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Original article

Submuscular bridge plating for pediatric femur fractures

Waleed Said Abdalkhalik [1], Osama Khalaf Yousef [2], Emad Gaber Elbana[1] and Ayman Abdelbaset Abdelsamad [1]

[1] *Orthopedics department, Faculty of Medicine, Beni-Suef University, Egypt*

[2] *Orthopedics department, Fayoum insurance hospital, Fayoum, Egypt*

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Corresponding Author:

Osama Khalaf Yousef

osa.kh.y@gmail.com

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Abstract

Background: Pediatric femur shaft fractures account for 1.4%–1.7% of all pediatric fractures and have an estimated annual rate of 19:100,000. Road traffic accidents and fall from height are the most common cause of femur shaft fractures in pediatric group. The method used for surgical treatment of pediatric femoral shaft fracture is still controversial with multiple options available and no clear consensus on the preferred modality of management. The goal of this study is to evaluate both functional and radiological outcomes of fixation of pediatric femur fractures with submuscular bridging plate in the age group between 6 to 12 years. **Patient and method:** 60 children with femoral shaft fractures were treated by submuscular bridging plate, with evaluation of this type of fixation regarding time to union and postoperative complication (limitation of knee motion, loss of reduction, delayed or non-union and limb length discrepancy) **Results:** Submascular bridging plate in pediatric femur fractures is a reliable method of fixation with excellent healing potential and minimal amount of complications. **Conclusion:** Submascular bridging plate in pediatric femur fractures is a reliable method of fixation with excellent healing potential and minimal amount of complications. It can be used in both length stable and unstable fractures regardless the patient's weight. It has advantages over the other methods of fixation. However it requires a high learning curve, more intraoperative time and more intraoperative exposure to fluoroscopy.

1. Introduction:

Pediatric femur shaft fractures account for 1.4%–1.7% of all pediatric fractures and have an estimated annual rate of 19:100,000.They are the most common pediatric fractures necessitating hospitalization and are associated with prolonged hospital stay, prolonged immobilization and impose a significant burden on the healthcare system as well as caregivers. They affect mainly preschool children and adolescents with twice as many boys as girls. In younger children, femur fractures result from low-energy trauma, such as same-level falls, whereas in adolescents, they occur mostly due to high-energy trauma [1].

The most common cause of femur shaft fractures in children is fall from height and road traffic accidents. However, it has been observed that up to 80% of femur shaft fractures occurring in children before walking age are due to non-accidental trauma [2].

Treatment of pediatric femoral fractures has been evolving from non-operative modalities to operative intervention, especially in older children. Different methods of fixation include flexible intramedullary nailing, modified locked intramedullary nailing, external fixation, open compression plating, and submuscular bridge plating. Treatment of complex pediatric femur diaphyseal fractures is difficult by conventional methods. External fixation can lead to malalignment and refractures, casting is difficult for polytrauma patients and larger children, elastic nails do not provide adequate stability to unstable fractures and metaphyseal areas, and lateral trochanteric entry rigid nails are unsuitable for very proximal and distal fragments and are ideal for older children for the want of larger medullary canal. Submuscular bridge plating has emerged as a viable alternative procedure [3].

Submuscular bridge plating has evolved into an effective treatment option for the management of pediatric femur fractures. Long plates have an increased working length, which leads to decreased strain on the construct and less pull out force on the screws. In addition, using a minimally invasive insertion technique avoids disruption of the soft tissues around the fracture site and promoting rapid union [4].

2. Patients and Methods:

This is a cohort prospective study performed in Beni-Suef University hospital after permission of ethical comity of the University (Approval No: FMBSUREC/08032020/ Yousef) from February 2020 till February 2021 involving 60 patients, verbal consents were obtained from the parents. This study included 60 patients with femoral shaft fractures between 6 and 12 years of age. Patients with open fractures (Gustilo-Anderson type II and III), pathological fractures or preexisting femur abnormalities were excluded.

A detailed history was taken, including patient's complaint, time and mode of trauma, pain, time passed after present fracture and history of any other associated injuries or underlying medical disease.

Inspection of the soft tissue for skin integrity, swelling, abrasions, skin bullae, contusions, ecchymosis, and any open wound was addressed according to its extent and size.

Complete physical examination of the patients was carried out for any deformity, swelling, shortening, tenderness, abnormal mobility, and crepitus to reach the diagnosis and rule out any other associated injury.

