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Case Report
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Bone Transport Using a Circular Frame Construct Over a Locking Plate for Femoral Non-Union: A Case Report

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Abstract

Non-union poses great challenges for both the patient and the attending surgeon. Apart from the physiological burden of the condition towards bone healing, the psychosocial effect on the patient should be paid attention to, especially if a lengthy treatment period and multiple surgeries are needed to address the issue. A 36 years old patient presented with aseptic non-union of his left femur six months after he underwent plating for the closed comminuted fracture of the left femur. Clinical, laboratory and radiological investigations confirmed the absence of infection. There was a significant bony gap despite the presence of multiple small bony fragments over the distal third diaphysis of the left femur seen on the radiographs. The patient subsequently underwent application of a circular frame and corticotomy meant for bone transport, with retainment of the previous plate. The transport was commenced for 8 weeks, followed by an additional two weeks of turning to further compress the docking site. At 5 months after the surgery, the circular frame was removed with radiological evidence of union seen and good quality of bone regenerate. The patient recovered with excellent radiological and functional outcomes. The treatment of aseptic non-union with large bone defect using bone transport by circular frame over a plate is a viable option. Apart from producing quality bone regenerate to fill up the defect, the reduced time-on-frame and avoiding mismatch or malalignment minimizing the need for docking site procedure to achieve union. These help to achieve excellent radiological and functional outcomes for patients who may benefit from such method.

Keywords: Fracture; Non-union; Bone transport; Circular frame; Plate; Femur

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Introduction

Fracture non-union poses great challenges for both the patient and the attending surgeon. Apart from the physiological burden of the condition towards bone healing, the psychosocial effect on the patient should be paid attention to. The patient's compliance and lifestyle will be affected especially if a lengthy treatment period and multiple surgeries are needed to address the issue. Despite various techniques described in the literature for the management of fracture non-union, there is no "one method fit all" mantra and the most appropriate option should be individualized according to multiple factors centered on the aim to achieve the best outcomes for the patient.

We describe an interesting case of a patient who had femoral non-union with a large bone defect, and was successfully being treated by utilizing bone transport using a circular frame over a plate.

Case Presentation

A 36 years old male was referred to us six months after sustaining a closed comminuted fracture of the distal third diaphysis of his left femur in a motor-vehicle accident. He had earlier undergone an internal fixation surgery for the femoral fracture using a locking compression plate. Despite an uneventful surgery, the fixation however was later complicated with non-union at the fracture site. He had minimal pain over the left thigh and was yet to be able to weight bear on his left lower limb.

On examination, the scar from previous surgery has healed. There was neither sign of infection nor erythematous area, swelling, sinus or discharge present. The limb lengths were equal for both sides, and the neurovascular examination was normal.

Subsequent radiographic evaluation revealed no radiological evidence of union with a large bone gap at the fracture site, despite the presence of multiple small bony fragments (Figure 1). There was

Figure 1: The preoperative radiographs showing the Anteroposterior (AP) view of the left knee (1a) and both the AP and lateral views of the left femur (1b and 1c). The radiographs clearly show that there is no evidence of union or presence of bridging callus at the fracture site at 6 months after the initial fixation. There is visible large bony gap seen at the distal femur, despite presence of multiple small bony fragments.

