

## The Sheffield Hybrid Fixator: Design Considerations and Clinical Experience

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**Introduction:** The third generation monolateral external fixators such as the dynamic axial fixator (Orthofix SRL, Bussolengo, Verona) have led to improved patient care and a resurgence of interest in external fixation techniques (Hull et al 1997, Hay et al 1998, Saleh and Rees 1995). Of particular merit is the 6mm tapered screw design and bimodal characteristics of the fixator body, which may be converted from rigid to dynamic support. Over a number of years of clinical trials, the 6mm cortical tapered screws have provided strong, durable fixation in diaphyseal bone. Osteolysis and infection are rare events, provided that good surgical technique is adhered to and the screws are inserted in the centre of the bone. By loosening occurring more frequently. The probable reasons for reduced performance related to the open "cell like" structure of fixators support the bone by cantilever loading (Figure 1) and this leads to concentrated high stresses on the near cortex. Repeated cyclical loading during gait is probably the explanation for the loosening which occurs. In one study, cortical screws have been shown to perform better than cancellous screws in metaphyseal bone (Lawes & Goodship, 1997) and in a further study, a zone of poor fixation described as "no-man's land" has been defined (Reed et al, 1997). Circular frames using tensioned Kirschner wires which cross from one side of the bone to the other, support the bone by beam loading (Saleh, et al 1997) and provide variable (multimodal) elastic support to the bone (Ilizarov 1992).

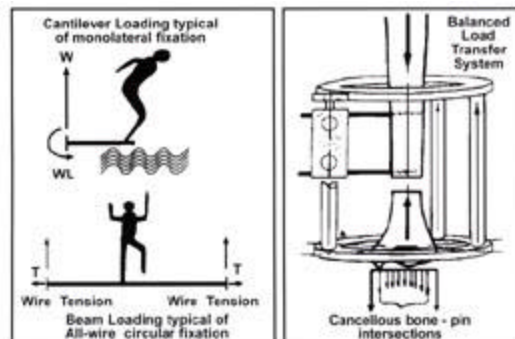


Figure 1 (a) Cantilever and beam loading. (b) Balanced load transfer system. Reproduced from the Operative Technique Manual for the Sheffield Hybrid Fixator with kind permission of Orthofix SRL, Bussolengo, Verona.

Stresses are absorbed by both cortical plates and distributed more evenly across the surface of the bone, an important feature in the support of metaphyseal bone (Figure 1). Clinical experience supports the improved performance of wires in long term fixation of metaphyseal bone, even where osteoporosis exists. An important pre-requisite of stable circular frame fixation is the use of wires with wide crossing angles centered within the central area of the bone. This is certainly possible in the metaphysis, however crossing angles are restricted in diaphysis due to other soft tissue constraints such as muscles, tendons, nerves and vessels (Faure & Merloz 1987). These narrow crossing angles within the diaphysis lead to instability where all-wire fixation is used. The combination of wires for fixation of the metaphyseal bone and screws to fix diaphyseal bone is attractive and is reflected by the number of hybrid external fixation frames which are now available. Most of these frames, however, retain their less desirable cantilever loading properties because of the lack of even load transfer between the monolateral and circular frame elements. By using an all-ring construct, a more efficient load transfer system can be achieved, leading

to a fixator design whose mechanical characteristics closely match those of the all-wire Ilizarov frame (Figure 1). Furthermore the exclusive use of wires in the metaphysis ensure that the device retains its elastic multimodal characteristics.



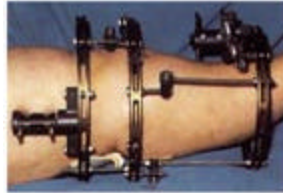
*Figure 2 The Sheffield Hybrid Fixator assembled with fracture reduction units.*

**The System Components:** The Sheffield Hybrid Fixator consists of 2/3 rings (Arches) which have a reinforced anterior sector and cross section making them capable of supporting up to four 2mm wires, tensioned to 1400 Newton's. The ring may be converted to a full ring by the attachment of a 1/3 component. These rings are used to support both metaphyseal and diaphyseal segments. In the metaphyseal segment, wires are attached to the ring using specially designed wire securing pins and wire slider units. The metaphyseal ring may be connected to a diaphyseal ring using the threaded bars or reduction units (Figure 2). Diaphyseal fixation is achieved with the Sheffield clamp. The Sheffield clamp looks similar to the standard DAF clamp (Orthofix SRL, Bussolengo, Verona), however, it has a broad flange connecting it to the ring, and a rotational element to ensure optimal screw placement.

Additional fixation may be achieved by attaching a single screw clamp to the ring itself. In this design, the fixator may be used for the treatment of metaphyseal and articular fractures of the proximal and distal tibia. With the addition of paddle plates, hinges and threaded bars, the device may be taken onto the foot or across the knee and may be used for more complex fracture patterns, as well as limb reconstruction surgery.

