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External Fixation of Long Bone Fractures in Children

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= **Abstract** =

Twenty-eight patients with 20 tibia fractures and 8 femur fractures were treated with external fixation. The average age at fracture was 10 years 10 months ranging from 5 years to 17 years 6 months. Of 28 fractures, 6 were closed fractures and 22 were open fractures. The average follow-up of these children was 23 months. Monofixators were used in 12 fractures and Ilizarov fixators in 16 fractures. The average time to healing of the fractures was 14.6 weeks(range, 6 to 44 weeks). Seven segmental bone defects(range, 2 to 17cm) were treated with the Ilizarov method of internal bone transport using the transport ring and bone grafting at the docking site. The average healing index for callus distraction was 25 days per centimeter. Seven patients had 10 major complications that necessitated additional operative procedures. There were 4 nonunions. Three patients had an infected nonunion, which was treated with the Ilizarov fixator and polymethyl-methacrylate antibiotic beads. One patient had a hypertrophic nonunion which was treated with plate fixation. Three patients who had an epiphyseal injury had shortening with angular deformity, which was treated by callus distraction. Three patients had a joint contracture, which was treated by the percutaneous tenotomy and Ilizarov fixator. The selection of the type of external fixator depends on the fracture pattern and the Ilizarov fixator is recommended for complicated fracture with severe comminution or segmental bone loss.

Key Words : Children, Long bone, Fractures, External fixation

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INTRODUCTION

External fixation has been indicated for open fracture, severe soft tissue injury multiple fractures[9], and polytrauma with multisystem injuries and/or head trauma in children. The technique of external fixation has the disadvantages including injury to the physeal plate, infection, limb-length discrepancy, and delayed union. Despite the disadvantages of external fixation, the previous studies have reported the expanded use of external fixation for treating acute fractures of femur and tibia in children and the successful results with early ambulation, maintenance of length, and good alignment[1,2,8,12]. The purpose of this retrospective study was to determine the complications and effectiveness of external fixation for treating the fractures of long bone in children.

MATERIALS AND METHODS

Between 1987 and 1992, twenty-eight patients with 20 tibia fractures and 8 femur fractures were treated with external fixation. All cases were followed to the completion of healing and were studied with the use of preoperative and postoperative radiographs and hospital and office records. The follow-up period ranged from 17 to 48 months, with an average of 23 months. Nineteen fractures occurred in males and 9 in females. The ages of patients ranged from 5 years to 17 years(mean, 10 years 10 months). Twenty-six fractures occurred in automobile accidents, and 2 in falls. Of the 28 fractures, 22 were open and 6 were closed. There were 3 type-II, 5 type-IIIA, 11 type-IIIB, and 3 type-IIIC fractures according to the classification of Gustilo et al[6]. Four of the 6 closed fractures were comminuted and 2 were spiral fractures in the multitraumatized patient with head injury. Thirteen of the 22 open fractures were comminuted, 7 were fractures with bone loss, and two were segmental and spiral fracture. Of the 28 patients, 5 had the floating knee due to ipsilateral fractures of the femur and tibia. Five patients had an epiphyseal injury with the fracture of metaphysis or diaphysis. There were 2 Salter-Harris type-V, 1 type-IV, 1 type-III, and 1 type II. Ten patients had 18 associated injuries, which included 12 other fractures, 4 abdominal injuries, and 2 closed head injuries.

All open fractures were irrigated, debrided with more extended incision through the open wound in the operation room after the general condition of the patients were assessed. Parenteral antibiotics were given according to the results of bacterial sensitivity tests.

All fractures were stabilized with external fixator at the initial surgery. Twelve monofixators including 6 Orthofix and the other types, and 16 Ilizarov fixators were used. The indications of monofixator were the fractures involving the diaphysis without severe comminution and bone loss. The indications of Ilizarov fixators were the comminuted fractures of the proximal and distal metaphysis, the segmental fractures of the diaphysis extending to the metaphysis, and the bone loss fractures.

In using monofixators for the femur and tibia fractues, 2 or 3 half pins were used above and below the fracture. As a reference pin, the 5 or 6mm Schanz screws or Orthofix pins were inserted parallel to the knee joint and ankle joint line at a point 2-5cm from the physis of the tibia and the distal femur. The proximal pin of the femur was placed from the base of the greater trochanter across to the lesser trochanter.

