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Research Article

MANAGEMENT OF COMPLICATED TRAUMA BY LIMB RECONSTRUCTION SYSTEM (MONO-LATERAL EXTERNAL FIXATOR) IN LOWER EXTREMITY

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ABSTRACT

Objective: High velocity trauma is the cause of maximum number of fatality in the younger age group worldwide. In the field of trauma surgery open fractures of the leg remain with the higher complication rate. Treatment options include wound debridement reduction and immobilization with cast, open reduction and plate fixation, external fixation, and IM nailing. Limb reconstruction system (LRS) is a unilateral rail system which consists of Schanz pins, rail rods, and sliding clamps. LRS was considered as definitive management for open fractures. LRS with its modular attachments, it is specifically designed to enable the surgeon to perform simple and effective surgery as it offers rigid fixation of fracture fragments, allows early weight bearing, and reduces the economic burden.

Aim: The aim of the study was to determine the efficacy of mono-lateral external fixator LRS for management of the lower extremity long bone fracture (tibia/femur).

Methods: A prospective study was carried out where 26 cases of lower extremity trauma (complicated) managed by LRS over a period of 5–6 months. The patients ranged from age 13 years to 67 years. Majority were male and predominant mode of injury was road side accidents. Majority of case were exposed to multiple the surgeries before LRS application. Most of the cases are of infection non-union. All the patients were treated at our hospital. These surgeries were done from June, 2005 to 2007. Any bone fragments that were protruding out we recovered with sterile dressing. The patient were taken to the operating room and treated by pulsed lavage and debridement the wound and splints. In patients, whose bone was exposed, as the wound condition improved the patients were planned for flap rotation. Assessment of quality of regenerate was done by plain radiography and clinical assessment at every follow-up. Final assessment for bone results and functional results was done using Association of the study and application of the method of Ilizarov (ASAMI) score.

Results: Among 26 patients, bony results as per ASAMI score were excellent in 73.07% (n=19), good in 19.23% (n=5), fair in 3.84% (n=1), and poor in 3.84% (n=1). Functional results were excellent in 84.7% (n=22), good in 11.5% (n=3), and fair in 3.8% (n=1). All the 26 cases of lower extremity fracture were kept on LRS external fixator for a period of 5–6 months on an average depending on the rate of union, after which the fixator was removed. For 2 patients nailing was done after LRS frame removal. Average time for frame removal was 28 weeks. In most cases union was complete by 7–8 months, the least being 5 months for a tibia shaft fracture. The average hospital stay for the patients was 7 days and as compared to multi staged surgery financial burden was reduced by 40%. The average time of return to work for the patients was 3 weeks.

Conclusion: Overall LRS proved to be an effective modality of treatment in cases of the lower extremity fracture with bone loss as definite modality of treatment for damage control as well as for achieving union and lengthening/transportation, deformity correction simultaneously, with the advantage of simple surgical technique, ease of application, minimal invasive, strong fixation, high patient compliance, early weight bearing, easy wound management, and the lower rate of complication.

Keywords: Complicated trauma, LRS, External fixator, ASAMI, Bone loss.

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INTRODUCTION

High velocity trauma is the cause of maximum number of fatality in the younger age group worldwide. The implication of losing a young active member of the population is obvious in terms of personal, social and economic losses to the family as well to nation. In the field of trauma surgery open fractures of the leg remain with the higher complication rate. Bone and soft-tissue injuries need aggressive yet careful treatment to avoid further damage that results in uncomplicated healing. Due to its location, structural anatomy and sparse anterior soft-tissue coverage the tibia is particularly prone to exposure and ischemia due to injury. The optimum treatment for open fractures of tibia remains controversial. Treatment options include wound debridement reduction and immobilization with cast, open reduction and plate fixation, external fixation, and IM nailing. External fixation of open fractures with severe soft tissue injury has been standardized during the 1980s. More recently closed undreamed nailing of open fracture of tibia has become popular. Nailing for tibia and femur has been shown to be a reasonable treatment option to external fixation in tibia and femur. The disadvantage of this technique is need for several operative procedures, longer period of hospital stay, increased chances of infection, financial burden, and prolonged immobilization. To overcome these disadvantages limb reconstruction system (LRS) was considered as definitive management for open fractures. LRS With its modular attachments it is specifically designed to enable the surgeon to perform simple and effective surgery as it offers rigid fixation of fracture fragments, allows early weight bearing, and reduces the economic burden [1].

