

Military external fixation of fractures

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A short history of fixation techniques

Almost 2400 years ago Hippocrates described a form of external fixation to splint a fracture of the tibia. The device consisted of closely fitting proximal and distal Egyptian leather rings connected by four wooden rods from a cornel tree.^{1,2} In 1840, Jean-Francois Malgaigne described a spike driven into the tibia and held by straps to immobilise a fractured tibia. In 1843 he used a claw-like device to percutaneously hold the fragments of a fractured patella.³ Parkhill and Lambotte independently invented the first practical external fixators, in 1894 and 1902, respectively.³ Lambotte was the first to use threaded pins.

From 1930 to 1950, the fixator became unpopular as complications like pin tract infections and non-union of bone were recognised. In 1940, American military surgeons banned the fixator as a "non-union machine".⁴ However, Raoul Hoffman reported encouraging results from 1938 to 1954.⁵ Since the Second World War, the external fixator developed as a unilateral frame in the West and as a ring fixator in Eastern Europe.⁶ The United States military experience in the Vietnam War of fractures associated with vascular injury treated by internal fixation suggested that this technique produced poor

Synopsis

- ◆ External fixation of fractures resulting from high velocity impacts is a useful technique, in keeping with the well accepted principles of managing such injuries by early stabilisation, swift evacuation and, finally, definitive treatment.
- ◆ External fixation offers the advantages of straightforward application, wound accessibility and ease of transport.
- ◆ In some situations, external fixation of the fracture facilitates secondary procedures such as reconstructive wound cover, bone grafting or bone transport.
- ◆ Indications include open wounds, fractures with burns and multiple trauma, all of which are likely events in the military environment.
- ◆ Complications include the inadvertent pinning of neurovascular structures and pin track infection.
- ◆ The Australian military external fixator (Rigidyne) has been used in Rwanda, during disaster relief in Papua New Guinea and in East Timor.

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results.⁷ Analysis of similar injuries in the civilian setting treated by an external fixation technique (pins and plaster) showed satisfactory results.^{7,8} Subsequently, external fixation became a well accepted mode of treatment for high energy fractures by the US and allied forces. By 1985, the United States Army, Navy and Air Force had reached a consensus to evaluate the widespread use of the device in combat zones.⁴

Since then, the failures and strengths of external fixation devices have been well investigated and their complications have been minimised. Meticulous techniques of pin insertion and pin site care, better understanding of fracture healing and improved fixator design have established the fixator as an invaluable therapeutic tool.

Indications in war and peace keeping operations

With advancing technology and clinical experience the indications for the external fixator are well defined (Box 1).

The fixator is widely used to stabilise some pelvic fractures and dislocations. It can be a life-saving tool in rapidly stabilising the fractures of severely traumatised soldiers to permit

I Indications for external fixation

Primary

- Open fractures types II and III, especially with highly contaminated field wounds.
- Fractures with burns.
- Fractures requiring subsequent secondary procedures, such as flaps, free vascularized grafts, or bone reconstruction.
- Fractures with bone loss and requiring maintenance of length.
- Fractures with infection
- Fractures associated with vascular or nerve injuries which are reconstructable.

Secondary

- Non-union.
- Arthrodesis.
- Limb lengthening.

swift evacuation to the base hospital. Certain closed fractures (eg, comminuted tibial plateau and the “floating knee”) are difficult to manage by internal fixation alone and are best stabilised with minimal osteosynthesis in conjunction with external fixation.

Ligamentotaxis is the method of reducing and immobilising intra-articular fractures (eg, distal radius) by using traction by the fixator on the capsular and ligamentous structures about the joint.

Principles and technique

Planning ahead and assessment of the injury is essential. Regardless of the method of fixation, debridement of the primary wound and adequate resuscitation always precede fracture management. The safety and effectiveness of the fixator depend on limb anatomy, indications and mechanical demands.⁶

Limb anatomy determines the safe zones for pin insertion, avoiding neurovascular and musculotendinous structures. The anteromedial sector of the tibia is the safe “corridor”.

The nature of the injury should be assessed and the question asked if external fixation is the best form of management. The mechanical demands are met by the frame geometry, the component structure and care in pin insertion. Increasing the diameter of a pin has an exponential effect on bending stiffness (X fourth power) and resistance to torsion (X third power).⁹

Most fixators now have two half pins on each side of the fracture and a unilateral frame or ring. The half pin engages both cortices but does not transgress the soft tissues on the opposite side. Half pins are self-tapping.