The preassembly of Ilizarov frame was done before operation. The femoral frame of one arch with or without one ring proximally and 2 rings distally was assembled. Half pins were used at the proximal arch and ring, and wires were used at the distal rings. A four-ring frame was assembled in the linear and comminuted fracture of the tibia and

a five ring-frame was assembled in the bone loss fracture for internal bone transport. For the patient who had an epiphyseal injury with a metaphyseal fracture of the proximal or distal tibia, additional rings were assembled above the knee joint and below the ankle joint for more stability. A proximal and a distal ring were assembled parallel to the knee joint and ankle joint line and two reference wires were inserted at a point 1-2cm from the physis. Two central rings were placed at 3-4cm distance from the fracture.

The half pin mounting technique with the Ilizarov apparatus was used for the open fracture and the fracture with compartment syndrome, Half pins were used with half rings in the open fracture with soft tissue defect for leaving the space to perform the secondary operation for the soft tissue coverage. After the secondary operation, half rings were changed to full rings for enhancing stability, and additional wires or half pins were inserted for reduction and bone transport. For the fracture with compartment syndrome and neurovascular injury, half pin mountings with half or total rings were used for avoiding more damage of soft tissue and neurovascular tissue. The reduction of the fracture was done with olive wires, conical washer, and hinge system with image intensifier during operation. For the closed fracture with comminution, the multiple fragments were stabilized or reduced with olive wires. Two of 6 closed fractures were treated with bone grafting during the follow-up to decrease union time. Seven fractures with bone loss ranging from 2cm to 17cm(mean, 5.4cm) occurred in 5 tibiae and 2 femorae, and were treated with internal bone transport after one-level corticotomy. The usual rate and rhythm of distraction after corticotomy was 0.25mm qid. The internal bone transport method using transverse full-ring could transport the soft tissue including skin and treat the soft tissue defects. After the bone transport, the residual soft tissue and bone defects were treated with the Papineau-type open cancellous bone graftings at the docking site.

Three of 5 patients with floating knee were treated by intramedullary nailing for the femoral fractures and by external fixation for the tibial fractures. One patient was treated by open reduction and K-wire fixation for the distal femoral epiphyseal fractures, and by external fixation for the tibial fractures. One patient had a segmental open fracture of the femur involving the diaphysis and epiphysis with a closed spiral fracture of the ipsilateral tibia. The femoral fracture was treated with Orthofix fixator and K-wire fixation and the tibial fracture was treated with open reduction and K-wire fixation.

Postoperatively in the operation room, roentgenographs were made on long cassettes (14 inch x 17 inch) so that the joint line of the knee and ankle or hip could be visualized on the same film for the evaluation of the overall alignment of the tibia and the femur.

The quadriceps strengthening exercise began on the first postoperative day. The gradual gait training began 4-6 days after operation, but was delayed for the patients with multiple fractures and open fractures until the patient is able to bear the weight with the aid of crutches or walker. Walking on three or four points was recommended to distribute the weight. In the patient treated with bone transport, intensive physiotherapy including splinting and stretching of the knee and ankle joint was done to prevent a joint contracture. Healing status was evaluated with anteroposterior, lateral, and both oblique radiographs. Before the frame removal, the patients were allowed to walk after destabilization of the frame, and the pain and motion were checked at the fracture site to confirm the clinical consolidation. If pain and motion were absent after walking and the roentgenogram showed the unchanged alignment of the fracture site, the frame was removed. After the frame removal, a patellar-tendon bearing cast or brace in tibial fractures and a long leg cast or brace were

applied for 4-6 weeks to prevent refracture. In the group of patients who refused to use a cast or brace, wires and half pins were removed one by one to transfer more stress at the fracture site as an alternative method for prevention of refracture.

RESULTS

Twenty-eight patients less than 18 years of age on the day of injury were reviewed 17 to 48 months after fracture healing. The average follow-up was 23 months. The average hospital stay in patients without other injuries was 28 days, including preoperative time in skeletal traction. The average time to union was 14.6 weeks(range, 6 to 44 weeks). The time to union was directly related to the fracture pattern and the severity of soft tissue injury.

