External Skeletal Fixation Using Methylmethacrylate for Infected Nonunion

SHIRO INOUE, M.D.

Department of Orthopedic Surgery, Murakami Memorial Hospital, Asahi University, 3-23 Hashimoto-cho Gifu City, Japan.

ABSTRACT: In 1970, auther invented an external skeletal fixation using self curing acrylic resin (methylmethacrylate) which was applied by inserting A-O cortical screws into the diaphyseal region and A-O cancellous screws into the epiphyseal and/or metaphyseal regions. The position of the screws was designed to secure three-dimensional fixation. Points of insertion are selected that avoid infected bone, open wounds, thick muscles, and skin that is relatively mobile during joint motion. After reduction the acrylic resin rather than conventional metal linking devices is used for fixation of the screws. Once the fixation is completed, it is adjustable and so rigid that exercises for joint function are possible. The apparatus is so light in weight and sufficiently so compact to fit under normal clothing that the patient can walk and easily be treated as an out-patient. In the 259 patients treated by this method, open tibial fractures occurred in 141; infected nonouion or delayed union in 38; metaphyseal and epiphyseal fractures in 36; femoral fractures in 10 children; and miscellaneous fractures and other conditions in 34 cases. Nearly all of the operations were successful. Four patients had refractures after removal of the fixation.

INTRODUCTION

Recently, many kinds of external skeletal fixation apparatus are on sale and have attracted attention of surgeons. It is because they have advantages of easy fixation, little effect on the the patient's general condition, no surgical damage of soft tissue at the fracture site by reduction and fixation, insertion of pins avoiding contaminated or infected area of fracture site, no foreign body for fixation at the fracture site and easy removal of the fixation. In 1970, auther invented an external skeletal fixation method using methylmethacrylate instead of conventional metal linking devices.[1] Since that time improvements have been made in the method.[2-7] Currently, A-O-type cortical or cancellous bone screws are inserted percutaneously into the bone and then externally connected by methylmethacrylate (Figure 1). By this method screws can be inserted into any area and in any direction, depending on the condition of soft tissue and bone fragments, thus avoiding the limitations of conventional linking devices. The method rigidly immobilizes the fractures segments in three dimensions once the devices are externally fixed by methylmethacrylate (Figure 1).

Due to the simplicity of the technique and the rigid fixation it produces as compared with the conventional external skeletal fixation devices, the method is becoming popular among Japanese orthopedic surgeons.[8] It can be applied to many kinds of fractures, giving exceptional individual flexibility.

The present paper describes the author's current technique of applying this external skeletal fixation for the every kind of fixation as well as infected non union, clinical results, and indications.

MATERIALS AND METHODS

Since 1970 the authors have used their external skeletal fixation method in 259 patients. Conditions treated were open tibial fracture with soft tissue damage (141 patients); delayed union or nonunion of the tibia with osteomyelitis (38 patients); comminuted metaphyseal and epiphyseal fractures of the tibia, most of which were open fractures (36 patients); femoral fractures in children (10 patients); comminuted femoral fracture too difficult to fix by conventional internal fixation (12 patients); comminuted humeral fracture (1 patient); comminuted fracture of pelvis (1 patient); tibial osteotomy (5 patients); arthrodesis of the knee and ankle (8 patients); facial fracture (zygoma, mandible; 4 patients); and plastic surgery (fixation of legs for cross-leg skin graft, 3 patients).

Technique

The methylmethacrylate cement used in this method is a radiolucent material used in dental

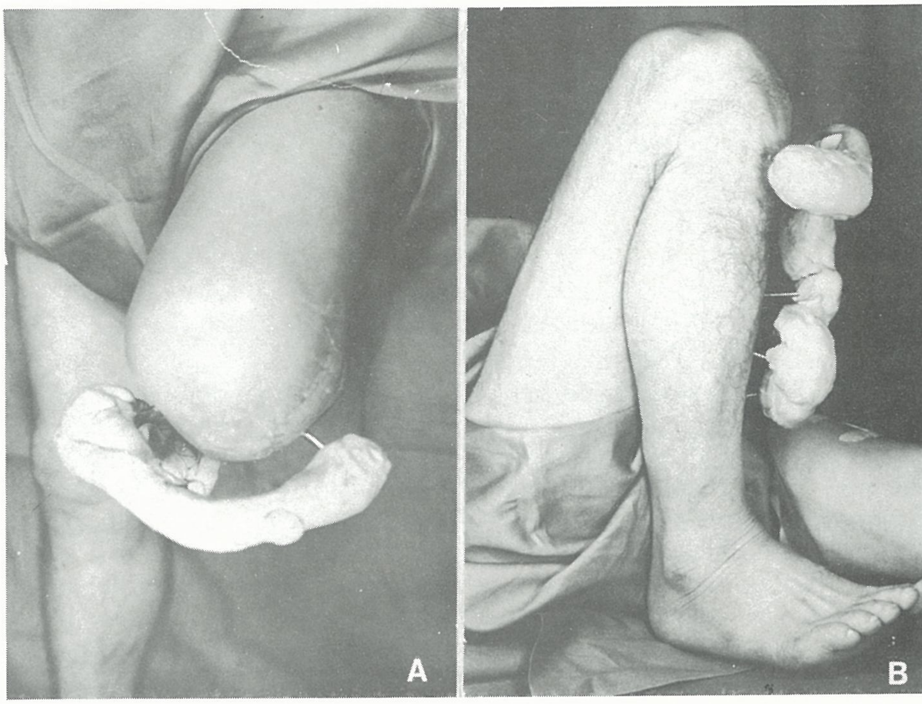


Fig. 1-A: In the metaphyseal region the screw must be inserted at approximately 45° into the anteromedical or anterolateral aspect, because the skin in these areas is least mobile during adjacent joint motion.

