100-point scoring system that assesses pain, function, range of motion, muscle  
7 strength, flexion deformity, and joint stability. Overall, "Excellent" was classified as a  
8 cumulative score of 85 or more, "Good" as 70 to 84, "Fair" as 60 to 69 and "Poor" as  
9 60 or less. Postoperative functional results were obtained regularly. Postoperative  
10 radiological parameters, including X-rays and CT scans, were taken every four weeks  
11 to evaluate bony fusion.

12

#### 13 **Results**

14 The mean non-weight-bearing period was 10.7 weeks (range was 8–15 weeks) and  
15 mean time to bone union (formation of a circumferential bridging callus across the  
16 fracture) was 5.4 months (range was 3–12 months). Three patients stopped visits and  
17 ceased communication during the follow-up period (Patients 21, 28, and 33).  
18 Outcomes for the remaining patients were “Excellent” for 10 and “Good” for 10,  
19 making the percentage of combined “Excellent” and “Good” scores 67.7%. The mean  
20 range of knee flexion was 105.6° (range of 80° -130°). More specifically, 2 patients  
21 had an 80° range, 4 patients had a 90° range, 7 had a 100° range, 12 had a 110° range,

1 and 5 had  $\geq 120^\circ$  range of knee flexion. All patients achieved full knee extension.  
2 Three patients had weakness in their quadriceps, but all others attained full quadriceps  
3 strength. Six patients had the implant removed (Table II).

4 One patient had a deep infection five days after the operation and underwent a  
5 secondary surgery (implant removal and external fixation). There were two patients  
6 who had minor surgical complications, including one superficial wound infection and  
7 one partial wound dehiscence. After debridement and suturing, both patients'  
8 complications were resolved. One patient with nonunion required bone grafting  
9 without hardware exchange. Post-traumatic arthritis was seen in one patient at the  
10 final follow-up, which was based on the radiologic assessment (Table II). Typical  
11 cases are shown in Fig. 1 (Patient 2), Fig. 2 (Patient 5), and Fig. 3 (Patient 10).

## 13 Discussion

14 Comminuted distal femur fractures are frequently associated with severe comminution,  
15 substantial soft tissue injury, and bone defects. Prior to the 1970s, non-operative  
16 management was the treatment of choice [2]. With the steady improvement of surgical  
17 techniques and implants, operative fixation has gained widespread acceptance.  
18 Historically, these fractures were treated with condylar buttress plates [6]. Gradually,  
19 retrograde nails and dynamic condylar screws took the place of condylar buttress  
20 plates. This shift was due to their superior biomechanical design that resulted in  
21 decreased varus collapse events when compared with the results using standard  
22 condylar buttress plates [15]. Recently, locking plates have become the main  
23 treatment for comminuted distal femur fractures, particularly for supracondylar and

1 intercondylar comminuted femur fractures. With the increased number of fixation  
2 screws used in the distal femur metaphysis, locking plates provide increased  
3 biomechanical resistance and stability [16]. However, perioperative and postoperative  
4 complications such as malunion, nonunion, implant failure, and infection are still  
5 common with this approach [14].

6 The main reasons for implant failure are primarily due to the following problems:

7 (1) high bending stress exerted on the laterally placed plates in the presence of marked  
8 cortical defects and (2) locking plates are usually implanted using the minimally  
9 invasive percutaneous plate osteosynthesis (MIPPO) technique. Since the MIPPO  
10 technique is relatively short range and intraoperative fluoroscopy has a limited range,  
11 there is a high incidence (approximately 30%) of axial malalignment after surgery.

12 Axial malalignment results in increased load on the plate, which can cause implant  
13 failure. Here, implant failure was found in two patients over the age of 60 who had  
14 been initially treated with a single-side plate and screws, followed by additional  
15 operations as needed. The current treatment approach for implant failure features scar  
16 tissue removal and large amounts of autologous iliac bone grafts, as well as implant  
17 replacement. Bilateral autologous iliac bone grafts have often been applied to repair  
18 cortical defects, which can increase surgical trauma and the chance of infection.

