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External Fixation of the Leg Using Unilateral Biplanar Frames

A. A. Fernández
Orthopaedic Surgeon, British Hospital, Avenida Italia 2420, Montevideo, Uruguay

Summary. A simple and reliable method is described for testing the stability of external fixators under stresses similar to those found in clinical practice. Unilateral uniplanar, unilateral biplanar, and bilateral uniplanar frames were used. It seemed important to measure deformations under bending stresses in different planes, because we have found a variable rigidity in some of the frames in the different planes. Our results show that a unilateral biplanar frame without transfixation pins can be set up with an overall rigidity as good as that of a bilateral frame. Using this on the leg, one can avoid putting pins through the anterolateral compartment.


External fixation of the leg is indicated mainly in grade-III compound fractures and in infected fractures or pseudoarthrosis. In these cases we prefer to avoid implants at the fracture level. Percutaneous placement of pins distant from the fracture site does not disrupt the already damaged blood supply of bone ends in compound fractures, and it seems the best method of fixation for infected bones. It seems better to avoid going through muscles, nerves, and vessels of the anterolateral compartment of the leg, as sometimes happens with transfixation pins.

How stiff must external fixators be? Usually, a rigid osteosynthesis cannot be achieved with an external fixator [8]. We then have movements that will stimulate osteogenesis, but these movements are detrimental to soft-tissue healing and infection treatment. Therefore, from the mechanical point of view, the stiffer the external fixator, the better. At a later stage of treatment we may want to reduced frame rigidity to encourage bone union. We would then, if possible, prefer a frame with an adjustable rigidity [7]. We thought that the V-shaped frame with Schanz screws inserted ventrally and medially [2] was very good, and we wanted to test the rigidity of this frame in the laboratory. Today there is no doubt about the importance that laboratory research has had in the development of external fixation [1–6], but it seems important to do the testing in a situation as similar as possible to that of real clinical practice [4]. Flexion stress, mainly in the sagittal plane, is apparently the most important in the clinical situation. Rotational and axial stresses seem to be of less importance [4].

We believe that gap mounting, without bone-end contact, is the best way to test an external fixator. There is no stability from the bone itself, and it is easily reproduced [1]. In clinical practice we would not let a patient with gap mounting of the external fixator put weight on his injured leg. Therefore, we should not test a gap mounting with axial compressive forces in the laboratory. We chose gap-mounting frames and tested them under flexion stresses of a magnitude similar to those found in clinical practice.
Material and Methods

A PVC tube was used; it is easier to handle than cadaveric bone, and as the material is more homogeneous, results can be reproduced with accuracy [1]. To set up the external fixator the ASIF tubular system was used.

Various frames were tested: unilateral uniplanar (type Ia), unilateral biplanar (type Ib) in several configurations, bilateral uniplanar (type II), and triangulation frames (type III) (Figs 1 and 2). Each frame was charged with 2 kg at 200 mm from the focus in eight positions. We placed the frame assemblies in a rotating base that allowed us to measure transverse and angular deformations at each 45° of rotation through 360°. After removal of the 2 kg force the residual plastic deformation was measured (Figs 3 and 4). Transverse displacement in the plane of charge was measured at the focus and at 120 mm distal to it. We then calculated transverse displacement at the focus and angular displacement of the distal tube with the following equations (Fig 3):

\[
\text{Transverse displacement} = C_2 - C_1 \\
\text{Angular displacement} = \arctan \left( \frac{C_4 - C_3}{120} \right)
\]

We plotted the results in graphics and did the analysis by maximal displacements.

With a torquemeter we carefully adjusted the torque of all the nuts and screws of the external fixator in each assembly. To control error of measure we built ten of the frames twice, using new tubes, and in this way obtained 80 twin measures.

Results

Shape of Graphics

Uniplanar frames with transfixation pins (Fig 1b) or with half pins (Fig 1a) have long, narrow graphics with maximal displacement in the sagittal plane and minimal displacement in the plane of the pins (Fig 5). Biplanar frames (Fig 1c) have round graphics with similar displacement in all planes tested (Fig 6).

Magnitude of Displacement Under Physiological Stresses

Unilateral Uniplanar Frames. Mean of transverse displacement was approximately 2 mm. These frames allowed a maximal angular displacement of 3°, which