Fig. 1B: External skeletal fixation using cement for an open comminuted fracture of the proximal tibia. The patient has full range of knee and ankle motion.

molding. Sometimes called self-curing acrylic resin, it is sterilized by ethylene oxide gas. It is much less expensive than the regular bone cement used in total arthroplasty. Methylmethacrylate will henceforth be referred to as "cement" (Figure 2).

The entire leg is prepared routinely. The wound is irrigated by copious saline solution, and devitalized tissue is debrided. All except small wounds are closed temporarily before screw insertion, because the skin tension around screws makes wound closure difficult; final closure is done later.

Screws are inserted into the fractured segments through a small stab incision. The authors prefer the A-O-type heavy cortical or cancellous screws (10-12 cm in length) to regular bone screws because of their durability and deep pitch. Cortical screws are inserted into the diaphysis and cancellous screws into the metaphysis and epiphysis percutaneously. Several screws are inserted into each proximal and distal segment in different directions, avoiding the damaged soft tissue, neurovascular structures, tendons, and thick muscle. The varied directions are essential if the fracture fragments are to be solidly anchored.

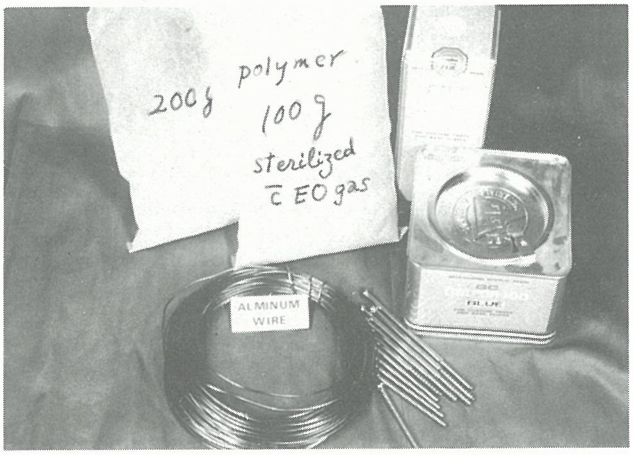


Fig. 2: Materials for external skeletal fixation using methylmethacrylate, polymer: powder, monomer: liquid aluminium wire 0 13 mm A-O cortical bone screw (10-12 cm in length) A-O cancellous bone screw (10-12 cm in length)

In the case of a diaphyseal tibial fracture the screws are usually inserted into the anteromedial aspect of the leg, where the tibia is free of important soft tisues. In the metaphyseal region the screw must be inserted at approximately 45° into the anteromedial or anterolateral aspect, because the skin in these areas is least moblile during adjacent joint motion. Therefore, irritation of soft tissues at the pin site does not often occur (Figure 1). Figure 3 shows the method for ascertaining the optimum screw site. Screws should be inserted through both cortices, and the head portion should remain about 5 cm outside of the skin, ensuring that the fragments will be held tightly.

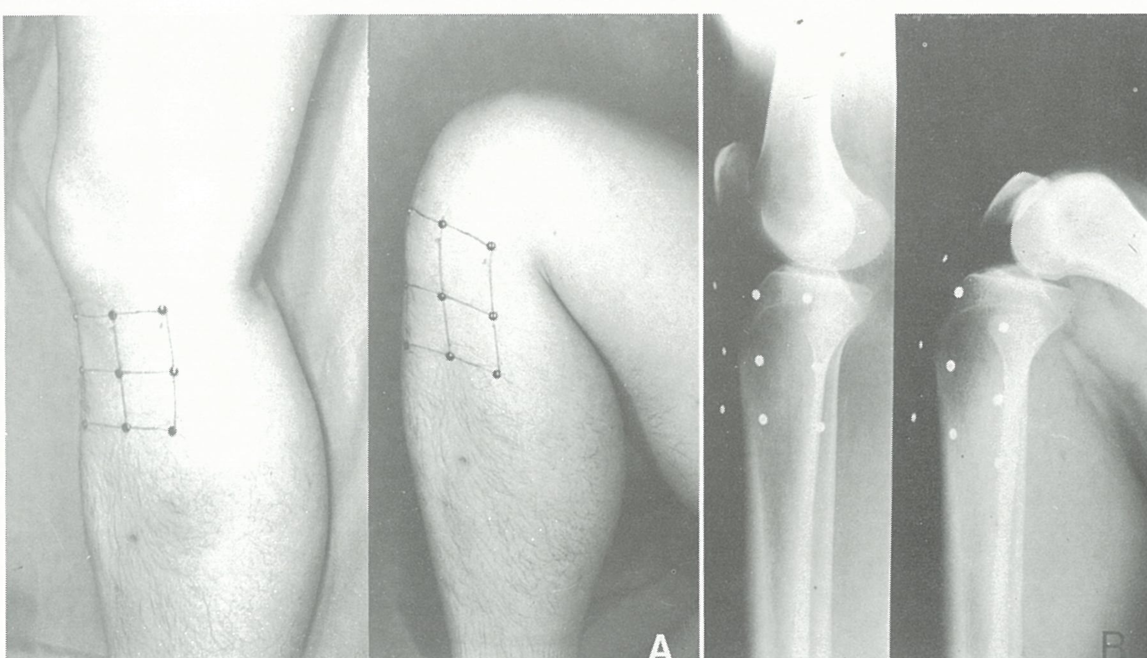
The fractured segment is reduced using either an image intensifier or direct vision. In an "easy" reduction, while the reduction is maintained, aluminum wires (1.3 mm) are strung from screw to screw and tied neatly around each screw to prevent the cement from dripping before it sets. Small balls of cement are then applied to the wire and screw connections to obtain snug fixation between cement and screws. After the cement sets a large amount of cement (about 200 gm) is applied, incorporating all wires and screws (Figure 4). So that dressing changes can be easily made, the cement should not cover the area over the wound.

