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Original Article

Effects of external fixation technique on hospitalization time, fracture healing time and complication rate of pediatric fracture

Shenghua Qiu[1*], Jian Liu[2*], Chengliang Liu[1]

Departments of [1]Pediatric Surgery, [2]Laboratory, Linyi Central Hospital, Linyi, Shandong Province, China. [*]Equal contributors and co-first authors.

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Abstract: Objective: To investigate the effects of external fixation on hospitalization time, fracture healing time and complication rate of pediatric fracture. Methods: Eighty children with fracture treated in our hospital from January 2015 to January 2017 were selected and divided into external fixation group (n=40) and internal fixation group (n=40) in accordance with therapeutic methods. Children in internal fixation group were treated by internal fixation while those in external fixation group were treated by external fixation. Hospitalization time, fracture healing time and postoperative total complication rates of children in two groups were statistically analyzed. Results: Hospitalization time and fracture healing time of children in external fixation group were significantly shorter than those in internal fixation group (P<0.05). Postoperative complication rate in external fixation group (10.0%, 4/40) was significantly shorter than that in internal fixation group (20.0%, 8/40, P<0.05). Conclusion: External fixation is more effective than internal fixation in reducing the hospitalization time as well as fracture healing time and lowering the total complication rates of pediatric fracture, which is worthy to be popularized in clinic.

Keywords: External fixation, pediatric fracture, hospitalization time, fracture healing time, total complication rate

Introduction

The 20th century has witnessed the huge development of internal fixation with steel plate, intramedullary nail, etc. as fixation materials. It is widely used in fracture and orthopaedic treatments, but limited in clinical application to some extent because of its drawback of high infection rate when the normal tissues are cut via surgery and the fixation materials are enclosed *in vivo* [1]. In recent years, however, influenced by the high causative factors of limb damage such as traffic accident, etc., trauma tends to have increasingly complex forms and growingly serious injuries. The principle of external fixation is to insert into steel needle on the bone through soft tissues like skin, meanwhile, assemble into some kind of mechanical construction like connecting rod with extracorporeal device; this mechanical configuration is firm and can effectively correct and treat fracture [2]. For better treatment on complex traumas, biomechanics of external fixation is further researched in clinic and the mechanics of external fixators is constantly designed and assessed at the same time; thus, external fixation has been widely used with each passing day since 1950s [3]. External fixation has unique advantages in the treatment of high energy damage, long bone defect, etc. External fixation plays a key role in the creations of suitably biomechanical and mechanobiological environment for fracture healing and bone lengthening [4]. It is mainly applied in the fixation of fracture at first, and it relies on external fixators in the process of fixing the far end and proximal end of fracture, which is more stable than indirect external fixation such as splint and gypsum [5]. In 1897, doctor Parkhill from America designed the first modern external fixator [6]. For more than a century, it is continually updated, and today, circular fixation and multi plane fixation have become popular. External fixation makes full use of thinner mental needle or mental nail while penetrating into the bone. Connecting with external fixator makes strong fixation *in vitro* and expands fixed range in the meantime. This process is strictly

conducted on the basic of actual demand with features of minimally invasion, convenience, etc., that is why it is more suitable in fixing complexly traumatic fracture and correcting bone malformation [7].

In clinical practice, manual reduction and gypsum fixation can correct the fracture of most children. The greatest advantage of plaster immobilization is noninvasive. But if the fracture lacks of stability, for example, if there exists a trend of displacement and shortening at the fracture end of short oblique fracture of tibia and fibula, it will be difficult to effectively maintain the fracture reduction when only relies on plaster immobilization. The older the children get, the slower the fracture healing is. The joints of adjacent parts of fracture will become stiff under the impact of plaster immobilization for a long time. Osteoporosis and disuse muscle atrophy will occur when lower limbs are non-weight-bearing for a long time [8]. Internal fixation can achieve reliable fixation and anatomic reduction, but the surgery will certainly further damage soft tissues and may cause infection and fracture nonunion, which needs re-operation to take out internal fixator and will increase children's pain as well as the charge; what's worse, it will leave big and permanent surgical scar [9]. While closed reduction is the main approach of external fixation fracture reduction and anatomic reduction. Percutaneous pinning is performed in fixing fracture and external fixator is fully used to reduce the secondary damage to fracture site. Closed reduction provides good preconditions for fracture healing. Also, demolition of external fixator is simple to operate and there is no need to perform re-operation generally [10]. To better treat pediatric fracture and effectively improve the prognosis, this study compared the therapeutic effects of external fixation with internal fixation on pediatric fracture, finding the former had more positive influences on hospitalization time, fracture healing time and total complication rates. Reports are as follows.