Seven patients had 10 major complications that necessitated the operative procedure. There were 3 infected nonunions and 1 hypertrophic nonunion. Treatment for infected nonunion involved radical debridement, the use of polymethylmethacrylate-antibiotic(gentamycin) beads, and fixation with the Ilizarov fixator. Four weeks after the use of PMMA-antibiotic beads, two patients were treated with bone grafting at the bone defect area and one patient was treated with internal bone transport and bone grafting at the docking site. One patient who was treated with the Orthofix fixator for the segmental fracture of the femur had a hypertrophic nonunion of the femoral diaphysis because of unstable fixation. Open reduction and internal fixation with plate and screws was performed.

Three patients who had an epiphyseal injury had an resultant angular deformity with shortening ranging from 3cm to 8cm. these deformities were treated with callus distraction using the Ilizarov fixator after corticotomy at the proximal metaphysis of the tibia for the correction of angulation and lengthening. Three joint contractures occurred during treatment and after removal of Ilizarov fixator. Two equinus deformities(25° and 30°) of the foot developed in one patient treated with 8 cm of internal bone transport and in the other patient who had the scar contracture at the ankle joint after severe soft tissue injury with open fracture. These patients were treated with slow distraction using hinge joint of the extended Ilizarov assembly distal to ankle joint after percutaneous tenotomy of tendo calcaneus. One 30° flexion deformity of the knee occurred in the patient, who had a floating knee and was treated with intramedullary nailing for the femoral fracture and bone transport with the Ilizarov fixator for the tibial fracture with bone loss(4cm). He was treated with the extended Ilizarov assembly above the knee joint without tenotomy of knee flexors.

The minor complications, which were solved with conservative method or minor operation, included pin and wire tract infection, loosening of pin and wire, refracture, and delayed union. Of 75 total half pins, 10(13%) had inflammation, 5 of which had infection with loosening. Of 106 total wires, 11(10%) had inflammation, 6 of which had infection with loosenings. A pin and wire tract infection treated with oral or intravenous administration of antibiotics and local injection of antibiotics around the pin and wire tracts. Five pin tract infections with loosening were treated with removal of pins and insertion of additional pins at the other sites. Six wire tract infections with loosening were treated with retensioning or additional wire insertion at the other site after removal of wires. No pin and wire tract infection led to a ring sequestrum or chronic bone infection. One refracture of the tibia was treated with plater cast.

Excluding the patients with epiphyseal injury, 2 of 6 patients who had a femoral fracture treated with external fixation had overgrowth from 5mm to 12mm and 4 of 18 patients who had a tibial fracture treated with external fixation had overgrowth from 4mm to 10mm. Of 5 floating knees, one patient who had a femoral fracture treated

with intramedullary nailing had overgrowth(2cm) of femur and one patient who had tibial fracture treated with K-wire and screw fixation had overgrowth(2.5cm) of tibia.

CASE REPORTS

Case 1(Fig. 1)

A 14-year-old boy was struck by a car. He sustained a type-IIIC open fracture of the left tibia with bone loss of 10cm and an injury of anterior tibial artery. He also sustained a closed transverse fracture of the middle third of the ipsilateral femur. The femoral fracture was treated with intramedullary nailing. The tibial fracture was treated by the fibular free flap transferred from the oppostie leg and external fixation with Orthofix fixator. The transferred fibula became necrotic and absorbed due to osteomyelitis. After radical debridement of the infected fibula and surrounding soft tissue, the bone defect of 17cm developed and was treated by internal bone transport with Ilizarov fixation after corticotomy at the proximal metaphysis of the tibia. The Papineau-type open cancellous bone grafting was performed at the docking site to cover the residual soft tissue defect and for bone healing. The fracture healed with 10° valgus and 10° posterior angulation 12 months after injury. Scanogram 14 months after injury demonstrated a leg length discrepancy of 6.0cm. The tibial lengthening was performed 18 months after injury.

