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ORIGINAL ARTICLE • LOWER LIMB - FRACTURES

Double plating of intra-articular multifragmentary C3-type distal femoral fractures through the anterior approach

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Abstract
Introduction In this prospective case series, we report a mean of 12-month follow-up of the utilization of a dual plating of distal femoral fractures. Our technique included a lateral distal femoral locked plate with a low-contact-locked medial plate and bone graft through an extended medial parapatellar anterior approach for the fixation of C3-type distal femoral fractures.
Patients and methods Sixteen patients (11 males and 5 females) presented with supracondylar femoral fracture type C3, according to Müller long-bone classification system and its revision OA/OTA classification. These were treated using dual plating through extended anterior approach and bone grafting. Our outcomes included clinical and radiological outcomes. Secondary outcomes included postoperative complications.
Results The mean time of complete radiological union in the studied population was 6.0 ± 3.5 months with a range of 3–14 months. We have not observed postoperative varus or valgus deformity in our cohort. The majority (68.75%) of the studied patients showed significant improvement in range of motion (90°–120°) during follow-up. Eleven out of sixteen patients (68.75%) had well-to-excellent functional outcome. Poor outcome was reported in only two patients (12.50%).
Conclusions Dual plating fixation using anterior approach for type C3 distal femoral fractures is an efficient method of management. It has several advantages such as precise exposure, easy manipulation, anatomical reduction and stable fixation. However, operative indications and instructions should be strictly followed. The surgical technique must be rigorous, and the biomechanical qualities of these implants must be understood to prevent the development of major complications.

Keywords Distal femoral fracture · Dual plating · Intra-articular fractures · Anterior approach

Introduction

Despite the recent advances in techniques and implants, the treatment of intra-articular multifragmentary distal femoral fractures remains a challenge. Long-term disability can occur in patients with extensive articular cartilage damage and marked comminution. Fracture shortening with extension and varus deformities of the distal articular surface is a typical presentation [1]. Numerous problems can occur during manipulation of distal femoral fractures. These include: anteromedial displacement with external rotation of the condylar part of the femur, articular penetration and excessive penetration of the medial cortex [2, 3]. OTA C3-type fractures are complete articular fractures of the distal femur, with no part of the articular surface in continuity with the diaphysis; they are not uncommon.

The principles of management are to achieve anatomical articular reduction and preserve the blood supply while providing rigid stable internal fixation that is strong enough to withstand early functional mobilization. During fixation of such injuries, the surgeon aims to reconstruct and anatomically reduce the articular surface. Subsequently, the chosen approach must adequately expose the articular surface of the distal femoral condyles. There is no consensus on the benefits and harm of

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different implants used to fix these fractures. Intramedullary nails (IMN) were associated with decreased infection and wound complications compared with plating. Yet, there was no statistical difference between the two groups [4]. Hypothetically, the IMN utilize indirect reduction in the metaphyseal fracture—which would offer a less invasive approach with decreased risk of infection, yet anatomic reduction is not achievable with nails [4].

Anatomic reconstruction of the articular surface is only achievable by the plating group. The stabilization of the fracture in the sagittal plane is generally trickier than in the frontal plane due to rotation of the condyles [2, 3]. To achieve this, distal femur fractures prerequisite sufficient exposure to achieve adequate visualization and reposition of the small osteochondral fragments. Malunion, especially the medial femoral condyle, is not uncommon, which is hard to reduce anatomically due to extension by the pull of medial head of gastrocnemius [5].

There is a scarcity of evidence reporting the outcomes of the reported technique in this type of fracture. Moreover, this is the first study reported for this cohort of patients in a Middle Eastern population. The Middle East is a distinct and dissimilar region where politics and religion significantly affect daily life, including health care. Despite better socioeconomic conditions and living standards, the incidence of blunt trauma is rising significantly in this region [6] and represents a significant source of fatalities mainly in young age groups [7, 8]. The most common mechanism of injury is road traffic accidents followed by falls from height and being smacked by a heavy object [9]. Subsequently, more patients are presenting with complex comminuted fractures with associated injuries [10]. There are unique racial, cultural and socioeconomic factors that potentially affect outcome and require special attention when managing these knees. There is the need to undertake more demanding activities and postures in this population. Sitting cross-legged or sitting on the floor with maximum squatting is routine living activity that would constitute a common expectation in patients having their knees fixed or replaced in the Middle East. The same applies to most orthopedic procedures performed in the region [11].