Materials and methods

General materials

Eighty children with pediatric fracture treated in our hospital from January 2015 to January 2017 were selected. Inclusion criteria: All children were diagnosed with fracture via X-ray and CT examination. Themselves and all their parents were informed and signed informed consents. Exclusion criteria: Exclude those without complete clinical data. Divide these 80 children into external fixation group (n=40) and internal fixation group (n=40) based on their therapeutic methods.

Methods

Children in internal fixation group were treated by internal fixation technique, and then performed conventional open reduction and internal fixation [11]. Epidural anesthesia or general anesthesia was performed for children first. The fracture site was exposed by surgery, and the fracture end was fixed. According to the different condition of fracture, various internal fixation was chosen to keep the position after restoration. Priority should be given to vascular compression or injury, and there was no soft tissue between fracture ends. Calf anterolateral incision was made from the fracture end for lower 1/3 tibial fracture, periosteum was stripped, and soft tissues in the fracture end was cleaned. Fracture reduction was performed under the direct view, plate screws were pressured to fix, and two gramme needles were intersected for supracondylar fracture of humerus. After humerus fracture end was exposed, local hematoma was removed. Then, one gramme needle was inserted intomedial epicondyle, and one was into lateral epicondyle, directed towards the upper part of the lateral condyle, the internal and external fracture blocks was prized to make reduction of intercondylar fractures, and reduction condition was observed by X-ray. If it was good, two original gramme needles were inserted into proximal fracture ends or two newgramme needles were inserted into proximal fracture ends from medial and lateral epicondyles to cross fix intercondylar fractures. And in the end, after total hemostasis, the incision was sutured. Children in external fixation group were treated by external fixation technique. Specific operation: patients underwent epidural anesthesia or intravenous anesthesia. Perform closed manual reduction at first to those with closed fracture. After that, put external fixator inside for traction and fixation. If closed reduction failed or fracture displacement occurred, firstly open reduction should be performed in principle and then external fixation followed. Fracture site was opened, blood clots and soft tissues impacted at the fracture broken end should be thorough-

ly cleared. Fracture site was performed at the fracture broken end under direct vision and fixed temporarily. In this process, self-tapping screws and external fixator for external fixation were made full use. Then the fractured end was further adjusted in order to recover the length and biomechanical line of the fractured limbs. For the patients with open fractures, the pollutants, small pieces of fractured bones, etc. in their injury sites were removed completely, at the same time, their periosteum and soft issues at the fracture broken end were protected in priority. For the patients with humeral fractures, their radial nerves were protected effectively and injuring radial nerves was avoided strictly. For patients with large oblique bones existed in the fracture broken end, self-tapping screws were fixed in the main fracture segments at first, to promote the increase of stability of fracture; then situ suture fixation of small fractured fragments was carried out, and in this process, absorbable lines were used to twine fractures.

Postoperative treatments

A drainage tubes was placed into the postoperative wound, and pulled out according to patients' physical conditions after 2 days. At the same time, patient's injured limb was raised higher than the levels of his heart to provide a good precondition for diminishing local edema. Patients were allowed to carry out knee joints and ankle joints exercises 2 days after operation, and do weight-bearing exercise 2 weeks after operation. We did regularly X-ray examination every two weeks according to their fractured degrees during this period, and inspected their fracture sites and healing degrees. In general condition, 6-12 weeks later, external fixation devices could be removed gradually according to patients' fracture healing degrees strictly. Patients should active their distal or proximal joints of tibia fractures as early as possible so as to recover functions of joints.

Observation indexes

The hospitalization time and fracture healing time in the two groups were observed and recorded. Meanwhile, wound infections, traumatic arthritis, traumatic ossification, ankylosis and other postoperative complications in the two groups were collected.

Statistical analysis

SPSS20.0 statistical software was used to analyze data, postoperative complications and other enumeration data were presented as percentage (%), Chi-square test was adopted to test comparisons between the two groups; standard deviation ($\bar{x}\pm s$) was used to express hospitalization time and fracture healing time and other measurement data, t test was adopted to test comparisons between the two groups, and the test criterion was a=0.05.

