

Locking plate fixation in pediatric femur fracture: evaluation of the outcomes in our experience

Raffaele Vitiello^{1,2}, Marco Lillo^{1,2}, Fabrizio Donati³, Giulia Masci^{1,2}, Giovanni Noia^{1,2}, Vincenzo De Santis^{1,2}, Giulio Maccauro^{1,2}

¹Fondazione Policlinico Universitario A. Gemelli IRCCS, Roma, Italia; ²Università Cattolica del Sacro Cuore, Roma; ³Reperto di Ortopedia, Dipartimento Chirurgico, Ospedale Pediatrico Bambino Gesù-Palidoro, Roma

Summary. *Background and Aim:* Femoral shaft fracture is a common traumatic musculoskeletal injuries in pediatric population. The treatment of diaphyseal femoral fractures depends on age patient and pattern fracture. We present our record about the use of locking plate fixation and their outcomes. *Method:* We conduct a retrospective analysis in 22 patients, surgically treated for 26 diaphyseal femur fracture between 2008 and 2013. The mean age was 13 years. All the patients underwent a clinical and radiological follow-up for two years. We recorded time to weight bearing, time to union, complication (malalignment, dysmetria, infection), time to resumption to sport, plate removal, parents' satisfaction. *Results:* All the patients had a minimal clinical e radiological follow-up of 24 months. The average fracture healing time was of 7.4 weeks. All the patients had a full hip and knee range of movements. Fifteen patients developed minor malalignment (varovalgus or procurvatum femur) without clinical effects. No cases of infections. The mean time to a full weight bearing was 12 weeks and the return to sportive activity was 24 weeks. Four patients required a plate and screws removal. The average result of parents' satisfaction was 8/10. *Conclusions:* Locking plate fixation is to be considered a successful way of treatment for pediatric femur fractures, especially in patients older than 6 years, head-injured or in the treatment of polytrauma. The anatomic and functional outcomes are comparable to those of other fixation techniques for this kind of fracture. (www.actabiomedica.it)

Key words: pediatric fracture, femur, locking plate, malalignment

Introduction

Femur fractures are frequent in the pediatric and adolescent population. Femoral shaft fracture is one of the most common traumatic musculoskeletal injuries requiring hospitalization in young patients (1).

The peak of incidence occurs among 12 years old, at a younger age in the female and older age in the male. There is a male-to-female incidence ratio of 1.5. The most common mechanism of this type of injury was falling and abuse in the younger patients and motor/bicycle accidents in the older ones (2-4).

Among the treatments of fractures of the pediatric femur, we include surgical and non-surgical

treatments. Among the non-surgical treatments, we mention the use of traction and Spica casting. These treatments are reserved for patients with fractures with shortening less than 2 cm and under 5 years of age (5,6). These treatments show good clinical and radiological results at mid-long-term and represent the gold standard in this kind of pediatric population (7). These treatments, however, are not indicated in particular conditions such as: polytrauma, head injury, unstable fracture, shortening more than 2 cm or non-reducible fracture (8).

As the most frequent pathological mechanism in adolescent patients is a result of high-energy trauma, non-surgical treatments are often contraindicated.

Among the surgical treatments, the most frequently used are external fixation, intramedullary nailing with rigid or flexible nail and plate fixation (9).

In the correct indication, plate fixation offers several advantages: excellent stability, fully early motion, allows to manage proximal and distal fractures, and does not need a cast in post-operative periods. Moreover, this technique could be used in fragile adolescents, such as adolescents with polytrauma or in case of severe head injury (10, 11).

The purpose of our study is to present our report in the use of plate fixation in the diaphyseal femoral fractures in adolescences.

Materials and Methods

We conducted a retrospective analysis in 22 patients, surgically treated for 26 diaphyseal femur fracture in our center between 2008 and 2013. The average age of surgery was 13 years old (range: 8-16 years).

The inclusion criteria were: diaphyseal femur fracture, age under 18 years old.

The exclusion criteria were: open fracture.

All the baseline characteristics were obtained from the patient's recovery schedule. Clinical charts were reviewed to record follow-up data such as time to weight bearing, time to union, complication, time to resumption to sport and plate removal.

The radiographic review included a review of the initial fracture radiograph to record fracture

location and pattern (AO pediatrics classification). We also included post-operative radiographs and later check-ups to judge the bone healing.

At one year's follow-up, all the patients underwent a weight-bearing lower limbs radiography to analyze the lower limb axis, varo-valgus and rotation defect, asymmetry and state of plate and screws.

