acta orthopaedica belgica, 2024, 90, 355-378

doi.org/10.52628/90.2.H1

The history of skeletal trauma care: 5000 years of traumatology

W. DE GROOTE[1]

[1]*Department of Orthopaedics and Traumatology, AZ Sint Jan Brugge, Belgium.*

Correspondence at: Dr. William De Groote, Department of Orthopaedics and Traumatology AZ Sint-Jan Brugge, Ruddershove, 8000 Brugge, Belgium, Email : william.degroote@skynet.be

INTRODUCTION

Knowledge of trauma is as old as mankind and therefore traumatology can be seen as the earliest form of surgery. During millennia, only surgeons, especially army surgeons, exercised fracture treatment, because war was the only event with massive casualties. Until the 20th century, war has always been the main catalyst in the evolution of trauma treatment.

On the one hand surgeons have always been searching for better immobilization and fixation of fractures, and on the other hand for optimization of wound care. Up to now the latter remains the most crucial treatment in skeletal surgery.

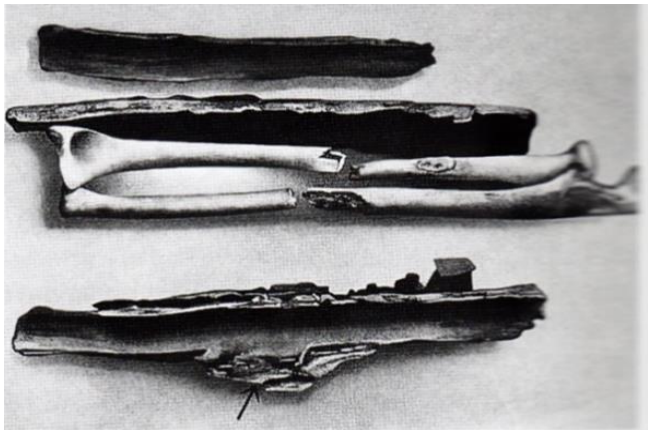
This article discusses diagonally, over the major step stones, the evolution of skeletal fracture care over a period of 5000 years, from external splint to internal fixation.

In the 21st century, skeletal trauma is still the leading cause of physical disability. And because of the growth of the world population, the increasing industrialization and the densification of traffic in the developing countries, there will be exponentially increasing demand for solid and minimally invasive trauma care.

TRAUMATOLOGY IN THE ANTIQUITY

Our current Western knowledge of trauma care has a history that, like the whole Western science, has made a trip around the Mediterranean sea, which starts about 2700 BC.

In the Egyptian Nile delta, basic fracture treatment was splinting of the limbs in support of the fractures. On the mummies in the sarcophagi splints made of linen, gum, palm, papyrus and acacia bark were found.



Open perimortem ulna - and radius - fracture of a mummy (2500 BC) splinted with acacia bark, with traces of blood on the dressing and without any sign of callus formation.

Noteworthy here is that the problem of open fracture treatment can be recognized . On some mummy splints traces of blood at the fracture side and underlying fractures without any callus formation were found, suggesting an early death after the accident[27].

Until the 20th century an open fracture was mostly fatal, and even today sometimes no solution to the wound- and infection-problems is found in these open fractures, making amputation unavoidable. Up to this day, the open fracture remains an enigma! (For many centuries amputation was the only possible treatment for an open fracture).

In ancient Greek medicine, fracture treatment was enshrined in the Hippocratic Corpus[6]. Also during this period splints and bandages are used as basic fracture stabilization techniques. Lesser bleedings were cauterized and open fractures amputated transarticularly (disarticulation).

During the next centuries Greek physicians recognized the infectious syndrome of wounds and

open fractures, but made a first fundamental error in wound care, based on the four humor theory. Arguing that pus had a cleaning function of the wound and was thus beneficial. Evacuation of pus did restore the humoral balance, or the homeostasis.

The humoral theory was defined as a dogma in the 2nd century AD by the Greek - Roman physician Galen (Pergamom 129-216, Rome). Galen suggested that - in order to maintain the balance between the four humors - by excess of one humor (blood, phlegm, black and yellow bile), this humor had to be removed from the body by purging, vomiting, bloodletting, as well as evacuation of toxic substances from the infected wounds. This theory has discredited an appropriate wound care for 1500 years.

Also in the Roman time, Cornelius Celsus (25BC - 50AD, Rome) introduced the vascular ligature for bleedings and proposed a daily wound cleaning with wine and vinegar. In order to facilitate the transosseous amputation, he also developed the amputation saw.

After the Roman time, medical science continued its journey around the Mediterranean sea via Constantinople, where in the 7th Century Paul of Aegina (625-690, Constantinople) transferred the surgical knowledge to the Arab surgeons. Initially in Baghdad and at a later stage in Cordoba, where the Arabic surgical school reached its peak under Al-Zahrawi or Albucasis (936 - 1013 Cordoba), who made a compilation of surgical knowledge in his "Al - Tasrif". This book would remain the standard in surgery for more than 700 years[38].

Al - Zahrawi recommended fracture splinting with soft splints of clay and egg white, which may be windowed to allow wound care and bone debridement. He performed only distal amputations below the elbow or knee in open fractures. However, the technique of the vascular ligature according to Celsus got lost and the Arab surgeons therefore treated any bleeding, even those in amputations, with cauterization. Cauterization continued to be the standard haemostasis for many centuries during the middle ages.

When in the 11th century the Almohads took the power in the Caliphate of Cordoba, there came an end to the peaceful coexistence between Muslims and Jews, who were expelled.

Jewish scientists, called Arabists, emigrated to southern Italy, up in Salerno, and to Lunel in the French Languedoc. There they transferred the Arab knowledge to Western Europe through translations of Arabic scientific books into Hebrew, Greek and Latin.

TRAUMATOLOGY IN THE WESTERN MIDDLE AGES

This immigration created the first Western medical schools in Salerno and Montpellier, which were the germ for the later development of Western universities (Bologna 1050, the first medical faculty in 1185). There, clerics with greater or lesser degree of ordination were formed as physicians.

However, because of decisions taken by the Catholic Church, these clergy medics had to leave surgery to artisan barbers, who were not formed at university. Indeed, the Council of Clermont (1095) proposed a ban on the monks clergy medicine and the Council of Tours (1163) banned clerics from all contact with blood. This is why traumatology disappeared from the academic context and the activity was left to locally trained surgeons. These surgeons, especially army surgeons and in cities more specialized bonesetters, took care of all injuries, wound care, fractures and fracture dislocations in the Western Middle Ages.

Abu al-Qasim al-Zahrawi (Albucasis, Cordoba), "the father of surgery", published in +/- the year 1000 an Arabic encyclopedia of medicine and surgery, his "Kitab al Tasrif".

Surgeon bonesetters during the reduction of a shoulder dislocation in the St. John's Hospital in Bruges 1778. (Jan Beerblock 1739 – 1806, Bruges)

During the Middle Ages there was little high-impact trauma. Interesting is the study of Carla L. Burrell on "the fracture patterns in the medieval period". This study compared the fracture prevalence of two medieval populations after excavations in two churches, namely rural Poulton and urban Gloucester. This study indicated that in Poulton 10% of the population showed signs of fractures, but this raised up to 20% in urban Gloucester, probably resulting from more violence in the cities[26].

The study also showed that, on average, 65% of fractures occurred in the male population, whereas 25% in women and 10% in children. It mainly concerned thoracic fractures. Fractures on the extremities occurred more at the left side (defence side), compared to the right and were in majority distal fractures of the long bones.

It is also remarkable that in the urban Gloucester more skull and lower limb fractures occurred. Malunions were observed, but there was usually a consolidation of the fractures. In Poulton there were no perimortem fractures found (fractures without any callus reaction), probably because heavy trauma patients were taken to the hospice and then buried there after death.

Of course there were war injuries in the high Middle Ages, but at that time these were mostly stab and crush wounds, so relatively low-energy trauma. According to the teachings of Albucasis, the surgeons attempted to treat these fractures by splinting and the bleedings by cauterization, and possibly amputation in case of open fractures.

TRAUMATOLOGY IN THE EARLY MODERN PERIOD

From the early modern period a significant turn in traumatology was seen with the introduction of gunpowder during warfare. Gunpowder was introduced in the west by the Mongols of China in the 14th century.

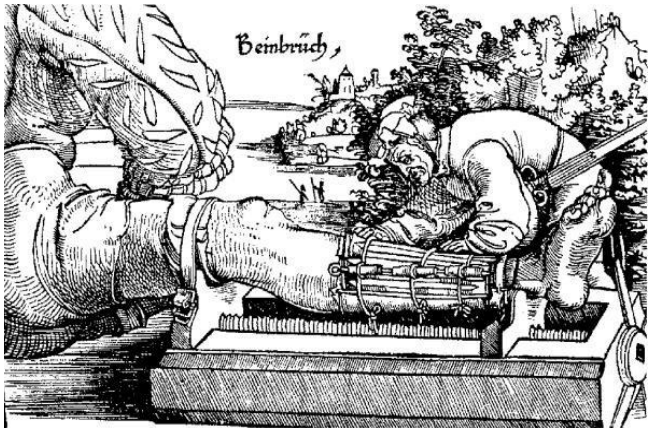
Because of this new technology army surgeons were faced with a new form of warfare, with shot wounds from guns and artillery, which produced high-energy injuries. Based on the still accepted humoral theory, a second major error was introduced in wound care. It was believed that the bullet wounds were highly inflamed by the gunpowder, which acted as a poison.

According to Giovanni da Vigo (1450 - 1525) and the humoral theory, poison should be treated with

Medieval low energy stab and crush wounds were treated with cauterization or amputation in case of open fractures.

fire, so with the hot iron cauter or boiling Sambuc oil (a mixture from elderberry oil and theriaca). This treatment gave rise to more inflammation, necrosis and pain, so amputation was even more unavoidable on the rare survivors[24 - 43].