In this study, we provide a descriptive analysis of our experience with the utilization of a dual plating technique that includes a lateral distal femoral locked plate with a low-contact-locked medial plate and bone graft through an extended medial parapatellar anterior approach in the fixation of C3 distal femoral fractures. We hypothesized that by using the proposed approach, the anatomic reduction in the articular surface is achievable with subsequent reduction in complications and improved outcomes.

Patients and methods

The current study was conducted as a prospective case series study and was approved by the Institutional Research and Audit Board of the X University. Ethical approval was obtained prior to the initiation of the study. Sixteen patients (11 males and 5 females) presented to our tertiary trauma center with supracondylar femoral fracture type C3, according to Müller long-bone classification system and its revision OTA classification, were treated using dual plating through extended anterior approach and bone grafting (Figs. 1, 2). All the patients were operated and followed up in X Hospitals from March 2013 to January 2015. All fulfilled our selection criteria of both genders, above the age of 18 years, presenting with type C3 distal femoral fractures, with no absolute medical contraindications to surgery, without associated neurovascular compromise prior to surgery. Patients with preoperative neuromuscular compromise in the symptomatic extremity, and those presenting

Fig. 1 Surgical approach to the anterior articular surface, using a pointed reduction forceps to hold the reduction

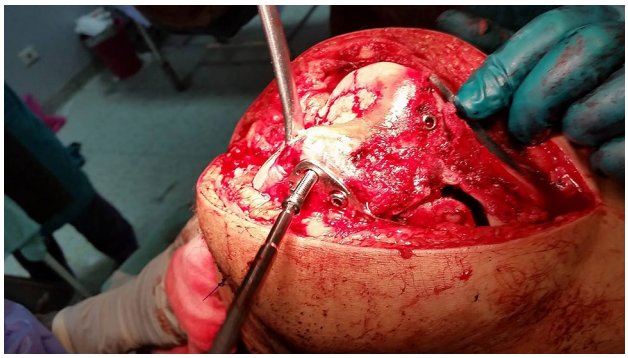

Fig. 2 Intraoperative reduction in the articular surface in one of the cases demonstrating the full exposure of the articular surface

with other types of distal femoral fractures or pathological fractures were excluded.

The study included sixteen patients with type C3 distal femoral fractures according to OA/OTA classification. Demographic and injury characteristics of the studied patients are tabulated (Table 1). The mean age of the studied patients was 36 years, and the female-to-male ratio was 5/11. Approximately 44% of the cases were smokers, and 37.5% were overweight or obese. In total, 18.75, 12.5 and 12.5% of the patients were hypertensive, diabetic and chronic liver disease, respectively. The mechanisms of injury in our cohort included falling from a height (18.75%) and road traffic accident (81.25%). The distal neurovascular state was not compromised in the entire cohort of patients. Two patients presented to the emergency department with other injuries: one case presented with stable L1 fracture that was managed conservatively and the other one presented with pubic ramus fracture that was also managed conservatively.

Table 1 Demographic and injury characteristics of the studied patients ($n = 16$)

Variables	Studied population ($n = 16$)
Age (years)	
Mean ± SD	36.0 ± 12.4
Range	18–59
Gender	
Female	5 (31.25%)
Male	11 (68.75%)
Smoking	
Non-smokers	9 (56.25%)
Smokers	7 (43.75%)
Gender	
Average weight	10 (62.5%)
Overweight/obese	6 (37.5%)
Comorbid conditions	
No	9 (56.25%)
Diabetes mellitus	2 (12.50%)
Chronic liver disease	2 (12.50%)
Hypertension	3 (18.75%)
Cause of injury	
Falling from a height	3 (18.75%)
Road traffic accident	13 (81.25%)
Associated injuries	
Pelvic fracture	1 (6.25%)
Cervical fracture	1 (6.25%)

Plain anteroposterior and lateral X-rays views and computed tomography (CT) scans (Fig. 3) were undertaken for preoperative surgical planning. CT scans obtained with coronal and sagittal reconstructions (Fig. 4) are useful to establish intra-articular involvement in preoperative planning and to identify separate osteochondral fragments in the area of the intercondylar notch with special emphasis to identify coronal plane fractures (Hoffa fractures) that has been postulated to occur in 38% of type C fractures [12].