The LRS consists of an assembly of clamps usually two or three which can slide on a rigid rail and can be connected by compression-distraction units [2-8]. The LRS may be used to achieve 15 cm or more of lengthening without the need to change the device for a longer one [1,9,10]. It may also be used to correct deformity acutely (using

an acute correction template) or progressively [3,8,11-14] (using progression correction clamps). In comminuted fracture with bone loss and in situation non-union or mal-union with or without same degree osteoporosis, the LRS may be used to obtain maximum stability since the construction of the device enables the position of the clamp for the bone screw to be varied over the whole length of the bone, depending on the length of rail used [2,15].

Aim and objectives

The objectives are as follows:

1. To determine the efficacy of this mono-lateral external fixator management by analyzing the results
2. To study the cases with respect to age, sex, mode of injury, site of fracture, degree of comminution, compounding, and associated injuries with multiple surgeries
3. To evaluate the results with respects to time for union, knee range of motion (ROM), and shortening.

METHODS

Twenty-six cases of the lower extremity trauma (complicated) managed by LRS. These cases are of infected non-union of tibia, femur, septic arthritis of knee, fresh trauma of both femur and tibia with severe soft-tissue injury and aseptic non-union, and shortening. The patients ranged from age 13 years to 67 years. Majority were male and predominant mode of injury was road side accidents. Majority of case were exposed to multiple the surgeries before LRS application. Most of the cases are of infection non-union. All the patients were treated at our hospital. These surgeries were done from June, 2005 to 2007. All the cases were seen and documented preoperatively, immediate postoperatively, and then at regular interval. The fracture was classified according to compounding grades of Gustilo-Anderson classification and comminution as per Winquist - Hansen classification.

Pre-operative-protocol

Emergency stabilization of patient included application of posterior slab or Thomas splint, correction of fluid volume and surgical or conservative management of head, chest and abdominal injuries as indicated. Initial resuscitation, splintage, and primary care for the wound were provided in the emergency room for the fresh trauma cases. Patients were administered intravenous antibiotics (third generation cephalosporin) and tetanus immunoglobulin. Pre-operative work up included complete hemogram, renal profile, coagulation profile, viral markers, and radiographs of the affected limbs in orthogonal planes. A radio-opaque scale incorporated in a comparative X-ray may be helpful in determining both bone loss and shortening. A weight bearing X-ray from hip to ankle may be required if correction of a deformityis involved. Any bone fragments that were protruding out were covered with sterile dressing. The patient was taken to the operating room and treated by pulsed lavage and debridement the wound and fixation of the fracture according to the criteria explained in methods. Under spinal anesthesia and with tourniquet in situ, thorough debridement of wound was performed which was followed by LRS application. Stab incisions were followed by blunt dissection until the bone was reached. Schanz pins were passed proximal and distal to fracture site followed by insertion of rail rods and clamps. Every attempt made to cover the expose part of tibia and femur with soft tissue. Flap cover required in some cases. The configuration of the external fixator (LRS) used was an unilateral uniaxial.