For closed fractures surgeons developed reduction techniques, as was found in the "Feldtbuch of Wundtartzney" von Gersdorff in 1517. Unfortunately particularly wooden rigid splints were recommended, which regularly gave rise to pressure ulcers.

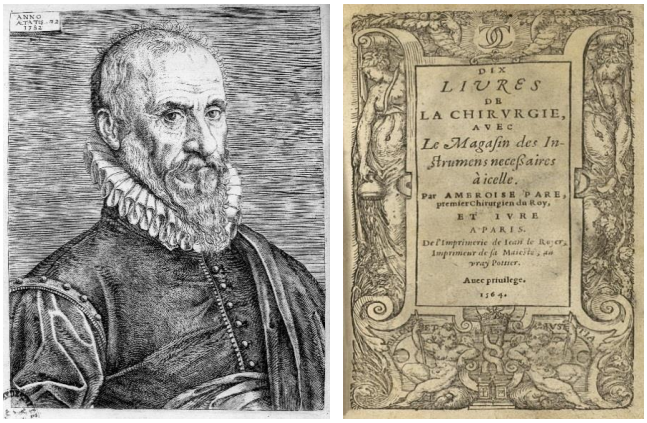


Fracture stabilisation with wooden splints. From "Feldtbuch der Wundtartzney" von Gersdorff 1517.

Reduction of a shoulder dislocation on the "Scammon of ambi device". From "Feldtbuch der Wundtartzney" von Gersdorff 1517.

The most groundbreaking surgeon of the 16th century was certainly Ambroise Paré (1510-1590 - surgeon of three French Kings), who described a number of key changes in trauma care exercise in his "Dix livres de la chirurgie - 1564"[15-22].

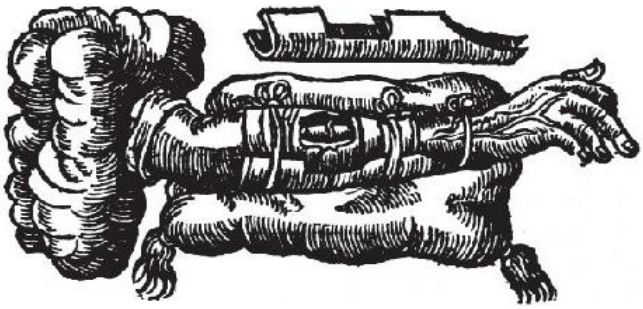
First by promoting regular splint change, he pleaded against the pressure ulcer lesions in the splint therapy. Secondly based on his experience in the battle of Susa - in 1537 during the French Piedmont campaign - where he lacked sambuc oil by the abundance of



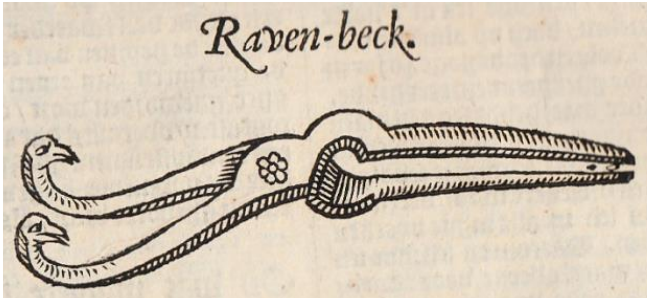
Ambroise Paré (1510 1590), "The father of modern surgery" published his " Dix livres de chirurgie" in 1564.

gunshots, he observed that rose water treatment for the gunshot wounds caused less inflammation than boiling oil. So he became the first ardent opponent of the use of boiling oil in the treatment of gunshot wounds. He stated : "Je me délibéray de ne plus jamais aussi brusler aussi cruellement les pauvres blessés de arquebusade"[25].

He also developed "the crow beak", a tool that allowed him to perform a vascular ligature during amputations in a simple manner. This way bleeding could be treated more adequately, which significantly increased the survival rate of the patients.



A windowed upper arm splint, according to Ambroise Paré, which allowed wound care in open fractures.



Ambroise Paré developed "the crow beak" to perform a vascular ligature in a more simple manner during amputations.

Remarkably however is that he kept supporting the humoral theory and still saw pus production in wounds as beneficial (pus bonum et laudabile).
Surgeons such as Ambroise Paré did have a clear progressive vision of trauma care but were limited in the realization of their ideas. On the one hand by a total lack of asepsis, resulting in a high rate of postoperative surinfections, and on the other hand by the total absence of pain control and anaesthesia with the consequence that only superficial surgery was possible.

Despite the improved knowledge of human anatomy in the 16th century (with Vesalius, Da Vinci ...) surgeons had no understanding of articular fracture pathology, due to a total lack of imaging. It took until 1814 before Abraham Colles (1773 – 1843, Dublin) finally defined a wrist dislocation as a wrist fracture[3].

Until the end of the Ancien Régime, also the dogma of total prolonged immobilization for patients with a fracture was still promoted. This was caused by the insufficient stabilization of the splints. This prolonged immobilization caused the fracture disease, with a significant muscle atrophy, osteoporosis and ankylosing of the surrounding joints. This is why a displaced fracture in the Ancien Régime became synonymous for a significant disability, provided that the patient, such as in open fractures, survived his trauma.

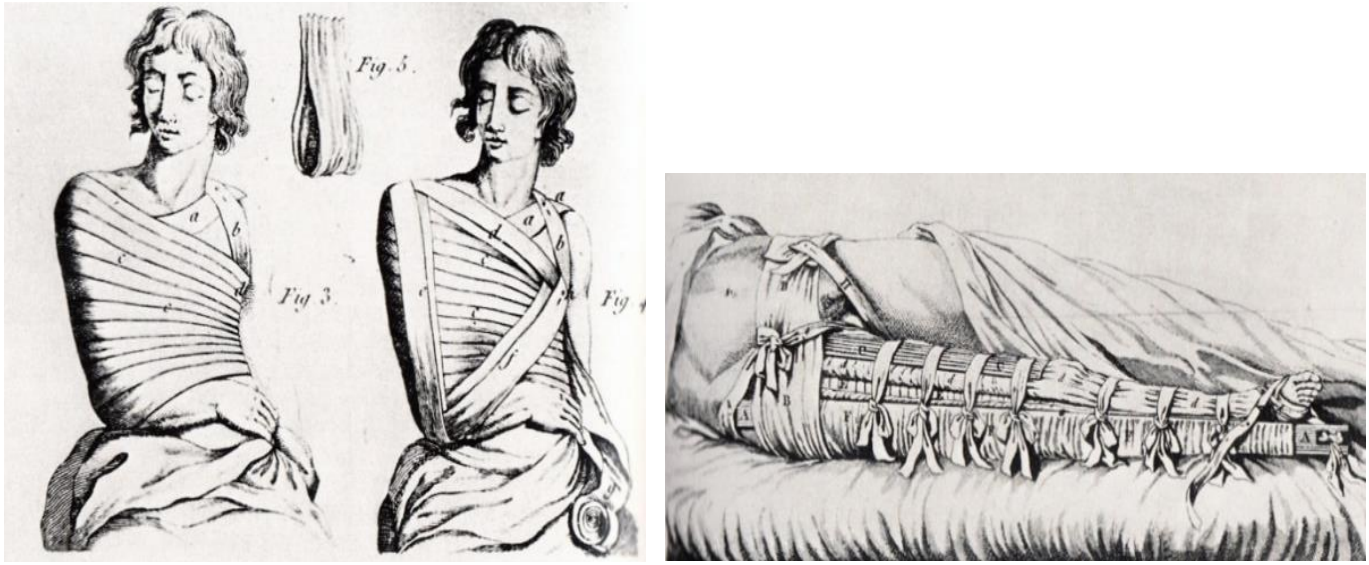
At the end of the 18th century a new trend for more softer and comfortable bandages and splints was seen as described by some surgeons, like Pierre Joseph Desault (1738 – 1795) in his "Les oeuvres chirurgicales" from 1798. But this new devices permitted only little or no fracture reduction and offered no possibility of joint mobilization[44].

TRAUMATOLOGY IN THE "NOUVEAU RÉGIME"

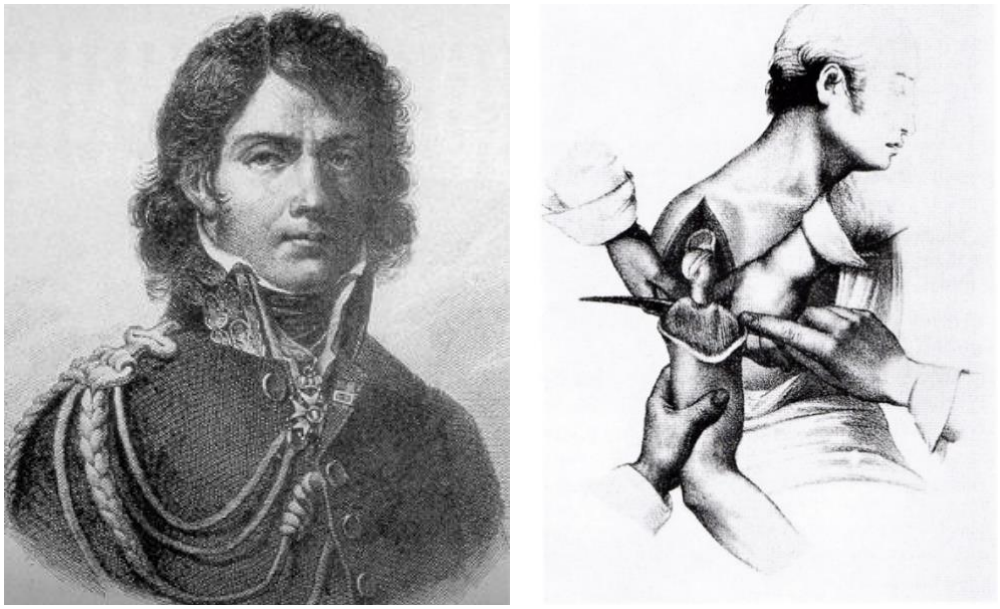
In the Nouveau Régime a sharp increase in the number of traumas was noted, due to the expansion of cities and the industrialization. Also the Napoleonic wars, carried out far from home, caused a need for ambulant fracture treatment.

