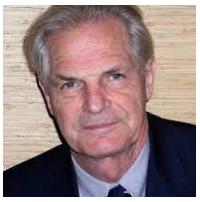

DENYS MONTANDON, MD – SWITZERLAND

PART 2. BONE DISTRACTION OSTEOGENESIS

SURGICAL USE OF PROGRESSIVE TISSUE EXPANSION AND ELONGATION SINCE ANTIQUITY

THE BED OF PROCRUSTES

In Greek mythology, Procrustes (·ροκρούστης "the stretcher [who hammers out the metal])", was a bandit living on the sacred way between Athens and Eleusis. He invited every passer-by to spend the night on a special iron bed. If they did not match the length of the bed, he would forcefully stretch and elongate them to fit the bed. In other myths, Procrustes would amputate the excess length if the guest was too tall. In fact, nobody ever fit the bed exactly. Fortunately for the travelers, Procrustes was captured by the hero Theseus. The bandit did not survive, but the "bed of Procrustes" has become proverbial for arbitrarily forcing someone or something to fit into an unnatural scheme or pattern[1].

Reducing limb fractures and joint dislocation by progressive stretch and traction is a very old method, previously promoted by Hippocrates (5th century BC), who described a kind of external fixation for the permanent extension of long bones. The extension consisted of two leather rings positioned above and below the site of the fracture. Four pieces of wood were then wedged between the rings at an equal distance around the leg holding the rings apart, the device allowing for the patient's body weight to be transferred between the rings rather than the bone. Hippocrates also described traction devices for other deformations like joint dislocations.

Figure 1: Niketas codex; hip traction on a scale, according to Hippocrates.

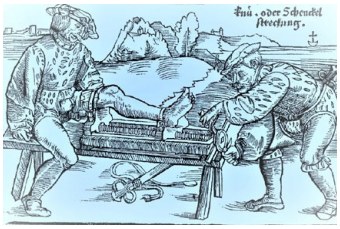

Figure 2: Limb extension bed (Von Gerdorff 1517).

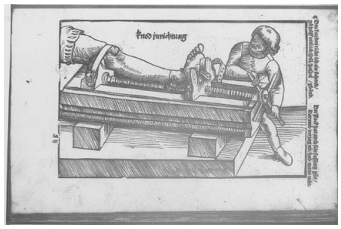

Figure 3: Straightening of the leg (Von Gerdorff 1517).

In 1500 AD, paintings referring to these methods were discovered in Greece. The *Niketas Codex* included 30 drawings exhibiting various traction and manipulation techniques for the treatment of spinal and limb deformities ***(Figure 1)***. Much more elaborate were the elongation devices used during the Renaissance to reduce fractures and dislocations, as exemplified by the special bed drawn in Hans von Gersdorff's treaty Feldbuch der Wundarzney ("Field Book of Surgery") in 1517, allowing very slow traction on the lower limbs thanks to a rotating screw ***(Figures 2 and 3)***.

LIMB'S ELONGATION

Attempts at elongating short or malformed limbs started during the early 20th century with reports of patients

operated by Alessandro Codivilla[2] of Bologna, who made oblique osteotomies and applied continuous traction of 25 to 30 kg through a calcaneal pin. However, the high level of complications, like dead skin, infection, and failure of the bone to join, did not encourage other surgeons to adopt his method. Putti, in 1921[3], reported an external distraction device

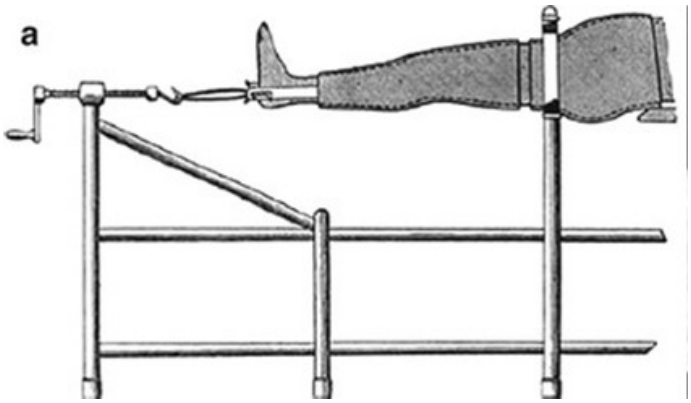

Figure 4: Codovilla apparatus for limb distraction.

for femur lengthening consisting of pins attached to bone segments and connected with a telescoping device and an internal spring that applied traction to the bone segments. In 1932, LeRoy C. Abbott presented his experience with lower limb lengthening of 73 patients (45 tibial lengthenings) at the Shriners' Hospital for Crippled Children in St. Louis. The basic principle was an osteotomy of the tibia and fibula and a slow continuous traction to overcome soft tissue resistance, and precise contact and alignment of the bone ends by applying two pins above and below the osteotomy, connected to a special apparatus ***(Figure 4)***.