Results

Comparison of the general data between the two groups

Among children in the external fixation group, there were 25 males and 15 females from 3 to 12 years old, with an average age of (7.1±3.2) years old; their course of disease was 0.6h-3d, with an average course of (5.4±2.2) d. As for classifications of fracture, 30 cases were closed fracture, and 10 cases were open fracture; as for types of fracture, 15 cases were fracture of middle lower 1/3 segment of tibia, 11 cases were humeral shaft fracture, 9 cases were supracondylar fracture of humerus, 5 cases were intercondylar fracture of humerus; as for sites of fracture, 23 cases were one site, 17 cases were two sites or more; as for causes of fracture, 26 cases were caused by traffic accident injury, 10 cases were falling-down injury, 3 cases were crashing injury, 1 case was chopped injury. Among children in the internal fixation group, there were 23 males and 17 females from 4 to 12 years old, with an average age of (7.6±3.1) years old; their course of disease was 0.5 h-3 d, with an average course of (5.2±2.3) d. As for classifications of fracture, 31 cases were closed fracture, and 9 cases were open fracture; as for types of fracture, 16 cases were fracture of middle lower 1/3 segment of tibia, 10 cases were humeral shaft fracture, 8 cases were supracondylar fracture of humerus, 6 cases were intercondylar fracture of humerus; as for sites of fracture, 24 cases were one site, 16 cases were two sites and more; as for causes of fracture, 25 cases were caused by traffic accident injury, 11 cases were falling-down injury, 2 cases were crashing injury, 2 cases were chopped injury. There was no significant difference among gender, age,

Table 1. Comparison of the general data between the two groups

Variable	Classification	External fixation group (n=40)	Internal fixation group (n=40)	t/χ^2	P
Gender				2.71	0.124
	Male	25 (62.5)	23 (57.5)		
	Female	15 (37.5)	17 (42.5)		
Age (year)		7.1±3.2	7.6±3.1	1.886	0.355
Course of disease (d)		5.4±2.2	5.2±2.3	1.638	0.256
Fracture classifications				4.61	0.655
	Closed fracture	30 (75.0)	31 (77.5)		
	Open fracture	10 (25.0)	9 (22.5)		
Fracture types				1.32	0.325
	Fracture of middle lower 1/3 segment of tibia	15 (37.5)	16 (40.0)		
	Fracture of humeral shaft	11 (27.5)	10 (25.0)		
	Supracondylar fracture of humerus	9 (22.5)	8 (20.0)		
	Intercondylar fracture of humerus	5 (12.5)	6 (15.0)		
Fracture sites				2.77	0.352
	One site	23 (57.5)	24 (60.0)		
	Two and more sites	17 (42.5)	16 (40.0)		
Cause of injury				4.11	0.325
	Traffic accident injury	26 (65.0)	25 (62.5)		
	Falling down injury	10 (25.0)	11 (27.5)		
	Crashing injury	3 (7.5)	2 (5.0)		
	Chopped injury	1 (2.5)	2 (5.0)		

course of disease, types of fracture in the two groups (P>0.05), so it was with comparability, see **Table 1**.

Comparisons of hospitalization time and fracture healing time between the two groups

The hospitalization time, fracture healing time of the external fixation group were significantly shorter than those of the internal fixation group (P<0.05), see **Table 2** and **Figure 1**.

Table 2. Comparison of hospitalization time and fracture healing time between the two groups ($\bar{x}$±s)

Group	Case	Hospitalization time (d)	Fracture healing time (d)
External fixation group	40	7.5±2.8	61.3±12.8
Internal fixation group	40	14.2±6.2	75.6±20.1
t		4.303	3.182
P		0.023	0.026

Comparison of intraoperative blood volume between the two groups

There was no statistical significance in intraoperative blood volume between the two groups (P>0.05), see **Table 3** and **Figure 2**.

Comparison of hospitalization expenses between the two groups

There was no statistical significance in differences of hospitalization expenses between the two groups. (P>0.05), see **Table 4** and **Figure 3**.

Comparison of postoperative complications between the two groups

Postoperative complication rate in external fixation group (10.0%, 4/40) was significantly lower than that in internal fixation group (20.0%, 8/40), (P<0.05), see **Table 5**.