During the Napoleonic campaigns new trends in fracture treatment were observed. First, the high number of amputations carried out in open fractures. However there was a very low chance of survival for the patient after an amputation, caused by the usually developed cascade of infection, gangrene to sepsis, and death.

As amputation technique, Dominique Larrey (1766-1842), chief surgeon of the Imperial Guard, advocated a fast disarticulation [38]. Others such as the Ghent surgeon major Joseph Kluyskens (1771-1843, Ghent) suggested a transosseous, more distal amputation[42]. His son Hippolyte Kluyskens published later the results of the amputations carried out by his father after the Battle of Waterloo in 1815. He observed that after closing of the amputation wounds, the majority of patients died. If stumps were left open, a lot of those recuperated. With the development of the tourniquet (Jean Louis Petit 1744), the amputation technique became more efficient but this was offset by the total lack of asepsis in the field hospitals. In summary, it must be said that in these war conditions, the patient was helpless and the surgeon hopeless.



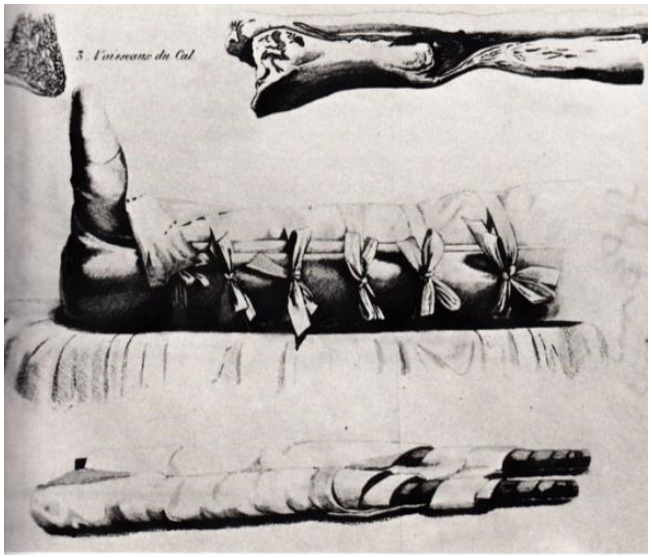
From "Les oeuvres chirurgicales - 1798 " of Pierre Joseph Desault, his "Desault's bandage" for immobilization of the upper limb (L) and his "Appareil à extension continue" for fractures of the lower limb (R).



Dominique Larrey (1766-1842) and his disarticulation technique of the shoulder.

THE SEARCH FOR AN AMBULATORY FRACTURE TREATMENT

Dominique Larrey provided two other innovations. With the development of the "ambulance volante" a quicker evacuation from the battlefield was possible. He was also the first surgeon to develop an "inamovible" cast for ambulant fracture care, consisting of bandages soaked in camphorated alcohol, lead acetate and egg white. This was the first switch from splint to a well-moulded cast. But this cast still did not provide sufficient rigidity[38].



"L' appareil inamovible " of Dominique Larrey, a first attempt for an ambulatory fracture treatment.

The Brussels surgeon Jean Louis Seutin (1793-1862, Brussels) further developed this idea with his "bandage amidonné" or "starch bandage", consisting of cardboard splints and laundry starch. This was the first "inamovible" cast, that showed a sufficient rigidity[42].

He also promoted the early mobilization of patients. He was the first surgeon to argue for a controlled adjacent articular mobilization in order to avoid oedema, atrophy and stiffness. He was the father of the "déambulation régime" to prevent the "fracture disease". Seutin can be regarded as the first modern traumatologist.

The definitive solution for a solid ambulant fracture immobilization was applied by Antonius Mathijsen (1802-1878, Budel) with the plaster cast or "Plâtre de Paris". Already in 1798, the British diplomat Eaton reported that he observed fracture treatment by the Ottoman surgeons with a "plâtre Coulé", immobilizing the limb in a coagulated plaster bed[27]. However, this technique was met with skepticism in the West. For example Joseph F. Malgaigne (1806-1866 Paris) was very critical about the swelling problem in such rigid casts. But in 1852 Antonius Mathijsen optimized this technique by applying the plaster, analogous to the technique of Larrey, on a cotton bandage, that must be wrapped around the limb[13]. This "plâtre de Paris" would become the standard technique for immobilization for 150 years ("The plâtre de Paris" got its name from the analogous gypsum mixture used by plasterers of the city of Paris).

DU

BANDAGE

AMIDONNÉ,

DU

RECUEIL DE TOUTES LES PIÈCES COMPOSÉES SUR CE BANDAGE

DEPUIS SON INVENTION JUSQU'A CE JOUR,

PRÉCÉDÉ

D'UNE ESQUISSE HISTORIQUE;

SUIVI

DE LA THÈSE DE M. HYP. LARREY SUR LE BANDAGE INAMOVIBLE

ET

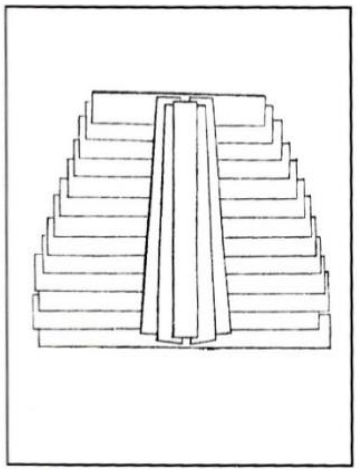
DE LA DESCRIPTION GÉNÉRALE

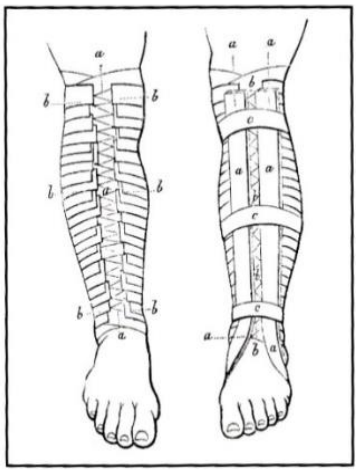
ET DU MODE D'APPLICATION DE L'APPAREIL AMIDONNÉ,

Par M. Seutin,

Louis Jean Seutin (1793-1862) developed with his "bandage amidonné" the first functional and ambulant cast, usable for fracture reduction and immobilization.

The "plätre coulé" : Ottoman surgeons used liquid plaster for fracture immobilisation.





Antonius Mathijsen (1802 - 1878, Budel) developed, out of the "plâtre coulé" technique, his plastercast or the "Plâtre de Paris" by applying the plaster on cotton bandages that must be wrapped around the limb.

THE SPRING OF MEDICINE, CARE BECOMES CURE

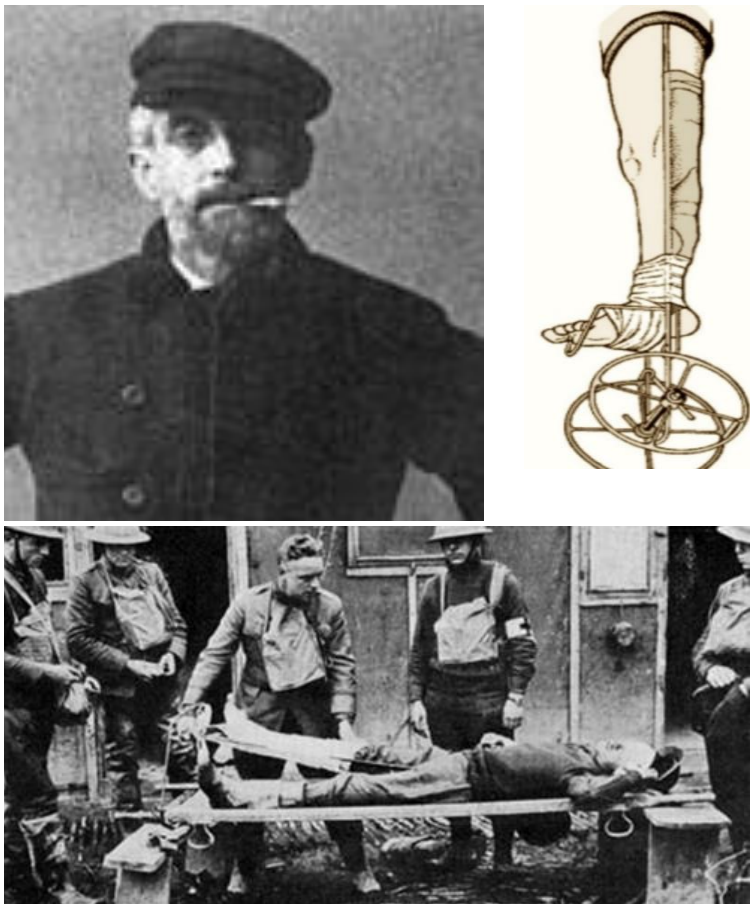
With the knowledge of bacteriology and the development of antisepsis (Joseph Lister 1810 – 1894[11]) and anaesthesia, soft tissue surgery was made possible, starting in the middle of the 19th century. From 1895 onwards, also the introduction of radiology offered a better understanding of fracture pathology. However, implant surgery, necessary for bone fixation, remained problematic due to the high number of surinfections. As a consequence in 1895 the "Congrès Français de chirurgie" condemned operative fracture treatment. However, individuals like William Arbuthnor Lane (1856 – 1943, London)[10], with his no-touch technique, and Albin Lambotte (1866 – 1955, Antwerp) were the rare advocates of surgical fracture stabilization at that time[9].

TRACTION THERAPY

After the plaster cast, a second conservative standard treatment was introduced in the 19th century: the osseous traction, focusing on the reduction of limb shortening in displaced fractures. A traction system was already proposed in the early 14th century Guy De Chauliac (1300-1386), but his technique was insufficient due to its problematic skin fixation with consequent pressure ulcer problems.