**Materials and Methods:** Extensive biomechanical and clinical trials have been conducted over a three year period, from January 1995 until December 1997. During this period the fatigue characteristics, loading characteristics, and biomechanical properties of the fixator have been defined. It has been shown in biomechanical tests, using a materials testing machine, to have the desirable properties of elastic axial fixation, beam loading, and near isotropic bending stiffness. In two ring form its mechanical properties closely resemble those of the four ring all-wire Ilizarov frame (Saleh et al 1997). As a result of its ease of use, strong mechanical support and comfort, it is indicated for severe tibial trauma situations and, in the majority of instances, permits early and often immediate weight bearing. During this three year period, 105 fixators have been applied, 59 for trauma and 46 for limb reconstruction. Stable fixation may be achieved in long spiral osteoporotic fractures of the tibia in the elderly, as well as the unstable short oblique fractures at the metaphyseal/diaphyseal junction. In combination with percutaneous articular surface reconstruction and cannulated screw fixation, it has been used for the treatment of both pilon and plateau fractures. The ability of the device to be extended across the knee (Figure 3) permits its use in more severely comminuted fractures and those associated with soft tissue injury. At an appropriate stage, post-operatively (usually

around the sixth week), the transarticular component of the fixation may be disconnected to permit joint mobilization. It is possible in most instances for patients with high energy tibial plateau fractures to mobilize immediately, partial to full weight bearing. This is supported by biomechanical studies, where four wires have been demonstrated to be the equivalent of medial and lateral buttress plates (Watson, 1996). The use of hybrid external fixation in these difficult trauma problems has led to improved results and a reduction in complication rates. As well as ambulating early, patients have been noted to be prepared to exercise, and even run with the fixator in place, undergo work retraining, cycling and build up muscle bulk (Figure 4).



*Figure 3. The addition of a further ring and Sheffield clamp allow the device to be taken across the knee.*

Forty-six limb reconstruction procedures have been performed, including ankle and knee arthrodeses, lengthening with deformity correction and the treatment by distraction of hypertrophic non-unions (Saleh and Royston 1996). It may be used as an adjunct to the Limb Reconstruction System (Orthofix SRL, Bussolengo, Verona) to extend the indications for monolateral frames and may also be used in its own right for cross joint fixation and progressive deformity correction. The combination of the limb reconstruction system in the femur, together with the Sheffield hybrid fixator in the tibia, has proved to be a strong reconstructive system (Figure 5). Proof that stable fixation may be achieved with diaphyseal screw fixation is demonstrated in examples where high forces are generated such as the diaphyseal stabilizing ring in the correction of an equinovarus deformity (Figure 6). The use of hybrid external fixation is a welcome advance over previous external fixation methods. The device chosen, however, should be capable of beam loading support and provide stable long-term fixation.



#### **References:**

**Faure C, Merloz P.** Transfixation: Atlas of Anatomical Sections for the External Fixation of Limbs. Springer-Verlag, New York. 1987.

**Hays SM, Rickman M, Saleh M.** Fracture of the tibial diaphysis treated by external fixation and the axial alignment grid. A single surgeon's experience. *Injury* Vol 28, No 7, 437-443, 1997.

**Hull JB, Sanderson PL, Rickman M, Bell MJ, Saleh M.** External Fixation of Children's Fractures: Use of the Orthofix Dynamic Axial Fixator. *J Paed Orthop Part B*, 6:203-206, 1997.

**Ilizarov GA.** *Transosseus Osteosynthesis: Theoretical and Clinical Aspects of the Regeneration and Growth of Tissue.* Springer - Verlag, Berlin, Heidelberg, New York, 1992.

**Lawes TJ, Goodship AE.** Cortical profile external fixation screws main torque in the metaphysis. *J Bone Joint Surg suppl* 1997 (in press).

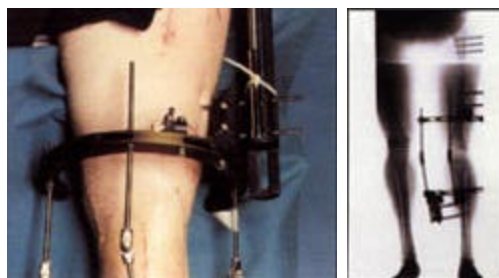
**Reed M, Yang L, Saleh M, Petrone N.** Metaphyseal "No man's land" - does it really exist? *J Bone Joint Surg suupl* IV p.462 1997.

**Saleh M, Rees A.** Bifocal surgery for deformity and bone loss after lower-limb fractures. Comparison of bone-transport and compression-distraction methods. *J Bone Joint Surg (Br)* 1995; 77(3):429-34.

**Saleh M, Royston S.** Management of non-union of fractures by distraction with correction of angulation and shortening. *J Bone Joint Surg (Br)* 1996; 78-B(1): 105-9.

**Saleh M, Yang L, Nayagam S.** Can a Hybrid Fixator perform as well as the Ilizarov Fixator? *J Bone Joint Surg suupl* IV p. 462, 1997.

**Watson JT.** Biomechanical stability of Schatzker 6 fractures treated with fine wire external fixation. *ASAMI North America*, Atlanta, 1996.



*Figure 5. Patient with a short arthrodesed leg in valgus undergoing bifocal lengthening and deformity correction, using a Limb Reconstruction System in the Femur and Sheffield Hybrid Fixator across the Knee (a) clinical appearance (b) radiological view at end of correction and lengthening, see Figure 6.*