In a "difficult" reduction, each proximal and distal fractured segment is fixed separately by cement after screw insertion and aluminum wiring (Figure 5). For manipulation of the displaced fracture, the two sections of cement are handled under the image intensifier or by direct vision through the open wound. While the reduction is maintained external skeletal fixation is complete by covering the previously fixed separate segments with another mass of cement.

In either situation the wound is closed primarily after confirmation of good reduction and fixation.

The methods of screws insertion and cementing should be changed according to the type and site of the fracture. In a diaphyseal fracture screws should be inserted into the proximal (Figure 6). If the fracture is in the metaphysis, several cancellous bone screws should be inserted into the metaphyseal fragment in various directions, and several screws should be inserted along the length of the fracture into the larger disphyseal fragment (Figures 7 and 8). In this manner stable fixation can be obtained. In comminuted fractures the butterfly segment can be secured by a screw, which places the fragment in contact with the other fragments, and maintained by external skeletal fixation.

When fixation is considered insufficiently strong, additional screws and cement can be applied easily any time after surgery. In the case of a malaligned fractured segment, the cement used for



Figs. 3-A and 3-B: To determine the optimum screw location, iron balls were glued to the skin near the knee joint; (A) photographs and (B) roentgenograms were then obtained. The anteromedial area shows the least distortion and mobility during knee motion. The same experimental procedure applied to the lateral side showed the anterolateral area to have the least distortion and mobility.

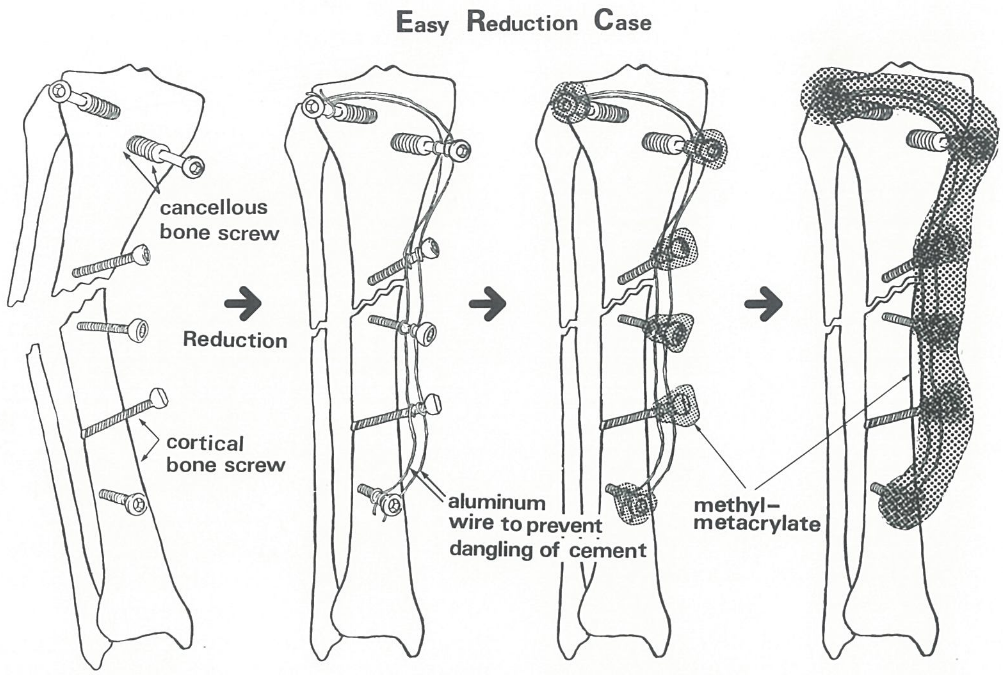


Fig. 4: In an "easy" case reduction is performed after screw insertion. While reduction is maintained, aluminum wiring to prevent the cement from dripping before it sets, and then small cement balls are applied to the connections. Cementing is then compelted.