Operative technique

A radiolucent table is used and the image intensifier placed at right angles to the table on the opposite side of the patient to the surgeon. The image intensifier should be used to identification of important bony landmarks. Each mark is made perpendicular to the axis ofthe bone so that a line drawn at right angles defines the axis of the bone and will be parallel to the final position of the fixator. With the defect in the distal femur, proximal osteotomy and to distal transport are indicated [16,17]. Cortical screws should be used in the diaphysis and cancellous screw only in wide metaphyseal or epiphyseal sites [6,14,18]. Schanz pins of LRS were inserted by longitudinal stab incision and separating the soft tissue down to the bone by blunt dissection on the antero-medial surface of tibia hence preventing the risk of neurological, vascular or tendon injuries. First the proximal most, Schanz screw was inserted by sequentially pre drilling with an appropriate-size bit, followed by manual insertion of the Schanz screw by the T handle, which lowers the risk of thermal necrosis and pin loosening. This proximal pin was placed at least 15 mm from the joint to avoid penetration of the joint capsule and avoid the pes -tendons and patellar tendon. Then the distal most, Schanz screw inserted in the same manner. The rod and assembly connected over these proximal and distal pins maintaining the leg length and this definitive fixator was used as a guide to pass the rest of the pins, to ensure that the rail is parallel to the long axis of the bone and all the remaining screws will be on the bone, in the same plane, perpendicular to the long axis of the tibia and parallel to the knee and ankle joints and aligning the tibial tuberosity with the second metatarsal. The foot and ankle were manipulated to ensure the absence of musculo-tendinous tethering. We used three Schanz screws each in the proximal and distal end clamps, respectively, and two screws in the middle mobile clamp. All Schanz screw were inserted under C arm control so that not more than about 2 mm was protruding beyond the distal cortex, as trying to back them out can cause pin loosening because of the tapering design of pins. After putting all the pins and the fixator on the limb, the pin holding nuts (clamps) were tightened. The compression-distraction unit was put on the proximal end clamp and middle clamp in the holes provided. Low energy osteotomy was done between the proximal and middle clamps using either a Gigli wire or with a thin osteotomy connecting the predrilled holes. Through two incisions anteriorly and postero-medially periosteum was elevated, and a Gigli saw was passed over a tape gauze subperiosteally from postero-medial to anterior incision. With the Gigli saw the bone was cut till it reached the medial cortex and then by periosteum elevator passed subperiosteally the osteotomy completed, protecting the periosteum. In none of the case, acute docking attempted. After thorough lavage and sterile dressing, the wound was left open without trying the wound coverage methods.

Postoperatively, systemic antibiotic was continued for 5 days and dressing done regularly. In immediate post-operative period, all patients were given limb elevation, analgesics, injection cefuroxime 1 g iv BD with injection gentamycin 80 mg iv BD with injection metronidazole 100 cc iv TDS for 5–14 days according to wound status. All patients were taught quadriceps and hamstring strengthening exercises from second post-operative day along with straight leg raising exercises to avoid joint contracture and muscle atrophy. Depending upon fracture configuration, partial weight bearing walking with walker or crutches was taught to patients. Wound coverage was planned once there was no evidence of infection in proximal or distal pin sites. Patients were followed up at monthly intervals for a minimum of 6 months. Assessment of complications such as muscle contractures, joint subluxation, axial deviation, neurological or vascular insult, premature consolidation, delayed consolidation, re-fracture, and pin-site infection was done at each follow-up visit and was managed accordingly. In patients, whose bone was exposed, as the wound condition improved the patients were planned for flap rotation. In the rest of the patients, the wound was left as such to heal, with secondary intention or if required, split skin grafting was done. Distraction of the osteotomy was started after a week of the osteotomy at the rate of one fourth turn 4 times a day resulting in a total bone transport of 1 mm/day or 7 mm/week. This bone transport was continued till the fracture end approximated. And when the bone ends approximated, the distraction was stopped and dynamization of the LRS system done,

Fig. 1:

Fig. 2:

which was followed by weight bearing mobilization by the patient as per his tolerance (Figs. 3 and 4).

The dynamized LRS system was left *in situ* for further 15–20 weeks for consolidation of the regenerate and fracture union to occur. In some patients, rate of distraction was altered during the distraction phase depending on the patient compliance and the type of regenerate. Patients were encouraged to attain knee and ankle ROM after the application of LRS, depending on the patient pain tolerance. Assessment of quality of regenerate was done by plain radiography at monthly intervals. Healing was defined radiologically by the presence of a bridging callus. If there was no radiological progress of healing at fracture site during subsequent follow-ups, bone grafting was done to achieve union at fracture site. Union was defined clinically by the absence of pain and motion at fracture site. The fracture was considered as united radiologically if three of four cortices showed bridging callus. Implant (LRS) was removed after achieving union at fracture site and the patellar tendon bearing cast was applied allowing full weight bearing, for further 6–10 weeks. Since the LRS remained clamps (usually two or three) which can slide on a rigid rail and can be connected by compression-distraction units to achieve bone transport. In this prospective study, we evaluated the outcome of the LRS in the treatment of the lower extremity long bone fracture with bone loss as a definite mode of treatment to achieve union, as well as limb lengthening, simultaneously. Final assessment for bone results and functional results was done using association of the study and application of the method of Ilizarov (ASAMI) score.

