Submuscular bridge plating in the treatment of length unstable femur fracture in adolescents

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Background
The most common fractures in teenagers that need hospitalization are femoral shaft fractures.
Aim
This study aims to evaluate the role of the submuscular bridging plate in the treatment of length unstable femur fracture as a safe and alternative option in cases where use of intramedullary nails and open reduction methods is debatable regarding healing and functional outcomes.
Patients and methods
Submuscular bridge plate for femur fracture was performed on 20 patients having length unstable femoral shaft fractures through a minimally invasive technique.
Results
There was a significant positive link between age and healing time, but no such relationship existed between healing time and patient sex, level, type of fracture, or injury mechanism. The patients' average age was 11 years (10–19 years). Overall, 12 patients were males and eight were females. There was no infection except for three cases of superficial infection. There was no significant swelling except in four cases; all patients restored full range of motion except four patients had limited knee flexion for a short period. No patient had a deformity greater than 10° in the frontal or sagittal planes, or a limb-length disparity greater than 1 cm. There has been no clinically obvious malrotation, late union, or nonunion.
Conclusion
Submuscular plating is a dependable method with excellent healing capacity and fixing mechanics. Submuscular plating is a surgical technique with a learning curve. It offers clear benefits over other operative procedures and is linked to minimization of complications.

Keywords:
adolescents, bridge plating, femur, submuscular, unstable

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Introduction

Femoral shaft fractures account for 1.4–1.7% of all fractures in children and adolescents [1]. Operative management is now preferred in older children and adolescents owing to the higher expense of hospitalization, risk of malalignment, and extended immobility brought on by conservative methods [2].

There are several different fixation techniques, including external fixation, open reduction, plate fixation, submuscular bridge plating, and intramedullary nailing with flexible or stiff nails [3]. Any surgical procedure aims to stabilize the fracture, protect the physis from harm, and preserve the femoral blood supply [4]. The major kind of management for children is the titanium elastic nail system. Stable midshaft stabilization of pediatric diaphyseal femur fractures with flexible intramedullary nails: a prospective analysis [5]. Titanium elastic nail system, however, may result in a worse-than-ideal outcome and more problems for fractures with proximal and distal fractures, spiral and comminuted fractures, and fractures in heavyweight (40–45 kg) patients [6]. Refracture, malunion, delayed union, pin tract infections, and ugly scars are some drawbacks of external fixation [7]. Interlocking intramedullary nails that enter through the piriformis fossa may cut off the blood supply to the femoral head, resulting in avascular necrosis. To solve this issue, a different intramedullary interlocking nail design was developed that uses the greater trochanter as an entrance site [8]. If the trochanteric physis is breached, there is a chance that the development of greater trochanter apophysis may be stopped, which might lead to coxa valga and heterotopic ossification [9].

The medullary canal must be sufficiently broad to accept the width of nail [10]. It is impossible to place intramedullary interlocking nails in smaller children because rigid nails are appropriate for shaft fractures with broader medullary canals. Due to the shorter length of nail-bone contact, intramedullary interlocking nails may not provide sufficient stability when used to treat fractures in the proximal and distal thirds [11,12].

Long incisions and delicate tissue dissection are necessary for the traditional open reduction and internal fixation with plate and screws [13]. It is more likely to become infected and heal more slowly [14]. Submuscular bridge plating method benefits from a minimally invasive surgical incision, effective soft tissue management, relative stability that allows for early range of motion, and excellent healing [15].

Submuscular bridge plating in adolescence age is a method for fixing length unstable fractures of femur shaft, which are defined as spiral, comminuted, or long oblique. According to AO pediatric comprehensive classification of long bone fractures [16], the fracture in our study should be classified as 32-D/5.1 and 32-D/5.2.

Patients and methods

This interventional prospective study was conducted on 20 patients from January 2021 to January 2022. Inclusion criteria were adolescent age 10–19 years, closed fracture, open fracture Gustilo type 1, isolated femoral fracture, polytrauma patient after stabilization of general condition, and length unstable femoral shaft fractures, which are comminuted, spiral, and oblique fracture patterns. Exclusion criteria were open fracture Gustilo type 2 and 3, pathological fracture, neurovascular injury, neuromuscular diseases, and metabolic bone disease. The study was approved by the institutional ethics committee in the Orthopedic Department of Orthopaedic Surgery, el Azhar, Cairo, Egypt.