Surgical procedure

Surgery was performed under general anesthesia with the patient in supine position on the operating table. An incision of different length, according to the specific fracture pattern, was made along an imaginary line between the greater trochanter and the lat-

eral epicondyle. The fascia lata was incised and split parallel to skin incision, the vastus lateralis was split, elevated from the intermuscular septum and retracted anteromedially. The femoral shaft was then extraperiosteally exposed. The fracture was provisionally reduced by manual traction or bone reduction forceps. Particular care should be taken in order to restore rotational alignment and length. Definitive fixation was performed with a pre-contoured LC-DC plate with 3 screws proximal and 3 screws distal to the fracture site. An X-ray check was required at the end of the procedure. Patients were clinically and radiologically followed up at week 1 and week 4 after surgery. Patients were mobilized without weight-bearing until the 4th-week X-ray follow-up. A progressive to full weight-bearing was allowed from 6th to 9th week after surgery according to fracture type, radiographic results and associated injuries.

Result

We enrolled 22 patients, 6 female and 16 males, affected by 26 femoral shaft fractures. The right femur was involved in 18 cases and there was 4 bilateral femoral fracture. The average age was 13 years old (range: 8-16 years). The most frequent injury mechanism was falls and vehicle accidents. All patients were admitted to our emergency care department with a diagnosis of "polytrauma". Three patients had spleen lesions, one patient had a liver lesions; all these injuries did not require surgery. Ten patients had a mild-to-severe head trauma. Three patients were affected by epilepsy and developed the fracture following an epileptic attack. Two patients had a previous femur fracture treated by TENs reduction but developed a new fracture (Fig. 1). One patient was affected by myelomeningocele and bone dysplasia and developed a spontaneous fracture; this patient had never walked, even before the fracture.

According to AO pediatrics classifications were treated 12 type 32.D/4.1, 4 type 32.D/4.2, 7 type 32.D/5.1, 3 type 32.D/5.2. Four patients were initially treated with external fixation than converted to plate fixation after 7 days and clinical stabilization.

All the patients had a minimum follow-up, clinical and radiological, of 5 years.