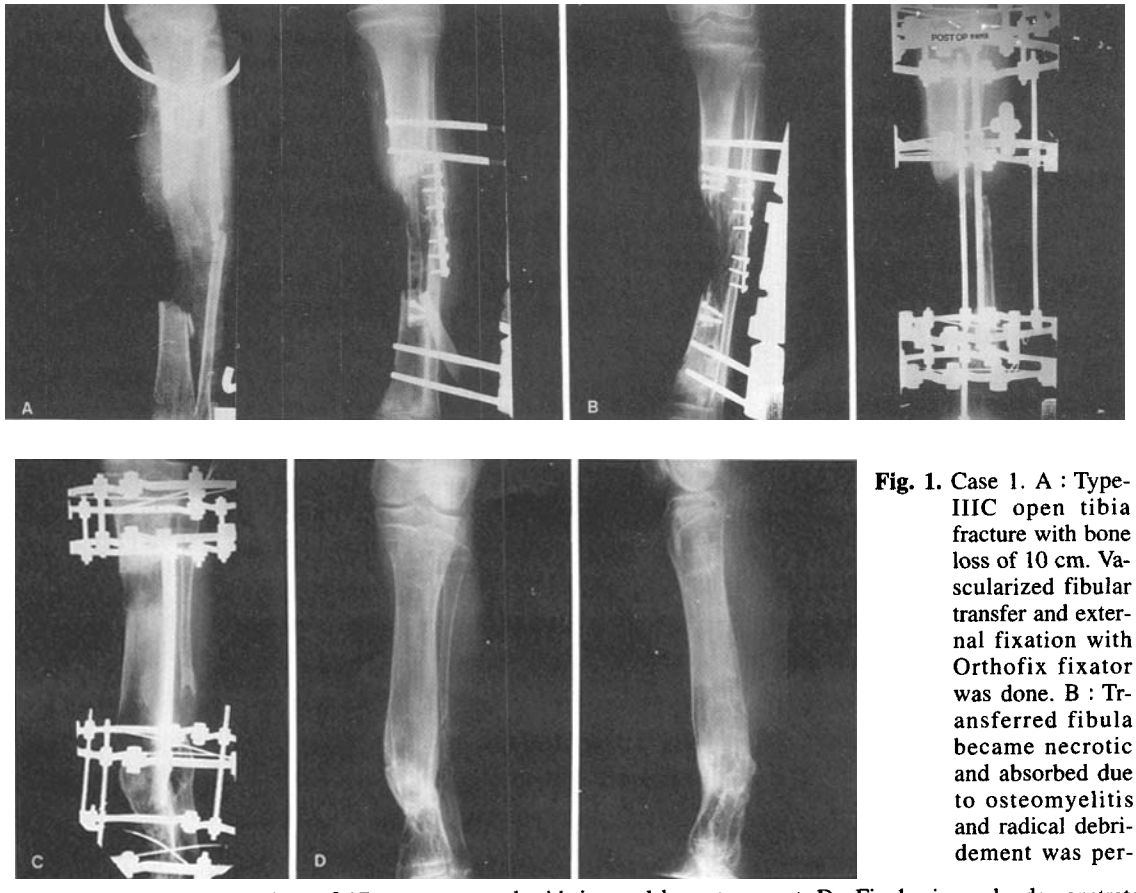
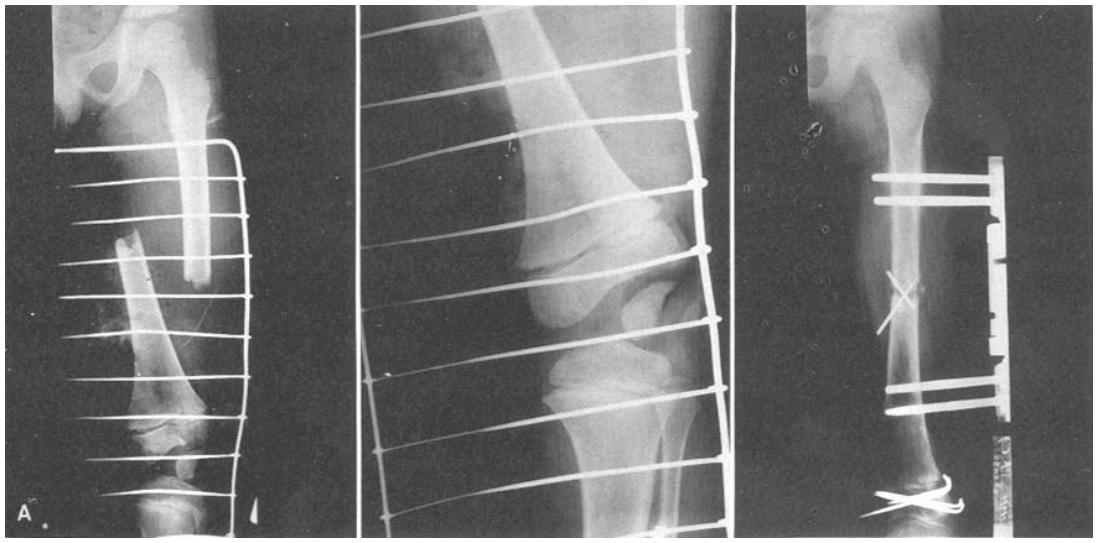