Neurovascular examination included assessment of the popliteal, posterior tibial and dorsalis pedis pulsations. Movements of ankle and toes were assessed together with sensation around the foot.

Radiological evaluation: Plain X- ray: each patient had the standard X-ray: antero-posterior (AP) and lateral views of the whole femur, including the hip and the knee joints Fig. (1), each view was assessed for: fracture location and morphology. The fractures were classified according to AO comprehensive classification system.

Preoperative laboratory investigations included: CBC, PT, PC, INR, SGOT, SGPT, Serum Urea and Creatinine.

All patients were admitted with skin traction on Thomas splint and in the inpatient ward received medical treatment and the duration between injury and operation was recorded for each patient.

Each patient underwent the scheduled surgical procedure according to general condition and associated injuries, but all of them were operated on within the first week of the injury.

Fig. (1): pre-operative x-rays Ap and Lat. views showing long oblique femoral shaft fracture.

Surgical technique and implants: While patient was placed in a supine position a 4.5-mm plate was layed over the injured thigh and fluoroscopy was used to determine the appropriate length for this plate. Then anatomical pre-contouring of the plate was done as needed.

A lateral, longitudinal skin incision of 3 cm at the distal part of the femur was made. Sharp dissection was carried down to the iliotibial band, which was split in-line with the incision. The vastus lateralis was elevated extraperiosteally from the femur and extraperiosteal dissection was performed.

The proximal skin incision was about 3m and sharp dissection was carried down to the iliotibial band which was split then the vastus lateralis muscle was split to allow extra periosteal dissection.

A precontoured 4.5-mm plate was introduced sub muscularly and epiperiosteally in retrograde manner from distal to proximal (Fig. 2-a), alignment was maintained by manual traction and manipulation (Fig. 2-b).

The plate position was adjusted using fluoroscopy. Fracture reduction was obtained using manual traction and was confirmed by antero-posterior and lateral views by fluoroscopy and the plate was then secured temporarily with K-wires (Kirschner wires) (Fig. 3) through the most proximal and distal holes

Screws were then placed in the proximal and distal ends of the plate to reduce the plate to the femur (Fig. 2-d). Final fluoroscopic images were taken to confirm the maintenance of the reduction and the placement of the plate and screws. Suturing of the wounds in layers and sterile dressing were then applied.

Postoperative radiology: AP and lateral views X-rays were taken in the 1st postoperative day.

Fig. (2): Clinical pictures for surgical steps of reduction and provisional fixation of the plate.

Fig. (3): Intraoperative fluoroscopic image showing fracture reduction and provisional fixation of the plate using K-wires.

Postoperative medications including: parenteral anti-biotics were continued for 2 days postoperatively then oral antibiotics were continued for an additional week, Anti-inflammatory, and anti-oedematous medications were continued until pain and edema subsided.

Static quadriceps exercise and progressive knee joint flexion were started as early as postoperative day 1. Partial-weight-bearing exercises with the help of crutches were allowed at 6 weeks postoperatively, and then the patient was permitted full weight bearing at 8 weeks. Both active and passive knee motion exercises begin 1 day after the surgery.

The patients are followed up at two weeks, six weeks, three month and final follow up visit at 6 months. Both clinical and radiological imaging was done for assessment of fracture healing. Patients were evaluated regarding operative time, exposure to c-arm fluoroscopy, intra-operative blood loss, time for radiological union by standard femur x-rays; AP and lateral views, time to return to full weight bearing, range of knee motion and postoperative complications including; infection, residual deformities in coronal and sagittal planes, limb length discrepancy, delayed union and nonunion.

Fig. (4): 3 months follow up x-rays showing complete fracture union of the femur fixed by submuscular plate.

Fig. (5): Clinical pictures showing range of motion at 3 months follow up.

3. Results:

The current study was conducted at Beni-Suef university hospital within 1 year from February 2020, the study included 60 patients.

Table (1): Operation and exposure to c-arm fluoroscopy time

	Min	Max
Operative time (m)	45	120
C-arm time (s)	45	120

Table (2): post-operative complications

Complications	No	%
Rotational deformity	0	0%
Angular deformity	0	0%
Limb length discrepancy	1	1.7%
Limited knee range of motion	2	1.7%
Delayed or nonunion	1	0%
Surgical site infection	1	1.7%

Table (3): Radiological union and time to full weight bearing

	Min	Max	Mean
Radiological union in weeks	6	12	7.30
Full weight bearing in weeks	7	13	9

All patients assessed at follow-up, At the 12th postoperative week all patient were united and achieved full weight bearing with no significant complications, no patients had clinically evident rotational or angular deformity, all patients achieved full range of motion except for one patient which had a limited knee flexion of 10 degrees, only one patient had limb length discrepancy of 1 cm, and 1 patient had surgical site infection which resolved by daily dressing and oral antibiotics.