Preoperative assessment

All patients enrolled in the study were informed of the type of the study, the type of procedure, and possible complications before obtaining a signed consent. Full detailed medical history was taken. General examination for chest, head, abdomen, and other injuries was done. Assessment of vascular status of affected limb was performed. Motor and sensory examinations were done to exclude associated nerve injury. Proper evaluation of soft tissue envelope regarding swelling, skin bullae, abrasions, and wounds was done. Radiological examination by anterior–posterior and lateral views of the femur showing knee and hip joints was performed. Routine preoperative laboratory investigations were done.

Operative procedure

Before the operation, assessment of the femoral shaft fracture and another associated fracture was done. A prophylactic broad-spectrum antibiotic (third-generation cephalosporin) was administrated.

Internal fixation was done within 5 days from admission for all patients. General or spinal anesthesia was used. All patients were placed in a supine position on the standard radiolucent table except one patient was placed in a supine position on the traction table due to difficulty in maintaining reduction by manual traction.

The C-arm was placed on the other side of the injured extremity and perpendicular to the patient to aid the technician with the orientation of the fracture to able to take radiographs in the antero–posterior and lateral views.

To enable the advancement and fixation of the plate, two incisions are made on the lateral side of the thigh. Usually beginning at the level of the distal femur physis and extending a few millimeters proximally, the distal incision is the first to be performed. The iliotibial band, which is divided in line with the incision, is subjected to sharp dissection all the way down.

Following that, the vastus lateralis is raised anteriorly for additional periosteal dissection. The trochanteric apophysis area marks the start of the proximal incision, which proceeds distally for 2–3 cm. Extraperiosteal dissection is made possible by a muscle-splitting approach.

A precontoured 4.5-mm nonlocked narrow dynamic compression plate was introduced submuscularly and epiperiosteally in a retrograde manner from distal to proximal, under fluoroscopic supervision; the proper plate length was chosen. and the plate was placed over the wounded thigh. To maximize the work area and lessen the load on the plate, a long plate with 10–16 holes was preferred.

Alignment was maintained by manual traction in all cases except one case in which the reduction was achieved and maintained using the traction table. Malrotation was minimized utilizing the C-arm intraoperatively to compare the profile of the lesser trochanter of the affected and unaffected sides and to evaluate radiographic marks of malrotation based on the cortical thickness and bone diameter.

K-wires are used to accomplish provisional fixation and are positioned at the proximal and distal ends of the plate. Antero–posterior and lateral images using fluoroscopy

Figure 1

Variables	Result			
	Excellent	Good	Fair	Poor
Malaligment				
Varus/valgus	5	5	10	> 10
Procuvatum/recurvatum	5	10	15	> 15
Internal rotation	5	10	15	> 15
External rotation	10	15	20	> 20
Shortening (in cm)	1	2	3	> 3
Range of motion (knee)				
Flexion	> 120	120	90	< 90
Extension deficit	5	10	15	> 15
Pain or swelling	None	Sporadic, minor	Significant	Severe

Thoresen scoring system.

were used. The plate was then reduced to the femur by inserting cortical screws into the proximal and distal ends of the plate. The maintenance of the reduction and the positioning of the plate and screws were confirmed by final fluoroscopic pictures. Fixation into six cortices on either side of the fracture was the goal.

Postoperative management and follow-up

Postoperative intravenous antibiotic in the form of third-generation cephalosporins (Ceftriaxone) was given to all patients starting from the day of surgery and continued for 72 h followed by an antibiotic taken orally for 1 week. Until the pain and edema reduced, anti-inflammatory and antiedematous drugs were maintained.

No postoperative immobilization was required. Patients began immediate hip and knee range-of-motion exercises. Partial weight bearing was allowed from 4 to 6 weeks postoperatively followed by a return to activity after the complete radiological union.

The patients often stayed in the hospital 3–5 days after surgery. For the first 4 weeks following discharge, it was suggested that all patients report any chest discomfort, significant edema in the affected limb for examination, and early detection and management of deep venous thrombosis, or pulmonary embolism, redness, or drainage from the incision right away to detect any early infection. Follow-up visits in the outpatient clinic were once weekly in the first 2 weeks for the checkup of the wound, changing the dressing, and removal of stitches after 2 weeks. The following visits were once monthly for 6 months for evaluation and documentation of the degree of fracture healing by radiographs and any possible complications. The end point of follow-up visits was decided for each patient after evaluation of complete radiological union, full weight bearing, and complete return to daily activities.

