Trauma Case Reports 38 (2022) 100616

Contents lists available at ScienceDirect

Trauma Case Reports

journal homepage: www.elsevier.com/locate/tcr

Single stage open reduction, intramedullary rod, bone grafting, and plate fixation for managing adolescent midshaft femoral fracture non-union, report of two cases

Omar Refai [a], Ahmed A. Khalifa [b,*]

[a] Orthopaedic Department, Assiut university hospital, Assiut, Egypt
[b] Orthopaedic Department, Qena faculty of medicine and university hospital, South valley university, Qena, Egypt

ARTICLE INFO

Keywords:
Plating
Intramedullary rod
Adolescent
Non-union
Femur fracture
Case report

ABSTRACT

Although rare, long bones fracture non-union in pediatric and adolescent patients is still being reported. It poses a challenge for the trauma surgeons, although principles for adult patient management apply to pediatrics and adolescents; however, there is no standard protocol to deal with such situations. We report two male adolescent patients, 11 and 12 years old, presented with non-united midshaft femoral fracture non-union after being multiply operated on. One patient was diagnosed with a septic non-union, while the other had an atrophic type. Both were treated following the same technique of open surgery where debridement and refreshing of the fracture site were performed, followed by initial fixation using an intramedullary rod, the biological environment was then enhanced by the addition of autologous iliac bone graft, and the fixation was finalized using a 4.5 dynamic compression plate. Both patients achieved complete fracture union and excellent functional outcomes by the last follow up. Adolescent patients presented with multiply operated non-united femoral fracture could be successfully treated using the described technique. It improves the mechanical and biological environment with the advantage of being a single-stage surgery.

Background

Although having a very low incidence reaching up to 0.002%, fractures non-union in children possess significant health and social implications both on the patient and his family and the health care system, owing to the requirement of multiple operations with a high possibility of impaired functional outcomes [1].

Pediatric femoral fracture non-union is considered rare owing to the favorable biological environment composed of a tough periosteum and enhanced remodeling potential [2,3]. The principles of managing non-union in adults apply to pediatric fracture non-unions as well, improving the biological environment for healing mainly by adding a graft, enhancing the mechanical environment by using rigid implants such as plates and screws, and getting rid of the infection if present, however, no clear management protocol for pediatric femoral fracture non-union was described due to this incident's rarity [2].

Here, we describe two cases of male adolescent patients presented with mid-shaft femoral fracture non-union after having multiple

* Corresponding author at: Kilo 6 Qena-Safaga highway, Orthopaedic and Traumatology Department, Qena University Hospital, South Valley University, Qena 83523, Egypt.
E-mail addresses: omarrefai@aun.edu.eg (O. Refai), ahmed_adel0391@med.svu.edu.eg (A.A. Khalifa).

https://doi.org/10.1016/j.tcr.2022.100616
Accepted 24 January 2022
Available online 31 January 2022

operations, whom we treated with a single-stage fixation using a combination of intramedullary rods, plate and screws, supplemented by bone grafting.

Clinical case

Two male patients, 11 and 12 years old, healthy, were presented with multiple operated mid-shaft femoral fracture non-union.

Patients' previous surgical history

The first patient (right femur) was operated on five times: 1-initial fixation after acute trauma using elastic nails which failed (Fig. 1A), 2- removal of the nails, which was performed early leading to refracture (Fig. 1B), 3- open reduction and internal fixation (ORIF) using a plate and screws which got infected and failed (Fig. 1C), 4- debridement, the femur was fixed using a mono tubular external fixator, and a cement spacer was placed (Fig. 1D), 5-the last surgery (which was performed by the first author) was further debridement with removal of all hardware and the cement spacer. This was a case of infected non-union.

The second patient (left femur) was operated on three times: 1-initial ORIF after acute trauma by plate and screws that developed delayed union, 2- then revision of fixation by another plate and grafting, and 3-the last operation was metal removal followed by a cast (unfortunately we were unable to obtain the previous surgeries radiographs). This was a case of atrophic non-union (Fig. 2).