At the end of follow-up, functional outcome was evaluated as that popularized by Sanders et al. [13]. Five parameters for clinical scoring were assessed. These included: range of motion (score 0–9 points), pain (score 0–10 points), deformity (score 0–6 points), walking ability (score 0–9 points) and return to work (score 0–6 points). According to total score points, functional results were classified into excellent (36–40 points), good (26–35 points), fair (16–25 points) or poor (0–15 points) outcomes. Our primary outcomes include postoperative complications. We have recorded medical complications as well. Our

Fig. 3 Preoperative CT scan for a fracture distal femur demonstrating the intra-articular nature of the fracture with comminution

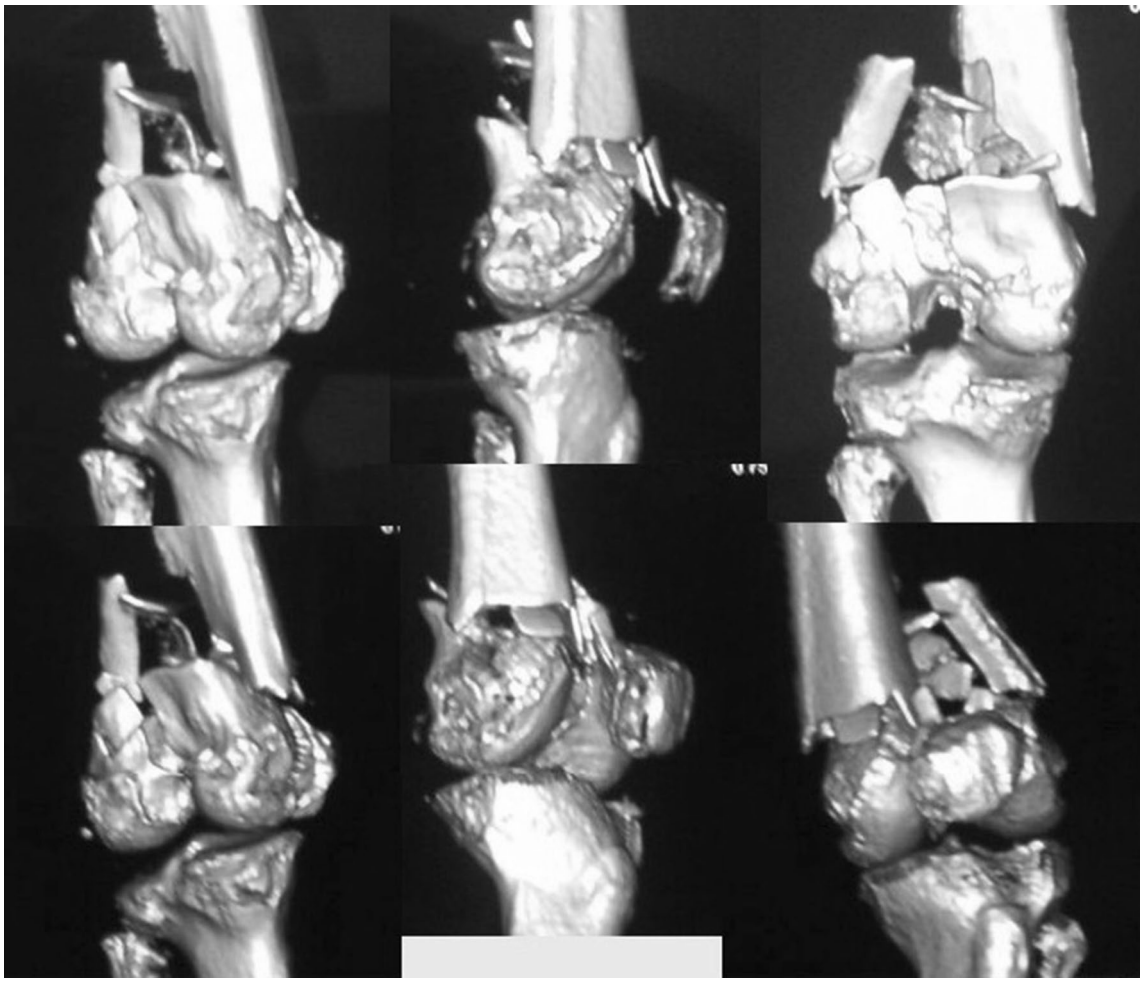

Fig. 4 Preoperative CT scan with 3D reconstruction for the same fracture demonstrating better understanding of the fracture geometry

secondary outcomes included clinical and radiological results.

Surgical approach

All procedures were carried out under combined spinal and epidural anesthesia without the use of tourniquet. With the patient lying supine, the affected knee was flexed to 90° by supporting it inferiorly. A longitudinal straight midline incision was utilized. Superficial dissection was carried out between vastus medialis (VM) and rectus femoris through the quadriceps tendon leaving a thin tendinous cuff for repair to VM and along medial patella and patellar tendon. The synovium was then incised in line with the capsular incision, and hematoma was washed out. Then, the patella was dislocated laterally and flex knee to 90°. This surgical plane was safely extended between aponeurosis of rectus femoris and vastus intermedius muscles on the lateral side and vastus medialis muscle on the medial side till full exposure of the fracture segments (Fig. 1).

The joint was thoroughly inspected to evaluate the severity of the injury and degree of intra-articular comminution of the femoral condyles. Reduction in small condylar fragments was made with pointed bone reduction clamps (Fig. 1). Then, preliminary wires fixation and cannulated interfragmentary screws of 4 mm were recruited to restore the anatomical condylar congruity. Definitive fixation were initiated with countersunk cancellous screws sizes; 4 or 6.5 mm, including those for Hoffa's fractures or osteochondral fragments, followed by applying a distal femoral locked plate sub-muscularly on the lateral surface of the condyle; being held in 20° internal rotation in the coronal plane to ensure the proper direction of the screws (Fig. 2). The intraoperative reduction is preoperatively planned based on preoperative CT scans with 3D reconstruction (Figs. 3, 4).