4. Discussion:

Management of pediatric femur fractures has evolved significantly over the last 50 years. Non-operative treatment with traction and immobilization was previously the mainstay of treatment but due to the morbidity associated with prolonged immobilization and the development of fixation devices geared toward treatment of pediatric fractures, operative treatment is now more prevalent but is still age-dependent [5]. The method used for surgical treatment of pediatric femoral shaft fracture is still controversial with multiple options available and no clear consensus on the preferred modality of management. Surgical options are external fixation, plating (conventional and submuscular bridge plating) and intramedullary nails which can be by flexible nails (titanium nail, Enders nail) or rigid nails [2].

The main goal of our study was to evaluate the functional and radiological outcomes of submuscular bridge plate for fixation of pediatric femoral fractures.

Our study included 60 patients, 21 female and 39 male. The mean age at the time of intervention was 9.35 years (range from 6 to 12 years). Du Toit J et al. 2020 [6] in a study reviewed the Short-term outcomes of submuscular bridge plating of length-unstable paediatric femoral shaft fractures in 29 children 20 males (69%), and 9 (31%) with a mean age of 9 years (ranges 7-11), Valenza W et al. 2019 [7] in a study reviewed the results of submuscular bridge plate in unstable femur fracture in 13 child, 1 female and 12 males with a mean age of 10.2 years (range, 7-13), Sutphen SA et al. 2016 [8] in a study of 196 children 35 of them were treated by submuscular plating, 8 females and 27 males with a mean age of 11.9 (range, 8-17 years), Samora WP et al. 2013 [9] in a study reviewed the result of submuscular bridge plating for length-unstable pediatric femur fracture in 32 children with 33 femur fractures, 7 females and 25 males with a mean age of 7.9 years.

In our study we had 36 patients (60%) with length unstable fracture patterns (6 patients (10%) with comminuted fracture, 15 patients (25%) with long oblique fracture and 15 patients (25%) was spiral fracture) and 24 patients (40%) with stable fracture patterns (15 patients (25%) with transverse fracture 9 patients (15%) with short oblique fracture). The fracture was located in the middle 1/3 in 36 cases (60%), proximal 1/3 in 15 cases (25%) and the fracture was located in the distal 1/3 in 9 case (15%). Du Toit J et al. 2020 [6] had 27 patients (93%) with length unstable diaphyseal fracture patterns and 2 patients (7%) with length stable diaphyseal fracture Patterns, Valenza W et al. 2019 [7] had 13 patients (100%) with length unstable fracture patterns, 6 fractures involved the proximal 1/3, 4 involved the middle 1/3 and 3 involved the distal 1/3, Sutphen SA et al. 2016 [8] had 105 patients (53%) with length unstable fractures and 93 patients (47%) with length stable fracture patterns, Samora WP et al. 2013 [9] had 27 patients (82%) with length unstable fracture patterns and 6 patients (18%) with length stable fracture patterns, fracture was located in the proximal 1/3 in 12 cases, middle 1/3 in 18 cases and distal 1/3 in 3 cases.

In our study we had no intraoperative complications, the mean operative time was 65.25 minutes (range from 45 m to 120 m), the mean C-arm fluoroscopy time was 67.50 seconds (range from 45 to 120 s) and the mean estimated blood loss was 56.50 (ranges from 30 to 100 cc). Du Toit J et al. 2020 [6] reported no intraoperative complications and had a mean operating time of 66±15 minutes, the mean C-arm fluoroscopy time was 88±28 seconds (range 23–138) and the mean estimated blood loss was 121±83 ml (range 20–400). Sutphen SA et al. 2016 [8] reported No intraoperative complications and had a mean C-arm fluoroscopy time of 85 seconds (range, 8-197 sec). Samora WP et al. 2013 [9] reported no intraoperative complications and the average C-arm fluoroscopy time was 69 seconds (range, 10 to 141 sec).