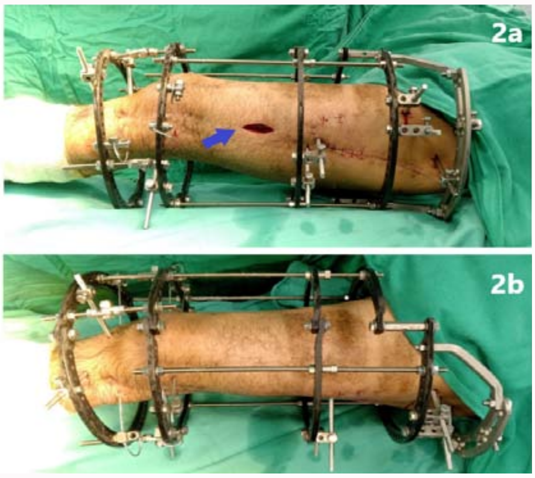

Figure 2: Intraoperative clinical image showing the left thigh and knee as seen from the lateral (2a) and anterolateral (2b) aspects. The circular frame construct consists of 5 ring levels, including one applied on the tibia to stabilize the knee joint throughout the bone transport process. The soft tissue clearance is good and the construct allows bone transport to commence from proximal to distal. The blue arrow shows the small incision made just to ascertain the absence of infection and to remove bony fragments which are sclerotic as seen under image intensifier guidance.

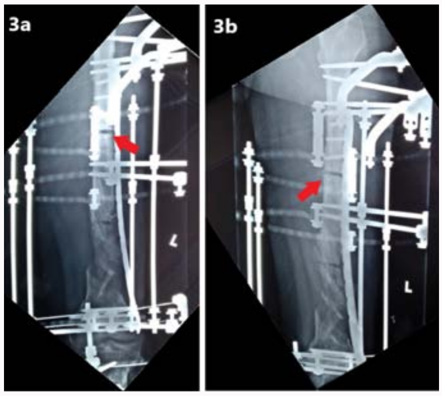

Figure 3: The immediate postoperative radiographs showing the Anteroposterior (AP) (3a) and oblique (3b) views of the left femur. The red arrows denote the area of corticotomy done, which is just proximal to the location of previous 2 locking screws which were removed. The presence of the plate and the circular frame construct provide necessary mechanical stability in this fracture pattern, and the plate acts to guide the transport segment towards the docking site at the distal femur.

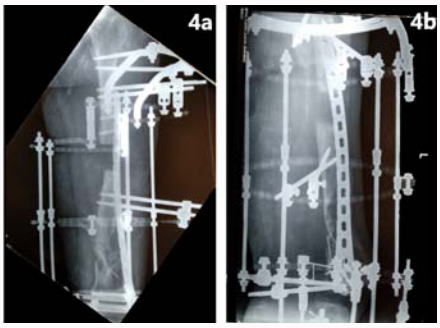

Figure 4: The Anteroposterior (AP) (4a) and lateral (4b) views of the left femur taken after the completion of the bone transport. The transport segment reached the docking site without any mismatch in position and alignment, and was further compressed towards it to ensure no gap was left. The regenerate bone is of good quality, especially appreciated on the lateral view.

no sign suggestive of infection such as periosteal reaction, sequestrum or involucrum. The blood parameters were also unremarkable-the full blood picture (hemoglobin level of 13.2 g/dL, total white cell count of 9.5×10^9/L, and platelet count of 237×10^9/L), the C-reactive protein (0.5 mg/dL) and erythrocyte sedimentation rate (23 mm/h) suggested that there was no active infection.

A diagnosis of aseptic non-union of the left femur was made. With a strong indication of the absence of infection and the presence of huge bone gap, the decision to retain the implant and to employ bone transport over the plate was made. In the operation theatre, the patient was placed in a supine position under regional anesthesia, with the whole left lower limb was cleaned and draped. With the alignment and length were confirmed to be correct under image intensifier guidance, a circular frame (Ilizarov external fixator) construct was then applied (Figure 2). A small incision was made at the fracture site-to confirm the absence of infection, to remove any devitalized bony fragment and to clear any interposed fibrous tissue. The two locking screws at the transport segment were removed percutaneously and corticotomy was done proximal to it (Figure 3).

There were no intraoperative or post-operative complications observed. The turning for bone transport was started on day 10 after the surgery, and with the rhythm chosen to be quarter-turn for 4 times per day (at the rate of 1mm/day bone transport). The turning was commenced for about 8 weeks until docking was achieved (Figure 4). During the bone transport procedure, the patient was allowed to partially weight-bear using axillary crutches. Afterward, turning was continued for another two weeks to allow compression at the docking site, while the patient was then able to fully weight-bear as he tolerated. The circular frame construct was then removed at the 20th week post-surgery. Subsequent X-rays taken after the removal of the circular frame revealed that evidence of radiological union has been achieved (Figure 5).