A second lateral mini-open incision was used when needed to insert screws in the long plate to fix the proximal locking screws and finally the application of the contoured

Fig. 5 Postoperative X-ray for a fracture distal femur (anterior–posterior view) at 4 months post-surgery demonstrating healing of the fracture

Fig. 6 Postoperative X-ray for a fracture distal femur (lateral view) at 4 months post-surgery demonstrating healing of the fracture

medial plate (proximal tibial plate in ten cases and distal tibial plate in six cases). Ultimately, bone grafting in the form of corticocancellous autograft harvested from the iliac bone was used to fill all bony defects when there was bone loss or marked comminution. In the event of the presence of small articular osteochondral fragments, fixation was performed using surgical sutures of suitable sizes. In other cases, it was grafted utilizing the mosaicplasty concept from the nearby non-weight-bearing cartilage.

Finally, closure of the quadriceps flap by side-to-side absorbable sutures was made. As per our local institutional protocol, we used a suction drain for 24 hours and the skin was closed with staples. All patients received wound infiltration analgesia peri-operatively as per local protocols. Intraoperative blood loss was calculated from the volume of fluid collected in suction drains and in weighed swabs.

Postoperatively, all the patients were immobilized in a hinged knee brace for eight weeks. Patients were locked in full extension in the first four weeks, and then, gradually assisted flexion up to 30° is encouraged and was then advanced every week to reach 90° at eight weeks. Under-arm-crutch-assisted partial weight bearing was allowed once there was radiographic evidence of callus formation. Full weight bearing postponed until there was radiological union with a minimum of 12 weeks postoperatively. Union is defined as complete bridging callus in 3 out of 4 cortices (Figs. 5, 6), together with painless full weight bearing. Mean follow-up period was 11.5 months with a range of 6–24 months.