The first performant traction system was developed by Hugh Owen Thomas (1834-1891, Liverpool). His traction splint or "the Thomas splint" was the first device that made an ambulant immobilization possible of displaced fractures of the lower limb[27–38]. This system became a standard treatment in the Allied camp during World War I. Along with the Carrel-Dakin intermittent irrigation (an antiseptic solution of sodium hypochlorite and boric acid), developed in 1916 during World War I in Compiègne by Alexis Carrel and Henry Dakin [38], this traction system reduced mortality in open femoral fractures from 80 to 20%. However, amputation remained a routine surgery in open fractures during World War I.

In the same period, in the Central camp (German-Austrian), transosseous traction was developed. This



Hugh Owen Thomas (1834-1891) developed the "Thomas splint", which in World War I made immobilization and transport possible of the wounded with displaced fractures of the lower limb.

was introduced in 1907 by Fritz Steinman (1872-1932)[38] and later optimised by Martin Kirschner (1879-1942)[19], and allowed a more optimal length traction.

FRACTURE TREATMENT DURING THE INTERBELLUM

In the interbellum period between World Wars I and II, fracture treatment was based on two basic conservative treatments.

On the one hand, the reduction of fractures under general anaesthesia (or under the developing rachi anaesthesia), followed by a plaster cast. On the other hand prolonged length traction[12] treatments, followed by a subsequent immobilization in plaster, sometimes with massive "thoraco pelvipedieux" plaster immobilizations, from the thorax to the foot, applied on the traction table[2].

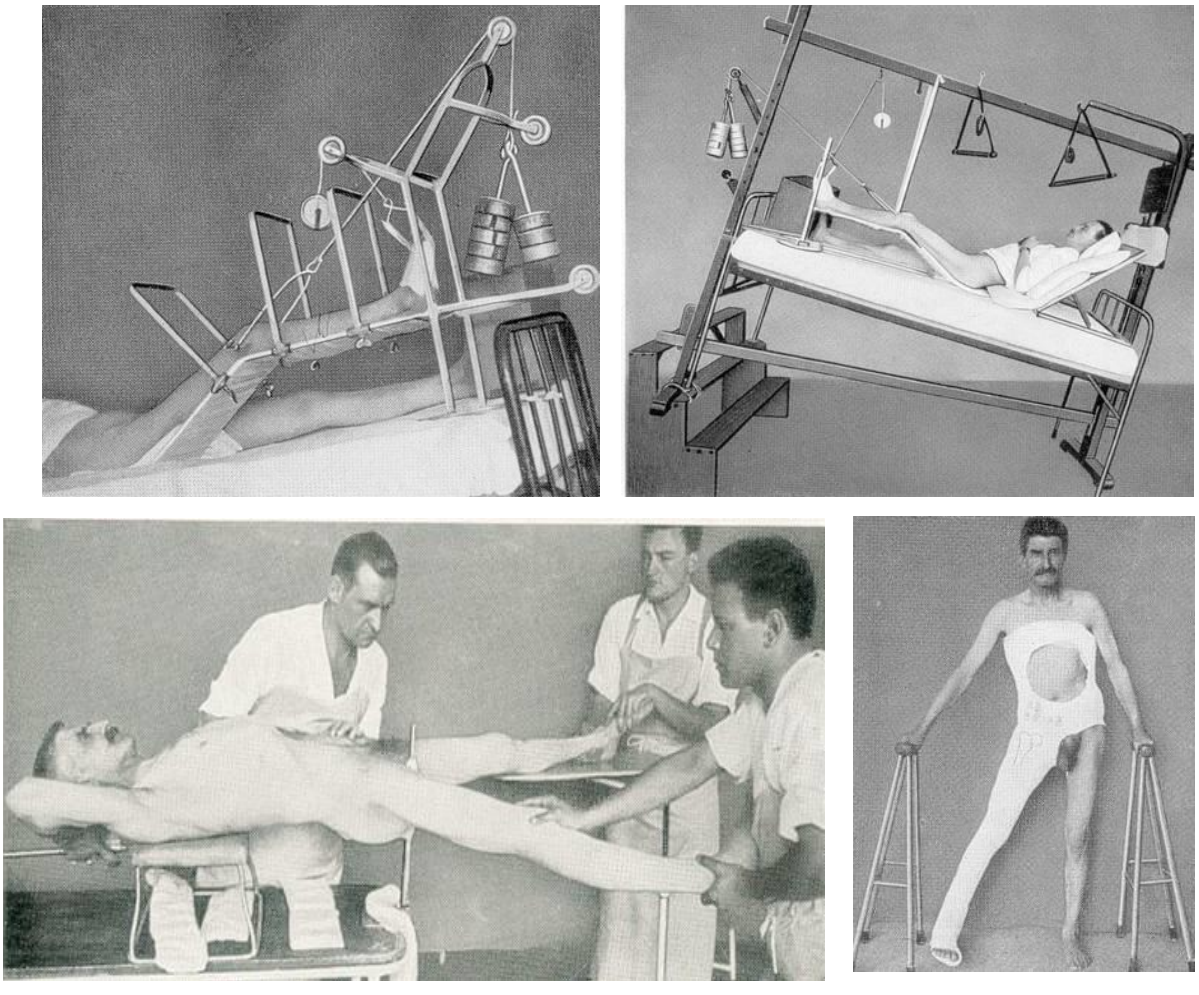
In the interwar period, the post immobilization gymnastics was introduced, the birth of physiotherapy. Even during World War II, plaster cast and traction remained the primary fracture treatments. However, in World War II the spectacular introduction of the sulfonamides and the first antibiotics was noted.

THE OPERATIVE FRACTURE STABILIZATION

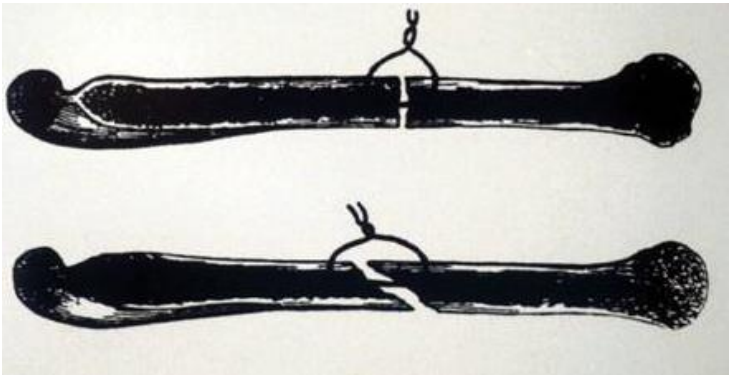
In the fifties of the 20th century, as a result of the optimization of asepsis, anaesthesia and popularization of antibiotic therapy, implant surgery became possible with the development of osteosynthesis.

THE PEHISTORY OF OSTEOSYNTHESIS

The Arabian surgeons already used the nuchal ligament of camels to perform a contention - cerclage in open patellar fractures. In the 17th century, Severin of Naples used a tin wire for the same indication. But it was the French navy surgeon J.B. Beranger-Feraud (1832-1900) who was the first to generalize the bone suture, "la suture osseuse". From 1854 onwards, he



The transosseous traction therapy for an proximal femoral fracture, followed by the casting on the traction table, with an "thoraco pelvipedieux", a cast immobilization from the thorax to the foot.



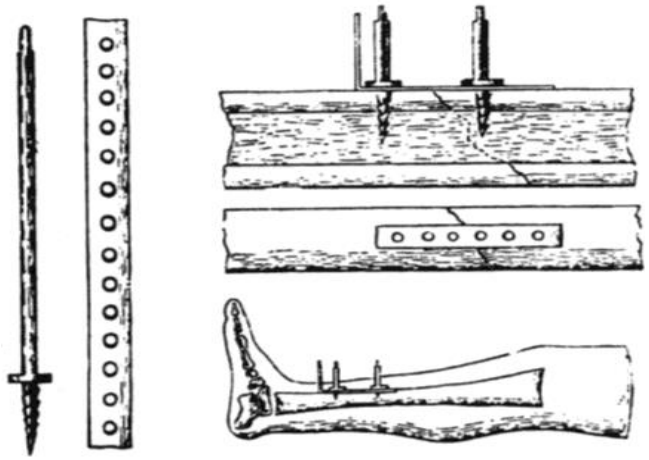
The French navy surgeon J.B. Beranger-Feraud (1832-1900), promoter of the "suture osseuse". He used lead wires to fix surgically fractures, a technique which he called "la synthésisation".

used lead wires to fix surgically fractures, a technique which he called "la synthésisation", the precursor of the osteosynthesis[38].

PLATE OSTEOSYNTHESIS

The first to propose an efficient plate fixation was Hansmann (1886 Hamburg). The disadvantage of his system was the fact that the screws needed to be placed transcutaneously[38].

Under the trim of William Arbuthnor Lane (1856-1943, London) [10] and Albin Lambotte (1866-1955, Antwerp) osteosynthesis was developed. Albin Lambotte defined osteosynthesis as follows: "On entent par osteosynthèse la contention artificielle des fragments osseux des fractures par des appareils spéciaux agissant directement sur les os et destinés à les fixer définitivement dans leur position quo ante"[9].



The plate fixation according to Hansmann (1886) with the transcutaneous screws.

Relying on the, at that moment, performant Belgian metallurgy, he developed plates in aluminium, steel, silver, copper and even resorbable magnesium fixation plates. He called his plate system the "prothèse interne" and he also immediately advocated a logical screw placement system, consisting of drilling, screwing and taping. The weakness in his technique was the fact that he used screws with a timber profile, which gave an inferior stability.

In 1907, he published in his book "L'intervention opératoire dans les fractures récentes et anciennes" his basic techniques for the, at that time, revolutionary osteosynthesis[33].