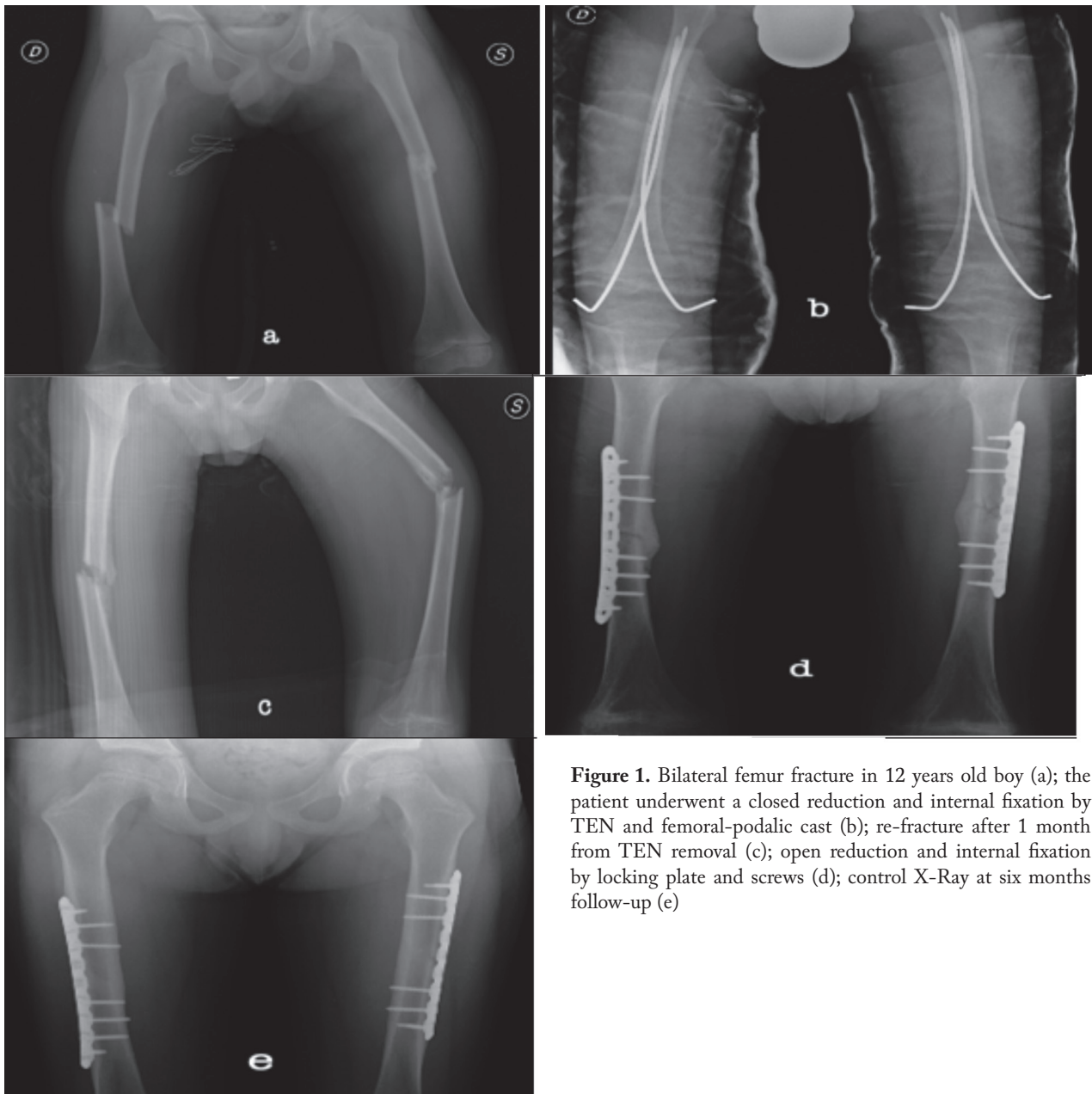


Figure 1. Bilateral femur fracture in 12 years old boy (a); the patient underwent a closed reduction and internal fixation by TEN and femoral-podalic cast (b); re-fracture after 1 month from TEN removal (c); open reduction and internal fixation by locking plate and screws (d); control X-Ray at six months follow-up (e)

At the last follow-up, excluded the myelomenin-gocele syndromic patient, all the patients had a full hip and knee range of movements. Two patients had a lengthening below 2 cm, three patients had a hypometria below 2 cm, only one patient had a lengthening higher than 2 cm corrected by a heel. We founded one case of varus knee below 5 grades, three cases of valgus knee below 5 grades and five cases of procurvatum femur without clinical effects.

During the follow-up no cases of infections or wound complication; one patient affected by a bilateral fracture, developed a delay of consolidation of the fracture, with a fully recover in 8 months.

The average fracture healing time was of 7.4 weeks (range: 6-10 weeks).

The average time to a full weight bearing was 12 weeks and the return to sportive activity was 24 weeks.

Four patients required a plate and screws removal after 1 year of surgery because of local discomfort.

We submitted to all the parents a scale to evaluate the satisfaction of the treatment (0 very low, 10 very satisfied): the average result was 8/10.

Discussion

The treatment of diaphyseal femoral fractures in pediatric patients has long been debated. The American Academy of Orthopedic Surgeons released guidelines for the treatment of these fractures in 2010. Given the low quality of the studies in the literature there are only two second level recommendations: in the case of femoral shaft fractures in patients aged less than 36 months the possibility of abuse should always be evaluated (2nd degree evidence, recommendation A); in the case of fractures with shortening less than 2 cm in patients younger than 5 years a Spica-casting should be used (2nd degree evidence, recommendation B) (5).

Conservative treatment remains the primary approach considering the high healing power and remodeling aptitude in children age six months to five years (12). These approaches have shown good mid-to-long-term clinical and radiological result; callus formation occurs quickly, and there are few long-term consequences observed (13). Neonate and infant (below 5 years old) should be treated with a Spica casting for up to 3 weeks (14). In this patient non-invasive treatment is still preferred, such as skin traction, eventually followed by hip Spica-casting. Fifteen degrees of varus or valgus angulation and 25 degrees of flexion or extension may be tolerated (15).

On the other hand, conservative treatments present some important limitation: skin traction needed prolonged hospitalization, patient and parents' discomfort, difficult management in hygienic care and long weight-bearing restrictions (14).

Considering these limitations, surgical treatments are progressively increased in the last years. Surgical treatments are first choice in patients suffering from multiple traumas, especially in head injury, and in fractures with significant deformities.

A recent systematic review compared the clinical and radiographic results and the incidence of compli-

cations in patients with conservatively or surgically treated (Titanium Elastic Nail or plate fixation). Patients who underwent surgery showed a better clinical outcome with a lower risk of non-union (11.5% vs. 8.1%), on the other hand they had a higher risk of complications (1% vs 4%). The authors, however, conclude that the data in the literature are burdened by heavy biases that do not allow a good quality statistical analysis and, so, to draw adequate conclusions (12).