Surgical procedures

The same technique was followed for both cases as follows. After ensuring normal inflammatory markers preoperatively (ESR and CRP) to exclude the possibility of an active infection, both patients were operated upon under general anesthesia, the position of the patient on the operative table was dictated according to the planned bone graft donor site (in a usual situation, the patient should be positioned supine and both iliac crests should be prepared and included within the surgical drape for the possibility of harvesting bone graft from both sides, details of current cases positioning will be explained later), through a direct lateral approach to the femur engaging the previous skin incisions whenever possible, the following steps were followed:

1-Debridement: after proper exposure, we excised any non-viable tissues and performed refreshment of the fracture site (for both cases, tissue samples were sent for histopathological and microbiological examination). In the second patient, we did not excise the atrophic segment; however, instead, after we osteotomized the atrophic segment proximally and distally (at the level of the two black lines as shown in Fig. 2), we beveled the segment longitudinally in line with the femur axis (by using a power saw on the lateral aspect of the segment). We retracted both halves medially to create an anterior and posterior half which are still adherent to the medial periosteum to act as a substitution to the medial femoral cortex.

2-Rod insertion: with the leg slightly adducted, rod insertion was performed in a retrograde fashion; after opening the medullary canal of the distal end of the proximal femoral segment (if closed as in the second patient) and performing slight reaming, the rod was advanced till it penetrates and exits through the proximal femur where a snip in the skin was created to retrieve the rod, then it was advanced in an antegrade fashion after fracture reduction to engage the medullary canal of the distal fragment to achieve initial reduction and stability. The rod's tip at the proximal femur is left outside the bone for about one centimeter under the skin to ease further removal when needed. Regarding the rod used for fixation: in the first patient, we used a rod from the spine fixation kit, while in the second patient, we used an elastic rod; both were made of titanium alloy.

3-Harvesting of iliac bone graft: which was then impacted at the fracture non-union area to enhance the biological environment for healing. For the first patient, he had a previous grafting procedure (as a solution to treat non-union), and autografts were obtained

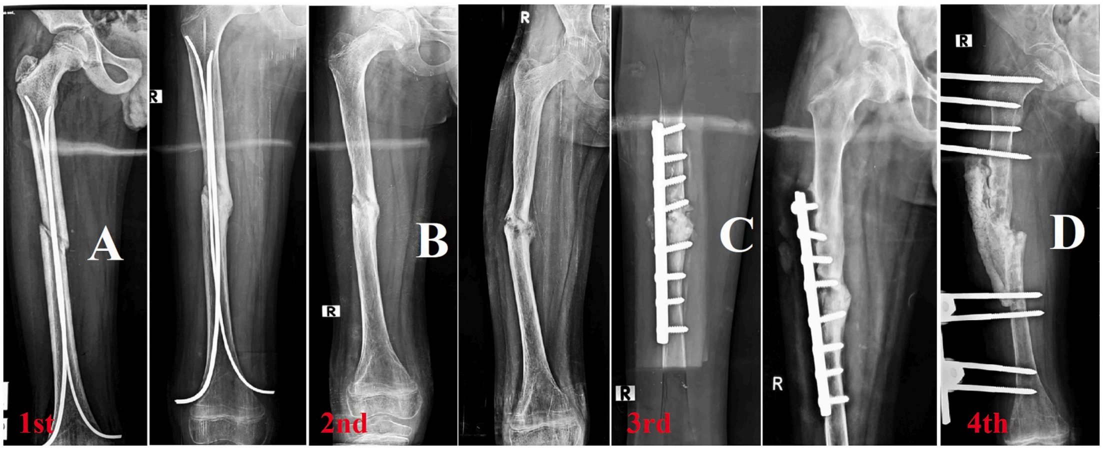

Fig. 1. Plain radiographs show the first patient's multiple operations. A, first surgery, fixing the femur fracture using elastic nails. B, refracture after nail removal. C, failed and infected femur plating. D, fixation using external fixator with the application of a cement spacer.