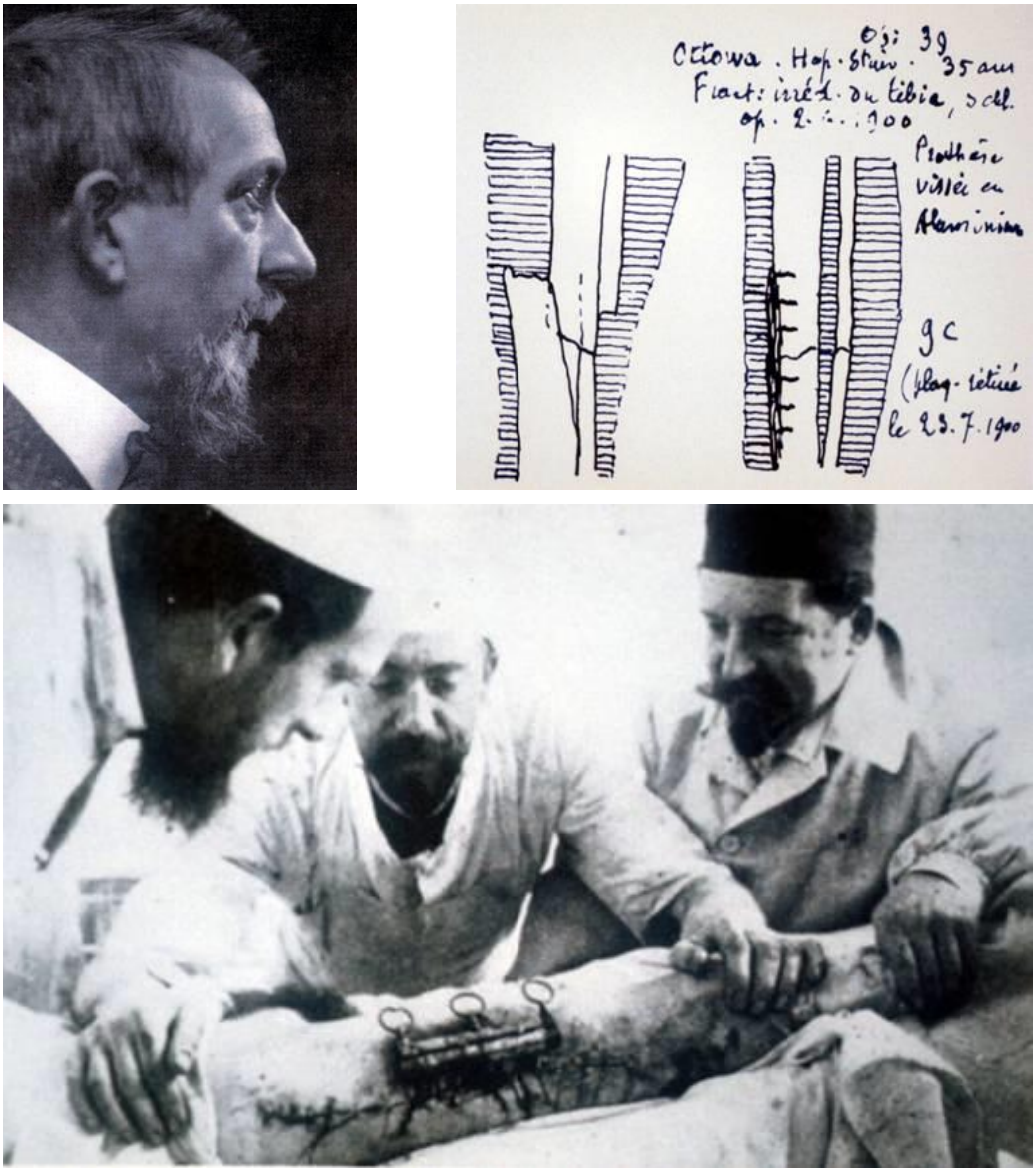
Albin Lambotte was a multitasker, who also optimized surgical instruments, for example the still being used "Coapteur of Lambotte" for fracture reduction. He also developed the first stable external fixator and started intramedullary nailing in clavicular and trochanteric fractures. This particularly handy surgeon and also excellent violinist, produced 182 violins.

In 1926 William Sherman (1880-1979) optimized the osteosynthesis system to a more stable fixation, supported by the Carnegie steel company in Pittsburg, with his vanadium steel plates and the self-tapping screws.

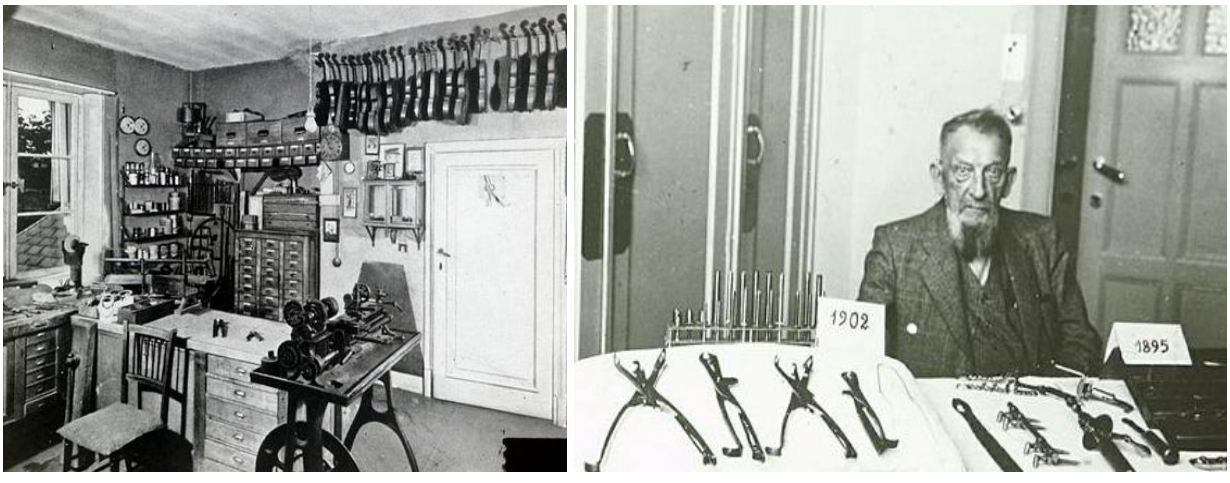
THE COMPRESSION PRINCIPLE

The major optimization of the internal immobilization was applied by Robert Danis (1880-1962, Brussels) with his "compression principle".

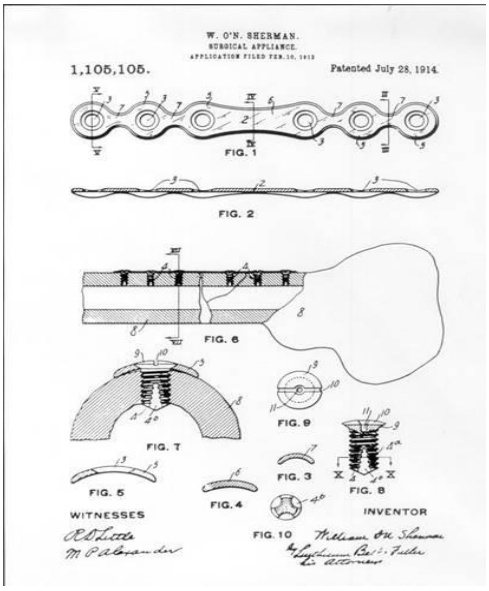
In his basic work "Théorie et pratique de l'osteosynthèse", he explained his basic principles for the optimal osteosynthesis[4].



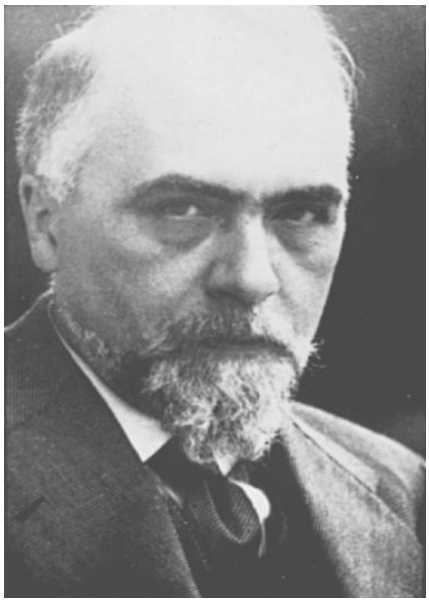
Albin Lambotte (1866- 1955), the " father of osteosynthesis", with his planning for a "prothèse interne" (above). Lambotte during a fracture reduction in the Stuivenberg hospital in Antwerp (below).

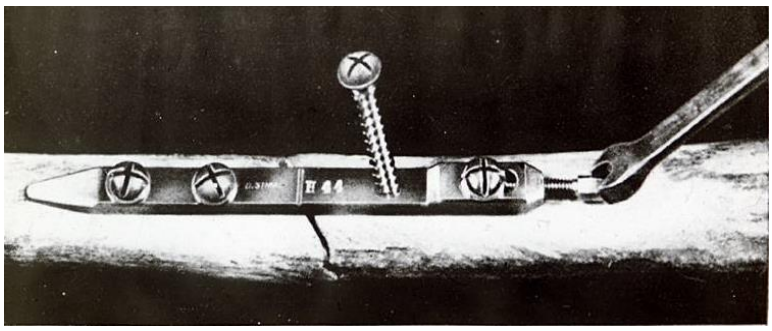


Albin Lambotte, this particularly handy surgeon and also excellent violinist, produced himself 182 violins and also multiple new instruments for fracture reduction.



William Sherman (1880-1979), optimized the osteosynthesis system with his vanadium steel plates and his self-tapping screws.





Robert Danis (1880-1962, Brussels) with his "coapteur", derived from the compression principle.

