THE HISTORY OF EXTERNAL FIXATION, A REVOLUTION IDEA FOR THE TREATMENT OF LIMB’S TRAUMATIZED AND DEFORMITIES: FROM HIPPOCRATES TO TODAY.

Michele Bisaccia (1), Cristina Ibáñez Vicente (1), Luigi Meccariello (2), Giuseppe Rinonapoli (1), Gabriele Falzarano (2), Giovanni Colleluori (1), Andrea Schiavone (1), Pellegrino Ferrara (1), Raffaele Pezzella (3), Enrico Manzi (4), Auro Caraffa (1).

1) Division of Orthopedics and Trauma Surgery, University of Perugia, S. Maria della Misericordia Hospital, Perugia, Italy
2) U.O.C. Orthopedics and Traumatology, Azienda Ospedaliera “Gaetano Rummo”, Benevento, Italy
3) Clinic Of Orthopedic and Traumatology, 1Ind University Of Naples, Naples, Italy.
4) U.O. Orthopedic and Traumatology, Tarquinia Hospital, Tarquinia (Viterbo), Italy.

Corresponding Author:
Luigi Meccariello, MD
U.O.C. Orthopedics and Traumatology, Department of Emergency Azienda Ospedaliera “Gaetano Rummo”,
Via dell’Angelo 1, Benevento, Italy
E-mail: drlordmec@gmail.com
Phone: +393299419574

This work is licensed under a Creative Commons Attribution 4.0 International License.

Abstract

Nowadays external fixation was sold as a final synthesis for fracture, but it remains a gold standard for the correction of limb’s deformities and for orthopedic damage control. In this paper, we retrace the history of this valuable surgical technique.

Key Words: History External Fixation, HIPPOCRATES; MONOAXIAL, MODULAR, RING.
INTRODUCTION

Currently, external fixation (EF) is a widely utilized method for the treatment of fractures, pseudoarthrosis, infections, the correction of deformities and osteotomy. EF is performed with pins or wires that pass through the bone at a variable angle with respect to the long axis; the pins or wires are then connected to each other by a rigid scaffolding of which exist a varied number of designs. It is precisely this external structure that gives its name to a variety of fixator types. In EF, the fractured bone segments can be re-aligned, placed in compression or distraction, the area of the wound is easily visible and treatable and additional surgical procedures can be carried out with minimal discomfort for the patient. Moreover, the stabilization of the bone segment allows the elevation of the limb as well as an early mobilization of the articulation.

An ulterior advantage of EF is that it permits for a rapid stabilization of fractures with minimal invasion and consequently results being the technique of first choice for poly-traumatized patients [1]. In order to thoroughly understand the history of EF, one needs to distinguish mono-lateral EF from circular EF. These two types of EF underwent differing developments in diverse parts of the world.

MONOLATERAL E.F.

The history of EF dates back to 400 B.C. when Hippocrates described a simple external fixator utilized for a fracture of the tibia. This device was made up of leather rings that covered the limb. These rings were connected to each other by four rods made of cherry wood that travelled from the knee to the ankle. The rods were placed laterally with respect to the ankle, so not to interfere with the movement of the ankle and permit for an inspection of the skin. (Fig.1)

The first known description of a fixator was made by the American, J. Emsberry in 1831. Later in 1843 the French physician Malgaigne[1] introduced a device to treat fractures of the knee-cap and the olecranon. It resembled a clamp and was known as the “Malgaigne fixator.” This mechanism was made of a clamp that approximated four transcutaneous metal prongs and was presented by its inventor 12 years prior to the introduction of plaster casting techniques (Fig. 2)

Fig.1: External fixator for tibial fracture as applied by Hippocrates
Fig. 2: Malgaigne fixator

The first description of treatment for a long bone is attributed to the English physician Keetley in the year 1839[2-3]. (Fig.3) It was here that Keeley described a technique where rigid pins were inserted at the level of the femur and connected to an external system of splints with the objective of reducing the incidence of pseudoarthrosis. In the Keeley fixator the pins were made of plated steel and inserted into the bone through a mini-incision of the skin. The pins were connected to each other by two horizontal braces and the entire fixator was covered in iodoform gauze.

Fig. 3: Keetley's fixator.

In 1897, in Denver, Clayton Parkhill [4-5], utilized an external fixator similar to the currently used monolateral types. This fixator by Parkhill was made up of four screws of which two were inserted into the proximal fragment and two into the distal fragment. The screws were connected among each other with plates and bolts. Parkhill used this technique to treat fractures and pseudoarthrosis of the tibia. In all cases he used supplemental plaster immobilization to increase stability(Fig.4). Clayton Parkhill died five years later of an appendicitis and therefore was not able to further develop his technique.
Fig. 4: Parkhill external fixator

Over the same period [6-8], in Colorado, Freeman developed an EF system similar to that of Parkhill. Specifically, a single pin was inserted both above and below the fracture. These two pins were connected to each other by metal bars which were covered in wood. Furthermore, Freeman developed a trocar in order to position the pins in the most sterile manner as well as to protect the soft tissue. Freeman is credited with inventing a “T handle” for facilitating an easy insertion of the pins through the skin. Moreover, he affirmed that the pins should be inserted at a certain distance from the fracture and this insertion should be performed through the skin incision. (Fig.5).