OBSERVATION AND RESULTS

In this study, LRS was performed in 26 cases of lower extremity trauma closed and open fracture (Tibia or Femur). Open fractures were graded

Fig. 3:

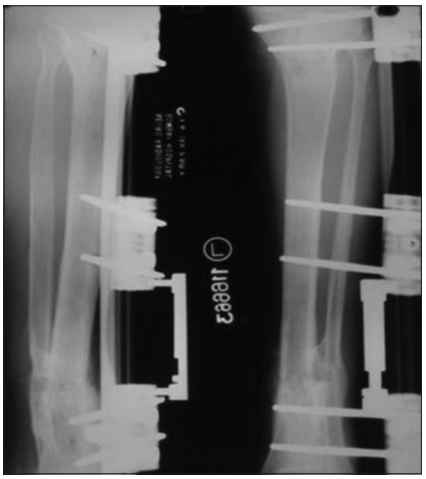

Fig. 4:

by the Gustilo-Anderson classification. The patients were between 13 and 67 years of age with a mean age of 37 years. A total of 19 patients were male and seven patients were female and road traffic accident being the most common cause of injury. Thirteen (50%) patients had fractures in middle one-third tibia shaft. More patients with trauma and non-union had higher grade of comminution. A total of 16 out of 26 patients had associated injuries (57.69%) of these 3 (11.53%) had multiple injuries. One patient underwent LRS fixation for bilateral tibia fractures, seven patients with bone loss underwent bone transport and one patients underwent split thickness skin grafting and flap repair. One patient with type IIIB fracture developed deep infection with pin loosening which warranted fixator removal, it was reapplied after the infection was under control. In two patients with type IIIA fracture, fibular osteotomy was done (Fig. 5) as intact fibula was not allowing compression at the fracture site. The most common complication encountered in this study was pin tract infection, which was treated with suitable antibiotics post culture and sensitivity testing. Out of 26 patients 4 knee orthodesis done. Hence, from 22 patients achieved good range of movements in the follow-up period. Among 26 patients, bony results as per ASAMI score were excellent in 73.07% (n=19), good in 19.23% (n=5), fair in 3.84% (n=1), and poor in 3.84% (n=1). Functional results were excellent in 84.7% (n=22), good in 11.5% (n=3), and fair in 3.8% (n=1). All the 26 cases of the lower extremity fracture were kept on LRS external fixator for a period of 5–6 months on an average depending on the rate of union, after which the fixator was removed and limb immobilized with Patella Tendon Bearing cast for another 3–4 weeks (Fig. 6).

Bony results	Description	Number of patients
Excellent	Union, no infection, deformity <70, limb length discrepancy <2.5 cm	19
Good	Union+any two of the following: No infection, deformity <70, limb length discrepancy <2.5 cm	5
Fair	Union+any one of the following: No infection, deformity <70, limb length discrepancy <2.5 cm	1
Poor	Nonunion/refracture/ union+infection+deformity >70+limb length discrepancy >2.5 cm	1
Functional results		
Excellent	Active, no limp, minimum stiffness (loss of <15 knee extension/< 15 dorsiflexion of the ankle), no reflex sympathetic dystrophy, insignificant pain	22
Good	Active with one or two of the following: Limp, stiffness, RSD, significant pain	3
Fair	Active with three or all of the following: Limp, stiffness, RSD, Significant pain	1
Poor	Inactive (unemployment or inability to return to daily activities because of injury)	-
Failure	Amputation	-

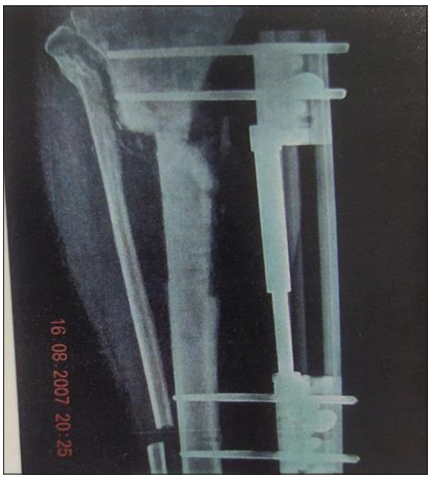

Fig. 5:

Fig. 6:

Bony and functional results as per ASAMI criteria

For two patients nailing was done after LRS frame removal. Average time for frame removal was 28 weeks. In most cases union was complete by 7–8 months, the least being 5 months for a tibia shaft fracture. The average hospital stay for the patients was 7 days and as compared to multi staged surgery financial burden was reduced by 40%. The average time of return to work for the patients was 3 weeks.