Outcome criteria

Patients were assessed clinically by evaluation of wound condition, swelling, range of motion, frontal and sagittal plane deformity, and leg-length discrepancy.

Table 1 Age, sex, affected side, mode of injury, level of fracture, and fracture pattern.

Age	Number of patients
10–12 years	7
12–15 years	9
15–19 years	4
Sex	
Male	Female
12	8
Affected side	
Right	8
Left	12
Mode of trauma	
RTA	6
Fall from height	12
Fall of Heavy object	2
Level of fracture	
Prox one-third Mid one-third junction	5
Mid one third	10
Mid one-third distal one-third junction	5
Pattern of fracture	
Spiral	15
Comminuted	1
Oblique	4

RTA, road traffic accident.

Antero–posterior and lateral views of plain radiography images were taken following surgery to evaluate the development of bone healing, and probable complete radiographic union was described as continuity of both cortices in two radiographic planes. Regarding functional outcome, patients were evaluated according to the Thoresen scoring system [17] (Figure 1).

Results

Data were collected, coded, revised, and entered into the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, Version 27.0, Released 2020. Armonk, NY: IBM Corp.). The age of the patient at the time of diagnosis ranged from 10 to 19 years. Most of the patients (45%) were between 12 and 15 years of age, with a mean±SD value of 11.00 ± 2.16 years. The patients included in the study were 12 males and eight females, with the male sex predominating with 60% of femur fractures. The left side (60%) was affected more commonly in our study. Mode of injury varied from road traffic accident, fall from height to fall of heavy object. Fall from height was the more common mode of injury (60%) in our study. In our study, middle one-third (50%) fractures were more common. The types of fracture in this study were 15 patients with spiral fracture type, four patients with oblique type, and one patient with spiral comminuted. Spiral (75%) was the most common pattern in our study (Table 1). The alignment of the fracture was assessed using the Thoresen grading method, which takes into account the fracture's valgus or varus, procurvatum or recurvatum, shortening, and rotational (internal or external) alignment. The anterior–posterior and lateral views of the radiography radiographs were used to determine this. During a physical examination, rotation was assessed clinically by looking at the patella and second toe in relation to the anterior superior spine on the same side. By measuring the length of the limb, shortening was calculated. The Thoresen scoring method also allowed us to evaluate clinically the patient's knee function in terms of deficits in flexion and extension, discomfort, and edema (Table 2). Tape measurement was performed for all patients 6 months postoperatively to assess limb length discrepancy (LLD), and there were no LLDs more than 10 mm either shortening or lengthening. There were two patients with shortening of the affected side by five and 6 mm correspondingly and three patients with lengthening of the affected side 5, 7, and 10 mm correspondingly, whereas there were 10 patients with no evidence of LLD (Table 3).

Table 2 Postoperative alignment and range of movement according to the Thoresen scoring system

Valgus/varus	
Excellent (%)	20 (100)
Good	0
Fair	0
Poor	0
Procurvatum/recurvatum	
Excellent (%)	20 (100)
Good	0
Fair	0
Poor	0
Internal rotation	
Excellent (%)	20 (100)
Good	0
Fair	0
Poor	0
External rotation	
Excellent (%)	20 (100)
Good	0
Fair	0
Poor	0
Shortening	
Excellent (%)	20 (100)
Good	0
Fair	0
Poor	0
Flexion	
Excellent (%)	16 (80)
Good	0
Fair	0
Poor (%)	4 (20)
Extension deficit	
Excellent (%)	20 (100)
Good	0
Fair	0
Poor	0
Pain or swelling	
Excellent (%)	16 (100)
Good	0
Fair	0
Poor	4 (20)

Table 3 Limb length discrepancy

	Number of cases	Percentage
Limb length discrepancy		
10 mm overgrowth	1	5
7 mm overgrowth	1	5
6 mm overgrowth	1	5
5 mm overgrowth	1	5
3 mm overgrowth	1	5
No LLD	15	75

LLD, Limb length discrepancy

Figure 2

Preoperative radiography.

Figure 3

Skin incisions.

Figure 4

Immediate postoperative radiography.

Case presentation

Case 1

A 12-year-old male patient presented with painful right thigh and inability to walk after falling from height. Antero–posterior and lateral radiography of the right femur showed spiral fracture of the proximal third. The patient was treated by submuscular bridge plating. The patient was followed up regularly weeks at the outpatient clinic both clinically and radiologically (Figs 2–5).