Among the surgical treatment Titanium Elastic Nail (TEN) showed to be safe and useful in the management of isolated femoral fractures in pediatric population older than six years and under 45 kg of weight (8, 16).

Plate fixation provides excellent stability (17) and to manage proximal, medial and distal fractures. This kind of surgery allowed a full early motion, good mobility, easy hygienic management. Various studies have demonstrated the usefulness of plating in multiple injury, in particular head trauma (10). On the other hand, this surgery can involve significant blood loss and longer operative time (compared to TEN) (18, 19); other complication could be delayed union, scar related problems, screw and plate prominence, femoral varo-valgus and rotation deformity and exceptionally infections (6). A review about treatment options in midshaft femur fractures reported only 1 infection in 142 fractures fixed by plating (9).

Kregor et al reported 12 multiply injured children affected by shaft femur fracture treated by plating; all fractures healed, there were no angular deformities and no infections were observed, overgrowth could occur but asymptomatic (10). Similar results were reported by Hedequist et al. in their paper: 32 patients, 6 months to 5 years old, were treated with plate fixation, all the patients gained a full weight bearing in an average time of 75 days, all fractures united with an anatomic alignment, among the complication there were one valgus angulation of 12 degrees, and one distal end of the plate fracture (20). Fyodorov et al demonstrated good outcome also in non-polytrauma patients with a record of 23 uncomplicated femoral fractures in children between 8 and 12 years old (21).

The results of our series are overlapping with the literature. Any rotational or varus-valgus defects are usually well tolerated and not require further treat-

ment. The development of hypometria or lengthening is partly compensated during growth and not require further surgical treatments. The evaluation of parents' satisfaction is fundamental to better understand the simplicity of management of these patients at home. In the literature there are no guidelines regarding the need of plate removal; this choice is left to the operator experience.

The use of plate fixation using minimally invasive plate osteosynthesis (MIPO) technique has increased over the last ten years (20,22-24). MIPO technique allowed to increased stability, small incisions and preserved the blood supply (23), moreover decreased risk of infection (22), operative time and blood loss (the difference was not clinically relevant as there was no difference in the need for blood transfusions) (24). About the complications the MIPO technique showed an increase in rotational asymmetry that not require corrective treatment (24) and rarely refracture following plate removal (25). Regarding plate removal, a more extensive procedure could be necessary due to bony overgrowth above the plate (6, 26).

Conclusion

Locking plate fixation is to be considered a successful way of treatment for pediatric femur fractures, especially in patients older than 6 years. The evaluated outcomes in this paper are comparable to those of other fixation techniques for this kind of fracture. Plating has generally been reserved for head-injured children or in the treatment of polytrauma with thoracic trauma.

Recently, there has been a considerable trend in minimally invasive plate osteosynthesis. In the right circumstances and indications, locking plate is still an effective method of fixation of pediatric femur fractures in terms of anatomic and functional outcomes.