Fig. 1. Case 1. A : Type-IIIC open tibia fracture with bone loss of 10 cm. Vascularized fibular transfer and external fixation with Orthofix fixator was done. B : Transferred fibula became necrotic and absorbed due to osteomyelitis and radical debridement was performed. C : Bone loss of 17cm was treated with internal bone transport. D : Final raiographs demonstrate solid union with 10° valgus angulation and 10° posterior angulation



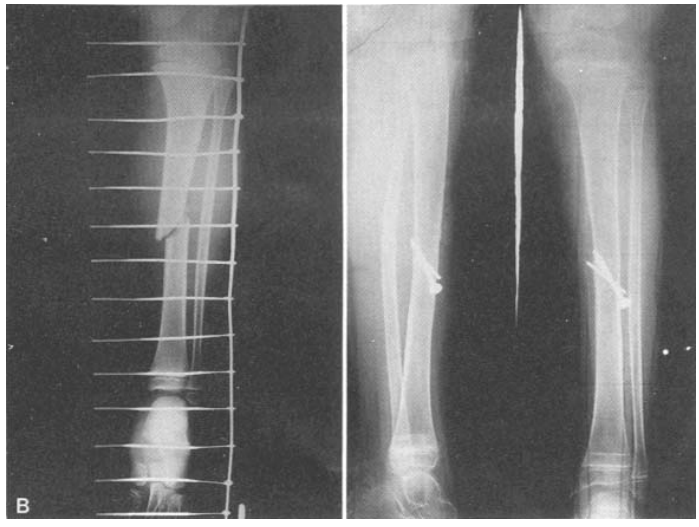


Fig. 2. Case 2. A : Type-IIIB open segmental fracture of the femur involving diaphysis and the distal epiphysis (Salter-Harris type III) that was treated with Orthofix fixator and K-wire fixation. B : Closed fracture of the ipsilateral tibia treated with open reduction and K-wire and screw fixation.

Case 2(Fig.2)

A 12-year-old boy was struck by a truck. He sustained a type-IIIB open segmental fracture of the left femur including the fracture of diaphysis and the distal femoral epiphyseal injury(Salter-Harris type III). He also sustained a closed spiral fracture of the ipsilateral tibia. The anterior half of knee joint was exposed at the time of injury. The quadriceps tendon, vastus medialis muscle, medial and lateral collateral ligament and joint capsule were ruptured with partial loss and repaired partially. The Orthofix fixator was applied for the diaphyseal fracture and the epiphyseal fracture was treated with open reduction and K-wire fixation. The tibial fracture was treated with open reduction and K-wire with screw fixation. A split-thickness skin graft was performed for wound coverage. The hypertrophic nonunion occurred due to unstable fixation and was treated with open reduction and plate fixation. The 45° genu valgum deformity occurred due to the growth arrest of lateral physis of the distal femur during follow-up. The open

