TECHNICAL REPORT

M. Mooney • J. Gilbody

Techniques in splintage and support during reconstruction of the tibia

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Abstract The aim of this article is to help clinicians and allied professionals understand problems that may arise with use of external fixators in limb reconstruction and trauma, and in particular describe how preventative strategies can be implemented. The indications for splinting and orthotic use with external fixators can be broadly subdivided into those that facilitate functional loading and those that maintain joint integrity and function. Specific techniques to accompany use of external fixators in fracture management and limb reconstruction are described. In particular, problems concerning knee, ankle and foot support together with leg length issues are covered and proposals for dealing with joint subluxation, forefoot deformity and toe clawing, regenerate deformity after fixator removal and oedema control are discussed. The solutions described and illustrated are intended to assist those who use external fixators but do not have regular therapist input for support in the after-care of their patients.

Key words Ilizarov • External fixator • Splint • Orthotic • Fracture • Deformity

Introduction

Limb reconstruction surgery, developed on the science of tissue regeneration through distraction [1–4], has become invaluable in the treatment of limb length discrepancies, angular limb deformities, recalcitrant bone infections, fracture non-unions and complex limb deformities. Practitioners of the technique range from dedicated, tertiary-level limb reconstruction specialists to ‘occasional’ users in general hospitals and the demand for places on limb reconstruction training courses is testimony to its increasing popularity. However, as with any surgical technique, it has problems and these issues can be technically difficult, time-consuming or expensive to treat, but are relatively easy to prevent. The aim of this article is to help clinicians and allied professionals understand problems that may arise with the use of external fixators in limb reconstruction and trauma, and in particular describe how preventative strategies can be implemented.

A keystone in the implementation of the classic Ilizarov technique over some conventional techniques of fracture fixation is early functional loading of the limb as distinct to early functional use. A considerable body of literature attests to the importance of functional loading (weight bearing) in promoting fracture healing; by minimising the size of the fracture gap and reducing torsional and shear stresses while allowing small amounts of axial strain, physiological loading of the bone in the immediate post-operative period can significantly reduce the time taken for healing to occur and reduce the incidence of delayed or non-union [5–13]. Early loading also preserves muscle tone, proprioceptive sensation and gait, thereby optimising rehabilitation. Follow-up studies of patients who have had leg-lengthening procedures show that the recovery of knee range of movement is excellent in the long term, although patients with congenital leg length discrepancies tend to do slightly worse [14, 15].

The indications for splinting and orthotic use with external fixators can be broadly subdivided into those that

M. Mooney
Occupational Therapy, Orthopaedic Trauma
Royal Liverpool and Broadgreen University Hospital NHS Trust
Prescot Street
Liverpool L7 8XP, UK
e-mail: madeleine.mooney@rlbuht.nhs.co.uk

J. Gilbody
Trauma and Orthopaedics
University Hospitals Coventry and Warwickshire NHS Trust
Clifford Bridge Road, Coventry, UK

facilitate functional loading and those that maintain joint integrity and function. Specific techniques to accompany use of external fixators in fracture management and limb reconstruction will be described.

Referral and assessment

In preferred circumstances, all patients who undergo fracture management or limb reconstruction with external fixation are referred to a therapist for appropriate splintage and footwear. Communication ahead of surgery facilitates preparation for and anticipation of problems; an accurate assessment ensures that splintage, footwear and any other support are appropriate to the patient's needs. This process details the planned operative procedure, anticipates post-operative requests and considers the patient's medical history prior to action; as with any intervention, an explanation for the assessment and treatment is given and verbal consent is obtained.

The following areas need to be considered:

1. The type of fixator used (circular or monolateral type) and number of joints crossed; joint-spanning fixation may obviate the need of splintage in some cases
2. Presence of oedema
3. Pain – the patient's response to surgery and type of analgesia used
4. Sensation – a check for sensory loss will avert problems from splinting an insensate sole
5. Circulation – a check for ulcers or necrotic areas before splinting. Some guidance can be obtained from skin temperature and colour
6. Range of movement of joints, both active and passive
7. Resting position of the joints
8. Liaison with other medical and paramedical staff with regard to possible problems with pin sites, skin grafts (if present), wounds and pain relief.

The decision to splint is made according to the above information. A patient who has full range of movement at the ankle joint, who is allowed to weight bear fully and is not lengthening should not really require splinting. Active physiotherapy and mobility should avert problems. If there is reluctance on the part of the patient to weight bear or difficulty with active exercise of the joint, contractures may ensue and prompt splinting is needed. Any patient not provided with a splint is closely monitored and reviewed to ensure that deterioration does not occur.