DISCUSSION

Open fractures remain to be one of the important challenges in orthopedics trauma. Although, newer and better treatment approaches for the management of open fractures are available. The conventional methods of treatment such as nailing or fixator with acute docking had a high rate of complications including bone loss leading to shortening, soft-tissue healing problems, increased morbidity, multiple surgeries, and longer hospitalization, finally increased chances of mal union and non-unions [2-5,12,13]. LRS is designed primarily for limb lengthening and in non-union and deformity correction, which includes different types of clamps (usually two or three) which can slide on a rigid rail and are connected with compression and distraction units. LRS uses osseous callus distraction for bone lengthening in a variety of procedures such as bone transport, simultaneous compression and distraction at different sites, mono-focal lengthening, bifocal lengthening, and correction of deformities with shortening. We studied 26 cases of the lower extremity trauma treated with a unilateral external fixator, LRS done by senior orthopedic surgeon in our hospital. All 26 cases of the lower limb were treated for various indications. There were 12 cases of infective non-union, 9 aseptic non-union, 3 fresh trauma, 1 infected TKR, and one case of septic arthritis knee due to osteomyelitis. The age of our patients ranged from 13 to 67 years with mean age 38 years. Majority of patients belongs to third and fourth decades of life. Sen [19], Mehmet MD, had a mean age of 34 years. It was 35.5 years (17–53) in series of Ali and Saleh [14,20-22] and 41 years in series of Treadwell [23]. Our patients had an overwhelming male predominance (73.7%), only seven were female (26.42%). This was similar to reported by Ali and Saleh [14,20-22] (40%) and 13 female in Treadwell study [23]. The mode of injury among our case was most commonly a road traffic accidents 16 case (61.53%), accidental fall was responsible in 23% cases, similar to observations of other authors. Anatomically, majority of fracture were of middle 3rd tibia (13 cases) as compared to femur (8cases). In Sen [19], series there were 7 tibia and 6 femur.

Comminution was graded by the Winquist-Hansen classification as grade -1 in 1%, grade-2 in 4%, grade - 3 in 14%, and grade - 4 in 5%, higher grades of comminution predominated probably due to high velocity mechanisms in the mode of injury. Fourteen cases with open fracture, 3.84% having grade - 1, 11.53% grade - 2, 7.69% grade - 3a, 26.92% grade - 3b and rest were closed fracture, single case of grade - 3c fracture as per the Gustilo-Anderson classification. The proportion of open fracture in series of Ali and Saleh was 60% [14,20-22]. Associated injuries were observed in 57.69% of our patients. This reflects the high velocity nature of trauma. In our study, bone was assessed for union, infection, limb length discrepancy, and mechanical insufficiencies at the docking site. The result considered excellent when there is union, no infection, deformity of <7° and limb discrepancy of <2.5 cm in femur, tibia, and fibula. The result was considered good when there was union and any two of other criteria, fair when there was union and one of other criteria. Poor where there was non-union or re-fracture or none of other criteria. LRS fixator gave us excellent or good result in 92% cases. Average time for frame removal in 28 weeks (10–96 weeks). A single case had a poor results due to persistent deep infection (3.84%), ten cases had pin site infection sufficiently severe to require antibiotic treatment. One patient had infection severe enough to require pin removal. Treadwell [23], studied 16 cases, four cases developed pin tract infection, five required isolated pin removal, two cases required entire frame removal. Hoffman *et al*. reported pin tract infection in 3%,

skin reaction in 6%, similar to our study. Mohr *et al.* reported 50% pin tract reaction which is more than our results. Three cases required readjustment of frame due to pin loosening [24,25].

