External fixation in contemporary fracture management

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SUMMARY

Important advances have been made within the last two decades in the field of fracture management. The development of the AO internal fixation system and the advances in cast bracing techniques are but two of the improvements worthy of mention. It is, however, in the field of external fixation of fractures that the greatest advances have been made. This paper traces the history of external fixation up to the present day and discusses, with examples, the application of external fixation in the management of complex limb fractures.

INTRODUCTION

More than a century ago, Malgaigne reported the first use of external fixation when he described a bone clamp (Fig 1) which percutaneously gripped patellar fragments and fixed them in the reduced position. This initial report was followed in the succeeding decades by others. Modern external fixation devices, however, began with Lambotte who, in 1902, described an apparatus used in the treatment of diaphyseal fractures of long bones and consisting of four iron screws clamped together between two plates (Fig 2). With further experience of external fixation came the first reports of associated problems, i.e. pin tract infection, inadequate fixation and difficulties with realignment after application of the fixator.

Fig 1 (below). The original bone clamp described by Malgaigne.

Fig 2 (right). Lambotte’s external fixation device (1902), the forerunner of all the modern single-sided devices.

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In 1931, Boevers summarised the indications for this technique, maintaining that it was the most aseptic method of osteosynthesis and, once a fixator was applied, movements of adjacent joints could be resumed. However, despite the considerable contributions of Anderson, external fixation gradually fell into disrepute, especially in the United States. The recurring problems of lack of rigid fixation and of pin track infection led the American Academy of Orthopaedic Surgeons to conclude that external fixation was of limited value in the treatment of fractures.

In Europe, however, developments continued with the work of Hoffmann, who produced the first commercially available external fixator, a device consisting of two clamp units with universal ball joints and a connecting bar. This flexibility permitted reduction of the fracture even after the application of the fixator, a process which Hoffmann termed ‘osteotaxis’. The unilateral nature of the fixator compromised its rigidity and limited its overall usefulness. The bilateral frame and clamp described by Charnley in 1948 was very much more stable and, although popularised as a device for knee arthrodesis, it was responsible for a revival of interest in external fixation.

The original one-sided Hoffmann device was modified by Vidal and Adrey to a bicortical apparatus, greatly increasing its stability and widening the indications for its use. Jorgensen, Olerud and others further documented its role in a series of compound and complicated fractures. Great stability was a feature of the devices described by llisarov and Wagner. The latter device, although introduced as a leg lengthening apparatus, became widely used as an external fixator. As a single-sided device, the Wagner apparatus could be applied to the subcutaneous border of the tibia without impaling the anterior compartment musculature. This overcame the tethering effect of double-sided frames which frequently resulted in residual equinus deformity of the foot.

Burny recognised the shortcomings associated with rigid double-sided fixation and proposed a single-sided bar and pin system, thereby introducing a degree of elasticity to trigger bulkier callus and more rapid fracture union. De Bastiani et al further developed the concept of elasticity at the fracture site with their introduction of the Dynamic Axial Fixator (DAF) which had a telescopic facility to allow for conversion to ‘dynamic fixation’ once callus formation had commenced, a process which they termed ‘dynamisation’. In reporting their results in 288 patients, De Bastiani et al claimed a success rate of 94% with an average time to union of under five months. Many reports now attest to the efficacy of external fixation in the treatment of complex limb fractures and it is likely that the indications for, and the use of, external fixation in the treatment of such fractures will continue to increase.

THE CURRENT ROLE OF EXTERNAL FIXATION

It is now generally accepted that external fixation has a major role to play in fracture management, especially where other forms of immobilisation are either inappropriate or impracticable. The most common indication therefore is in severe open fractures where treatment by cast or traction methods would not permit sufficient soft tissue access. In addition, with injuries of such severity, the exposure necessary to implant an internal device may contaminate larger areas and might significantly increase the risk of infection or loss of the limb itself. With these grossly compound wounds, where the fracture site itself is exposed, an anatomical reduction can be achieved and maintained using an external fixator (Fig 3).

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External fixation of fractures

The indications for external fixation are constantly being extended. Fractures associated with burns are optimally treated by this method, allowing wound toilet, dressing changes and skin grafting to be performed without disturbing the fracture alignment. Thus, rigid external fixation allows for aggressive and simultaneous management of the bone and soft tissue injuries. Where bone loss is present, especially in one of paired bones, external devices can be applied to restore and maintain bone length (Figs 4 and 5). In such cases, bone grafting can also be applied at the time of fixator application. Where there are vascular or nerve lesions in association with fractures, rapid fracture stabilisation can reduce the time taken to restore effective circulation and lower the incidence of limb loss (Fig 6). External fixation has undoubtedly saved many limbs which would previously have been lost.

Many closed fractures are now being treated by external fixation. The difficult spiral fractures of the distal tibia have a justified reputation for shortening and malunion (Fig 7). Treatment previously involved skeletal traction through a calcaneal pin which, although it improved fracture alignment, often compromised...
subtalor movement. The application of an external fixation device improves and maintains alignment (Fig 8) while permitting immediate movement of the proximal and distal joints. This early mobilisation facilitates the reduction of oedema and limits capsular fibrosis, muscle atrophy and disuse osteoporosis.