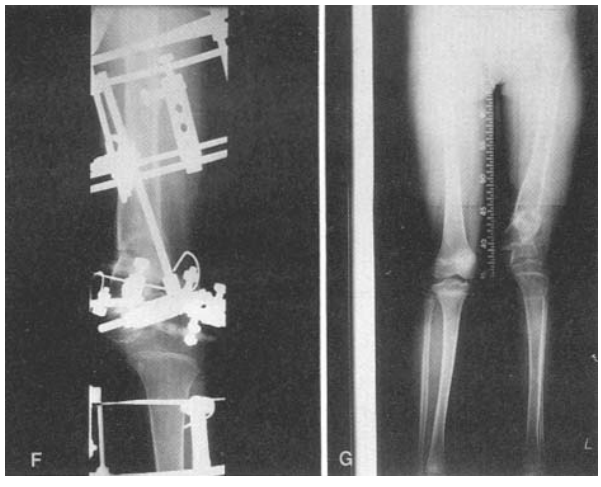


Fig. 2. Case 2. C : The hypertrophic nonunion occurred due to unstable fixation and was treated with open reduction and plate fixation. D : The genu valgum deformity with shortening of 3cm occurred due to the growth arrest of lateral physis of the distal femur. E : Even though genu valgum deformity was treated with open wedge osteotomy and plate fixation, this deformity recurred 14 months after operation. F : Hemiepiphysiodesis and Ilizarov fixator was applied for gradual correction of deformity. G : Final radiograph 14 months after removal of Ilizarov fixatior.

wedge osteotomy with plate fixation was performed for deformity correction. The genu valgum deformity with the shortening of 3cm recurred during follow-up after corrective osteotomy. The percutaneous hemiepiphysiodesis was done when Ilizarov fixastor was applied after plate removal for the lengthening and deformity correction. The genu valgum deformity was corrected but 15° genu valgum deformity remained during valgus stress test or full weight bearing due to the laxity of medial collateral ligament of the knee joint.

Case 3(Fig. 3)

A 14-year-old girl was struck by a car, causing a type-IIIB open comminuted fracture of the right tibia with epiphyseal injury(Salter-Harris Type IV) and extensive skin loss over the medial portion of the leg and ankle. The Ilizarov fixator was applied on the day of injury after debridement and irrigation. The multiple fragments were stabilized and reduced with olive wires. The fracture healed 5 months after injury. The 15° varus angulation of