However, most of our contemporary knowledge about bone lengthening originates from the Ilizarov method. In the 1950s, the USSR surgeon **Gavriil Ilizarov** (1921–1992) ***(Figure 5)*** observed that by carefully dividing a long bone without severing the periosteum after 7 to 10 days and applying a distraction device through an external fixator system, he was able to stimulate bone growth between the two fragments. Originally, in 1951, the material and the procedure were inspired by a shaft bow harness and bicycle parts used for the frame. After studying the biological laws of tension stress or distraction osteogenesis, Ilizarov applied its principle to various conditions, such as bone shortening, non-union osteomyelitis, dwarfism, congenital deformities, bone defects, and problematic fractures[4].

Although more and more patients were treated successfully by this method, Ilizarov faced skepticism and resistance, mainly from the medical establishment in Moscow, where he was considered a quack. However, having successfully treated hundreds of patients throughout the country, including Valeriv Brumel, the 1964 Olympic champion and long-time world record holder of the high-jump, Ilizarov became increasingly known as "the magician from Kurgan,"in his city of residence in Siberia. Nevertheless, he remained unknown in western countries up until 1981, when, after the successful treatment of the famous Italian explorer Carlo Mauri, who called Ilizarov "the Michelangelo of Orthopedics," he was invited to an orthopedic meeting in Italy where he received a standing ovation for his invention.

Figure 5: G.A. Ilizarov 1991.

In 1982, the Association for the Study and Application of the Methods of Ilizarov (ASAMI) was formed in Italy and organized courses in several European countries. Only from 1986–1987 was the technique brought to North America and became a standard orthopedic procedure worldwide. Bone lengthening is now applied to lengthen the different levels of the upper and lower limbs. A special mention should be given to the Bulgarian surgeon, Ivan Matev, for the report of thumb reconstruction through elongation of the first metacarpal[5].

DISTRACTION OSTEOGENESIS IN THE CRANIOFACIAL SKELETON

Although the expansion of the hard palate had been performed for decades by orthodontists and several canine experimental distraction osteogenesis of the craniofacial region in dogs, we owe recognition to **Joseph McCarthy**, who in 1992[6], first reported distraction osteogenesis procedures in patients with congenital mandible deformities, which was first published during the 1980s.

In a recent editorial for the 30-year anniversary of this innovation, Roberto Flores pointed out that, ironically, Illizarov, himself was an inpatient at New York University while McCarthy was developing the technique of craniofacial

distraction in dogs. Taking this opportunity, McCarthy visited Ilizarov and presented his idea of applying the principles of distraction osteogenesis to the mandible; however, Ilizarov dismissed McCarthy's idea, claiming that it would never work.

Since 1992, several large series with longer follow-up periods have appeared. After mandibular osteotomies and a waiting period of a few days, a slow distraction is applied through various pins and devices, which may be external to have better control, or inside the mouth to hide the apparatus. More recently, distraction osteogenesis has been applied to advance the skeleton for all kinds of mid- and upper-face congenital and post-traumatic deformities such as the Lefort1, 2, or 3 impacted fractures. Anterior and posterior vault distraction has also been achieved to correct cranial deformities.

CONCLUSION

For generations, mankind acknowledged the possibilities of tissue growth when submitted to progressive physical expansion, traction, or distraction. Except for the reduction of fractures and dislocations and a few scattered reports, one had to wait until the end of the 20th century before surgeons could make real practical use of distraction to stimulate the natural phenomenon of osteogenesis, thanks to pioneers like Ilizarov and McCarthy.

The complex phenomenon of osteogenesis in bone lengthening is similar to the "secondary healing" of disrupted post-traumatic fractures. After hematoma formation and a variable latency period, fibrocartilaginous callous formation starts progressively. The latency period allows an organization of the hematoma and the fibrous tissue matrix, which will serve as a mold for osteoblast proliferation. Ilizarov considered the preservation of the periosteum and the medulla vascularization as mandatory to obtain better results on distraction osteogenesis. Ultimately, the callous undergoes remodeling and is replaced by hard bone. Elongation of muscles, aponeurosis, nerves, and skin, follows, according to Ilizarov, the *Law of Tension-Stress*. He postulated that the simultaneous distraction of the soft tissues results in both a reorganization of collagen and other connective tissue elements and neo-histogenesis.

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