Amongst 26 cases 4 knee arthrodesis done with various indication, single case done for infected TKR [26-28]. All patients had shortening of affected limb following knee Arthrodesis. The LLD has ranged from 2.5 to 4 cm. 22 cases from 26 were assessed for knee ROM. About 84.6% cases having good ROM with >120°. Mohr *et al.* reported 80% full ROM. Average flexion is 130°. Ali and Saleh [14] reported 80° average ROMs. Average time for union is 28 weeks. Paolo et al. reported average time for union in aseptic cases was 7 months (3–15 months), but in septic cases it was much longer, that is, 11 months (3–23 months). Ali and Saleh [14] reported that the average union time in their study was 10.4 months (4–24). Rothacker and Cabanela [28] reported a mean time for clinical union of 20.8 weeks (7–60 weeks) after knee arthrodesis. Wood *et al.* studied 27 cases and found a mean of 2.2 months longer for fusion to heal in patient who had the arthrodesis at the site of infection. In our series nine cases with LLD and rest 17 cases having pre-operative 3–15 cm shortening. The limb length nearly equalized in most of the cases. Saleh and Hammer [29], suggested bifocal lengthening in cases of extreme shortening or shortening with meta-physeal deformity. Overall, we got good results in doing management of complication trauma in the lower extremity using (LRS) unilateral external fixator.

CONCLUSION

On the basis of our clinical observation our study of 26 cases of the lower extremity fractures with complicated trauma managed by LRS unilateral external fixator. Overall, LRS proved to be an effective modality of treatment in cases of the lower extremity fracture with bone loss as definite modality of the treatment for damage control as well as for achieving union and lengthening/transportation, deformity correction simultaneously, with the advantage of simple surgical technique, ease of application, minimal invasive, strong fixation, high patient compliance, early weight bearing, easy wound management, and the lower rate of complication. It is a cost-effective mode of treatment. It saves time for the patient by reducing hospital stay and is a simple technique compared to Illizarov ring fixator. Patient compliance is excellent. Implant can be reused which brings down the cost of surgery considerably.

AUTHORS CONTRIBUTION

KU - Concept and design of the study, MB - Concept coordination, interpreted the results, preparation of manuscript, and revision of the manuscript, SS - statistical analysis and interpretation, reviewed the literature, HRJ - Thesis guide and he helped in concept and design of the study preparation first draft of manuscript.