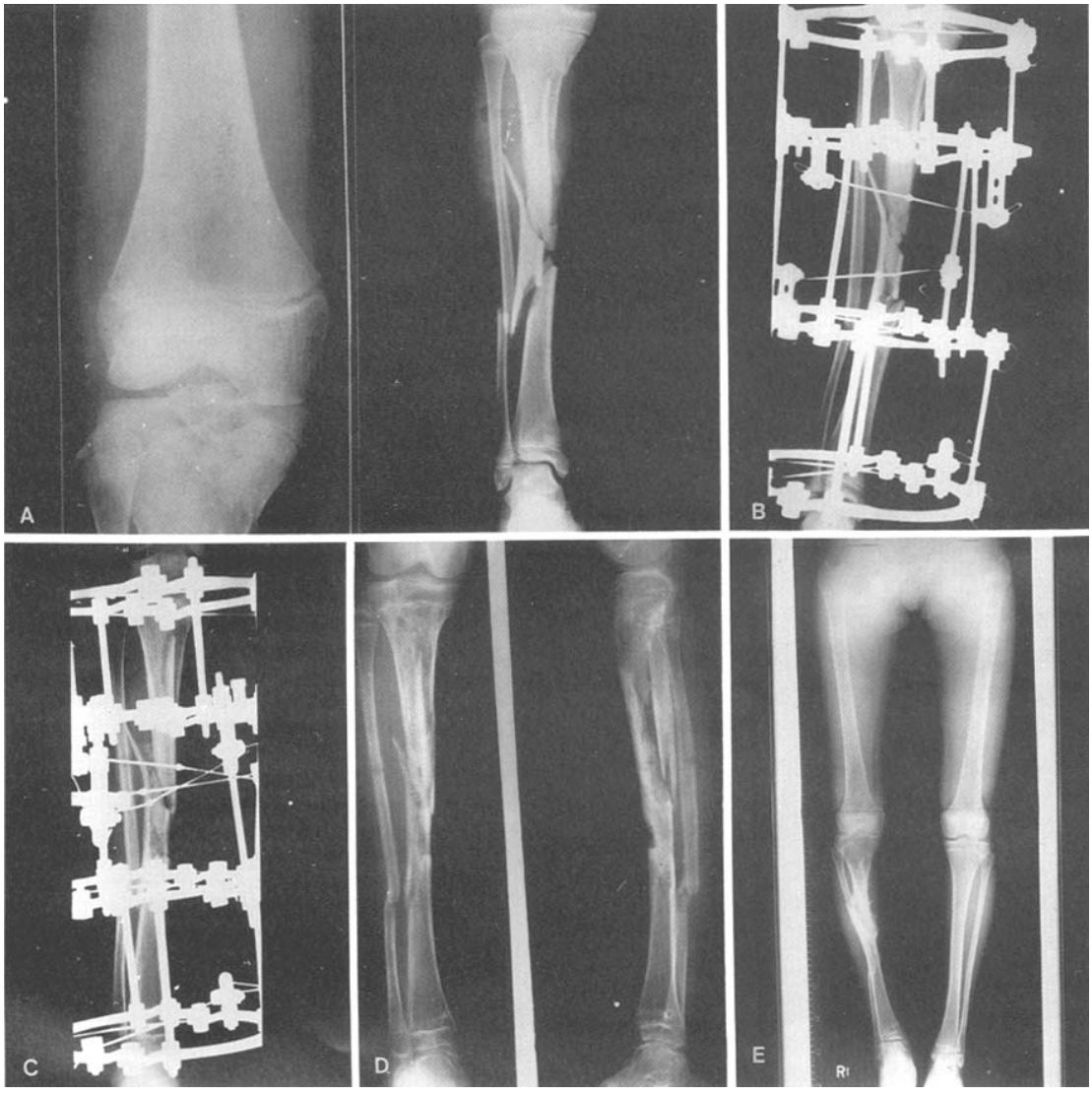


Fig. 3. Case 3. A : Type-IIIB open comminuted fracture of the tibia with the epiphyseal injury(Salter-Harris type IV). B : Closed reduction and external fixation with Ilizarov fixator. C : At 1 month after injury, bone grafting and stabilization with multiple olive wires was performed to decrease time to union. D : Fracture of tibia healed 5 months after injury. E : Tibia vara deformity occurred 12 months after injury because of premature growth arrest of proximal medial physis.

the proximal tibia with the shortening of 3cm developed during follow-up due to the growth arrest of the proximal metaphysis. The equinus deformity of the ankle joint occurred due to the scar contracture of ankle joint. The Ilizarov assembly with a 5-ring frame at the tibia and below ankle joint was reapplied for correction of deformity and shortening after the corticotomy and percutaneous tenotomy of tendo calcaneus.

DISCUSSION

The outcome of fractures of long bone in children treated with conventional method has been well documented, but a few studies[1,11] have reported the outcome of fractures in children treated by

external fixation because the indication was limited to the open fracture and head injury. the unilateral frame fixator including Wagner, Orthofix, and AO/ASIF have been popularly used because of its simplicity and easy manipulation. The unilateral frame fixators cannot allow correction of rotational alignment with a limited correction of valgus, varus, and anterior(or posterior) angulation. It is difficult to use unilateral fixators for the fracture of metaphysis with comminution, segmental fracture, and fracture with a large bone defect. The circular fixators including Ilizarov, Volkov and Oganesyan apparatus[13] have been used in Russia from 1951, Ilizarov apparatus has the elastic stabilization and the adjustability with wide indication as compared with unilateral fixator.

Authors used the unilateral fixators for childrens fracture before the introduction of Ilizarov method to our country in 1989. After then, we used the Ilizarov fixator with the tensioned wire and experienced frequently the side effect which is the decreased range of motion of the joint due to the transfixion of muscle and tendon. From 1991, we started to perform the modified Ilizarov method with transfixation wire combined with half pin mounting technique to decrease the side effect of transfixion wire. With Ilizarov apparatus, half pins can be inserted at a different level and with a different angle and plane. This half pin mounting technique has the stability and the capability of angular correction in three dimensions[5].

Nonunion has not been reported in fractures of children treated with external fixation. Three of our ptients have infected nonunion due to chronic osteomyelitis after treatment with Orthofix fixator in open fracture. The thorough initial irrigation and debridement is recommended for prevention of infection[4]. Pin-tract or wire-tract infection was not related to the development of chronic osteomyelitis.

Previous studies[2,3,11] reported the rate of pin tract infection from 8.5% to 40% and all pin tract infections were treated successfully with adequate pin care. In this study, pin tract infection(13%) occurred more than wire tract infection(10%). Pin and wire tract infections occurred at the metaphysis and juxta-articular area more than at the diaphysis and this incidence appeared to correlate with soft tissue irritation and tethering effect of pin and wire during frequent joint motion.