19 Furthermore, the stability immediately following the structural allograft cannot  
20 support early postoperative functional exercise, which is important for recovery.

21 Therefore, we performed a medial implant of the cortical bone plate allograft  
22 integrated with a lateral LISS plate for the two patients with implant failures. Patient 2  
23 was a 61-year-old male patient with a type A3 fracture that had been initially treated  
24 using dynamic condylar screws. The implant failure was observed seven months  
25 following surgery and required reoperation. After treatment with a cortical bone plate

1 allograft combined with LISS plate fixation, bone union was observed five months  
2 later ([Fig. 1](#)).

3       Types C2, C3, and partial A3 fractures of the distal femoral are prone to induce  
4 nonunion and implant failure, particularly in the cases of severe cortical defects in the  
5 medial femur. On the basis of lateral LISS plate implantation using MIPPO  
6 technology, a suitable length and width allogeneic cortical bone plate was implanted  
7 from the medial epicondyle of the femur, which achieved an integrated fixation of the  
8 triangular support and avoided excessive elevation of the periosteum at the fracture  
9 site. For severe comminuted fractures and/or periprosthetic fractures of the distal  
10 femur, double plating with autogenous bone grafting executed via a modified Olerud  
11 extensile approach was also used. Although acceptable clinical outcomes were  
12 achieved, there are some limitations to this approach, including excessive elevation of  
13 the periosteum, large trauma (tibial tuberosity osteotomy), and lack of integrated  
14 fixation [[17](#)]. Recently, a double-plating technique was used for the treatment of  
15 supracondylar femur fractures. Based on promising follow-up results, they  
16 recommended this technique specifically for patients with poor bone quality,  
17 comminuted fractures, and very low periprosthetic fractures [[18](#)]. However, no  
18 detailed functional outcomes were described in their results and some important  
19 points were needed to be clarified [[19](#)].

20       The application of allogeneic cortical bone plates in repairing bone defects has  
21 been frequently reported and satisfactory clinical results have been achieved with this  
22 approach [[20,21](#)]. In our study, an allogeneic cortical bone plate was used in the  
23 treatment of comminuted distal femur fractures and has the following advantages: (1)  
24 wide scope of application; (2) the union of the allogeneic cortical bone plate and host  
25 bone can reconstruct cortical defects of the medial femur, and when combined with an

1 autologous iliac bone graft, this treatment has a strong osteoinductive effect and can  
2 promote bone healing; (3) LISS plates and allogeneic cortical bone plates were  
3 implanted using MIPPO technology, which minimized periosteal elevation and  
4 disruption of blood supply at the fracture site, which not only increased fixation  
5 rigidity, but also contributed to fracture healing; (4) allogeneic cortical bone plates are  
6 a biomechanically sound alternative to metal plates fixed with screws, and could  
7 markedly improve stability and rigidity after lateral LISS plate fixation; (5) utilization  
8 of a LISS plate and allogeneic cortical bone plate presented firm integrated fixation of  
9 the triangular support. Furthermore, knee function exercises were conducted soon  
10 after the operation, resulting in overall better therapeutic outcomes.

## 11 **Conclusion**

12 We recommend that a cortical bone plate allograft combined with the LISS plate  
13 fixation technique be used for treatment of comminuted distal femur fractures. This is  
14 especially indicated in cases of severe medial femur cortical defects and implant  
15 failure after surgery. However, there are some limitations to this study, including its  
16 retrospective nature as well as the relatively small group of patients studied. A  
17 long-term study with a larger number of patients and control groups that include other  
18 fixation methods should be performed to further validate our findings here.

19

## 20 **List of abbreviations**

21 CT, computer tomography; HSS, special surgery knee rating scale; LISS, less  
22 invasive stabilization system; MIPPO, minimally invasive percutaneous plate  
23 osteosynthesis.