Case 2

An 18-year-old male patient presented with a painful left thigh and inability to walk after road traffic

Figure 5

Fracture union at 12 weeks.

accident. Antero–posterior and lateral radiography of the left femur showed spiral fracture of shaft. The patient was treated by submuscular plating. The patient was followed up regularly at the outpatient clinic both clinically and radiologically (Figs 6–8).

Discussion

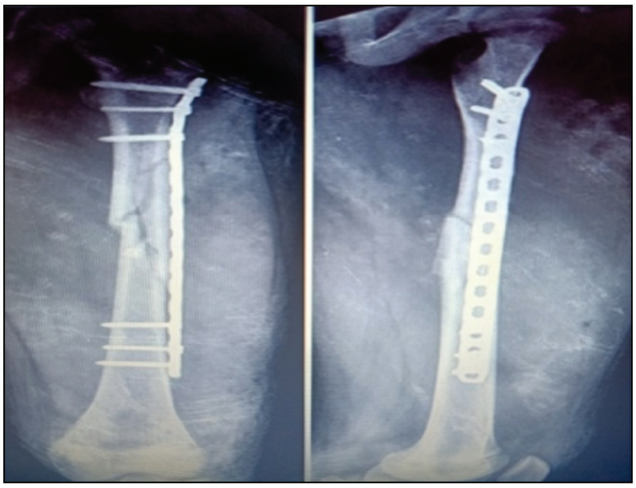
The surgical management of length-instable femur fractures is still evolving. In the past, children under the age of 6 years were treated for these fractures with skeletal traction and delayed hip spica casting [18]. This method has drawbacks, such as an extended hospital stay and the patient's ongoing dependency on a caretaker. Patients can be moved right away and spend less time in the hospital with rapid surgical treatment for length unstable femur fractures. Open femoral plating, intramedullary fixation, external fixation, and submuscular plating are common surgical procedures [19].

It is debatable whether retrograde, flexible intramedullary fixation for length unstable femur fractures is beneficial for patients under the age of 11 years who weigh less than 50 kg. Retrograde elastic femoral nails may enable the fracture to shorten by rotation or compression in length unstable femur fractures [20].

Figure 6

Preoperative radiography.

Figure 7



Immediate postoperative radiography.

Strong lateral entry femoral nails are recommended whenever the greater trochanteric apophysis starts to form in an appositional growth pattern, usually after the age of 8 years. The femoral canal's constriction at this young age makes therapy challenging. Defects in proximal femoral development and osteonecrosis of the femoral head are drawbacks of antegrade intramedullary nailing [21].

For the treatment of adolescent femur fractures, submuscular bridge plating has developed into a useful choice. Long plates have a longer working length, reducing pressure on the structure and the pull-out force on the screws. Additionally, employing a minimally invasive insertion approach prevents damage to the soft tissues around the fracture site and encourages quick union [15].

Figure 8

Showing fracture union.

As the femur will be reduced to the contour of the plate with screw placement, plate precontouring as closely as possible to the anatomic plate structure is a crucial issue. Plate precontouring can be accomplished by molding the plate to the contour of the un-fractured femur based on preoperative radiography or intraoperatively using fluoroscopy after reduction of the fracture [22].

Eidelman and colleagues assessed the efficacy of submuscular plating, which was carried out on 11 patients with a mean age of 10.8 years (range, 8–16 years). All fractures were successfully sewn together. There were no significant difficulties. They conclude that submuscular plating with precontoured plates is an efficient, reliable, and secure method for treating adolescent femoral fractures [18].

Elgohary evaluated the outcomes of submuscular plating employing locking plates to bridge the fracture site in 28 fractures in 26 children with closed fractures of the shaft of the femur following biological repair of the fracture. No patient exhibited a malformation of the frontal or sagittal planes. No infection, nonunion, delayed union, or clinically obvious malrotation existed. They claimed that biological fixation of femoral shaft fractures in children using locking plates is an effective fixation technique with great healing potential and straightforward fixing mechanics [23].

The American Academy of Orthopedic Surgeons protocol is a highly helpful guide for treating pediatric femur fractures. The type of the fracture, the location of the affected part of bone, the presence or lack of instability, body weight, concomitant pathologies, and the mode of injury are all critical considerations when selecting the right treatment method in this group, in addition to age. Instability in length of a fracture happens when it has a spiral, oblique, or comminuted shape [24].