He is currently has no pain at the fracture site, and is able to full weight-bear and walk without aid. The knee range of motion was around 5° to 100° flexion. At 6 months after the surgery, the Lower Extremity Functional Scale (LEFS) was recorded to be 76 out of 80 (95% maximal function). He has returned to his work as a technician

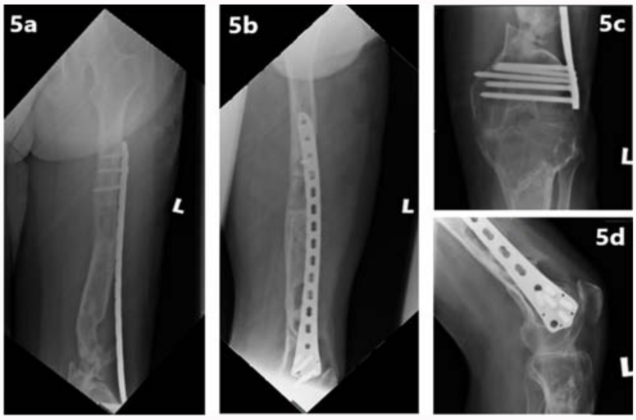

Figure 5: The radiographs showing the Anteroposterior (AP) and lateral views of the femur (5a-5b) and the knee (5c-5d), taken 5 months postoperatively after the removal of the circular frame construct. The regenerate has started to show consolidation with good quality and the docking site has achieved radiographic union.

and is able to perform his activities of daily living without major issues.

Discussion

Non-union is still contributing substantially as one of the most dreaded complications of long bone fracture. This is despite advancement in multiple aspects of fracture treatment including surgical techniques, anatomical and biomechanical understandings, implants and devices, and adjuvant therapy. Non-union is still prevalent and becomes the sequela in 5% to 10% of all fractures, with tibia, femur and humerus being the most affected long bones [1,2]. While the factors which may lead to non-union can be divided into local (e.g. vascularity, bony defect, poor immobilization, etc) and systemic factors (e.g. malnutrition, immunocompromised state, smoking, diabetes etc) [1,2], the management for non-union is usually hinged on the status of infection, the presence of pre-existing bony defect and the potential of healing.

Before deciding on the best method to manage non-union in an individualized case, a systematic approach should be employed to avoid suboptimal management. Early suspicious should arise when serial clinical and radiological assessments show evidence of non-progression or cessation of bony healing over a period of time. This temporal assessment is traditionally guided by the Perkins timetable [3]; however, there are variations of acceptable expected timeline for fracture union (6 to 9 months) [4]. Clinically, mobility at the fracture site with or without pain is a leading physical sign; whereas radiographical assessment usually denotes the observation of the absence of bridging callus on three out of four cortices as the parameter for non-union, including the scoring system it derives [4,5]. More importantly, radiological assessment is important to assess healing potential (hypertrophic or atrophic non-union), the possibility of infection (septic or aseptic non-union) and fracture gap suggestive of a critical bony defect. Employment of Computed Tomography (CT) scan or Magnetic Resonance Imaging (MRI) are further useful tools to ascertain these.

The emphasis on the "diamond" concept of bone healing has lately become a major influence in the principles of management of non-union [6]. Mechanical stability and cessation of infection are considered to have equal importance with the biological factors including osteogenic cells, osteoinductive mediators and osteoconductive framework. Taking all these into consideration, the presence of a bony defect or ongoing infection requiring resection will further determine the type of surgical management best employed to treat the non-union. These surgical interventions can further be divided into a few broad categories, including bone grafting procedure alone (autologous cancellous graft, synthetic graft, allograft, vascularised graft, etc), implant stabilization (exchange nailing, etc), induced membrane technique (Masquelet technique, etc) and distraction osteogenesis (bone transport, acute docking with lengthening etc) [7].