Discussion

Pediatric fracture belongs to a kind of pediatric trauma which is common clinically. The main difference between pediatric fracture and adult fracture is epiphyseal plate. If there is no proper treatment for pediatric patients with epiphyseal injury, it will lead to bone growth stagnation or deformity. Therefore, active and effective protection should be carried out to epiphyseal plate during the process of the treatment for pediatric fracture [12]. Plaster splint external fixation and open reduction with internal fixa-

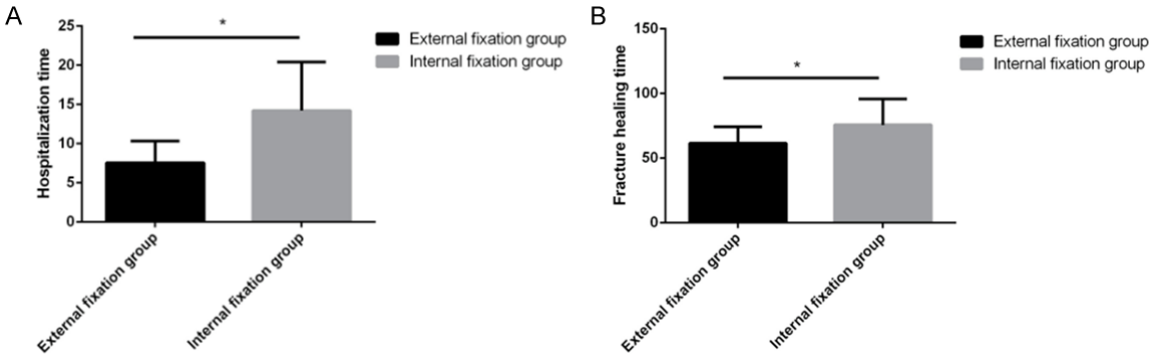

Figure 1. Comparison of hospitalization time and fracture healing time between the two groups. A. Comparison of hospitalization time between the two groups, *P<0.05; B. Comparison of fracture healing time between the two groups, *P<0.05.

Table 3. Comparison of intraoperative blood volume between the two groups ($\bar{x}\pm s$)

Group	Case	Intraoperative blood volume (ml)	t	P
External fixation group	40	125.3±10.4	1.476	0.255
Internal fixation group	40	130.2±10.3		

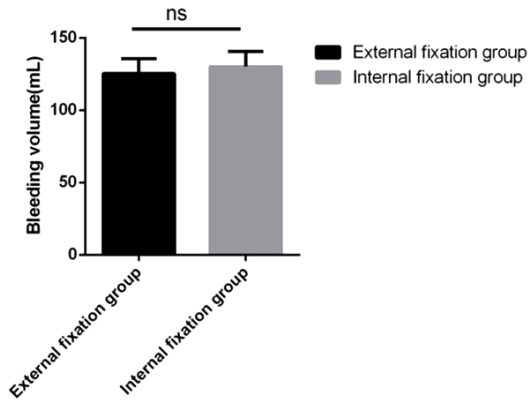

Figure 2. Comparison of intraoperative blood volume between the two groups, ns, P>0.05.

tion are traditional methods of treating pediatric fracture commonly used in clinic. Besides, plaster splint external fixation lacks precise fixation and has many complications, so it easily causes fracture deformity on corresponding fracture site, thereby leading to obstacle of limb movement [13]. Open reduction with internal fixation has great damage to body and causes serious skeletal injury in some cases. Serious adverse effects will occur in pediatric skeletal growth and development once epiphyseal plate is damaged. And due to fast healing speed of pediatric fracture, open reduction and internal fixation easily causes damage to periosteum, so the healing speed of fractureis seriously affected [14].

In the treatment of trauma, superiorities of external fixation are reflected in the following aspects specifically. First, it has wide range of application. Modern external fixator has high quality, good stability and flexible and diverse assembling forms. It is extremely useful in all kinds of complex or simple fractures of the trunk and limbs, especially for severe bone defect, comminuted fracture, etc. It is effective in maintaining the length and force line of injured limbs, thereby providing effective prerequisite to necessary follow-up treatment and fracture healing. Second, it has flexible fixed range. According to the design principle of external fixator, fixed range can be selected based on actual requirements: fix a single bone or fix bones across joint. Over-articular fixation can increase fixation stability in the course of treatment of intra-articular fracture and adjacent joint fracture. Furthermore, it has reliable fixed effect. Modern external fixation fully utilizes conical screw nails fixation and other techniques to promote the stability of system. Fracture angulation and bone displacement caused by unstable external fixator rarely occur in the course of fixation. A stable system can effectively eliminate the shearing stress that leads to adverse effect of fracture healing and provides a good prerequisite for micro-axial motion of fracture healing. Meanwhile, it effectively guarantees early postoperative activities and load-bearing needs of patients, as well as provides a good prerequisite for rehabilitation and early return to society of patients. In addition, it is able to deal with open injury of soft tissues simultaneously. The