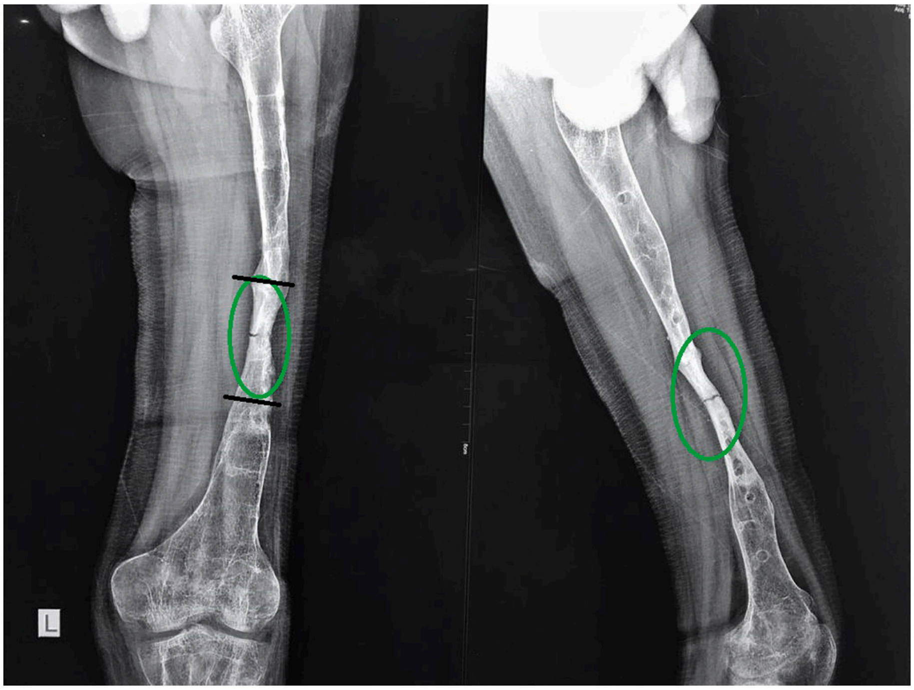

Fig. 2. Preoperative plain radiograph (anteroposterior and lateral views) of the second patient showing the atrophic non-union (green circle) and the osteotomy level of the atrophic segment, which as later beveled and retracted medially (black lines). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

from the iliac crest bilateral, so we operated on the patient in a lateral decubitus position to harvest a graft from the posterior aspect of the iliac bone. While in the second patient, the iliac bone graft was harvested from the intact contralateral iliac bone while the patient was supine.

4-Definitive fixation: this was achieved using 4.5 mm dynamic compression plates (DCP) and screws in both cases; fixation was finalized with cortical screws and augmented by cerclage wires.

No intraoperative complications were reported; the first patient received two units of blood intraoperatively while the second patient received one; both patients received another unit during their hospital stay.

Post-operative protocol

First-generation cephalosporin every 12 h adjusted for patients weight was administered for two weeks postoperatively (parenteral during the hospital stay and oral at home). Follow up visits were scheduled at two weeks (for wound check and sutures removal), six weeks for initial radiographic assessment, then after three, six, and 12 months (Figs. 3 and 4).