In our study the mean time of returning to full weight bearing was 9 weeks (7-13 weeks) and the mean time for radiological union in weeks was 7.30 weeks (6-12 weeks). Du Toit J et al. 2020 [6] had all their patient fractures were fully united by their 3rd month post-surgery, Valenza W et al. 2019 [7] had their patients permitted 10% of weight-bearing in the immediate postoperative period, followed by progressive weight-bearing after the 6th week until full weight-bearing. All fractures were consolidated at the 12th week, Sutphen SA et al. 2016 [8] submuscular plating group mean time to return to full weight bearing was 7 weeks and the mean time for radiological union was 6 weeks. Samora WP et al. 2013 [9] Mean time for full weight bearing was 8.1 weeks (range, 3 to 17.6 wk), All patients were radiologically healed by their 12-week.

In our study 1 patient (1.7%) had surgical site infection which resolved by daily dressing and oral antibiotics, 59 patients (98.3%) had full knee range of motion by their 24 weeks visit and only one patient (1.7%) had a limited knee flexion of 15 degrees (1.7%). Du Toit J et al. 2020 [6] reported no patients with infection and all their patients achieved full knee range of motion by their 24 weeks visit. Sutphen SA et al. 2016 [8] had no patients with surgical site infection, Samora WP et al. 2013 [9] reported no cases with infection and all their patients achieved full knee range of motion by their last follow up visit.

In our study there were no clinically evident residual rotational or angular deformities at

24 weeks postoperatively, no patients with delayed union or non-union and only 1 patient (1.7%) had significant limb length discrepancy of 1 cm which was not clinically evident while 59 patients (98.3%) had no significant limb length discrepancy by the 24 weeks visit. Du Toit J et al. 2020 [6] reported that 1 patient (3.5%) had a rotational deformity of 25 degrees of internal rotation but none of their patients had significant limb length discrepancy, delayed union or nonunion. Valenza W et al. 2019 [7] reported no case of substantial malalignment, length inequality requiring correction, delayed union or nonunion. Sutphen SA et al. 2016 [8] reported that out of his submuscular group 4 patients (11.8%) with malunion, 1 patient (1.9%) with significant limb length discrepancy at the 12 weeks follow up, no patients with delayed union or nonunion. Samora WP et al. 2013 [9] reported no cases with anglular deformities, limb length discrepancy, delayed union or nonunion.

Abbott MD et al. 2010 [10] in comparative study of 79 patients between Submuscular and Open Plating of Pediatric femur fractures; his open plating group had a mean age of (7.9 ±3.5 Years), they had an intraoperative time of (114 ± 54 Minutes) and estimated blood loss of (140±98 CC), 1 patient had postoperative infection. In our study we had a mean operative time of 65.25 minutes (range from 45 m to 120 m, a mean estimated blood loss of 56.50 (ranges from 30 to 100 cc), and 1 patient with postoperative surgical site infection.

Kapil Mani KC, et al. 2015 [11] in a study of 28 patients with a mean age of 8.14 years (range 5-13) to evaluate the effectiveness of elastic intramedullary nail in pediatric femur fracture had 5 cases (17.58%) with angular deformities, the mean time for radiological union was 9.57 weeks (range 6-14 weeks), all their patient recovered full knee range of motion by their last visit but there were 6 cases (21%) who developed bursa over the nail entry site because of friction between the tip of the nail and the skin. In our study we had no cases with angular deformities, the mean radiological union for our patients 7.30 weeks (6-12 weeks) and all our patients recovered full knee range of motion by their 24 weeks visit.

Kirmani TT et al. 2020 [12] in a study of 45 patients with mean age of 10.2 years (range 6-12) to evaluate the results of flexible intra medullary nail in pediatric femur fractures had; their patients achieving radiological union and full weight bearing at an average of 9 weeks (range of 7-22 weeks), one patient (2.2%) with deep infection which resulted in deep infection and knee stiffness, 2 patients with superficial infection (4.4%), 5 patients (11.1%) with skin irritation and bursa formation, 2 patients (4.4%) with angular deformities and 1 patient (2.2%) with rotational deformity but they were not clinically evident. In our study our patient achieved full weight bearing at a mean of 9 weeks (7-13 weeks) and the mean time for radiological union in weeks was 7.30 weeks (6-12 weeks). We had no patients with deep infection or knee stiffness, no patients with clinically evident rotational or angular deformities and only one patient with superficial surgical site infection.

5. Conclusion:

Submuscular bridging plate in pediatric femur fractures is a reliable method of fixation with excellent healing potential and minimal amount of complications. It can be used in both length stable and unstable fractures regardless the patient's weight. It has advantages over the other methods of fixation. However it requires a high learning curve, more intraoperative time and more intraoperative exposure to fluoroscopy.

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