Table 4. Comparison of hospitalization expenses between the two groups ($\bar{x}$±s)

Group	Case	Hospitalization expenses (thousand Yuan)	t	P
External fixation group	40	11.1±2.2	1.533	0.645
internal fixation group	40	10.2±3.1		

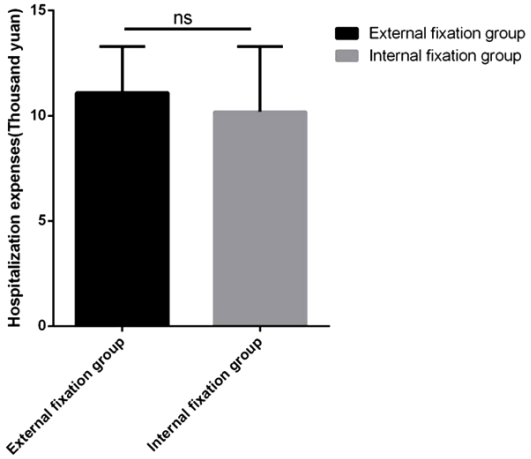

Figure 3. Comparisons of hospitalization expenses between the two groups, ns, P>0.05.

results in this paper showed that the hospitalization time and fracture healing time in the external fixation group were significantly shorter than those in the internal fixation group (P<0.05). It may because the external fixator can provide the exact external fixation to prevent displacement of fracture segments effectively during the treatment of pediatric fracture. Meanwhile, longitudinal traction can enable stress occur on the longitudinal direction of fracture segment, to provide a good prerequisite for fracture healing.

High-energy injury results in serious fracture and easily induces severe soft tissue injury, such as large area of skin stripping injury and open fractures. Additionally, relevant medical studies have confirmed that the infection rates of contaminated wounds increase to a large extent under the effect of metallic foreign body [15, 16]. The distance between the fixation needle of the external fixator and wound can be fairly far, which effectively avoids the direct infection of vulnerable parts. When percutaneous fixation must be conducted, the external fixation needle can give a full play of drainage to significantly reduce the morbidity of severe intraosseous infection. Stable external fixation allows simultaneous treatment of bone and soft tissue damage, as well as osseous apposition and orientation won't be affected after fracture reduction. Last, the operation is minimally invasive. Percutaneous needle/nail will damage the soft tissues, which is the only surgical trauma of external fixation, and patients almost have no blood loss, so it won't directly affect the fracture site. Removal of the external fixator does not promote the second surgical trauma [17, 18]. The results of this study showed that the postoperative total complication rate of pediatric patients in the external fixation group was (10.0%, 4/40 significantly lower than that in the internal fixation group (20.0%, 8/40, P<0.05), indicating that the external fixation is more effective in reducing the incidence of complications in pediatric fracture patients. This probably due to the fact that external fixation can maximize the protection of epiphyseal plate and periosteum so that it will not be damaged, which contributes to the reduction of the impact of bone development in children and provides a good prerequisite to relatively fast healing speed of pediatric fracture [19]. Therefore, compared with other treatment methods, external fixation treatment has a significantly treatment effect. Meanwhile, small surgical operation difficulty, less trauma and less complication enable external fixation technique extremely applicable in primary hospitals [20].

In conclusion, the external fixation technique is valuable to be applied extensively in clinic, because it is more effective in shortening the hospitalization time and fracture healing time and reducing complication rate of pediatric patients than the internal fixation technique. However, due to the small sample capacity of this study, the results may not have representativeness and universality; more samples should be added to further studies by relevant medical scholars.

Disclosure of conflict of interest

None.

Address correspondence to: Chengliang Liu, Department of Pediatric Surgery, Linyi Central Hospital, No.17 Jiankang Road, Linyi 276400, Shandong Province, China. Tel: +86-0539-2225007; Fax: +86-0539-2263541; E-mail: qll0601zzn@163.com

Table 5. Comparison of postoperative complications between the two groups (case, %)

Group	Case	Infection	Traumatic arthritis	Traumatic ossification	Ankylosis	Total
External fixation group	40	0 (0)	1 (2.5)	1 (2.5)	2 (5.0)	4 (10.0)
Internal fixation group	40	3 (7.5)	1 (2.5)	2 (5.0)	2 (5.0)	8 (20.0)
χ^2						12.83
P						0.015

References

[1] Al-Daghri NM, Aljohani N, Rahman S, Sabico S, Al-Attas OS, Alokail MS, Al-Ajlan A and Chrousos GP. Serum 25-hydroxyvitamin D status among Saudi children with and without a history of fracture. J Endocrinol Invest 2016; 39: 1-6.