Statistical analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 20.0 for Windows (IBM SPSS Inc.). Data presentation was based on means and standard deviations (SD) for continuous or quantitative data. Meanwhile, categorical or qualitative was presented as frequencies and percentages.

Results

The follow-up time of the studied cohort ranged from 6 to 24 months with a mean of 11.5 ± 4.7 months. The average blood loss during the operative procedure was 565.6 ± 99.5 ml. Bone grafting was required in 10/16

(62.5%), while mosaicplasty was undertaken in 2/16 (12.5%). Two cases (12.5%) were treated for infection: one case (6.25%) showed signs of nonunion in postoperative X-rays and one case (6.25%) needed a second procedure (Table 2). Proper debridement was conducted to the cases that showed signs of infection. Re-grafting was performed to one patient at the 8th month with a complete union at 14 months' duration. We have no recorded DVT or pulmonary embolism in our cohort.

Outcome characteristics of the studied patients are listed in Table 3. The mean time of complete radiological union in the studied patients was 6.0 ± 3.5 months with a range of 3–14 months. We have not observed postoperative varus or valgus deformity in any patients in our cohort. The majority (68.75%) of the studied patients showed significant improvement in range of motion (90°–120°) during follow-up (Table 3). Eleven out of sixteen patients (68.75%) had well-to-excellent functional outcome. Poor outcome was reported in only two patients (12.50%).

Table 2 Operative characteristics of the studied patients ($n = 16$)

Variables	Studied population ($n = 16$)
Operative time (min)	
Mean ± SD	213.6 ± 25.8
Range	160–260
Blood loss (mm)	
Mean ± SD	565.6 ± 99.5
Range	400–750
Complications	
No	12 (75.0%)
Failure	1 (6.25%)
Infection	2 (12.50%)
Secondary procedure	1 (6.25%)
Follow-up (months)	
Mean ± SD	11.5 ± 4.7
Range	6–24
Management of complications	
No	12 (75.0%)
Revision	1 (6.25%)
Debridement	2 (12.50%)
Re-graft	1 (6.25%)

Table 3 Outcome characteristics of the studied patients ($n = 16$)

Variables	Studied population ($n = 16$)
Union	
Mean ± SD	6.0 ± 3.5
Range	3–14
Deformity	
Present	0 (0.0%)
Absent	16 (100.0%)
Range of motion	
<90°	1 (6.25%)
90°–120°	11 (68.75%)
>120°	4 (25.00%)
Mean ± SD	114.6 ± 21.8
Range	70–140
Functional outcome	
Poor	2 (12.50%)
Fair	3 (18.75%)
Good	7 (43.75%)
Excellent	4 (25.00%)

Discussion

In our study, sixteen patients with type C3 distal femoral fracture were treated using dual plating (medial and lateral) through extended anterior approach and bone grafting. In our experience, the anterior approach provides more anatomical reduction and rigid fixation. It exposes the anterior and lateral aspects of the femur and avoids unintended medial dissection.

The ORIF of complex C3 fractures is technically challenging [5, 13–16]. Less experienced surgeons tend to place a retractor medially because of difficulties with exposure and reduction while utilizing the traditional commonly used lateral approach. Double plating utilizing the medial parapatellar approach delivers superb visualization and permits controlled access to the distal femur while minimizing inadvertent stripping of the medial side. The ability to supplement a lateral plate with an anterior plate increases structural stability in the form of a 90–90 construct as this resists deformation in both sagittal and coronal planes. The standard fixation used for other types of distal femoral fracture is not optimum for anatomic articular surface reduction, and in the setting of medial comminution, there is a high prevalence of fixation loss and varus collapse [17]. Finally, the closeness of these fractures to the knee joint makes it more difficult to manage. As very distal fracture segments might show varus collapse due to the lack of stable fixation and subsequently require a supplemental fixation [17]. The anterior approach allows for increased reduction and application of fixation devices, allows visualization of anterior and lateral walls of the femur and prevents medial dissection. Additionally, both an anterior and a lateral plate can be placed at 90° to each other to deliver improved structural stability; the concept is somewhat analogous to fixation of the distal humerus.