External fixation is also used extensively in limb lengthening, arthrodesis and in the treatment of infected fractures and non-unions. In limb lengthening two techniques are in common usage. The first involves distraction at the osteotomy site once callus is radiologically apparent, a process which has become known as 'callustasi'. The second involves distraction at the growth rate towards the end of skeletal growth with encouraging early results.29 It was Charnley who described the first rigid external device used for arthrodesis.14 Originally proposed as a primary treatment for osteoarthritis of the knee, its indication in this area has been removed by the increasing acceptability of total knee replacement. Arthrodesis is however the salvage procedure for failed total knee replacement and, in the presence of infection, is ideally achieved using external fixation devices.30

Some debate exists as to whether bilateral or unilateral fixation should be used in severe limb fractures. Without doubt, the greatest stability is afforded by the two-sided quadrilateral frame popularised by Adrey.16 This stability is gained,
however, at the cost of transfixing the adjacent musculature, which may cause restriction of movements at the distal joints. This is observed in tibial fractures where transfixion of the anterior compartment may lead to fixed equinus deformity of the foot. The rigidity afforded by the latest unilateral devices, such as the Orthofix or the Belfast (Fig 9), greatly reduces the indications for bilateral fixation, and many are now of the opinion that unilateral fixation is adequate for almost all limb fractures.

Every surgical technique has its complications, but, adherence to basic surgical principles can minimise their incidence. The chief complications of external fixation are those of pin loosening and pin tract infection. Pre-drilling of the bone and the use of wide-bore Schanz screws have greatly reduced both problems. With tibial fractures, the pins are inserted into the subcutaneous (antero-medial) border, thus avoiding completely the anterior compartment musculature. In fractures of the femur and the humerus, the fixator is generally applied from the lateral side, while in forearm fractures the device is applied from the radial side. In sitting the fixators thus, movements of the knee, elbow and wrist are largely unrestricted. Obviously, a good knowledge of the cross-sectional anatomy of the limb is required — in particular, the safe zones for pin insertion. The radial nerve in the distal half of the arm and proximal third of the forearm, the dorsal sensory nerve just above the wrist and, the anterior tibial artery and deep peroneal nerve in the distal third of the leg are the structures most at risk of impalement. Vascular penetration, thrombosis, late erosions and the formation of arteriovenous fistulas and false aneurysms have also been observed.

Compartment syndromes have also been reported. It is likely that this is more a pure association than a direct consequence of transfixion or transfixation of bone. Anatomical fracture reduction may increase compartment pressure by reducing the volume available to accommodate soft tissue swelling. Therefore, in applying an external fixator, the surgeon must be especially careful to guard against a compartment syndrome by clinically assessing for and, if necessary, taking action to reduce, the intrinsic soft tissue pressure.

The more rigid forms of external fixation may ‘unload’ the bone at the fracture site with consequent demineralisation and weakening of the cortex, similar to that observed with internal rigid compression plate fixation. The callus produced is entirely endostal, and delayed union rates of 20 – 30% have been reported.31 Rigid fixation, whether external or internal, is attended by a risk of refracture after removal of the device. Bony union which is the result of rigid fixation is endostal, with very little peripheral callus formation and thus very little intrinsic ‘splintage’. In addition, the demineralisation resulting from rigid fixation leads to a form of
disuse osteoporosis, and the risk of refracture is increased unless the limb is adequately protected until remineralisation has taken place.

External fixation of fractures is a generally safe technique and its availability has saved many limbs which previously would have been amputated. The complications which have been discussed are much rarer than formerly, especially with the increasing use of single-sided fixators. The indications for, and potential of, external fixation are things with which every fracture surgeon should be familiar.

LOCAL EXPERIENCE WITH EXTERNAL FIXATION

Advances in other fields, such as vascular and reconstructive/plastic surgery, combined with an increasing number of severe limb injuries, led to a requirement among local orthopaedic surgeons to develop experience with external fixation techniques. From 1977, when the first fixators were applied, until the present, there have been more than 200 cases in which external fixators have been used. The earliest experiences were gained with the Hoffmann/Vidal and Wagner devices. Our experiences with the former confirmed the reports of other workers. Following application of these bilateral devices there was often difficulty with soft tissue access. In addition, there was a not inconsiderable incidence of residual equinus deformity following removal of the fixator. The Wagner device required an almost perfect reduction of the fracture prior to its application and, because of its rigidity, was associated with an increased risk of delayed union and of non-union.

Aware of the shortcomings imposed by existing devices, the senior author (JT) investigated the feasibility of developing a new single-sided fixator. The design incorporated a single external (outrigger) bar permitting maximal access for soft tissue procedures and twin clamps at either end of the outrigger to accommodate 6mm Schanz screws, these clamps being attached to the outrigger by means of universal joints which permitted adjustment of the fracture once the device had been applied. The device was engineered in such a way as to reduce weight and costs to a minimum. The outrigger bar permitted length adjustment during fracture reduction and could be locked using two 'Allen' grub screws which when unlocked allowed the fracture to 'dynamise'. A line diagram of the current Belfast fixator is illustrated in Fig 10.