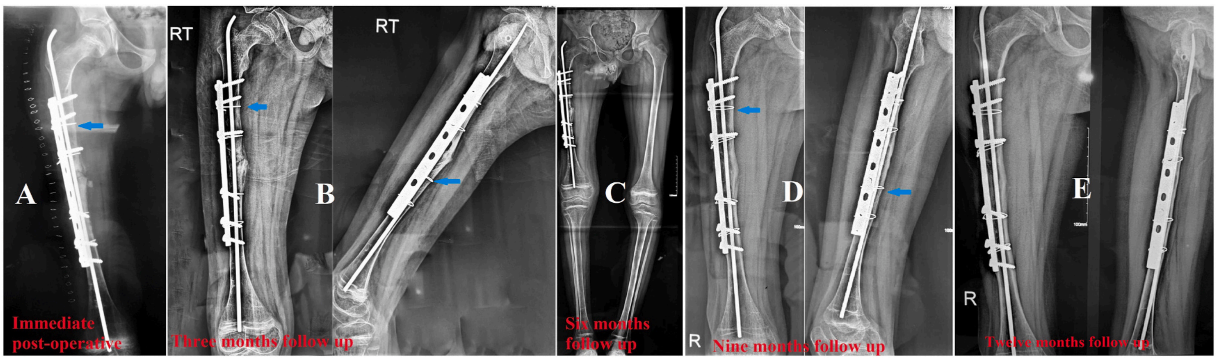

Fig. 3. A, Immediate postoperative and follow up plain radiographs at: B, three months. C, six months. D, nine months. E, 12 months (last follow up) of the first patient, where a complete union was achieved. Blue arrowheads indicate the cerclage wires used for fixation augmentation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Patients were allowed to flex the knee as possible under the observation of a physiotherapist; a non-weight bearing protocol was followed for the first six weeks; however, the patient was allowed to weight bear on the non-operated side with the help of two crutches and toe touch weight-bearing was started at the six weeks follow up visit at the operated side.

By the three-month follow-up visit, both patients achieved fracture union and were allowed for full weight-bearing with the help of crutches. At six months visit, the second patient had the rod migrating superiorly, causing tenting of the skin, which was removed as an outpatient procedure. No wound infection was reported in any of the patients; by the last follow up, 12 months for both patients, complete fracture union was achieved, patients were ambulating without crutches (mild limp in the first patient), and full knee flexion was achieved in both patients (Fig. 5). Both patients achieved excellent clinical results according to Flynn's criteria [4].

Discussion

Femoral shaft fracture occurs commonly in boys than girls and constitutes 1.4 to 1.7% of all pediatric fractures, with an incidence reaching about 19 in 100,000 [5,6]. The management evolved from the conservative lines as traction or casting; however, minimally invasive approaches such as elastic intramedullary nails and ORIF using plates and screws had been suggested in older children to achieve solid fracture union and early mobilization [6,7].

Although elastic nails had been reported as an acceptable management option for children aged five till 12, complications such as malunion, non-union, and loss of reduction were reported primarily due to improper technique or less optimum implant size [6–8]. Older children are better treated by rigid fixation using plates and screws. Although union rate was reported up to 100% with a shorter hospital stay; however, it carries the risk of increased blood loss and the need for other surgery for plate removal [7–9]. In a study by Kruppa et al. reporting on a cohort of children and adolescents treated for femoral shaft fractures using various methods, the authors reported an overall incidence of complications of 16.7%, 4.8% deep infection and 2.4% non-union, nearly all the complicated cases needed re-operation, hardware removal was performed in about 91% of the patients [10].

In a recent study describing the technique of plating and intramedullary nailing (IMN) at the same setting for management of multiply operated femoral shaft fractures presented with non-union in adults, the authors reported the efficacy of this technique in achieving union in these complex situations where the biological and mechanical aspect are jeopardized [11]. For an adult patient, the use of IMN is generally safe; however, its use in the pediatric population carries the risk of growth plate injury and femoral head avascular necrosis, so in the current report, we followed those same principles reported in the previous study; however, we tried to avoid the possible complications of IMN by using intramedullary rods, which does not require reaming, relatively small circumference which could fit inside a child femur medullary canal, the area at which the rod penetrated the proximal femur is relatively small with less possibility of growth plate damage.