Broadly speaking, the surgical options here are internal fixation or primary replacement. If the knee had been symptomatic, it may be more appropriate to perform primary arthroplasty. Because of the position of the fracture, this would be likely to involve a distal femoral replacement with a constrained articulation such as a rotating hinge. Thus, this decision should involve a surgeon with the necessary expertise as well as an analysis of the physiological capacity of the patient to withstand this procedure. However, this will be a major surgery with very few bailout options [2].

Muller et al. proposed the treatment of low condylar fractures having medial comminution and loss of medial cortex, with a lateral plate combined with a medial buttress plate and bone grafting [17]. To enhance fixation in these fractures with poor screw purchase, injection of cement into screw holes may be used [18]; however, extravasation into the intra-articular surface may occur and has been reported [19].

Traditional methods for treatment of AO/OTA type C fractures of the distal femur have utilized the lateral approach with soft tissue preservation. Several trials with minimally invasive plating techniques have been published (Table 4) but can incur greater operative times and are technically challenging [20–25]. Proper use of the lateral approach can be difficult and can result in more significant soft tissue dissection if not performed correctly. ORIF through lateral plating is associated with different challenges and pitfalls. The preference when plating the femur in fractures in the elderly is to use as long a plate as possible, spanning the whole femur, and to use minimally invasive techniques if appropriate. In this case, a small distal incision to allow the plate to be inserted will be needed. It is essential that this allows the iliotibial band to be divided as the plate must sit deep to this; if it is not deep to this layer, the patient will suffer from irritation and prominent metalwork.

When plating, it is also essential that the plate is orientated correctly to the joint on the anteroposterior projection.

Table 4 Summary of literature

References	Year	Cases#	Approach	Type of ORIF	Fracture type	Follow-up (month)	Union	Function	Complication
Sanders et al. [13]	1991	9	Anterior–medial	Dual	C3	26	100%	6 PT (90–100° flexion) 3PT (<90°)	Extension LAG 5° in all PTs
Ziran et al. [32]	2002	36	Anterior–lateral	Dual	C2 = 16 PT C3 = 19 PT	7	66.7%	ROM 5–100°	2 died 2 lost 3 poor reduction 5 MUA
Zhang et al. [33]	2012	12	Anterior–medial	Dual	C3	24	100%	33.3% Excellent 50% Good 0.08% Fair 0.08% Poor	No
Agrawal et al. [14]	2017	12	Swashbuckler approach	Single lateral plate	C3	12	100% 14.3 WK	ROM 120° 58.3% Excellent 25% Good 8% Fair	1 PT →Bone graft 3PT→ OA
Khalil et al. [5]	2012	12	Modified Olerud approach	Dual	C3	13.7	100%	16.7% Excellent 41% Good 25% Fair 16.7% Poor	16.7% ROM <90°
Fankhauser et al. [22]	2005	16	Lateral MIPO	LISS plate	8 PT →A 3 PT→B 5 PT→ C	23	100% 30 WK	6 Excellent 9 Fair 1 Poor	2 failed proximal fixation
Kohli et al. [16]	2016	27	Lateral	LCP	C2 C3	12	90% 20 WK	ROM 113° 59% Excellent	1 superficial infection 3 shortening and varus >7° 3 implant failure 1 fat embolism

The plate also sits at an inclined angle on the lateral femoral cortex matching the shape of the native femur; it is important to recognize this; otherwise, my distal screws will aim anteriorly and penetrate the patellofemoral joint. Proximally, it is essential that the plate sits along the mid-axis of the shaft and not too anterior or posterior, which is a common error in percutaneous plating. The number of screws and their configuration are also controversial—distally we prefer to use as many locked screws as possible in our construct, effectively filling the metaphysis with metal. Proximally, we prefer a near–far pattern of locked screws, with a total of at least five or six screws.

We report no varus deformities after the operation, and approximately 69% of them showed significant improvement in range of motion (90°–120°) during follow-up. Eleven out of sixteen patients had good-to-excellent functional outcome, and poor results were reported in only two patients.

