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Mini External Fixation for Hand Fractures and Dislocations: The Current State of the Art

Renata De Kesel, MD, Franz Burny, MD, PhD, Frédéric Schuind, MD, PhD*

Department of Orthopaedics and Traumatology, Cliniques Universitaires de Bruxelles, Hôpital Erasme, ULB 808 Route de Lennik 1070, Brussels, Belgium

The origin of external fixation dates back to Malgaigne [1] who, in 1843, described a percutaneous claw device to compress and immobilize the major fragments of a displaced patellar fracture. Parkhill [2], in 1897, described the use of two half-pins above and two half-pins below the fracture, externally joined by an ingenious clamp, for fixation of bones after resection, or in some fractures. The Belgian surgeon Albin Lambotte [3,4], as early as 1904, used a simple configuration for the hand—two screws connected by an external plate (Fig. 1). The authors are indebted to Raoul Hoffmann [5] for a major advance in external fixation, when, in 1938, he introduced the concept of ''universal ball joins,'' permitting the reduction of the fracture after the application of the fixator. Several authors later reported the use of various mini external fixation (MiniFix) devices for bone fixation at the hand, foot, or mandible, and for fractures occurring in children [6–8]. Most of these fixators, however, lost popularity because of lack of stability and difficulty of application. Henri Jaquet [9] developed a new concept of minifixation in the years 1975 and 1976, particularly designed for applications in the hand and wrist. The Brussels school has been using this implant since 1977 [10,11]. In 1990, the results of a prospective study of the school's first 516 cases were published [12]. Since 2004, the authors have used the new Micro Hoffman II fixator developed by Stryker following the concept of the Hoffman II. The MiniFix is currently a well-known minimally invasive technique for the treatment of hand fractures and dislocations.

Bone healing characteristics with external fixation

The bone healing process in the hand is the same as in other bones. In compact bone the healing pattern is normally with formation of a periosteal callus, leading to the production of endochondral bone, of periosteal origin, and forming a bridge between the fragments [13,14]. The callus remodels until the shape of the diaphysis is reconstituted. The shape of this callus gives a high resistance to bending and defection. With this high ''second moment of inertia,'' the callus is biomechanically favorable. This callus formation is seen when viability of the surrounding structures at the fracture are preserved (bone and periosteum) and when there is slight interfragmentary motion. Another pattern of compact bone healing is the primary bone healing process, occurring after perfect interfragmentary contact with minimal micromovements and preserved viability of the fragments [15,16]. There is no periosteal callus formation but a progressive, direct fusion of the cortices by formation of new osteons crossing the fracture line. This primary bone healing, seen in rigid bone fixation (classical plate osteosynthesis), is a slow phenomenon and presents a risk of refracture after implant removal. The healing of fractures through trabecular bone is different, but in general much faster, by apposition of bone on trabeculae with or without periosteal callus formation [17].

* Corresponding author.
E-mail address: fschuind@ulb.ac.be (F. Schuind).

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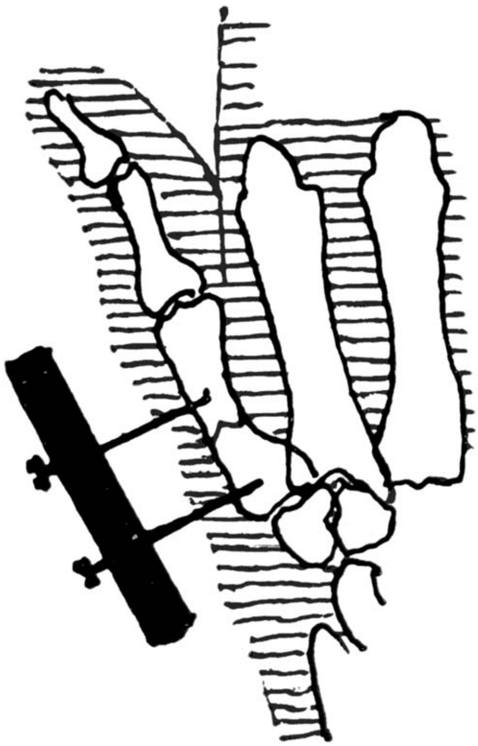

Fig. 1. Lambotte's small external fixator used in the treatment of a diaphyseal fracture of the first metacarpal.

Biomechanical considerations

External fixation is based on the principle of load transfer. Forces, normally transmitted through the fracture site, are bypassed by way of the fixation frame [18,19]. Such load transfer characteristics rely on the stability of the external fixator. Fracture stiffness is defined as the ratio of the applied load on the bone ends versus the displacement, measured at the fracture site. Fracture stiffness is expressed into axial, bending, and torsion values. Compared with rigid internal fixation, external fixation provides a high axial stiffness and a low bending rigidity, depending on the frame configuration [20]. The fracture stiffness property can be adjusted by varying the geometry of the MiniFix. Fitoussi [21] compared the rigidity of internally (plate osteosynthesis) and externally (MiniFix) treated phalangeal fractures and concluded that external fixation provides higher torsion rigidity but a lower compression and palmar bending rigidity, as compared with internal rigid fixation. The optimal elasticity of the osteosynthesis allows the early formation of a strong periosteal callus. However, the ideal elasticity is currently unknown [22]. The key factors to increase frame stability include increasing the pin diameter, increasing the pin number, decreasing the sidebar separation, increasing the pin group separation, and applying pins in different planes [23,24]. It is not always possible to follow these rules, as increasing the pin diameter increases the risk of fracture at the pin insertion site. But, once again, the optimal stiffness is unknown, and overly stiff prevents quick bone healing. In the authors' clinical study of 516 Jaquet external minifixators there was no case of fractures through pin holes using 2-mm pins [12]. In external fixation applied to distal radius fractures, there was a 0.4% rate of fractures at the site of implantation of 3-mm pins in the second metacarpal bone [25]. At the metacarpal level, the surrounding soft tissues provide an additional mechanical stability to the bone fixation.

Surgical technique and postoperative care

The surgical technique has been described by Asche and colleagues [9,11] and Burny and colleagues [10]. Surgery must be performed under general or locoregional anesthesia. The patient is positioned on the operating table with the upper limb on a lateral radiolucent table. The use of a tourniquet is useful but not mandatory, if there is no associated procedure on the soft tissues. The entire upper limb is sterilized and draped.

In the phalanges and metacarpals, the use of threaded pins of 2 mm is recommended. Anatomical considerations suggest that half-pins are better suited in most locations than transfixing pins. The pins must be strongly fixed in both cortices of sound, uninjured parts of the bone. The half-pins must protrude distally no more than 2 mm to avoid the flexor tendons and the palmar neurovascular bundles. There must be a minimum of two pins on either side of the fracture. One incision of 1 cm is used for the insertion of two parallel pins. The first pin to be implanted in each group should be closest to the fracture. The tendons and neurovascular structures are protected, and the bone is clearly visualized before pin insertion. Pilot holes of 1.5 mm are created with a power drill. To avoid pin loosening by thermal necrosis, the pins should be inserted manually. The pins are manually tested to ensure that they are firmly anchored. Each cluster of two pins is held in a pin holder, which is positioned