Transfixation pins emerge from the opposite side of the limb

and are threaded in the middle in order to grip one or both of the cortices to provide stability. They have bilateral frames and provide greater rigidity. Smooth pins should not be used, as they do not provide the same degree of rigidity, allowing movement within the bone, which compromises fracture fixation and generates tissue fluid that predisposes to pin track infection.

Recent research presented by Major E Schuyler DeJong (Fort Sam Houston, Texas) to the Society of Military Orthopedic Surgeons 2000 Meeting suggests that chlorhexidine and hydroxyapatite coating of the pins reduces infection and promotes a stable interface between pin and bone.

The ring fixator has fine wires passing through both cortices which are held under tension. This allows even small comminuted fragments to be held in position.

2 The military external fixator should:^{4,6}

- ◆ Provide stability, allowing emergency stabilisation of the fracture and the limb.
- ◆ Provide rigidity in the bone–device construct.
- ◆ Be versatile, able to accommodate a wide variety of fractures and wounds.
- ◆ Allow adjustment of the alignment of the fracture and the fixator. The device should allow compression and distraction where necessary.
- ◆ Allow dynamic treatment. After initial rigid immobilisation for a short period the fixator should allow axial micromovements—this is normally part of definitive management after stabilisation and evacuation.
- ◆ Be easy to apply under local anaesthetic in field conditions.
- ◆ Provide for definitive and secondary treatment. The fixator should allow subsequent or simultaneous treatment (eg, internal fixation or sequential intramedullary nail). The fixator should provide an adequate environment for definitive fracture healing in its own right.
- ◆ Withstand autoclave sterilisation. Carbon fibre has the disadvantage of deteriorating on steam sterilisation.
- ◆ Be light weight and inexpensive.
- ◆ Have self-contained instruments to allow insertion without power or hand drill.
- ◆ Be easily convertible to a more definitive fixator so that the final phase of management can be completed or a secondary treatment (eg, limb lengthening) can be undertaken.
- ◆ Be efficiently packaged for transport and delivery under field conditions. The internal cavity of the fixation tube (if large enough) can be used in an innovative manner (eg, Rigidyne M—see Box 4).

Pre-drilling before pin insertion minimises loosening and infection. The dense anterior cortex of the tibia is avoided and a slow speed drill is used to minimise thermal necrosis.^{10,11} The care required during pin insertion cannot be overemphasised. The pin–bone interface is the weakest link in the mechanical stability of the fixator–bone construct.¹² The position of the frame should be close to the bone but allow enough room for wound access and pin site care. Pin site care with saline and dilute hydrogen peroxide can be carried out by the patient after careful instructions.

Minimal osteosynthesis together with external fixation has shown encouraging results in Croatia.^{13,14}

The high incidence of infection and non-union from secondary intramedullary nailing after initial external fixation of open tibial fractures was well known.^{15,16} However, external fixation for a relatively brief period (average 17 days in one study),¹⁷ followed after a delay with intramedullary nailing, minimises the risk of bacterial colonisation of the pin sites and produces satisfactory results.^{17,18}

Complications and pitfalls

The usual complications¹⁹ of external fixation are:

- *Pin track infection.* Meticulous technique and pin site care with judicious use of antibiotics have reduced this problem, although a 10% infection rate has been reported.²⁰
- *Unintended neurovascular injury when inserting the pins.* Planning and knowledge of anatomical safe zones can prevent this problem.
- *Musculotendinous impalement.*
- *Delayed union or non-union.* The first generation of fixators tended to hold the bone position and fracture gap too rigidly, making union more difficult. It has since become clear that axial compression and micromotion play a role in bone healing,²¹ and newer fixators allow for a “dynamisation” —that is, short periods of axial micromovement applied within two weeks of fracture. These movements enhance healing, provided they are within specific limits.²²
- *Compartment syndrome.* Highly improbable in the acute setting. Awareness is essential.
- *Fracture through pin site.*
- *Refracture.* With dynamisation the quality of external callus or primary bone union is much better and therefore this complication is minimal.
- *Materials/component failure.* The design and material of the fixator is responsible for the mechanical strength essential for early mobilisation. Even though fixators are meant to slide axially, some jam when loaded so that dynamic treatment is not possible. In a technical study for the United States military, Bosse et al found the Howmedica Ultra-X military fixator to be inferior and unsuitable for military use when compared to the Synthes Trauma-Fix fixator.⁴

Although easy to apply, the Howmedica device did not withstand steam sterilisation and was mechanically weaker.