REFERENCES

1. Tornetta P 3rd, Bergman M, Watnik N, Berkowitz G, Steuer J. Treatment of grade-IIIb open tibial fractures. A prospective randomised comparison of external fixation and non-reamed locked nailing. J Bone Joint Surg Br 1994;76:13-9.
2. Aldegheri R, Renzi-Brivio L, Agostini S. The callotasis method of limb lengthening. Clin Orthop Relat Res 1989;241:137-45. PMID 2924457
3. Donnan LT, Saleh M. Monolateral external fixation in pediatric limb reconstruction. Curr Orthop 1998;12:159-66.
4. Giebel G. Callus Distraction: Clinical Applications. Stuttgart, New York: Georg Thieme Verlag; 1992.
5. Saleh M. External Fixation of Long Bone Fractures in Children. British Orthopaedic Association Autumn Meeting. Cambridge; 1991.
6. De Bastiani G, Aldegheri R, Renzi-Brivio L, Trivella G. Limb lengthening by callus distraction (callotasis). J Pediatr Orthop 1987;7:129-34. doi: 10.1097/01241398-198703000-00002, PMID 3558791
7. Aronson J, Shen X. Experimental healing of distraction osteogenesis comparing metaphyseal with diaphyseal sites. Clin Orthop Relat Res 1994;301:25-30. doi: 10.1097/00003086-199404000-00005, PMID 8156684
8. Kojimoto H, Yasui N, Goto T, Matsuda S, Shimomura Y. Bone lengthening in rabbits by callus distraction. J Bone Joint Surg 1988;70-B:543-9.
9. Biermann JS, Marsh JL, Nepola JV, Lavini F, Renzi Brivio L. Unilateral Bone Transport System for Segmental Deficiency of Bone. In: Presented at the American Academy of Orthopedic Surgeons. Anaheim: California; 1991.
10. Saleh M, Burton M. Leg lengthening: Patient selection and management in achondroplasia. Orthop Clin North Am 1991;22:589-99. doi: 10.1016/S0030-5898(20)31692-8, PMID 1945337
11. Bohler L. The treatment of pseudoarthrosis. In: The Treatment of Fractures. Vienna: Wilhelm Maudrich; 1929. p. 23-8.
12. Raschke MJ, Mann JW, Oedekoven G, Claudi BF. Segmental transport after unreamed intramedullary nailing. Preliminary report of a "monorail" system. Clin Orthop Relat Res 1992;282:233-40. PMID 1516319
13. Saleh M, Royston S. Management of nonunion of fractures by distraction with correction of angulation and shortening. J Bone Joint Surg Br 1996;78:105-9. doi: 10.1302/0301-620X.78B1.0780105, PMID 8898138
14. Ali F, Saleh M. Treatment of distal femoral nonunions by external fixation with simultaneous length and alignment correction. Injury 2002;33:127-34. doi: 10.1016/s0020-1383(01)00032-8, PMID 11890914
15. Glowacki J, Mulliken JB. Demineralized bone implants. Clin Plast Surg 1985;12:233-41. doi: 10.1016/S0094-1298(20)31694-1, PMID 3886260
16. Saleh M, Rees AR. Bifocal surgery for deformity and bone loss-bone transport and compression distraction compared. J Bone Joint Surg 1995;77-B:429-34.
17. Noonan KJ, Leyes M, Forriol F, Cañadell J. Distraction osteogenesis of the lower extremity with use of monolateral external fixation. A study of two hundred and sixty-one femora and tibiae. J Bone Joint Surg Am 1998;80:793-806. doi: 10.2106/00004623-199806000-00003, PMID 9655097
18. Kamegaya M, Shinohara Y, Shinada Y. Limb lengthening and correction of angulation deformity: Immediate correction by using a unilateral fixator. J Pediatr Orthop. 1996;16:477-9. doi: 10.1097/00004694-199607000-00010, PMID 8784700
19. Sen C, Kocaoglu M, Eralp L, Gulsen M, Cinar M. Bifocal compression-distraction in the acute treatment of Grade III open tibia fractures with bone and soft-tissue loss. J Orthop Trauma 2004;18:150-7.
20. Saleh M. Nonunion surgery. Part I. Basic principles of management. Int J Orthop Trauma 1992;2:4-18.
21. Saleh M. Nonunion Treated with the Dynamic Axial Fixator: Results Presented at the Second Riva Congresson Current Perspectives in External and intramedullary Fixation. Riva del Garda, Italy, Abstract Book; 1992.
22. Staheli LT, Corbett M, Wyss C, King H. Lower-extremity rotational problems in children. Normal values to guide management. J Bone Joint Surg Am 1985;67:39-47. PMID 3968103
23. Treadwell JR. Rail external fixation for stabilization of closing base wedge osteotomies and lapidus procedures: A retrospective analysis of sixteen cases. J Foot Ankle Surg 2005;44:429-36. doi: 10.1053/j.jfas.2005.07.022, PMID 16257671
24. Colchero FR, Orst G, Vidal J. Scarification: Its role in the treatment of chronic fistulated pyogenic osteoarticular infection. Int Orthop 1982;6:263-71. PMID 7183579
25. Saleh M, Howard AC. Improving the appearance of pin-site scars. J Bone Joint Surg Br 1994;76:906-8. doi: 10.1302/0301-620X.76B6.7983116, PMID 7983116
26. Barrack RL, Butler RA, Andrews P, Rorabeck CH, Engh G. Managing the infected knee: As good as it gets. Orthopedics 2000;23:991-2. doi: 10.3928/0147-7447-20000901-33, PMID 11003109
27. Wasielewski RC, Barden RM, Rosenberg AG. Results of different surgical procedures on total knee arthroplasty infections. J Arthroplasty 1996;11:931-8. doi: 10.1016/s0883-5403(96)80134-3, PMID 8986571
28. Rothacker GW Jr., Cabanela ME. External fixation for arthrodesis of the knee and ankle. Clin Orthop Relat Res 1983;180:101-8. PMID 6627781
29. Saleh M, Hamer A. Bifocal lengthening-preliminary results. J Pediatr Orthop 1993;B2:42-8.