24

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9

10 **Availability of data and materials**

11 The datasets analysed during the current study are not publicly available due to patient  
12 confidentiality.

13

14 **Ethics approval and consent to participate**

15 This study was a retrospective and clinical study and approved by the Xiamen  
16 University institutional review board. Written informed consent was obtained from all  
17 patients preoperatively.

18

19 **Consent for publication**

20 All authors are in agreement with the content of the manuscript and have approved the  
21 manuscript for submission.

22

23 **Competing interests**

1 The author(s) declared no potential conflicts of interest with respect to the research,  
2 authorship, and/or publication of this article.

3

4 **Authors' contributions**

5 ZG: Writing the paper, data analysis and collection.

6 CS: Searching the related articles, data analysis.

7 HL: Data collection.

8 ZC: Writing the paper, data analysis and collection.

9 YL: Searching the related articles, data analysis.

10 JW: Data collection, performed surgeries, research team manager.

11 All authors have contributed significantly and are in agreement with the content of the  
12 manuscript.

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1 **Fig. 1.** Representative images of patient 2 (61-year-old male patient with a type A3  
2 fracture that had been initially treated with dynamic condylar screws). Implant  
3 breakage was observed seven months after surgery (a, b). X-ray at 5 months after  
4 operation. Bone union was observed (c, d). Follow-up X-ray at 36 months (e, f).  
5 Follow-up X-ray at 60 months (g, h). Follow-up X-ray at 73 months (i, j).

6

7 **Fig. 2.** Representative images of patient 5 (29-year-old male who suffered a heavy  
8 object crush to his left thigh). X-ray at admission (a, b). X-ray 5 days after the  
9 operation (c, d). Follow-up X-ray at 3 months (e, f). Follow-up X-ray at 30 months (g,  
10 h). Full-length radiography showing the lower limb at a 33 month follow-up visit.  
11 Limb alignment and length was good (i). Range of knee joint motion at a 33 month  
12 follow-up visit. The patient achieved full knee extension. However, the range of knee  
13 flexion was only 90° (j, k).

14

15 **Fig. 3.** Representative images of patient 10 (21 year old male patient with a Gustilo  
16 IIIB fracture resulting from a traffic accident). X-ray at admission (a, b). X-ray after  
17 emergency operation. Limited internal fixation combined with external fixation was  
18 utilized (c, d). X-ray 3 months after an interfixation operation (e, f). Follow-up X-ray  
19 at 9 months (g, h). Follow-up X-ray at 12 months. Removal of the tibial implant (i, j).  
20 Follow-up X-ray at 69 months (k, l).