Tibial fractures

Ankle and foot support

Fractures around joints can pose particular problems if the fixator assembly physically restricts full movement of the

joint, e.g., if a ring or bar just above the ankle restricts maximum dorsiflexion and prompts the patient to adopt a plantarflexed posture (Fig. 1). In this case it is important that the foot is kept plantigrade to discourage equinus. This is done with Thera-Band (the Hygenic Corporation, Ohio, USA) attached between the fixator and footwear (Fig. 2). Such splintage also allows the patient to mobilise the ankle through plantarflexion against the resistance of the Thera-Band, which then returns it to plantigrade upon relaxation (Fig. 3a, b).

Fig. 1 Distal portions of external fixators (arrow) can restrict a plantigrade resting position for the ankle

Fig. 2 Moulded foot splint with Thera-Band support attached via a plate on the fixator

Fig. 3a, b Active ankle exercises against the resistance of the Thera-Band can be encouraged

If the fixator is extended across the ankle by use of a calcaneal ring or similar adaptation, it ensures the hindfoot is kept plantigrade but interferes with the normal gait pattern. The locked hindfoot position abolishes the normal foot progression through the stance phase of walking and even blocks subtalar inversion and eversion. This problem can be resolved with a rocker sole.

Knee support

Similar problems are encountered near the knee. The most proximal ring can restrict knee flexion through posterior impingement of hamstring muscles. Full extension can also be lost either from a poor resting position or by instruction to non-weight bear, prompting a flexed knee posture when walking. Although extending the fixator across the knee can maintain extension, it is uncomfortable. A knee extension brace attached to the most proximal tibial ring is a more practical solution (Fig. 4). Whilst not routinely used, they are indicated if a significant degree of collateral knee ligament insufficiency is associated with a tibial plateau fracture. In these cases the hinges are locked in knee extension for mobilisation and weight bearing but unlocked during physiotherapy. The brace is made of a thermoplastic femoral cuff to which the hinges, constructed from fixator components, are attached (Fig. 5). This has proved to be extremely successful and is more comfortable than extending the fixator, which invariably involves transfixation half-pins or wires in the distal femur. The same general considerations are necessary when using circular fixators for the treatment of delayed or non-unions in this area.

Fig. 4 Extension to tibial fixator for knee support using a thermoplastic femoral cuff and attachments by components of the fixator system (arrows)

Fig. 5 Attachment of femoral cuff to fixator via hinges (arrow) which permit knee movement but can be locked for weight bearing

Assisted ambulation

Another aspect of limb support for patients with Ilizarov fixators is wheelchair modification. This may seem contradictory given the beneficial effects of functional loading, but for many patients (especially children) where prolonged periods in a fixator for limb lengthening or deformity correction are unavoidable, the wheelchair provides ready transportation to enable the child to maintain family-centred activities outside the home. In certain circumstances children are also able to attend school.

The size and circumferential nature of fixator rings or even bulky monolateral fixators create difficulties for comfortable sitting in a wheelchair, even with the knee flexed. A leg extension fitted to the chair overcomes the problem and has the added advantage of maintaining the knee in extension. In most instances, obtaining a wheelchair for modification is only possible with forward planning and communication between the surgical team and therapists; a standard leg rest has to be adapted to accommodate the rings of the fixator because an unmodified elevated leg rest is inadequate. The usual procedure is for rehabilitation engineers from the local Wheelchair Service to modify a Kings Stump Board (as used with amputees) to accommodate the circumference of the fixator rings and full length of the leg. It is important when issuing a wheelchair that all relevant Health and Safety standards and legislation are met.

Tibial reconstruction

This usually refers to bone lengthening, deformity correction (both bony deformities and joint contractures) and the technique of bone transport. The resistance of soft tissues to the distraction process underpins many of the problems

Fig. 6 AVI foot pumps can be used with Thera-Band slings

seen during reconstruction. These problems are greater in congenital deformities where an entirely new limb length or alignment is being created, as compared to post-traumatic cases where the issue is one of restoration to a previous state. The prophylaxis of such problems is a priority. The techniques of splinting outlined below have either been developed independently or modified from initial reports by others [16].