Regarding the difference of the used rods materials, titanium is known for its low modulus of elasticity than stainless steel and better biocompatibility. In contrast, stainless steel is more robust with higher tensile strength, less notch sensitivity, and more fatigue resistance [8]. Although Mahar et al. in a biomechanical sawbones study found that titanium nails were more Torsional and axial stable compared to stainless steel nails [12], however, in a systematic review comparing both materials for femoral fracture fixation in the pediatric population in clinical studies, the authors reported that no apparent advantage of one material over the other [8]. In contrast, in the current report, we believe that the material of the rod will not be a significant factor affecting the stability, as the rod acts as an initial reduction maintenance tool, compensating for the medial cortical defect, which will then be augmented by plate fixed to the lateral side.

For both patients in the current report, due to multiple operations, prolonged non-weight bearing, and holes from previous fixation

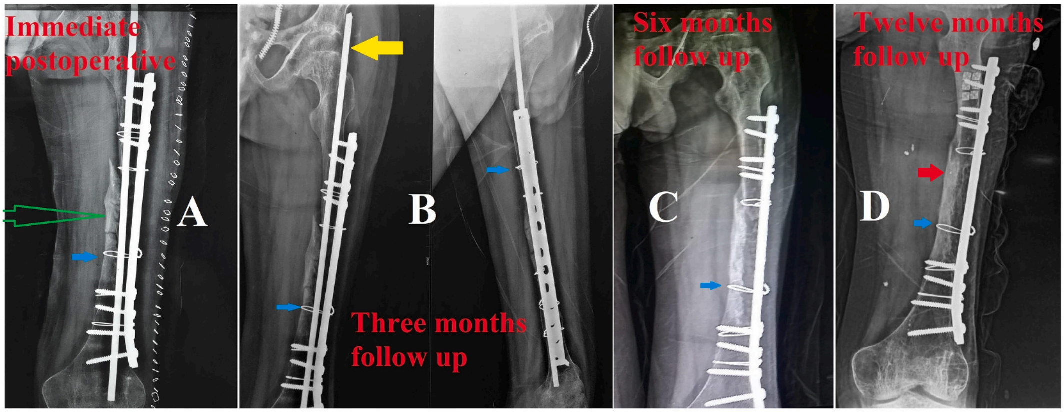

Fig. 4. A, Immediate postoperative and follow up plain radiographs at: B, three months. C, six months. D, 12 months (last follow up) of the second patient, the complete union was achieved. The atrophic non-united segment was beveled and retracted medially (green arrowhead), which was remodeled and united by the last follow up (red arrowhead). Prominence of the rod from the proximal femur (Yellow arrowhead) was removed as an outpatient procedure. Blue arrowheads indicate the cerclage wires used for fixation augmentation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