Distraction osteogenesis has been established as one of the efficient methods to fill up a large bony defect by the formation of new bone or regenerate through gradually moving a segment of vascularised bone *via* incremental traction [8]. The traditional way of achieving this is by employing the circular frame, as popularized by the famous Soviet surgeon Gavriil Ilizarov. This technique is preferred for large bony defects as it avoids the need of a large quantity of bone grafting needed in induced membrane technique and prevents donor site morbidity. Despite its effectiveness, a lengthy time-on-frame to get union and regenerate consolidation, construct complexity and complications related to the external frame such as non-union and mismatch at docking site, make it cumbersome and may cause some inconvenience to the patients [8,9]. In some patients, additional docking site procedures such as adjustment of the construct for re-alignment and bone grafting might be needed, and this will impose more surgery, and inadvertently more risks, to the patient.

As compared to the conventional method, employing bony transport by a circular frame over a bridging plate however helps to address most of the issues above. This technique has been shown to be effective in both animal and human studies [10,11]. With this method, the length and alignment of the bone are maintained throughout the transport process. As seen in our patient, the plate acts as a guide to direct the transport segment towards the docking site, and this will prevent any mismatch between the transport segment and the docking site. The periosteal envelope is also able to be preserved by avoiding removal of the pre-existing plate. This inevitably helps to reduce the possibility of non-union at the docking site. In our patient, no docking site procedure such as bone grafting was needed. The presence of the plate also means that mechanical stability is optimum, and the time-on-frame and the External Fixation Index (EFI) can be reduced [11]. The circular frame can then be removed earlier than what is expected in the conventional method. This improves the tolerance of patients towards the treatment plan and subsequently ensures their compliance and satisfaction.

On the other hand, the most dreaded disadvantage of this technique is the possibility of infection, especially involving the pin tract. If the infection tracks through the pin and causes osteomyelitis, the presence of the plate provides a good reservoir to harbor the microorganism. Other disadvantages include implant failure and the fact that this method is likely to be more technically demanding [11]. The presence of the plate means that there is a narrow bony window for pin insertion and corticotomy over the pre-existing hardware might be found difficult for an inexperienced surgeon. In our patient, these issues did not arise and our patient recovered with excellent radiological and functional outcomes.

Bone transports over an internal implant have been described earlier in the literature, especially since Paley et al. [12] popularized the method for femoral lengthening. Bone transport over plate have also been reported, and as was seen in our patient, the results have been promising [11,13,14]. In a series of ten patients, Oh et al. [13] described good results achieved, with all patients underwent bone grafting at the docking site. Mukhopadhaya and Raj [14] reported two similar cases which both required docking site procedures while one required pin site debridement and pin exchange. These additional re-operations were however having been managed to be avoided in our patient. The utilization of monorail external fixator as the transporting tool over a plate has also been described with successful results [15].

Conclusion

Treatment of aseptic non-union with a large bone defect using bone transport by circular frame over a plate is a viable option. Apart from producing quality bone regenerate to fill up the defect, the reduced time-on-frame and avoiding mismatch and malalignment minimizing the need for docking site procedure to achieve union. These help to achieve excellent radiological and functional outcomes for patients who may benefit from such method.

Authors' Contribution

Khairul Rizal Zayzan and Ahmad Arieff Atan conceived the original idea, acted as the manuscript's primary authors. Zamri Ab Rahman and Norhaslinda Bahaudin contributed in the literature review and acted as secondary authors. Abdul Rauf Ahmad gave clinical consultation on the clinical works carried out and the writing of the manuscript. Khairul Rizal Zayzan, Ahmad Arieff Atan, Zamri Ab Rahman and Norhaslinda Bahaudin contributed in the clinical works, investigations, images and resources-gathering and followed-up the patient.

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