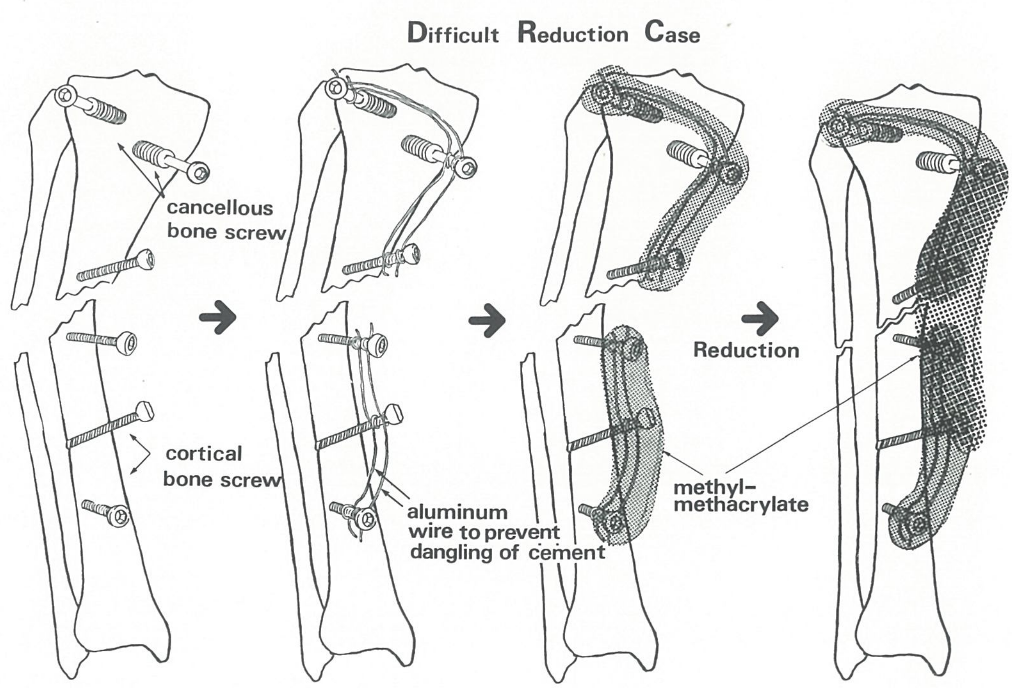
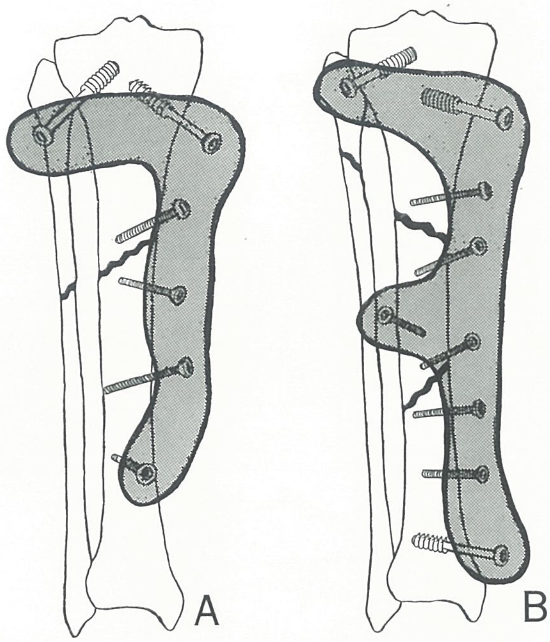
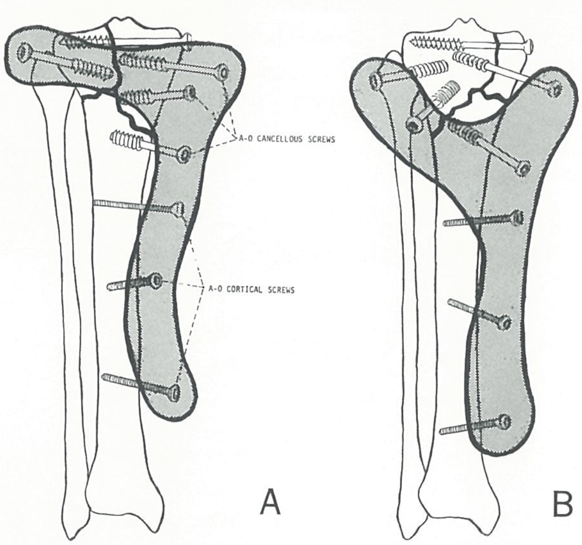


Fig. 5: In a "difficult" reduction screw insertion, aluminum wiring, and cementing of each segment are done separately. Reduction is then performed, followed by final cementing to bridge the two separate cementings.



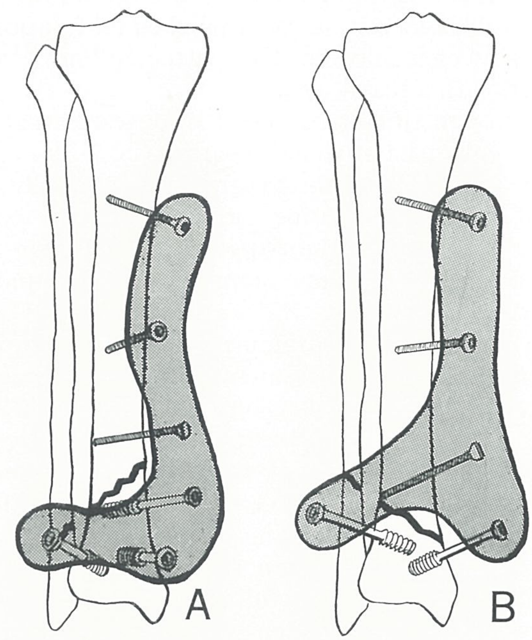
Figs. 6-A and 6-B: (A) Typical fixation for tibial shaft fracture. (B) Fixation for butterfly segment.



Figs. 7-A and 7-B: Two fixation methods for a comminuted fracture of the proximal tibia. A 6.5 mm A-O cancellous screw is inserted into the joint for internal fixation of the vertical fracture.

fixation is cut by a cast cutter; the alignment is then corrected and fixed by additional cement (Figure 9).

Of course, Kirschner wires or other devices can be applied to fix the fractured segments; however, because the Kirschner wire must extend from both



Figs. 8-A and 8-B: Typical fixation for fracture of the distal tibia.

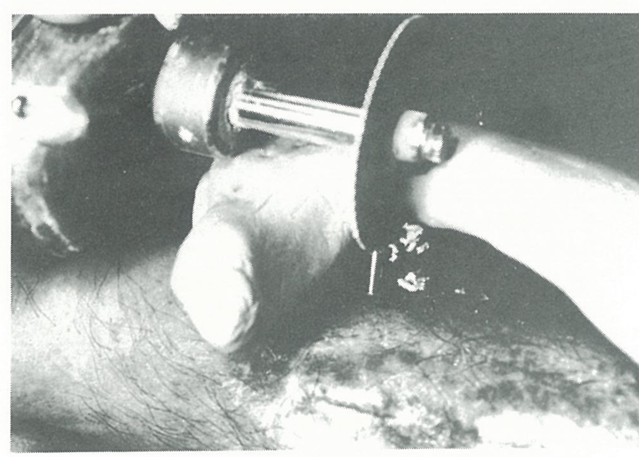


Fig. 9: In the cases of a malaigned fractured segment, the cement used for fixation is cut by a cast cutter; the alignment is then corrected and fixed by additional cement.

sides of the bone, it is difficult to avoid inserting it through muscle. Screws protrude from only one side of the bone allowing avoidance of muscles trauma.