These were :

• Restoration of the bone in its original form;

• "Soudure per primam" or "soudure autogène", the principle of primary bone healing without external callus formation;

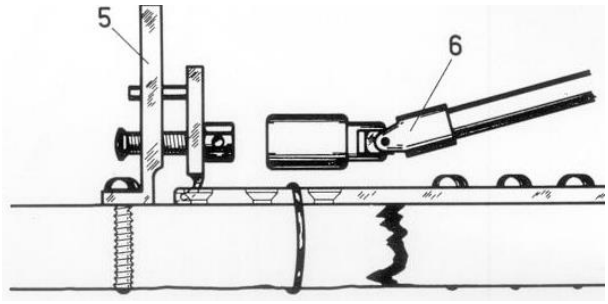
• Immediate mobilization of the surrounding joints. He agreed with the "early mobilizers" such as Seutin, Paget, Lucas - Championnière ...

To achieve its interfragmental compression, he developed his "Coapteur", a plate fixation with a lateral compression screw.

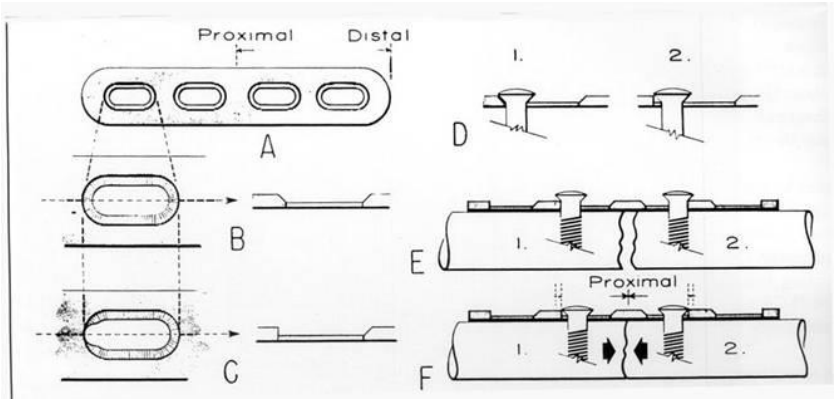
The young Swiss surgeon Maurice E Müller visited Robert Danis in Brussels in 1950, and was impressed by Danis' principles. He continued to develop this technique within the Swiss A.O. group (Arbeitsgemeinschaft für Osteosynthese Fragen), among others with Hans Willenegger, Martin Allgöwer…

The Swiss AO group adapted and modified the basic principles of Albin Lambotte and Robert Danis region specifically. They also optimized and systematized the plate arsenal and the specific instruments. By their teaching (The Davos courses), the plate osteosynthesis was globally propagated[36].

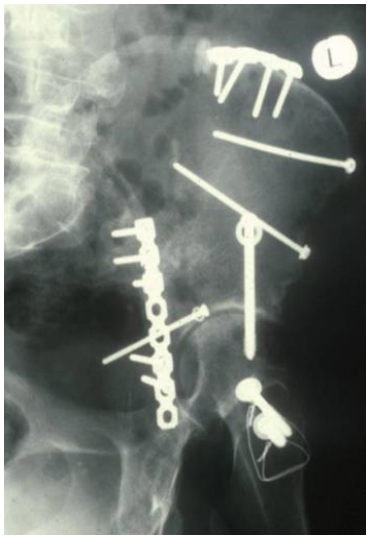
At a later stage, they also optimized the oval slot compression plate, a system that was previously developed in 1958 by George W. Bagby[1].



The Swiss AO-group, with Hans Willenegger, Maurice E. Müller en Martin Allgöwer, optimized the compression system of Robert Danis.



George W. Bagby developed the "oval slot system" in 1958 and introduced the compression plate technique.



Emile Letournel was, from 1981 onwards, the major stimulator of acetabular reconstruction (L). An acetabular stabilization carried out via the by Letournel developed extended iliofemoral approach (R).

Another important contributor to internal fixation is Emile Letournel (1927 – 1994, Paris). From 1981 he became the great advocate of the acetabular and the pelvic stabilization, developing new surgical approaches (extended iliofemoral approach) and reduction techniques[34].

In the last decades of the 20th century, the development of the minimally invasive approach, a more biological approach for the plate osteosynthesis (MIS - minimally invasive surgery) was observed.

However, the development of the angle stable screw on the locking compression plate was the "egg of Columbus" for the plate osteosynthesis. Mipo was a fact, the "minimally invasive plate osteosynthesis", which maximally respected the soft tissues and provided a much greater stability.

At the same time, also new techniques for bone substitution were developed.

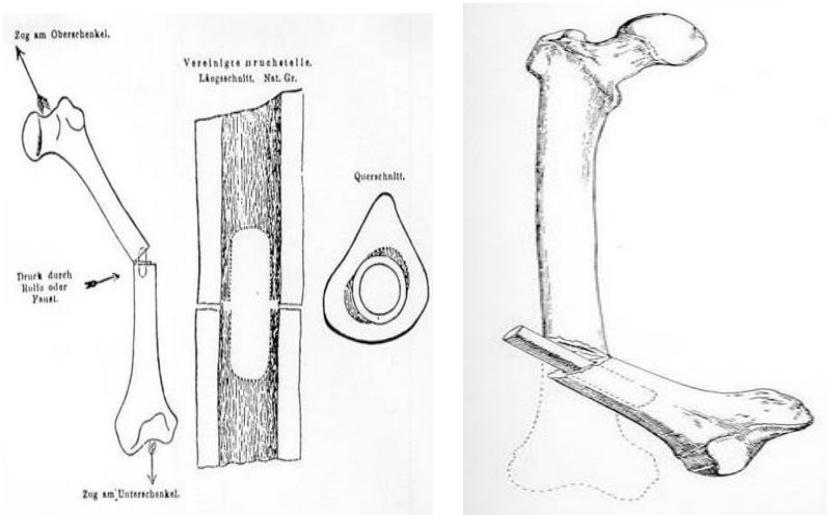
THE INTRAMEDULLARY FIXATION

Bernardino de Sahagun (1499 – 1590), a Spanish monk who travelled in 1529 with Hernán Cortes to Mexico, reported in his "Historia general de las cosas de la Nueva España" (the history of the things of New Spain) that Aztec physicians stabilized open fractures of long bones by putting wooden sticks intramedullary.

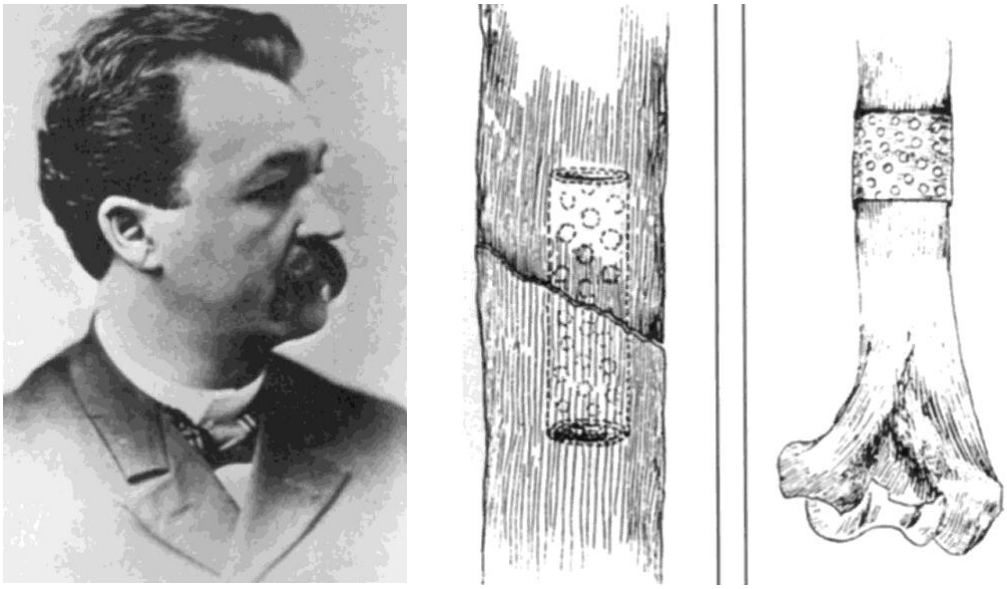
But it was not until the end of the 19th century that the promoters of the intramedullary technique started with intramedullary fixation of fractures, axially in the bone, this is in contrast with the inferior biomechanical lateral plate osteosynthesis. The first promoters were Gluck with an ivory intramedullary peg in 1890, N. Bircher[38] with a short metal rod in 1893 and Nicolas Senn with an animal bone allograft, also in 1893[18]; they introduced it centrally, via a direct open access in the medullary canal.

In the first decade of the 20th century, it was again Albin Lambotte who used simple metal carpenter nails to reduce clavicular - and trochanteric fractures[9]. He was

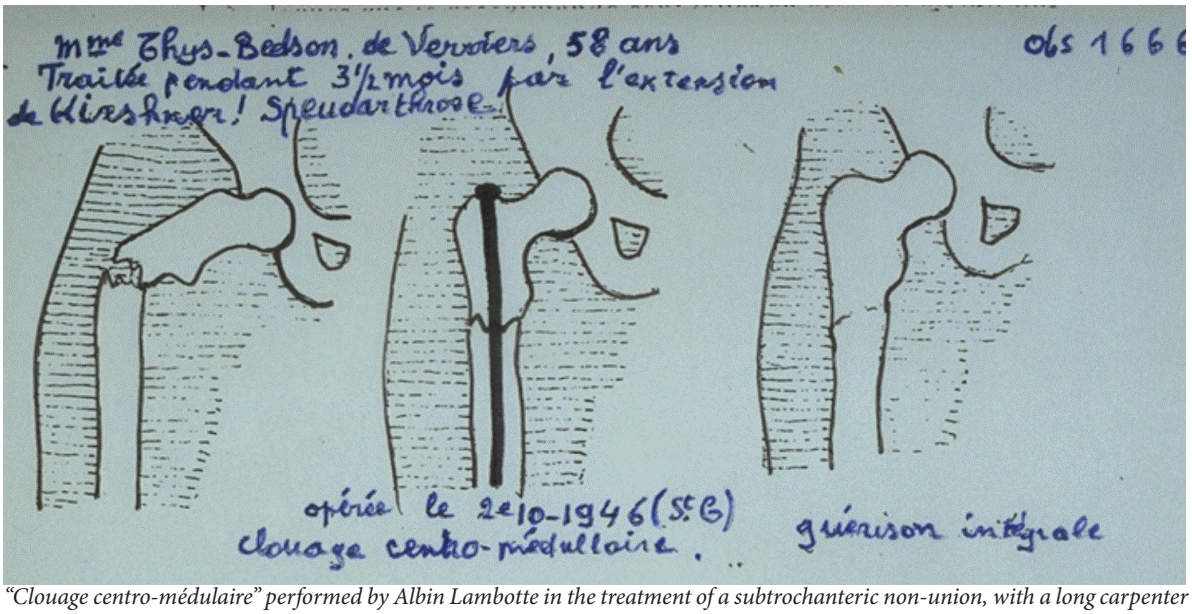
The angle stable screw was the "egg of Colombus", which finally gave the plate osteosynthesis its necessary stability .