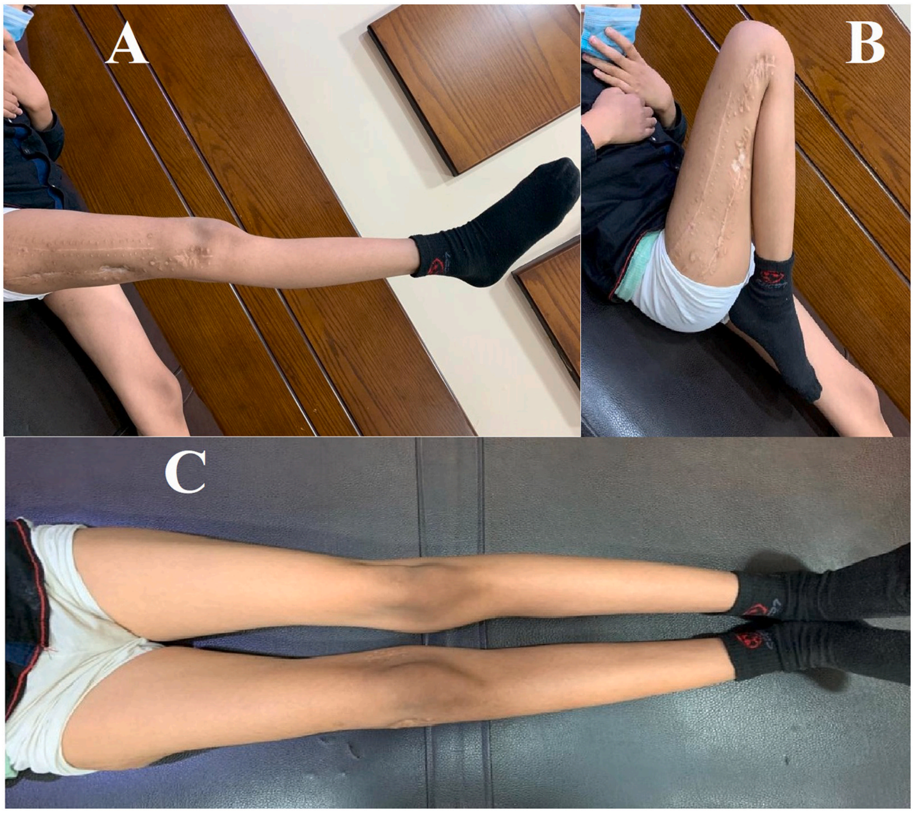

Fig. 5. Clinical image of the first patient showing scars of the previous operations and a full range of knee motion (A, full extension. B, full flexion and scars of previous operations. C, nearly equal leg length).

methods, the bone became soft and weak [13]; this makes plate and screws fixation challenging, for that reason and to secure the fixation, we tend to add cerclage fixation proximally and distally for more support.

Another option suggested for managing femoral shaft fractures in the pediatric population is the external fixator (either as a primary way of fixation or for dealing with complications such as infected non-union) [5,9]; however, it carries the risk of increased complications where pin tract infections were reported to occur in up to 70% [14], increased incidence of re-fracture after removal, need to be applied for a longer time, and the psychological impact on the patient and parents [15]. Furthermore, using an Ilizarov fixator for managing infected non-union showed promising results in some reports; however, it entails a longer time. The device is cumbersome and needs special care, and should be performed by a dedicated team [16].

Advantages of the technique

Intramedullary devices showed resistance to axial compression and bending; however, they are weak against torsional forces; while plates are efficient under torsional stresses, they are weak against bending; this weakness even exaggerate if a medial bone defect is present [17], Which makes fixation by any of the devices alone is weak, and the idea of using both methods of fixation in combination is much efficient. Furthermore, enhancing the biological environment with an autogenous iliac bone graft possesses osteoinductive and osteoconductive properties [18].

Limitations of the technique

The technique carries disadvantages and risks; 1-Being an open procedure with a relatively longer operative time, it is prone to more blood loss. 2-The added risk of complications after iliac bone graft harvesting. 3-As the rod used is smooth and non-locked, it could migrate, which occurred in one of the patients. 4-The need for hardware removal will subject the patient to another surgical procedure. Nevertheless, we preserve this technique for multi-operated complex cases where severe biological and mechanical environment deficiency is evident.

Conclusions

When facing difficult situations such as multiply operated non-united femoral fracture in an adolescent patient, the technique we described could help achieve fracture union as it offered improvement of the mechanical and biological environment with the provided advantage of being a single-stage surgery.

Ethics approval and consent to participate

The ethical committee of our institution waived ethical approval for this case report as this was considered a part of the usual patient care.

Consent for publication

A verbal and informed written consent was obtained from the patients' parents to use their clinical data and images to publish this case report; no identification of the patients' identity is present neither in the manuscript nor in the images. The authors confirm that this work was performed in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Availability of data and material

All the data regarding the presented case are included within the article.

Funding

We did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

O.R. carried out the idea and performed the surgery, A.A.K. carried out data acquisition and assessment. Both authors did the literature search, drafted the manuscript, and designed the figures; O.R. did the critical revision. Both authors discussed the results and commented on the manuscript. Both authors read and approved the final manuscript.

Declaration of competing interest

None for all authors.

Acknowledgments

None.