Postoperative Care

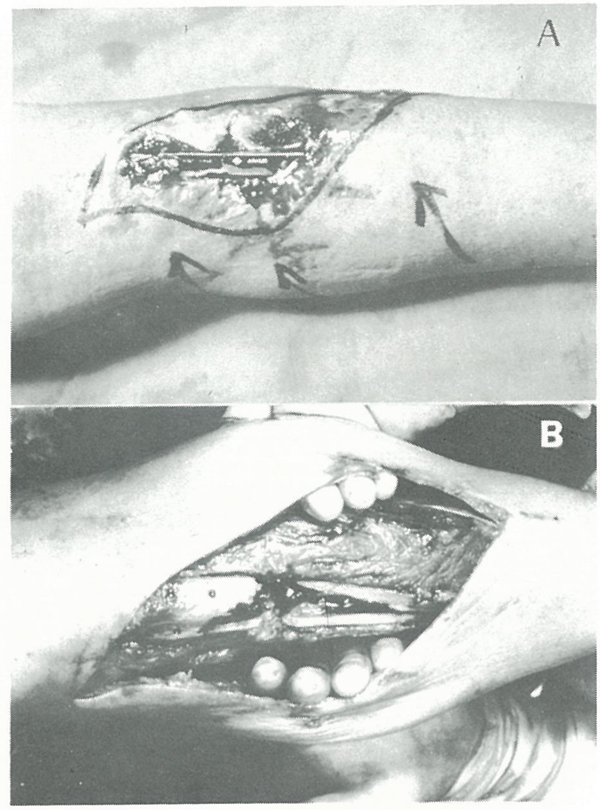
The fixation method provides enough rigidity to make a postoperative cast unnecessary. Exercise of the adjacent joints immediately after fixation is encouraged to prevent muscle atrophy and joint contracture. The dressing is generally changed once a week. Although patients are not allowed to take a tub bath during external skeletal fixation, a short shower is allowed if the affected limb is well covered with a plastic bag.

For open tibial fractures it is suggested that patients begin partial weight-bearing (20%-25%) two weeks after fixation, progressing gradually to almost full weight-bearing with crutches two weeks later, depending on the patients' general state and the condition of the fracture and surrounding tissues.

In the case of a draining, infected nonunion, dressings are changed frequently until the draining wound closes; additional curettage, bone grafting, or skin grafting can be performed through the external skeletal fixation, if needed, in later stages. These patients begin to exercise the adjacent joints immediately after fixation. Partial weight-bearing with crutches is instituted about ten weeks after fixation, progressing to full weight-bearing about four weeks later, although patients may continue to use crutches for safety. In general, the starting time of partial or full weight-bearing depends on the condition of soft tissue, the type of fracture, the age of the patient, and other factors.

When satisfactory bone union is observed, one or two screws distant from the fracture site in each segment are removed. To prevent refracture, however, the external skeletal fixator is not completely removed for another month. Patients are then asked to use crutches routinely for one month.

In the case of an open fracture of the tibia with soft tissue damage, the average duration of external fixation is eight to ten months, the fixation period is 12-15 months for nonunion of the tibia with osteomyelitis and to three months for femoral fractures in children.



Figs. 10-A,B: Case 1 (A) Infected non union of left tibia, bone and plate are exposed. (B) Infected skin and bone were excised and cleaned. Skin defect was covered by bipedicular skin flap.

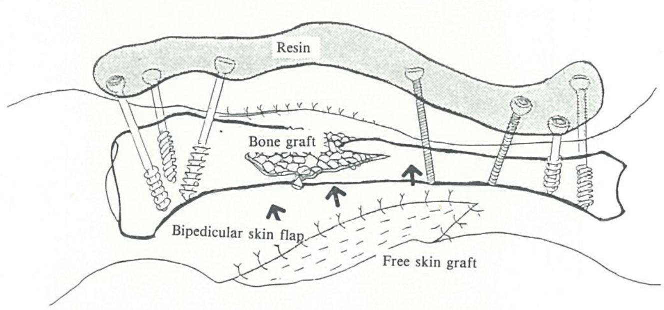


Fig. 11: Operation of case 1. After debridement of infected area, iliac bone was grafted into bone defect. Skin defect was covered with bipedicular skin flap and free skin graft on the dorsal site of left tibia. Fracture was fixed with external skeletal fixation using resin.

CASE REPORTS

CASE 1. A 32-year-old driver smashed into another truck on an express way and sustained open comminuted fracture of his left tibia. The fracture was fixed with plate by local surgeon.

The skin which covered the fracture site became necrotic and the fracture was ununited with osteomyelitis (Figure 10A). The patient was introduced to our hospital 3 months after first operation. His left knee and ankle joints above and below fracture were already contractured.

The infected nonunion was treated with complete debridement and bone graft (Figure 10B). Skin defect was covered by bipedicular flap and free skin graft (Figure 11). A-O cancellous bone screws and A-O cortical bone screws were inserted percutaneously into proximal and distal fragments avoiding infected area. The fracture was fixed with external skeletal fixation using resin (Figures 11, 12). Osteomyelitis did not recurred and the wound healed well. Three months after operation, fracture was not united and absorption of grafted bone was observed (Figure 12B). Electric stimulation started with semiinvasive method.