With this technique, Freeman wrote that he had successfully treated both the neck of the femur and pseudoarthrosis of the tibia [9].

Fig. 5: Freeman fixator

It was in 1902, subsequent to the work by Parkhill, when the Belgian physician Lambotte [10] applied a unilateral frame in a systematic manner. This fixator was made up of metal pins that penetrated into the bone and protruded through the skin. The pins were connected to each other by an external device, that permitted for the stabilization of the pins and bone segments. (Fig.6)

Fig. 6: Lambotte’s external fixator
The concepts proposed by Lambotte were taken up by Hoffmann in 1938 who started to use the external fixators that are used currently [11-12].

Hoffman realized that one of the principle limitations was the necessity for an open reduction before applying the fixator. For this fact, he coined the modern Greek term “osteosynthesis”, which means “put the bone in its place”. The Hoffman fixator was composed of an incorporated universal ball joint connecting the external ball of the fixator to strong pin-gripping clamps. This universal joint allowed for a reduction of the fracture in the three planes of space even after the fixator was applied. Hoffmann published his technique in 1938 and presented it to the French Congress of Surgery [13]. Here it was possible to apply a sliding compression distraction bar that allowed to apply the compression at the centre of either the fracture or the distraction.

Fig. 7: Hoffmann’s external fixator

Over the same years, the American physician Roger Anderson [14], developed an apparatus for the reduction of fractures which was made up of transfixion pins connected to metal clamps. This device permitted a multi-plane reduction of the fracture as well as the possibility of compression. Following the fracture reduction, a cast was applied with the fixator already in place; the fixator was removed after the application of the cast had been completed. Afterwards, Anderson built upon this concept and developed a fixator made up of transfixion pins connected to bars. This eliminated the previously required cast(Fig.8).

Fig. 8: Anderson's device with transfixion pins

In 1937, Otto Stader [15] developed a stabilization system for fractures that lead to a reduction of the fractures on three planes as well as the utilization in his veterinarian practice. In 1942, this system was modified by Lewis, Breidenbach and Stader in New York so it could be applied on humans(fig.9). The two described their experiences in treating twenty patients at Bellevue Hospital, in New York City. Lewis and Breidenbach [16] were the first to describe the advantages of positioning the pins as far away as possible from the fracture. Moreover, they stressed the importance of positioning the pins at angles from each other (not parallel) so to increase the stability[15].
At the beginning of WWII, the external fixator by Anderson became adopted by orthopaedics in North America and Europe. However, with its frequent application, it was observed that this technique resulted being overly specialized and too time consuming for the battle field. As well, the high incidence of complications including pin loosening and pin tract infection, lead to its disfavor among physicians as this technique was not deemed suitable for problems associated with open fractures [17]. Subsequently, especially between the 1950’s and 1970’s, E.F. became highly unpopular among American surgeons, whereas the pins and plaster technique continued to be utilized for fractures of the tibia and wrist.

At the same time in Europe, Vidal built upon the Hoffman fixator and designed a quadrilateral frame to guarantee a fixation even more rigid and stable demonstrating its utility in biomechanical studies[18].

In the 1960’s and 70’s, Franz Bernie further elaborated on Hoffman’s device consisting of a unilateral frame with a single connecting bar and half pins; by treating an elevated number of fractures, Bernie was able to demonstrate that EF could be successfully utilized for pseudoarthrosis, infections and arthrodesis[19-20]. During the 70s, De Bastiani [21] developed the “dynamic axial fixator” and Gotzen the “monofixator”(Fig.11).

These fixators were composed of four pins placed in groups of two at the two extremes from the fracture. The pins were connected to each other by a telescopic tubular rod of a great diameter. The advantage of these fixators, other than being better tolerated by the patient, was that they permitted micro-movements and axial loading during deambulation, therein enhancing the healing. Following these innovations, with the first being encouraging, and with the publication of scientific works on E.F., a renewed interest in this method took root in North America.
Fig. 11: De Bastiani's external fixator

Even the manual on AO/ASIF Tubular External Fixator in 1977 came out recommending the use of EF. This document provided precise indications on the use of these techniques and shortly after numerous North American surgeons returned to using these techniques with good results[22] (Fig.12).

Fig. 12: AO ASIF external fixator

In the 1990’s E.F. was popular again, especially for damage control orthopedics (DCO) and the treatment of complex peri-articular fractures (spanning external fixation).

At many institutions the utilization of minimally associated frames for delayed skeletal reconstruction using locking plates and IM nails has become the treatment of first choice by orthopaedics. In Perugia, both Professor Caraffa and Dr. Michele Bisaccia have promoted the use of monolateral EF for the treatment of humeral bone, wrist and pediatric fractures[23-24] (Fig13). Currently there are numerous types of monolateral fixators that permit to carry out distraction, compression and the correction of angular deformities. Furthermore, more recent fixators have been constructed with non-magnetic and radio-transparent materials, something that allows for exams including MRI (Fig.14).

Fig 14: Dr. Michele Bisaccia with humeral E.F. for complex humeral fracture
Fig.13: Hoffmann’s 3 MRI

References


6) Parkhill C. Further observations regarding the use of the bone clamp in ununited fractures, fractures with malunion and recent fractures with tendency to displacement. Ann Surg. 1898;27:553–570.