Other studies[7,12] reported the rate of overgrowth from 20% to 40% in treatment with external fixators. This overgrowth may be correlated with the increased blood flow and physeal stimulation from the presence of fixator pins. The mechanical release of the periosteal rastraint also attributed to the overgrowth after fracture but anatomical reduction with external fixator could minimize the overgrowth by restoring the periosteal restraint. Aronson[2] reported the minimal overgrowth from 2mm to 10mm in 38% of his patients after anatomical reduction and external fixation for femoral fractures. In this study, 25% of the patients had the overgrowth from 5mm to 15mm after external fixation and there was no difference of overgrowth incidence between the half pin using group and the wire using group.

The incidence of fracture with segmental bone defects was very rare in children. Segmental bone defects have been treated with bone grafting, vacularized fibular transfer, and bone transport. It is difficult to treat with extensive bone grafting and vascularized fibular transfer in children because of insufficient donor site for bone grafting and small neurovasucular structures as compared to the adult. Although the Ilizarov method of bone transport has advantages including the ability of soft tissue coverage using transport ring and early ambulation, it has the complications such as pain and damage to neurovascular structures and joint contracture[10]. These complications do not allow the patient to bear weight from the start, and lead to disuse osteoporosis and loosening of pin with instability of external fixation. Aggressive physio-

theraphy and early weight bearing are recommended during internal bone transport to achieve an excellent bony result and functional result. In this study, 7 segmental bone defects more than 2cm were successfully(100%) treated with internal bone transport with the Ilizarov fixator and the healing index for callus distraction was about 25 days per centimeter. Two joint contractures occurred during bone transport(4 and 7cm) and were treated with surgical treatment. Two patients had a joint stiffness with functional position at the ankle and knee joint after prolonged period of immobilization of the joint for stability and refused further treatment.

CONCLUSION

The fracture pattern should be considered as an important factor in selection of the type external fixator for successful outcome. Ilizarov method is more useful for the fracture with segmentation, comminution, and bone loss compared with monifixator. Monofixator is indicated for the diaphyseal fracture for early ambulation, and good alignment. Bone grafting is necessary in the open fracture with comminution in order to reduce the application time of external fixation and the time to union.

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= 국문 초록 =

소아골절에서 외고정기구를 이용한 치료

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송해룡 · 조세현 · 구경회 · 민영식 · 정연천 · 황선철 · 김재수 · 김지연

20명의 경골 골절과 8명의 대퇴골 골절환자 28명에게 외고정기구로 치료하였다. 환자의 나이는 최소 5세에서 최대 17세 6개월로 평균 나이는 10년 10개월이었다. 28례중 6례가 폐쇄성 골절이었고 22례가 개방성골절이었다. Gustilo의 분류에 다르면 Ⅱ형이 3례, ⅢA형이 5례, ⅢB형이 11례 그리고 ⅢC형이 3례 였다. 동측성 대퇴골 경골골절로부터 생긴 floating knee가 5례에서 일어났다. 이 소아들의 평균 추시기간은 23개월이었다. Monofixator가 12례에서 사용되었고 Ilizarov fixator는 16례에서 사용되었다. 골절의 치유기간은 최소 6주에서 최대 44주로 평균 치유 기간은 14.6주였다. 7례의 분절성 골결손은 transport ring을 이용한 internal bone transport의 Ilizarov방법과 docking site에서의 골이식으로 치료하였다. 평균 치유 지표는 1㎝ 연장에 25일이 소요되었다. 7명의 환자에서 추가적인 수술이 필요한 10례의 주요 합병증이 생겼다. 4례의 불유합이 있었다. 3명의 환자에서 감염성 불유합이 발생하여 Ilizarov fixator와 polymethylmetacrylate antibiotic bead로 치료하였다. 골단손상을 받았던 3명의 환자에서 각변형을 동반한 단축이 나타났고 가골 신연술로 치료하였다. 관절구축이 나타난 3명의 환자들은 피하건 연장술 및 Ilizarov fixator로 치료하였다. 소아 골절의 치료에서 골절의 양상에 따른 외고정 기구의 선택이 중요하다고 사료되며 단측 외고정 기구는 골간부의 단순 골절시 정확한 정복 및 조기 보행을 위하여 적용될 수 있으며 Ilizarov fixator는 심한 분쇄성 또는 분절성 골결손을 보이는 복잡골절인 경우에 권장된다.