Cathode and anode were made of stainless steel at that

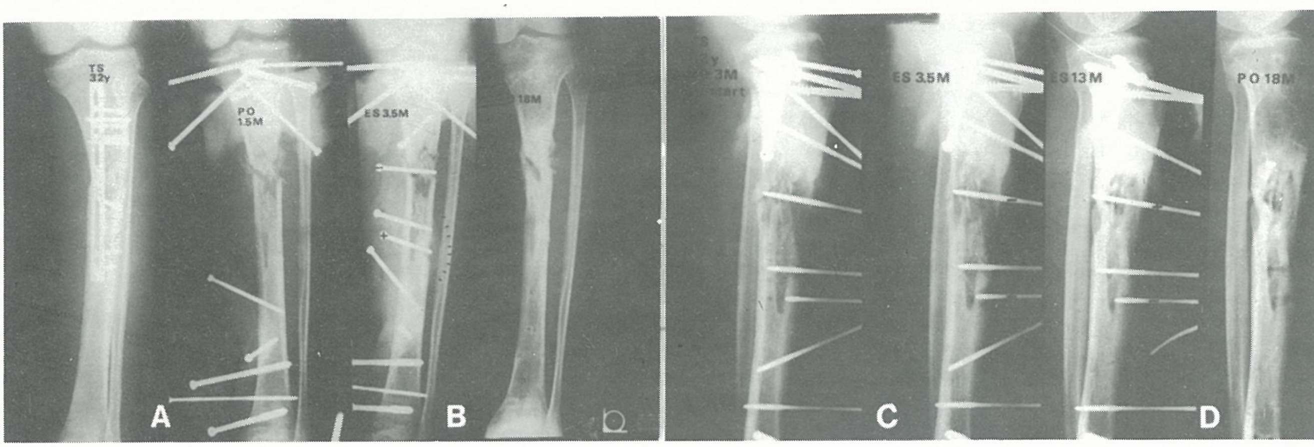


Fig. 12: Case 1 (A) Open comminuted fracture of left tibia was fixed with plate and ununited because of infection. (B) The screws were inserted to proximal and distal fragments avoiding infected are, the fracture was fixed with external skeletal fixation using methylmethacrylate. (C) Electric stimulation was added. (D) 18 months after operation, the fracture was united.

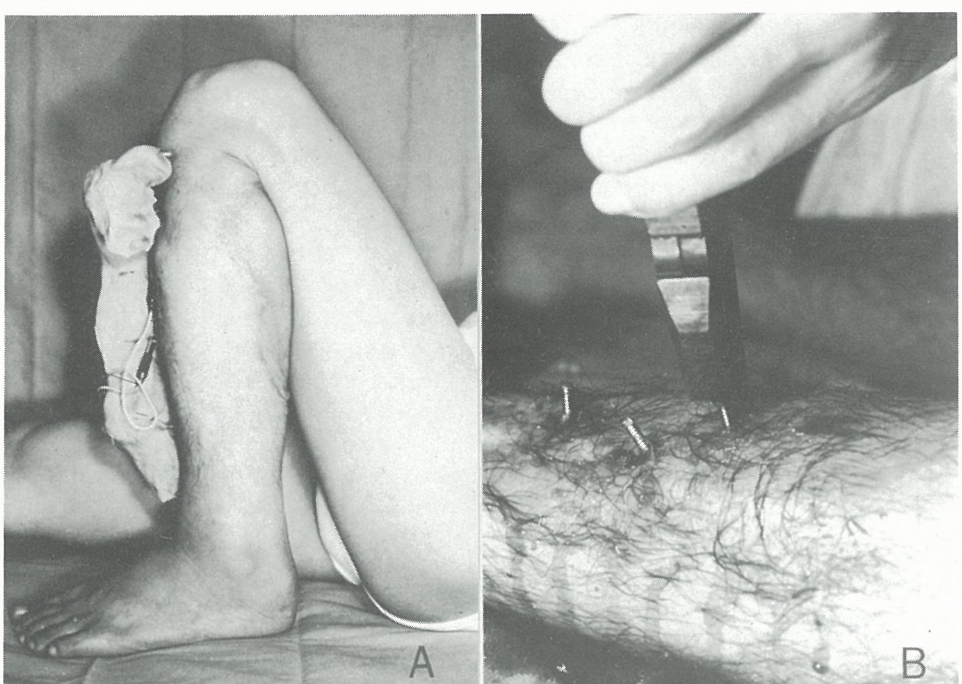


Fig. 13-A: Case 1 A In addition to the rigidity offered by this fixation method, the system allows joint movement above and below the fracture. Screws can be inserted into the anteromedial or anterolateral aspect of the proximal and distal tibia, where the skin is least mobile during joint motion. This patient was treated with electric stimulation also. This method has proved additionally convenient in this electric stimulation therapy. The stimulating cathodes and anodes can readily be fixed to the original cement by supplemental cement; the electrodes cannot loosen or fracture, and the cement acts as an insulator.

Fig. 13-B: When satisfactory bone union is observed, one or two screws distant from the fracture site in each segment are removed. The screw is cut by a large wire cutter and then removed by pliers. To prevent refracture, however, the external skeletal fixator is not completely revoved for another month. Patients are then asked to use a crutch routinely for one month.

time, and abundant callus around the anode was noticed in this case (Figure 12C). After we changed the position of anode to fracture site, the fracture was united ten months later (Figure 12D). During fixation with external skeletal fixation, the contracture of his knee and ankle were completely improved and he could walk and sit normally. (Figure 13A, B).

CASE 2. A 55-year-old male was hit by a car while he was walking and sustained open comminuted fracture of left tibia and closed fracture of right ulna.

Ten months later, patient came to our hospital with infected nonunion of left tibia which was fixed operatively with plate and non union of ulna which was fixed with cast (Figure 14A).

The tibia was so deformed and infected that it was impossible to fix with internal fixation using plate or intrameduallary nail.