References

- Galano GJ, Vitale MA, Kessler MW, Hyman JE, Vitale MG. The Most Frequent Traumatic Orthopaedic Injuries From a National Pediatric Inpatient Population. *J Pediatr Orthop.* 2005;25(1):6.
- Hedström EM, Svensson O, Bergström U, Michno P. Epidemiology of fractures in children and adolescents: Increased incidence over the past decade: a population-based study from northern Sweden. *Acta Orthop.* 2010 Feb;81(1):148-53.
- Hinton RY, Lincoln A, Crockett MM, Sponseller P, Smith G. Fractures of the femoral shaft in children. Incidence, mechanisms, and sociodemographic risk factors. *J Bone Joint Surg* 1999; 81A:500-507.
- Loder RT, O'Donnell PW, Feinberg JR. Epidemiology and Mechanisms of Femur Fractures in Children: *J Pediatr Orthop.* 2006 Sep;26(5):561-6.
- Kocher MS, Sink EL, Blasier RD, Luhmann SJ, Mehlman CT, Scher DM, et al. American Academy of Orthopaedic Surgeons Clinical Practice Guideline on Treatment of Pediatric Diaphyseal Femur Fracture: *J Bone Jt Surg-Am Vol.* 2010 Jul;92(8):1790-2.
- Heyworth BE, Suppan CA, Kramer DE, Yen Y-M. Management of pediatric diaphyseal femur fractures. *Curr Rev Musculoskelet Med.* 2012 Jun;5(2):120-5.
- Catena N, Sénès F, Riganti S, Boero S. Diaphyseal femoral fractures below the age of six years: Results of plaster application and long term followup. *Indian J Orthop.* 2014;48(1):30.
- Donati F, Mazzitelli G, Lillo M, Menghi A, Conti C, Valassina A, et al. Titanium elastic nailing in diaphyseal femoral fractures of children below six years of age. *World J Orthop.* 2017;8(2):156.
- Anglen JO, Choi L. Treatment Options in Pediatric Femoral Shaft Fractures. *J Orthop Trauma.* 2005;19(10):10.
- Kregor PJ, Song KM, Routt ML Jr, Sangeorzan BJ, Liddell RM, Hansen ST Jr (1993) Plate fixation of femoral shaft fractures in multiply injured children. *J Bone Joint Surg Am* 75(12):1774-1780.
- Caird MS, Mueller KA, Puryear A, Farley FA. Compression Plating of Pediatric Femoral Shaft Fractures: *J Pediatr Orthop.* 2003 Jul;23(4):448-52.
- Madhuri V, Dutt V, Gahukamble AD, Tharyan P. Interventions for treating femoral shaft fractures in children and adolescents: Interventions for treating femoral shaft fractures in children and adolescents. *Evid-Based Child Health Cochrane Rev J.* 2014 Dec;9(4):753-826.
- Brousil J, Hunter JB. Femoral fractures in children: *Curr Opin Pediatr.* 2013 Feb;25(1):52-7.
- Khoriati A, Jones C, Gelfer Y, Trompeter A. The management of paediatric diaphyseal femoral fractures: a modern approach. *Strateg Trauma Limb Reconstr.* 2016 Aug;11(2):87-97.
- Wallace ME, Hoffman EB (1992) Remodelling of angular deformity after femoral shaft fractures in children. *J Bone Joint Surg Br* 74(5):765-769.
- Caglar O, Aksoy MC, Yazc M, Surat A. Comparison of compression plate and flexible intramedullary nail fixation in pediatric femoral shaft fractures: *J Pediatr Orthop B.* 2006 May;15(3):210-4.
- Porter SE, Booker GR, Parsell DE, Weber MD, Russell

- GV, Woodall J, et al. Biomechanical Analysis Comparing Titanium Elastic Nails With Locked Plating in Two Simulated Pediatric Femur Fracture Models: *J Pediatr Orthop*. 2012 Sep;32(6):587-93.
18. Allen JD, Murr K, Albitar F, Jacobs C, Moghadamian ES, Muchow R. Titanium Elastic Nailing has Superior Value to Plate Fixation of Midshaft Femur Fractures in Children 5 to 11 Years: *J Pediatr Orthop*. 2018 Mar;38(3):e111-7.
19. May C, Yen Y-M, Nasreddine AY, Hedequist D, Hresko MT, Heyworth BE. Complications of plate fixation of femoral shaft fractures in children and adolescents. *J Child Orthop*. 2013 Jun;7(3):235-43.
20. Hedequist D, Bishop J, Hresko T. Locking Plate Fixation for Pediatric Femur Fractures: *J Pediatr Orthop*. 2008 Jan;28(1):6-9.
21. Fyodorov I, Sturm PF, Robertson WW Jr (1999) Compression- plate fixation of femoral shaft fractures in children aged 8 to 12 years. *J Pediatr Orthop* 19(5):578-581.
22. Sutphen SA, Mendoza JD, Mundy AC, Yang JG, Beebe AC, Samora WP, et al. Pediatric Diaphyseal Femur Fractures: Submuscular Plating Compared With Intramedullary Nailing. *Orthopedics*. 2016 Nov 1;39(6):353-8.
23. Kuremsky MA, Frick SL. Advances in the surgical management of pediatric femoral shaft fractures: *Curr Opin Pediatr*. 2007 Feb;19(1):51-7.
24. Abbott MD, Loder RT, Anglen JO. Comparison of Submuscular and Open Plating of Pediatric Femur Fractures: A Retrospective Review. *J Pediatr Orthop*. 2013;33(5):5.
25. Kanlic EM, Anglen JO, Smith DG, Morgan SJ, Pesntez RF. Advantages of Submuscular Bridge Plating for Complex Pediatric Femur Fractures: *Clin Orthop*. 2004 Sep;426:244-51.
26. Pate O, Hedequist D, Leong N, Hresko T. Implant Removal After Submuscular Plating for Pediatric Femur Fractures: *J Pediatr Orthop*. 2009 Oct;29(7):709-12.

Received: 26 October 2018

Accepted: 10 December 2018

Correspondence:

Vitiello Raffaele

Università Cattolica del Sacro Cuore, Roma

Tel. +393407723095

E-mail: lele.vitiello@gmail.com