In 1890, Gluck reduced - as the first surgeon - a diaphyseal fracture with an intramedullary peg (L). In 1893, Bircher stabilized the same fracture with a short metal rod (R).



In 1893, Nicolas Senn reduced an diaphyseal humeral fracture with a turkey bone allograft.



"Clouage centro-médulaire" performed by Albin Lambotte in the treatment of a subtrochanteric non-union, with a long carpenter nail.

the first to perform antegrade centro-medular nailings, technique that he described as "Clouage de l'os".
During World War I, Ernest Hey-Groves (1872-1944, Bristol) used - as the first surgeon - long metal intramedullary nails, introduced through a retrograde "va-et-vient" system at the fracture level[5].

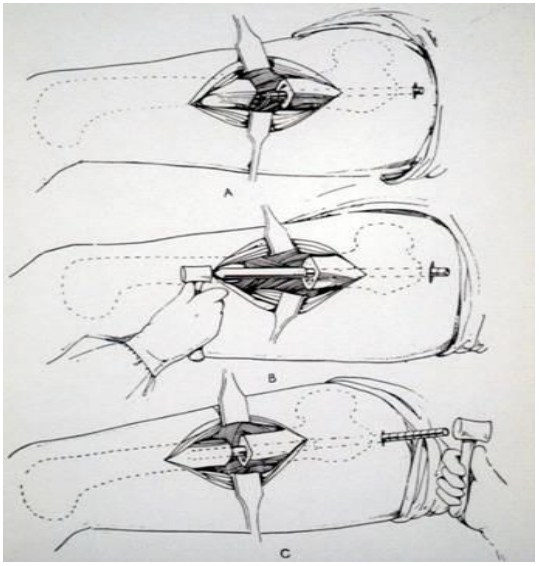
The great advantage of his system was the greater rigidity. The disadvantage was the significant surinfection risk, earning Hey-Groves the nickname of "Septic Ernie"[27].

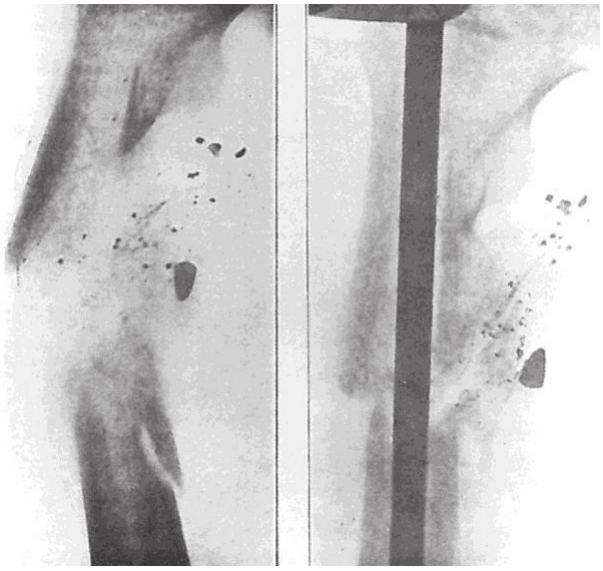
In 1936, the brothers Leslie and Lowry Rush started with the indirect fracture reduction with their flexible intramedullary Rush pins, using a three point fixation[17].

But the real breakthrough of the intramedullary technique was introduced by Gerhard Küntscher (1900-1972, Hamburg) with his "elastic nailing". A minimally invasive fixation system, using an open elastic cloverleaf nail, introduced axial in the medullar canal of the bone, with respect to the periosteal vascularization[8].

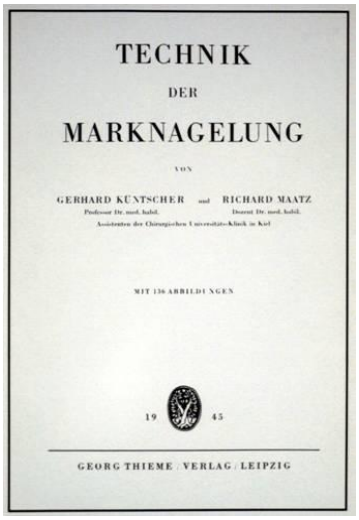
He also developed the medullary reaming, which not only facilitated the nail introduction but also realized bone grafting at the fracture side.

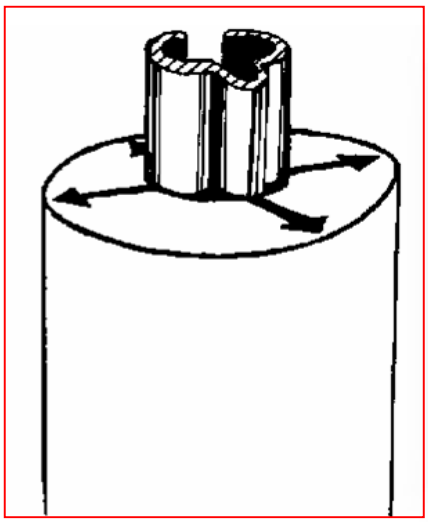
The "Küntschernail" became the optimal fixation technique for mid-diaphyseal and relatively transverse fractures of the femur and the tibia, and even the humerus.

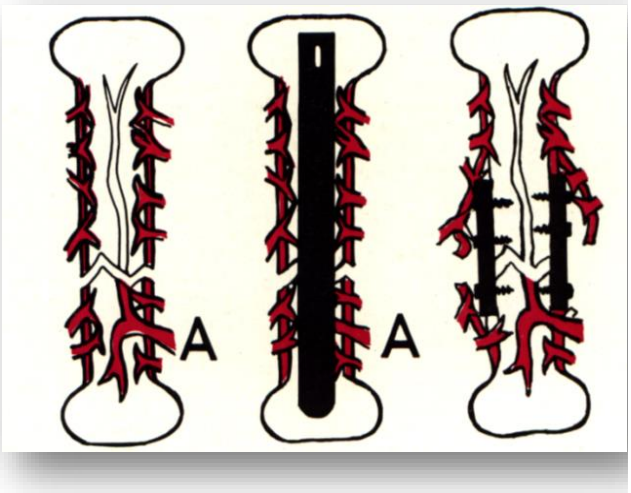




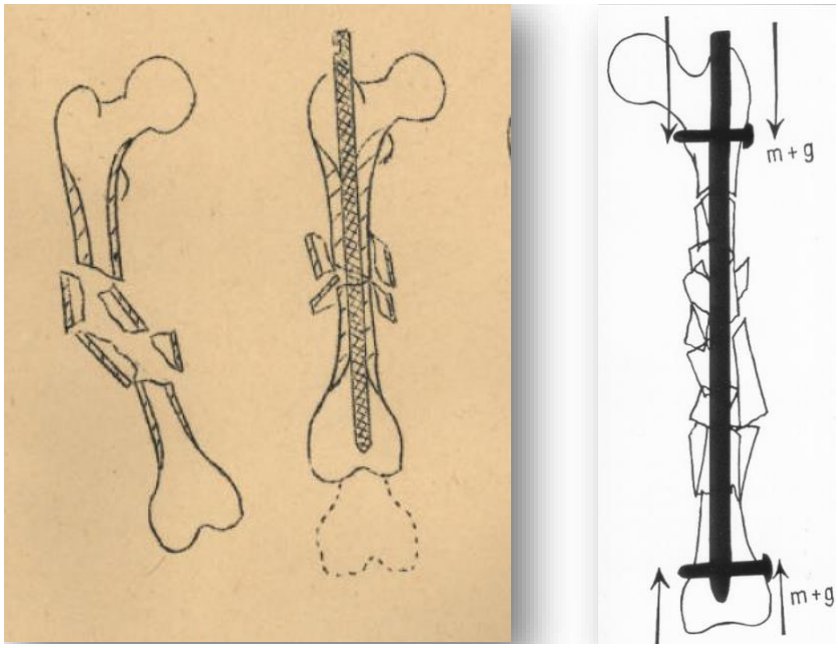
From 1916 onwards, Hey-Groves introduced open and retrograde long intramedullary rods at the fracture site, like in this shot wound, with femoral fracture.







Gerhard Küntscher (1900-1972, Hamburg) developed the "elastic nailing", an open cloverleaf nail (L), axial introduced intramedullary, with respect of the periosteal vascularization, this in contrast with the cortical plate osteosynthesis (R).