Lengthening in cases of congenital deficiency arguably places the greatest demand on the soft tissues. Distraction of the muscles produces tension, which in turn pulls joints into characteristic postures. In the case of the tibia there are the gastrocnemius and soleus muscles which tend to flex the knee and plantar flex the ankle, creating contractures if left unattended. The splint is applied on either the first or second day post-surgery; this may be delayed if the patient has a problem with swelling which is being addressed with an arterial-venous impulse (AVI, Orthofix SRL, Verona, Italy) foot pump [17], but even in this instance the use of the splint and pump may alternate – close liaison with the physiotherapist is important to discuss the relative priorities (Fig. 6).

Equinus deformity

There are several ways to keep the patient's foot plantigrade. Contractures are avoided if muscles are placed under tension for as many hours as possible but stretching exercises do not necessarily result in prevention of contractures unless maintained for at least six hours a day [16]. Attaching a wooden-soled shoe to the fixator by Velcro to hold the ankle plantigrade has been tried but found limited success at our hospital; problems arose from the constant high pressure to the heel and the forefoot, which patients found difficult to tolerate for any period of time. To over-

Fig. 7 Foot splints can also be held to the fixator using Velcro straps

come this complication, a piece of thermoplastic contoured to the sole of the patient's foot is attached with soft strapping and Velcro. The splint is supported by either Velcro (for a static splint) or Thera-Band (for a dynamic splint) looped over one of the fixator pins or an extension plate built off a fixator ring (Figs. 2, 3 and 7).

Patients are encouraged to use the splint for an hour initially. It is then checked by the therapist for any problems and adjusted accordingly. The patient is also provided with an advice sheet detailing the use and care of their splint and limb in a regime specific to their needs as determined by the therapist. This takes into account the balance between the aim of splintage and the expected compliance or patient's ability to care for the splint; due leeway in the regime is required for those who need assistance applying or removing their splint.

A statically applied splint, e.g., to immobilise a joint, is provided with a recommendation for prolonged use but will require checks at least twice each day for hygiene and physiotherapy. This splint regime is then reviewed when active joint movement is started. Even with dynamic splints prolonged use is encouraged, but additional advice is given to use the resistance of the Thera-Band as an aid to exercise. These splints are removed during weight bearing and replaced with a shoe; if necessary the Thera-Band can be placed around the shoe to encourage normal ankle dorsiflexion. Night-time use is also encouraged to avoid contractures. It is important the splints remain in place during the lengthening phase of treatment and for longer if problems persist.

Forefoot deformity/toe clawing

Problems with the forefoot may occur in patients despite adequate hindfoot splinting, whether this is done through

Fig. 8 Toe slings attached to a metatarsal ring for support of the metatarsophalangeal joints

orthotics or extension of the external fixator. Toe contractures are common during lengthening or foot deformity corrections; toe slings can be used effectively as a means of prophylaxis [18]. Care is required in applying these in order to ensure comfort and correct positioning as it is easy to pull the toe into hyperextension at the metatarsophalangeal joint. The material for the sling needs to be soft; either a soft strapping, which may stretch with time and require replacing, or a soft leather material, which is more durable. The strap is placed around the patient's toe, pinched together at the top and a hole punched in it. Thin elastic threads, strips of Thera-Band and fishing line have all been used to attach the sling to the fixator (Fig. 8). All have a similar durability and require replacement from time to time when the tension is lost. For good positioning the angle of pull is best perpendicular to the joint, and often a plate attached to and extending in front of the fixator is needed to achieve this.

Although toe slings are occasionally used in this unit, the authors' preference is to use a custom moulded forefoot splint. A piece of thermoplastic is moulded under the toes and metatarsal heads and into the arch of the foot. The toes are held in a neutral position and the splint prevents clawing (Figs. 9a, b). It is attached to the fixator by Velcro fastened over a plate, which is positioned in order to achieve the correct angle of pull. These are static splints; continual use is encouraged but with regular removal for hygiene and physiotherapy.

If there is difficulty adapting to the prescribed regime of splinting for reasons of tolerance, circulation or sensory problems, the protocol would need adjusting and a gradual build-up of tolerance sought. A typical routine would

Fig. 9a, b Forefoot supports are important to prevent plantaris or toe deformities

be 20 minutes in every hour during the day with the splint removed at night. This is then supplemented with physiotherapy and regular monitoring.

Joint subluxation

This is more common in congenital disorders with an associated joint instability. The imbalance of muscle tension across the joint from lengthening or deformity correction may precipitate the complication and a warning sign is an unyielding contracture in spite of physiotherapy or splinting. The knee is most vulnerable and prevention is accomplished by a check on the resting position (to encourage knee extension), appropriate splints (as described for tibial plateau fractures) and exercises to maintain movement.