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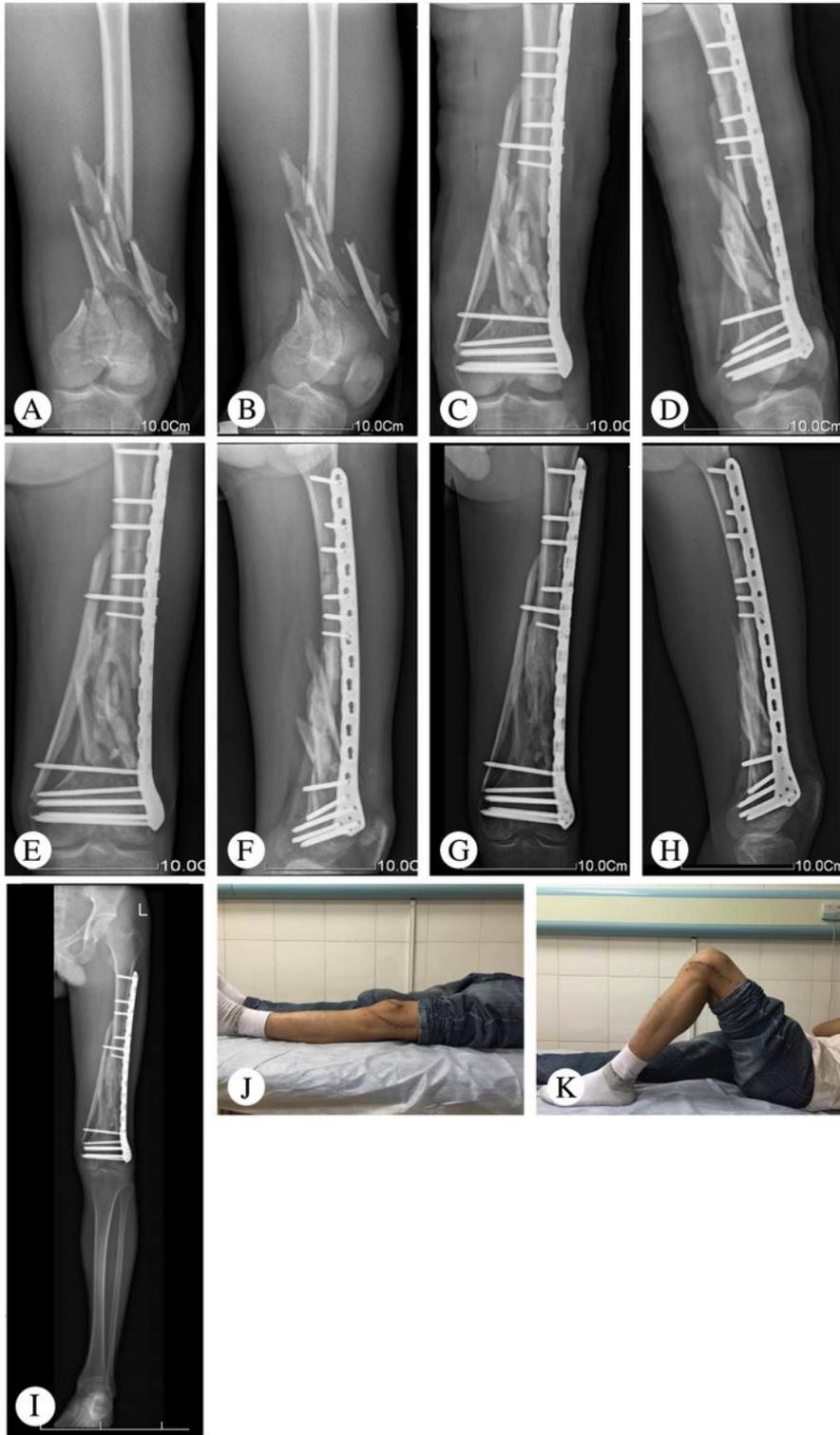
# Figures



**Figure 2**

Representative images of patient 2 (61 year old male patient with a type A3 fracture that had been initially treated with dynamic condylar screws). Implant breakage was observed seven months

after surgery (a b). X-ray at 5 months after operation. Bone union was observed c, d Follow-up X-ray at 36 months (e, f ). Follow-up X-ray at 60 months (g, h ). Follow up X-ray at 73 months (i, j).



**Figure 3**

Representative images of patient 5 (29-year-old male who suffered a heavy object crush to his left thigh). X-ray at admission (a b ). X-ray 5 days after the operation (c, d). Follow-up X-ray at 3 months (e, f). Follow-up X-ray at 30 months (g, h). Full length radiography showing the lower limb at a 33 month follow-up

visit. Limb alignment and length was good (i). Range of knee joint motion at a 33 month follow-up visit. The patient achieved full knee extension . However, the range of knee flexion was only 90 ° j, k



**Figure 6**

Representative images of patient 10 (21 year old male patient with a Gustilo III B fracture resulting from a traffic accident). X-ray at admission (a,b ). X-ray after emergency operation. Limited internal fixation combined with external fixation was utilized (c d) X-ray 3 months after an interfixation operation (e f).

Follow-up X-ray at 9 months (g h ). Follow up X-ray at 12 months. Removal of the tibial implant (i,j).  
Follow-up X-ray at 69 months (k, l)

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table11.pdf](#)
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