After debridement of infected soft tissue and bone, bone graft with iliac bone and external skeletal fixation using resin were performed (Figure 14B). Osteomyelitis did not recurred and after inflammation was subsided, two more screws were inserted to reinforce the fixation and patient began to walk with a crutch (Figure 14C). Fracture was united 8 months after operation and the external skeletal fixation was removed.

Left tibia was still deformed, but the aligment was improved satisfactorily. Patient complaints no disturbance of walking (Figure 14D).

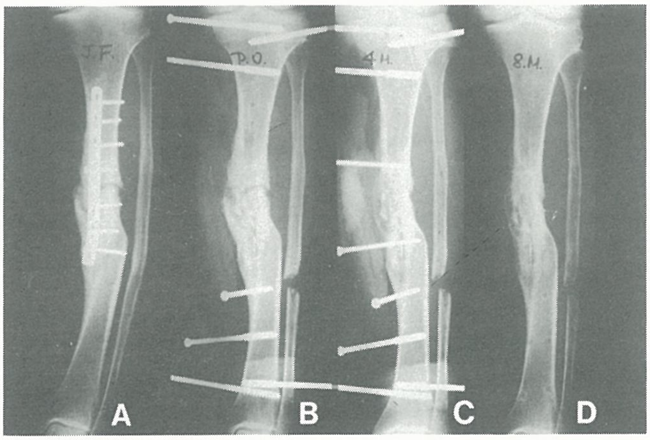


Fig. 14: Case 2 (A) Infected nonunion after plating of open fracture of left tibia. (B) After debridement of infected soft tissue and bone, A-O cancellous or cortical bone screws were inserted into fragments avoiding infected area. The fracture was fixed with external skeletal fixation using resin. (C) After subsiding of the infection, additional two screws and cement were applied to get enough fixation for weight bearing walking. (D) 8 months after operation, the fracture was united and the external akeletal fixation was removed.

RESULTS

In 256 of the 259 cases in the present series (the 3 exceptions being cases of cross-leg fixation), the fractures eventually united. Four patients refractured the tibiae in careless falls after removal of the fixation device.

In no patient did infection at the fracture site or recurrent osteomyelitis develop. Because A-O-type screws, which do not move in the bone, were used, there were very few pin tract infections. Kirschner wires were initially used in this method; although inserted at different angles, the wires moved slightly, probably encouraging occasional pin tract infections (but not osteomyelitis).

In the midshaft fractures no significant adjacent joint contracture occurred. Among 25 patients who had proximal tibial fractues, including intra-articular fractures, 22 patients had very good flexion (> 150°) of the knee, 3 had good flexion (120°-150°), and none had less than 120° of flexion.

DISCUSSION

This method of external skeletal fixation using methylmethacrylate was invented, researched in the laboratory, and applied in clinical cases in 1970 and published in 1971.[1]

The methylmethacrylate cement, a selfcuring acrylic resin used as a dental molding material, has significant advantages: (1) It is must less expensive than bone cement. (2) Since the cement is radiolucent, it does not disturb roentgenographic fracture observation, unlike the metal linking devices used in conventional skeletal fixation. (3) Because the screw insertion site is not limited by the external fixation apparatus, it is possible to avoid severely damaged soft tissue, open wounds, muscles, and osteomyelitic area. (4) If the reduction of the fractured segments is found to be unsatisfactory after surgery, the cement can be cut by a cast cutter and the malalignment corrected and fixed by additional cement. (5) if the external skeletal fixation device does not prove strong enough to hold the fractured segment, additional screws can be inserted and fixed with more cement at any time. (6) The system is so light and compact that the patient can wear normal clothing and can easily be treated as an out-patient (Figure 15). A follow-up visit once weekly to the clinic to have the wound and pin sites checked is sufficient. By comparison, the conventional external fixation apparatus is inconveniently bulky and heavy. It is

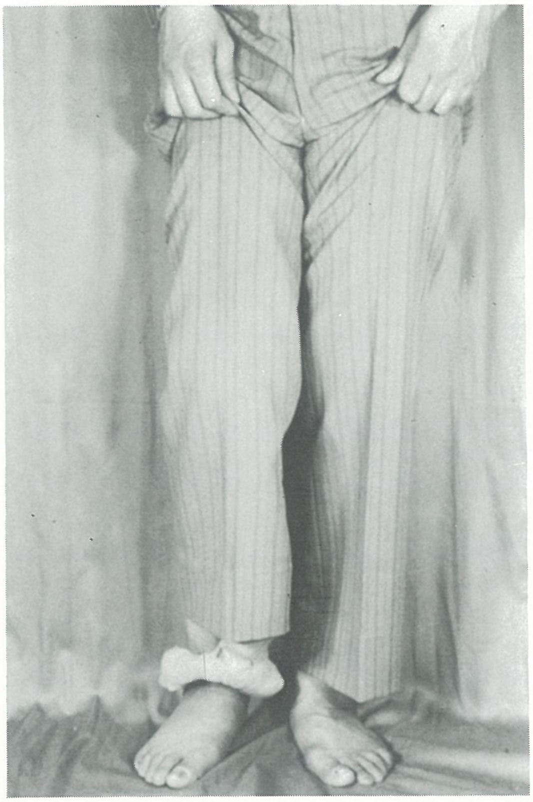


Fig. 15: The system is so light and compact that the patient can wear normal clothing and can easily be treated as an outpatient.

difficult to walk with the apparatus and almost impossible to wear trousers.

Furthermore, by using the thick A-O screws, which do not move in and out of the bone, rather than Kirschner wires or regular cortical bone screws, the mechanical strength of the fixation has been greatly increased (Figure 16). With the current method there have been few pin tract infections; neither infection of the open fractures nor recurrent osteomylitis has occurred.