Li *et al.* [25] compared the fixation of subtrochanteric femur fractures with flexible nails versus open plating and submuscular plating and found an increased risk of complications, especially in unstable fractures, with nailing fixation having four times as many complications as plating fixation and less excellent and satisfactory results. Therefore, we do not advise using flexible nailing for fractures that are unstable or comminuted in patients who are older than 12 years old or who weigh more than 50 kg. In these cases, other alternatives can be considered, including external fixators, fixation with submuscular bridge plate, and rigid intramedullary nailing with trochanteric insertion [7]. External fixation should be reserved for the treatment of open or severely comminuted femur fractures, owing to their increased risk of loss of reduction, vicious consolidation, pseudoarthrosis, and refracture, in addition to the common occurrence of nail tract infection [26].

Another treatment option for patients older than 9 years is fracture stabilization with locked intramedullary nailing, if the medullary canal is greater than 8 mm in its narrowest portion [10]. Complications described by Gordon *et al.* [27] with nails inserted through the piriformis fossa included abnormal proximal femur growth, avascular necrosis of the femoral head, and limb-length discrepancy.

Very proximal and distal fractures are difficult to treat with hard nails, which also require a relatively large medullar canal to accommodate them [14]. Traditional compression plating necessitates a lengthy incision and is linked to increased soft tissue damage, an increased risk of infection, and an increased likelihood of healing delay. The American Academy of Orthopedic Surgeons recommends submuscular bridging plates as a therapy option for children from the ages of 11 years to skeletal maturity [24].

In comparison to alternative modalities of therapy (casting, external fixation, or flexible nailing), the use of a submuscular bridging plate for complicated fractures consistently results in improved alignment and leg length. None of our patients who needed a shoe lift had clinically significant malrotation, or shortening. In our research and others, the relative stability produced by biologic bridge plating fixation has been acceptable, consistent, and trustworthy. Numerous studies have demonstrated that flexible nails are linked with a significant risk of malunion for comminuted and length unstable fractures.

Sink and colleagues observed that age, weight, or the location of the fracture in the patient had no effect on the outcomes with the submuscular bridging plate. This technique does not have a weight limit [28].

A negative outcome was shown in heavier patients treated with flexible nails, and Moroz and colleagues concluded that patients weighing more than 49 kg were five times more likely to experience a poor outcome. There is no age restriction as the submuscular bridging plate is unaffected by the medullary canal's size [29].

The indications for submuscular plate removal by Hoffmann and colleagues are well-healed fractures without complete osseous overgrowth of the implant. The mean time from plate insertion to plate removal was 8 months (range, 4–26.6 months) [30].

Our study assessed the clinical and radiological outcomes of submuscular plating in 20 patients with closed fractures through two incisions in the lateral aspect of the thigh: one distal and the other proximal without touching the fracture site. In our technique, precontouring of the plate helps in the reduction of the fracture. The mean age of patients was 11 years; all patients had radiological union within a mean time of 8.2 weeks (6–12 weeks).

There was no frontal plane deformity of more than 5° and sagittal plane deformity of more than 10°. There was no delayed union, nonunion, infection, or clinically evident malrotation. There was a significant positive correlation between the age and the time to healing, and there was no significant correlation between time to healing and patient sex, fracture level, fracture type, or mechanism of injury.

Submuscular bridge plate in pediatric and adolescent femur fractures is a reliable method of fixation with excellent healing potential with minimal complications in children aged 9–19 years. However, there was a limitation in the study, as we did not deal with open fractures, metabolic bone disease and pathological fractures, and further studies analyzing long-term follow-up are needed to support these findings.

Conclusion

Adolescent femur fractures can be effectively fixed with the submuscular bridging plate, a surgical technique with a learning curve and has advantages of being a minimally invasive technique with minimal soft tissue dissection and an effective biological method for secondary bone healing without affection of femoral head blood supply or epiphyseal plate growth arrest. It also gives a clear and suitable solution for argument about ideal method of femoral shaft fracture fixation in the critical age of adolescence, where there is a conflict between ordinary open reduction and internal fixation by compression plate, rigid intramedullary nails, elastic intramedullary nails, and external fixator.

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Conflicts of interest

There are no conflicts of interest.

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