Plastic deformation/fracture of lengthened bone (regenerate)

This may follow fixator removal if excessive load is carried through an as yet incomplete or immature regenerate (leng-

Fig. 10 Custom moulded tibial gaiters can be useful for support after removal of tibial fixators

thened) bone column. Fractures after fixator removal are treated in a cast or by reapplication of the fixator but prevention is simpler. The use of a tibial brace has proved useful in several patients, especially for distal tibial regenerate. The brace is custom made from thermoplastic material, although off-the-shelf devices are available. Partial weight bearing is advised, even though full weight was allowed with the fixator. This is increased to full weight when X-rays confirm the absence of regenerate deformity. Moulding a brace to a patient with significant soft tissue loss or bulky muscle flaps may prove difficult and it may be impossible to obtain adequate compression of the tissues for skeletal support. Such problems may be resolved through use of casting tape and a removable heel cup. In lesser cases it may be possible to pack the area with an elastomer so that the thermoplastic material conforms uniformly to the limb. The thermoplastic brace is convenient as an easy fit under normal clothing and is quick to remove (Fig. 10).

Footwear and leg length discrepancy

In order to facilitate loading of the treated limb it is necessary to provide the patient with appropriate footwear. Footwear modification is also required if the fixator spans the ankle through use of a heel ring and fixation in the calcaneum. This is managed with a simple Shuform slipper (Salts Healthcare, Birmingham, England) to which a layer of foam (which strengthens the sole) and a non-slip rubber sole are added. Velcro fastenings allow ease of adjustment should the foot swell up. The back (counter) is cut away and a Velcro strap is looped over the pin sites and attached to the slipper (Fig. 11). It is necessary to line the Velcro to stop the hooks from catching on the pin site dressings.

For a short limb the amount of shoe raise is adjusted by adding additional layers of foam to the base of the slipper. It is advisable to have the shoe height a little less than the true discrepancy during lengthening; it increases the 'life-span' of the shoe and reduces the number of alterations needed (Fig. 12). Shoes are monitored weekly in patients

Fig. 11 Modified Shuform slipper to accommodate heel ring of fixator. Velcro strap (arrow) loops over pins and the back of heel

Fig. 12 Leg length discrepancy can be addressed through layers of foam on the modified shoe

who are lengthening to ensure the raise does not exceed requirements.

On occasions when it has not been possible to fit a shoe, we have used an extension to the fixator (built from Ilizarov fixator components) and bolted on a walking sole. This obviously increases the weight of the entire assembly (Fig. 13).

Additional problems in limb reconstruction

Oedema

This might be considered an issue throughout the whole procedure. With the fixator in place, it is managed by positioning the limb in elevation or by use of the foot pressure pumps (AV Impulse, Orthofix SRL, Verona, Italy). Even after fixator removal, swelling and oedema may take sev-

Fig. 13 Extension built onto the fixator with a non-slip sole affixed to the lowest ring

eral months to resolve. This can be greatly assisted by the donning of a pressure garment, which reinforces tissue hydrostatic pressure and in turn improves venous and lymphatic flow. There is an added benefit of reducing scarring as the applied pressure imparts tension which controls vascularity, collagen alignment and accelerates the maturation process within the wound [19]. Pressure garments are made to fit. Patients are generally issued with three garments, which permits continuous use but cater for laundering in between. The garments are removed twice daily for washing the skin; use of an emollient cream and massage are encouraged. Pressure garments have to be monitored on a regular basis because any change in the level of oedema necessitates a new garment. Ill-fitting garments are of no benefit (Fig. 14).

Fig. 14 Pressure garments are useful in control of oedema and scarring after fixator removal

Patients with two tibial fixators

The issues for these patients are essentially the same as for patients with one fixator, except that mobility is disproportionately more difficult as the two fixators tend to obstruct one another. Weight bearing is still encouraged but the impracticalities of extended walking make optimising mobility with a wheelchair an effective solution. Obviously the adaptations have to be made for both limbs.

Summary *In this article we have outlined the common soft tissue problems associated with the use of external fixators for fractures and deformities of the tibia, together with the solutions we have adopted for prophylaxis and treatment. Solutions to the problems may vary and individual practitioners may opt to develop their own strategies using locally available resources, both human and material. It is hoped this article will help those who work with this versatile and innovative technique to understand the nature of these problems and assist their efforts to resolve them.*

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