[2] Fatah RMN, Amin BRM, Mahmud HA and Yusif AJ. Assessment of the outcome of anterior versus posterior approach in the management of displaced pediatric supracondylar humerus fracture. Open Journal of Orthopedics 2016; 06: 113-119.

[3] Hennrikus W, Slough J, Jensen K, Armstrong D, King S, Urish K. Measurement of radiation exposure when using the Mini C-Arm to reduce pediatric upper extremity fractures. J Pediatr Orthop 2016; 36: 122-125.

[4] Khaffaf RMN and Altaweel AH. Comparative Study between the Elastic Nail versus Hip Spica Cast in Early Treatment of Pediatric Femoral Shaft Fractures. Open Journal of Orthopedics, 2016; 6: 259-267.

[5] Naranje SM, Gilbert SR, Stewart MG, Rush JK, Bleakney CA, McKay JE, Warner WC Jr, Kelly DM, Sawyer JR. Gunshot-associated fractures in children and adolescents treated at two level 1 pediatric trauma centers. J Pediatr Orthop 2016; 36: 1-5.

[6] Ali, Ahmed AA, Kabbash, Mansour M, Said, Samia MA, Shoeib, Mohamed A, Osman and Mohamed H. Use of biodegradable plates and screws in the treatment of pediatric facial bone fractures. Egyptian Journal of Oral & Maxillofacial Surgery 2016; 7: 86-93.

[7] Kumar P, Purohit NR and Gahlot TK. Clinical study on mandible fractures in dromedary camels (Camelus dromedarius). Trop Anim Health Prod 2014; 35: 64-66.

[8] Lee DJ and Elfar JC. External fixation versus open reduction with locked volar plating for geriatric distal radius fractures. Geriatr Orthop Surg Rehabil 2014; 5: 141-143.

[9] Iobst C and Liu R. A systematic review of incidence of pin track infections associated with external fixation. 2016; 2: 6-16.

[10] Ahmed A. An innovative external fixator for the management of trochanteric fractures of the femur. 2014; 49: 1-5.

[11] Lareau CR, Daniels AH, Vopat BG, Kane PM. Emergency department external fixation for provisional treatment of pilon and unstable ankle fractures. J Emerg Trauma Shock 2015; 8: 61-64.

[12] Barbier D, Neretin A, Journeau P and Popkov D. Gradual metatarsal lengthening by external fixation: a new classification of complications and a stable technique to minimize severe complications. Foot Ankle Int 2015; 36: 1369-1377.

[13] Chaudhuri A, Datta S, Roy DS, Singh AK, Ghosh S and Dutta S. Comparative analysis of external and internal fixation in lower radial articular fractures. 2014; 7: 596-602.

[14] Jain A, Thompson JM, Brooks JT, Ain MC and Sponseller PD. Implant-related fractures in children with proximal femoral osteotomy: blade plate versus screw-side plate constructs. J Pediatr Orthop 2016; 36: e1-5.

[15] Cisneros LN, Gómez M, Alvarez C, Millán A, Caso JD and Soria L. Comparison of outcome of tibial plafond fractures managed by hybrid external fixation versus two-stage management with final plate fixation. Indian J Orthop 2016; 50: 123-130.

[16] Morelli I, Sabbadini MG and Bortolin M. Orthopedic injuries and their treatment in children during earthquakes: a systematic review. Prehosp Disaster Med 2015; 30: 478-485.

[17] Şerban AI, Obadă B, Turcu R, St A and Botnaru V. Distal tibial fracture treated by minimally invasive plate osteosynthesis after external fixation Retrospective clinical and radiographic assessment. Ars Medica Tomitana 2014; 20: 44-49.

[18] Kao HK, Chen MC, Lee WC, Yang WE and Chang CH. A prospective comparative study of pin site infection in pediatric supracondylar humeral fractures: daily pin care vs. no pin care. Arch Orthop Trauma Surg 2014; 134: 919-923.

[19] Galal S. External fixation of paediatric subtrochanteric fractures using calcar rather than neck pins. Strategies Trauma Limb Reconstr 2016; 11: 99-104.

[20] Kong H and Sabharwal S. External fixation for closed pediatric femoral shaft fractures: where are we now? Clin Orthop Relat Res 2014; 472: 3814-3822.