References

[1] L.A. Mills, A.H. Simpson, The risk of non-union per fracture in children, J. Child. Orthop. 7 (2013) 317–322.
[2] B.A. Kelly, B.J. Shore, Adolescent femoral diaphyseal fracture nonunion, Curr.Orthop.Pract. 26 (2015) 481–486.
[3] R. Zura, S.C. Kaste, M.J. Heffernan, W.K. Accousti, D. Gargiulo, Z. Wang, et al., Risk factors for nonunion of bone fracture in pediatric patients: an inception cohort study of 237,033 fractures, Medicine 97 (2018), e11691.
[4] J.M. Flynn, T. Hresko, R.A. Reynolds, R.D. Blasier, R. Davidson, J. Kasser, Titanium elastic nails for pediatric femur fractures: a multicenter study of early results with analysis of complications, J. Pediatr. Orthop. 21 (2001) 4–8.
[5] A. Dickens, Management of pediatric femur shaft fractures, UNM Orthop.Res.J. 2 (2013) 11.
[6] W.P. Bassett, S. Safier, M.J. Herman, S.H. Kozin, J.M. Abzug, Complications of pediatric femoral shaft and distal physeal fractures, Instr. Course Lect. 64 (2015) 461–470.
[7] R. Govindasamy, R. Gnanasundaram, S. Kasirajan, S. Ibrahim, J.J. Melepuram, Elastic stable intramedullary nailing of femoral shaft fracture-experience in 48 children, Arch. Bone Joint Surg. 6 (2018) 39–46.
[8] A. Mohamed, A.S. Rajeev, Clinical outcomes and complications of titanium versus stainless steel elastic nail in management of paediatric femoral fractures-a systematic review, Eur. J. Orthop. Surg. Traumatol. 27 (2017) 157–167.
[9] A. Jain, A. Aggarwal, D. Gulati, M.P. Singh, Controversies in orthopaedic trauma–management of fractures of shaft of femur in children between 6 and 12 years of age, Kathmandu Univ.Med.J. 12 (2014) 77–84.
[10] C. Kruppa, G. Wiechert, T.A. Schildhauer, M. Dudda, Complications after operative treatment of femoral shaft fractures in childhood and adolescence, Orthop. Rev. 9 (2017) 7493.
[11] Khalifa AA, Fadle AA, Elsherif ME, Said HG, Elsherif E, Said G, et al. Concomitant intramedullary nailing and plate augmentation as a single-stage procedure in treating complicated nonunited femoral shaft fractures. Trauma.0:14604086211007037.
[12] A.T. Mahar, S.S. Lee, F.D. Lalonde, T. Impelluso, P.O. Newton, Biomechanical comparison of stainless steel and titanium nails for fixation of simulated femoral fractures, J. Pediatr. Orthop. 24 (2004) 638–641.
[13] M. Talbot, R. Zdero, D. Garneau, P.A. Cole, E.H. Schemitsch, Fixation of long bone segmental defects: a biomechanical study, Injury 39 (2008) 181–186.
[14] T. Miner, K.L. Carroll, Outcomes of external fixation of pediatric femoral shaft fractures, J. Pediatr. Orthop. 20 (2000) 405–410.
[15] H. Kong, S. Sabharwal, External fixation for closed pediatric femoral shaft fractures: where are we now? Clin. Orthop. Relat. Res. 472 (2014) 3814–3822.
[16] P. Yin, Q. Ji, T. Li, J. Li, Z. Li, J. Liu, et al., A systematic review and meta-analysis of Ilizarov methods in the treatment of infected nonunion of tibia and femur, PloS one 10 (2015), e0141973.
[17] J. Coquim, J. Clemenzi, M. Salahi, A. Sherif, P. Tavakkoli Avval, S. Shah, et al., Biomechanical analysis using FEA and experiments of metal plate and bone strut repair of a femur midshaft segmental defect, Biomed. Res. Int. 2018 (2018) 4650308.
[18] G. Schmidmaier, P. Schwabe, B. Wildemann, N. Haas, Use of bone morphogenetic proteins for treatment of non-unions and future perspectives, Injury 38 (2007) S35–S41.