In addition to the rigidity offered by this fixation method, the system allows joint movement above and below the fracture. Screws can be inserted into the anteromedial or anterolateral aspect of the proximal and distal tibia, where the skin is least mobile during joint motion. Also, since the insertion can avoid muscles, full motion of an adjacent joint can be obtained shortly after surgery. (In the original application of this method, the Kirschner wires had to be inserted through the muscle in various derections to obtain stable fixation; consequently, the patients did not move the leg due to muscle pain at the pin site). Even open fractures near the ankle and knee joints had a very satisfactory end result with regard to range of motion; the patients were able to sit Japanese style.

The rigid fixation provided by this method, however, can be a cause of refracture. Therefore, depending on the degree of bone union, the distant

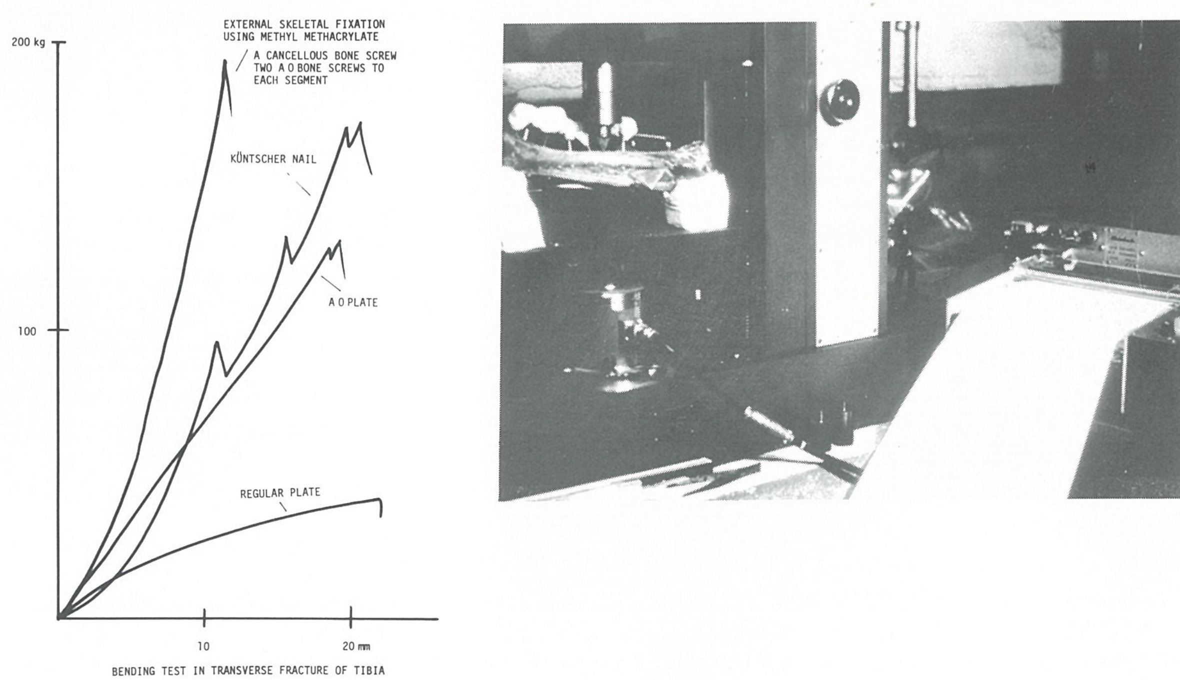


Fig. 16: Bending test in transverse fracture of tibia. The method rigidly immobilizes the fractured segments in three dimensions once the devices are externally fixed by methylmethacrylate.

screws are usually removed first; later, the fixation system is removed completely. Partial removal can easily be performed under intravenous anesthesia in a short time; the cement is cut by a cast cutter, and the screw is cut by a large wire cutter and then removed by pliers.

For delayed union or nonunion of the tibia, since 1975 the authors[9-11] have been using 20-μA constant direct current stimulation, with good results. The external fixation method has proved additionally convenient in this electric stimulation therapy. When such therapy is needed during the course of bone union, the stimulating cathodes and anodes can readily be fixed to the orginal cement by supplemental cement; the electrodes cannot loosen or fracture, and the cement acts as an insulator.

For the past four years, this method has been applied to femoral fractures in children. Such fractures usually require a long hospital stay when treated by skeletal traction and a hip spica cast. With external skeletal fixation, however, the patient need not be confined in traction or a large cast and is able to go home within a few days, which is both economical and beneficial for the family. In a femoral fracture, because the screws must pass into the femur through the muscles, the full range of knee motion is prevented. Patients are able to walk, however, and no permanent limitation of knee motion develops, since the fixation time is usually two to three months.

This method of external skeletal fixation is so simple that it does not greatly affect the patient's general condition. Therefore, the patient with multiple injuries, multiple fractures, and/or cerebral damage is a good candidate for this innovative means of fracture fixation.

Finally, the technique of applying this fixation device is sufficently simple and adjustable that any orthopedic surgeon can apply it at any hospital in any country and without any special device, providing that long, thick bone screws and a sterilized, inexpensive cement equivalent to methylmethacrylate are available. Because this system of using cement in external fixation is so adjustable, the method is widely indicated in many fields, even plastic surgery.

The present indications for the use of this external skeletal fixation by cement include the following conditions: (1) open tibial fracture with soft tissue damage; (2) nonunion or delayed union of the tibia with osteomyelitis; (3) comminuted metaphyseal and epiphyseal fractures of the tibia; (4) comminuted femoral fractures that are difficult to handle with conventional internal fixation devices; (5) femoral fracture is children; (6) multiple injuries and multiple fractures in patients in poor general condition; (7) osteotomy and arthrodesis; (8) facial fractures; and (9) conditions requiring plastic surgery.

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