Commencing in 1981, when the first model became available, the Belfast external fixator was used in severely compound fractures of the tibia where maximal soft tissue access was required. With experience, it could be applied in under 15 minutes and, with open fractures, an anatomical reduction could be achieved under direct vision. The ease of application of the fixator and general satisfaction with the early results led to a general widening of the indications for its use. Eventually, almost all compound tibias and closed fractures where
satisfactory reduction could not be obtained or maintained were treated by external fixation.

From October 1981 until April 1986, 42 patients with fractures of the tibia were treated using the Belfast external fixator. Twenty-eight cases involved compound injuries, the remainder closed tibial injuries. The majority of these injuries resulted from road traffic accidents, particularly cases involving motorcyclists. Many patients had multiple limb injuries and some had severe head injuries. The majority of patients were young males in the age-group 18 – 35 years. Patients were kept in hospital so that any problems relating to the apparatus could be identified and dealt with immediately. When the fracture showed radiological evidence of callus formation, the fixator was removed, a cast applied and the patient discharged from hospital. On average, the fixator remained in situ for six weeks and a further eight weeks was required in cast.

Thirty-nine of the 42 patients treated using the Belfast external fixator were available for follow-up. Seven patients required remanipulation of the fracture as in-patients, but, because of the flexibility of the device, this was achieved without having to remove or re-sitethe fixator. Five patients had a pin tract ooze for variable periods and in one of these cases repositioning of the pin was required. None of these became persistent pin tract infections. Three patients developed non-union necessitating bone grafting and/or plating. There were three cases of delayed union in this series. In one patient, fracture healing was achieved with an unacceptable degree of shortening (in excess of two centimetres), whilst another patient was left with a residual equinus deformity which required subsequent corrective surgery. Of the 39 patients available for review, 30 achieved a good result, this being defined as healing in good alignment with less than one centimetre of shortening and within six months of injury. Although this might appear a high rate of indifferent results (23%), it must be acknowledged that all these fractures were complicated and often attended by risk of limb loss. Results would certainly have been much worse without the option of external fixation.

The more than 200 cases of complex limb fractures in which external fixation devices have been used have confirmed our belief that this method of fracture treatment will have a major and increasing role to play in the future. No longer reserved for the complicated and compound fractures, external devices are now being routinely applied to closed fractures which are reducible but likely to displace in plaster. Increasingly, it is the single-sided devices which are being used, thus avoiding the problems inherent in the bilateral fixators. Apart from the Belfast fixator, the results of which have been described, other devices commonly in use include the Hughes, AO and Wagner devices and, latterly, the excellent Orthofix external fixator. A programme is now under way to standardise external fixation in all the Belfast trauma centres, reducing the large variety of devices in use to two or three (the Belfast, Orthofix and possibly, the AO) but increasing their general availability.

**FUTURE DEVELOPMENTS**

The future for external fixation is very exciting. The increasing frequency of severely injured limbs as a result of high speed accidents has stimulated and maintained a general interest in its use. In some centres, external fixation has already become the mode of treatment for almost all major fresh fractures. Whilst we would not advocate such general use of the technique, with increasingly reliable fixators, more and more fresh fractures will come to be treated by this
method. In the area of fractures involving the joint surfaces, the concept of ‘ligamentotaxis’ is being increasingly reported in the European literature. This permits the reduction of comminuted epiphyseal fractures by creating strong distraction on both sides of the joint, placing tension on the capsuloligamentous structures and aligning the fracture fragments. By combining this with a hinged external device, continuous active movement is permitted at the joint surfaces allowing congruity to be restored and preventing joint stiffness. A similar hinged external fixation apparatus has been described for interposition arthroplasty.

Undoubtedly, as the physiology of fracture healing becomes better understood, the design of fixators will further improve. The concept of fixators made from elastic materials is being investigated. The dynamisation feature of modern fixators is a response to the observation that micromovement at a fracture site produces bulkier callus and therefore a reduced likelihood of delayed or non-union. Our early experience with these dynamising fixators generally supports this hypothesis.

External fixation also has a significant and increasing role outside the field of fracture treatment. Its role in arthrodesis following failed total joint replacement has already been mentioned. It is, however, in the difficult clinical area of limb lengthening that the potential is greatest. The earlier work of Wagner and the more recent work of De Bastiani and his colleagues suggest that this is indeed the case. In the latter, De Bastiani et al report their results with 100 limbs lengthened using the Orthofix device. Increases in limb length of up to 65% were reported with no nerve or vascular lesions and no bony infections. No case required bone grafting and pin tract complications occurred in only 1.5% of pin sites. Not only are these exceptionally good results, but the lengthening was achieved within an acceptable time period and the child was able to walk, attend school and enjoy many normal activities while the fixator was in situ.

As it is now generally accepted as a major treatment mode in fracture management, the technique of external fixation is a skill which all who deal with bony trauma must master. Many limbs have been saved which previously would have been amputated. Reliable and safe external fixation of fractures has been ranked with arthroscopy and total joint replacement as a revolutionary advance in the field of orthopaedics and traumatology.

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