Although favorable results have been reported using intramedullary nailing of distal femoral fractures [26], others have shown the intramedullary nail to be inferior to plating concerning mechanical properties such as stiffness [27]. Surgeons promoting the use of nail claim that rigid internal stabilization can yield to a high incidence of complications, including delayed union, implant failure and infection [28]. We have not seen this observation in our cohort reported in this study. Our study included participants with the mean age of 36 years. Supplemental bone grafting is frequently needed [29]. Furthermore, intramedullary nailing cannot be used for the more severe intra-articular fractures. Distal femoral nailing cannot secure these fractures due to distal fracture lines in accompanied with articular comminution and the requirement of screws to fix the fragments. Consequently, poor outcomes, failure of nailing and other surgical complications including instability and malreduction in the fragments were reported [17].

External fixators with minimal internal fixation have several problems in treating type C femur fractures. These include septic arthritis, pin site infection and osteomyelitis. Also, inadequate reduction, delayed union or nonunion with the requirement of grafting, stiffness and subsequently the need for manipulation under anesthesia have been reported [30, 31].

Likewise, Ziran et al. [32] assessed 19 patients with displaced AO-type C3 distal femoral fractures. The patients were treated with an anterior approach and double plating using similar protocol as ours. Reductions were near anatomic in all but three patients. They concluded that dual plating of the distal femur can be fixed using a single anterior approach. It is associated with minimal medial dissection while providing excellent exposure. Zhang et al. [33] obtained similar findings, as they investigated the clinical efficacy and feasibility of double plating fixation via anterior/middle approach in treating type C3 distal femoral fractures. They included twelve cases of type C3 distal femoral fractures; among them, there were eight males and four females with an average of 40 years (ranged 25–55 years). Nine cases injured in a motor car accident and three cases by falling from a height. After skin traction for 5–8 days, the surgery was performed by double plating fixation via anterior/middle approach and bone grafting was used as well.

Four cases got excellent results, six good, one fair and one poor.

Sanders et al. [13] evaluated nine patients with compound fracture of the distal femur and a deficient medial cortical buttress. Stable fixation was inadequate with the utilization of lateral plate alone. Intraoperatively, the authors noted the collapse of the distal fragment into varus angulation. Medial plate with a bone graft was needed for extra stabilization, and it was applied in all cases. The functional results revealed five cases with good outcomes and four with fair outcomes. In six patients, the knee flexion was ranged between 90° and 100°.

We report a mean of 11.5 ± 4.7 months follow-up, while the mean time of union was 6.0 ± 3.5 months with a range of 3–14 months. A similar observation had noted by Sanders et al. [13]. They reported that the average duration of follow-up was 26 months, and during follow-up, all the fractures had healed properly. Zhang et al. [33] reported that a 16- to 36-month (mean 24 months) follow-up with bone union was achieved from 18 to 24 weeks with an average of 21 weeks post-surgery. In our study, only one case (6.25%) showed signs of nonunion in post-operative X-rays. This finding might be due to the bone grafting and the biological fixation using dual plate with maintenance of periosteal blood flow as reported by Gwathmey et al. [17] and Lujan et al. [34].

A limitation of this study is the relatively short follow-up period in some of the cases. However, we plan to continue to follow up this cohort of patients. Another limitation is the relatively small number included in this study that is mainly because we have excluded multiple trauma patients that required multiple procedures. On the other side, we have no patients lost to follow-up, which could be a source of bias [35]. This is the first study reporting outcome in distal femoral fracture type C3 from the Middle East. Finally, operative indications and instructions should be strictly followed. The surgical technique must be rigorous, and the biomechanical qualities of these implants must be understood to prevent the development of major complications.

Conclusions

The surgical technique is the fundamental factor that affects the surgical outcome, and it is the only guarantee for obtaining good radiological and clinical results in distal femoral fractures. Dual plating fixation using anterior approach for type C3 distal femoral fractures is an efficient and safe method of management. It has several advantages such as precise exposure, easy manipulation, anatomical reduction and stable fixation.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest in relation to this paper.

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