There are some practical pitfalls of external fixation:

- The correct application is technically demanding.
- The frame can be unwieldy and not acceptable to the patient.
- The frame can be manipulated by non-compliant patients.

World experience

A concise account of recent global experience illustrates the use and difficulties in use of fixators in treating war injuries.

Vietnam

During the Korean and Vietnam wars, high energy fractures were usually treated with pins and plaster.⁴

A report from the Brooke Army Medical Center, Fort Sam Houston, Texas,²³ on the management of 84 soldiers with open tibial fractures caused by missiles (23 high velocity) found benefit in early ambulation and external fixation as treatment methods. After primary wound surgery in the field in Vietnam, these soldiers were evacuated to Brooke Army Medical Center, arriving on average three weeks after being wounded. Early application (ie, when soft tissue healing allowed) of a snug-fitting cast that supported the patella tendon allowed soldiers weight-bearing mobility. All the fractures united, including those high velocity injuries with extensive soft tissue wounds.

Israel

Ronen et al described their experience of external fixation with five patients in the October 1973 conflict.²⁴ They had four fractures unite in 8–14 weeks and one non-union. The fixators were not applied immediately, as they were not available at the front line.

Iran–Iraq conflict

Habboushe reported a series of 340 open tibial fractures from gunshot or missile injuries treated at the Al-Rasheed Military Hospital, Baghdad.²⁵ External fixators were made out of Schanz pins transfixing the bone and plastic tubing containing polymethylmethacrylate cement used as bars. A turn-buckle device was incorporated if length adjustment was necessary. Full-frame bilateral fixators were used for 40 patients, but this technique was abandoned in favour of a half-pin unilateral device because of complications including pin track infection, joint stiffness and foot drop. The results for the 300 fractures treated with this simple, light, cheap and versatile method were satisfactory.

Afghanistan

Rautio and Paavolainen described the experience of treating the war wounded in Afghanistan several days after injury at the Red Cross Hospital in Quetta, Pakistan.²⁶ The average

evacuation time from Afghanistan was 5.4 days. Primary debridement and fasciotomies of severe fractures associated with soft tissue wounds were followed by application of an *Arbeitsgemeinschaft für Osteosynthesefragen* (Association for the Study of Internal Fixation) fixator. The femur was fixed with unilateral and the tibia mostly with bilateral frames. Despite the relative lack of hygiene, pin track infection was uncommon and was invariably caused by pin placement “too close to the fracture”. In the short follow-up period, the reduction and control of osteomyelitis was evident, but the fracture healing time could not be obtained.²⁶

Gulf War (British experience)

Few military external fixators were used in the Gulf War, as the Coalition side had so few casualties. The fixators mainly used were made by Owandar Medical. They had self-tapping pins and came with two bars, four pin-to-bar connectors and a bar-to-bar connector. The introducer and nut tightener was one device (looking like a Hudson brace). The advantages of this design were a low price and adaptable modular design. More complex frames could be assembled by combining sets together, as was done, for example, on an elbow and ankle. The disadvantage was that it was difficult to insert the pins by hand, so that pilot holes had to be predrilled before inserting the fixator (personal communication, Schranz PJ, Wing Commander, RAF (rtd)).

A second type of fixator used was the military fixator made by Howmedica. It was more robust, but less versatile, having less ability to adjust pin insertion angle. The self-drilling pins were of better quality and worked better, but cost twice as much as the Owandar product (personal communication, Schranz PJ, Wing Commander, RAF (rtd)). There are no available figures on clinical outcome.

Croatia

From 1991 to 1992, 205 patients had 220 fractures treated by

external fixation. One group had external fixators applied along with minimal osteosynthesis and another had external fixation alone.¹³ Complications (mainly delayed union and non-union) were more frequent in the group with external fixation alone when compared with the group that had additional lag screw fixation or minimal osteosynthesis.

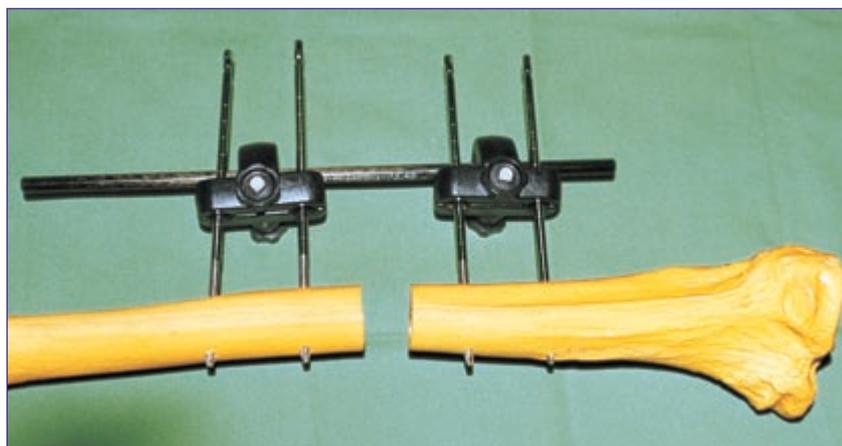
Recent Australian experience

Developed at the Royal Adelaide Hospital, South Australia, as a result of the lessons learned in the Gulf War, the Rigidyne fixator (Box 3) has been in use for over 10 years. It is a clamp-type fixator and has addressed three fundamental requirements for external fixation: rigidity, versatility and capacity for dynamic treatment.

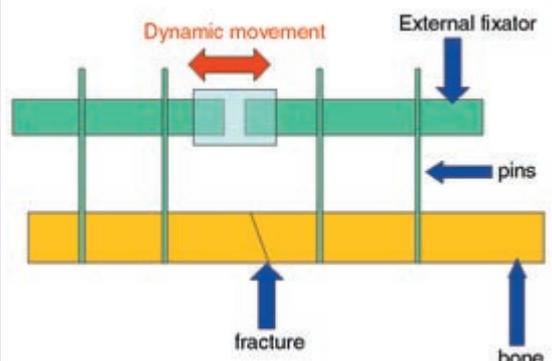
The military version (Box 4) has taken into account the importance of simplicity when working in field conditions. The anodised aluminium on polymer frame makes it light weight and gives it rigidity and a low coefficient of friction (which virtually eliminates the problem of jamming of the fixator during dynamic treatment). The lower limb version of the military external fixator (Rigidyne M) has been used with success in Rwanda, Bougainville, Papua New Guinea and, most recently, East Timor. The fixator frame houses the self-drilling and self-tapping screws and itself converts easily to a hand drill (like a Hudson brace) for inserting pins (Box 5), eliminating the need for power instruments in the war theatre. There is a connector for pelvic fractures. The upper limb version of the fixator is much smaller and lighter.

The ADF Defence Health Service logistics system carries a number of fixators that can be requested through the supply system. They are normally carried by a level 3 medical facility, which is essentially a small field hospital where initial wound surgery is performed.

3 Rigidyne external fixator, developed at Royal Adelaide Hospital



The Rigidyne fixator is designed to allow controlled micromovements of the fractured bone—adjustments that assist the healing process.



The way forward

The importance of rapid stabilisation and evacuation of the high energy trauma victim cannot be overemphasised. The need for suitable military external fixators in sufficient numbers as far forward as possible is self-evident. The light, rigid, versatile, easy-to-apply fixator could almost form an extension to the first aid kit of every soldier, sailor and airman in the front line, enabling rigid fixation at the level 1 facility devoted to combat first aid before any transportation. The materials required for cast immobilisation are over 20 times heavier and 30 times bulkier. The materials for external fixation are more expensive, but some of the parts can be recovered for reuse. Simple, fast external fixation would seem the best practice for soldiers with fractures.

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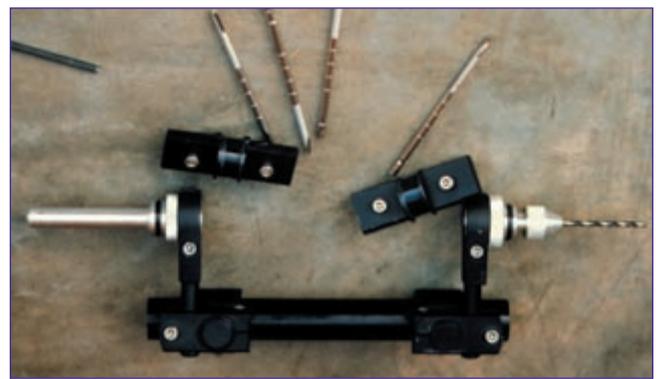
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4 Rigidyne M external fixator



Developed at the Royal Adelaide Hospital for military applications, the hollow frame rod of the Rigidyne M is designed to carry the pins and accessory materials.

5 Rigidyne M external fixator transformed into a hand drill



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