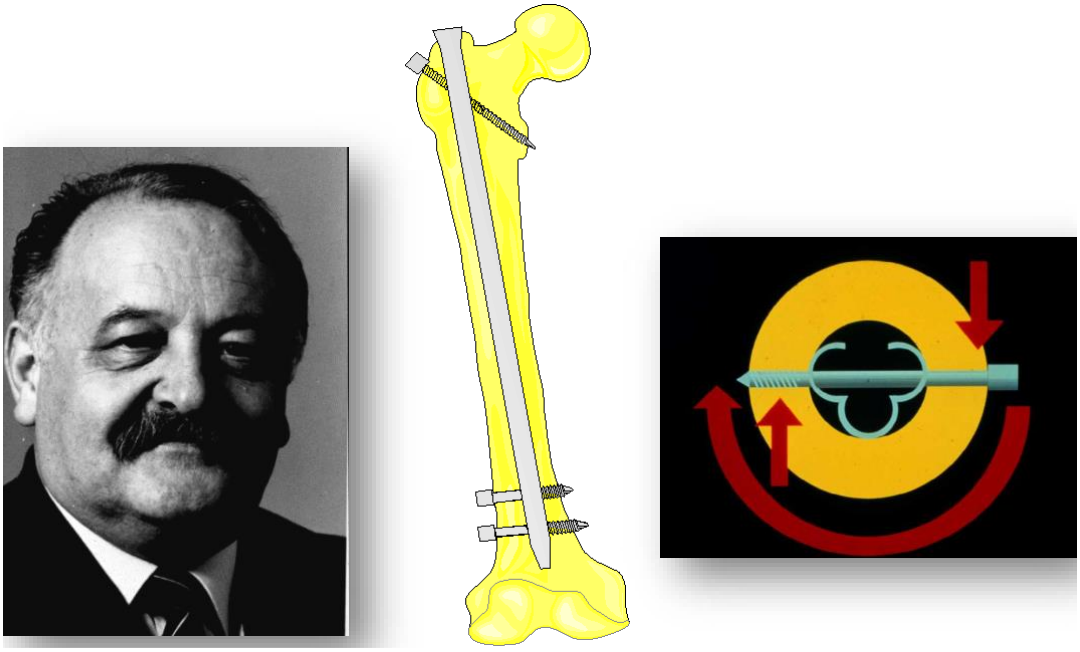
In 1970, Gerhard Küntscher described the solution for the telescoping problem in multifragmental fractures (L), with his "detensions nagel", a stabilization of the fracture by locking the nail proximally and distally by transverse transosseous screws (R).

The fixation principle of Küntscher based on a three point fixation, was however deficient in multifragmental diaphyseal fractures and fractures in the metaphyseal region.

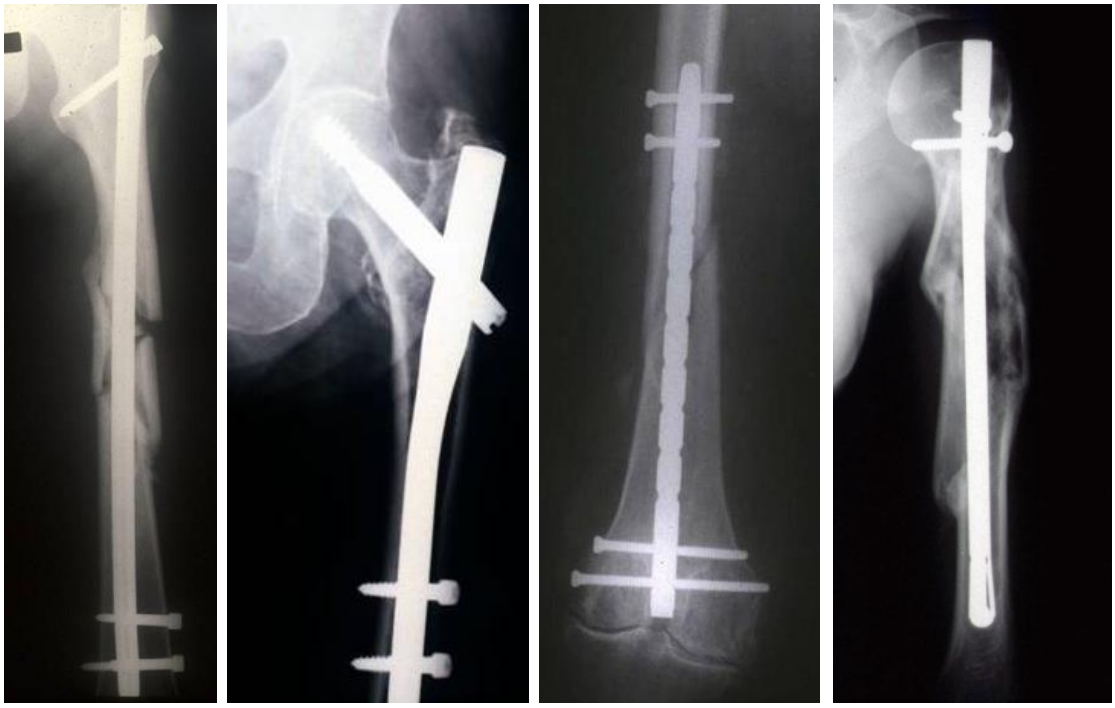
Just before his death in 1970, Gerhard Küntscher described the solution for this instability (telescoping) problem with his "detensions nagel", a stabilization of the fracture by locking the nail proximally and distally by transverse transosseous screws[32].

Up to his death there was a twenty years' conflict between Gerhard Küntscher and the AO-group, because of an idiological trauma dispute between the believers of the indirect - and direct fracture stabilization.

After Küntschers death, the locking nail stabilization system was further optimized. First by Klaus Klemm



Arsène Grosse (Strasbourg), the great promoter of the "enclouage verrouillé", the locking nail with the bipolar screw fixation, anti-telescoping and anti-rotating.



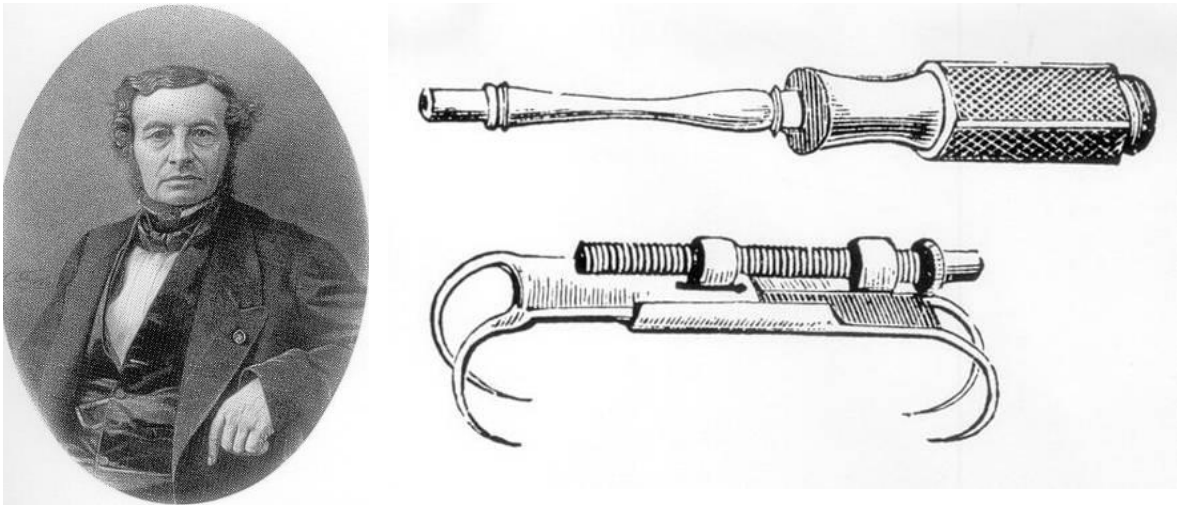
Out of the Enclouage verroullé (1), the Gamma nail (2), the Supracondylar nail (3) and the Humeral nail (4) were developed.

(1932 - 2001) and W. D. Schellmann and later by Ivan Kempf and Arsène Grosse (AIOD – Association Internationale pour l'Osteosynthèse Dynamique, Strasbourg), who developed their "enclouage verrouillé". With the use of the traction table and the image intensifier, the nail could be more easily and in a minimally invasive way locked bipolarly[31].

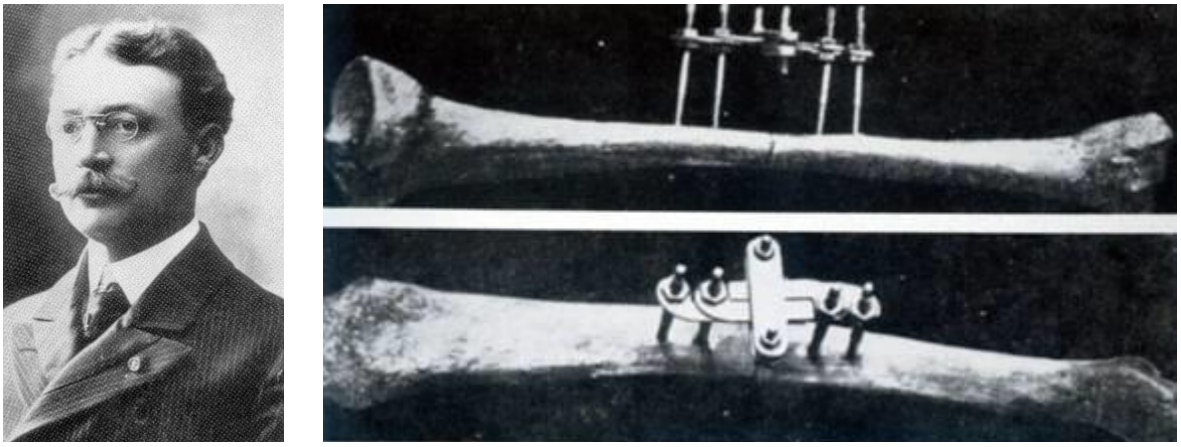
From the "enclouage verrouillé", originally indicated for diaphyseal fractures, also meta - and epiphyseal applications were developed such as the Gamma nail (Gilbert Taglang) for trochanteric fractures, the Supracondylar femoral nail (David Seligson) and the Humeral nail (H. Seidel). The locking nail evolved to the most optimal and reliable fracture stabilization, called the "wonderbra of traumatology".

THE EXTERNAL FIXATION (EXFIX)

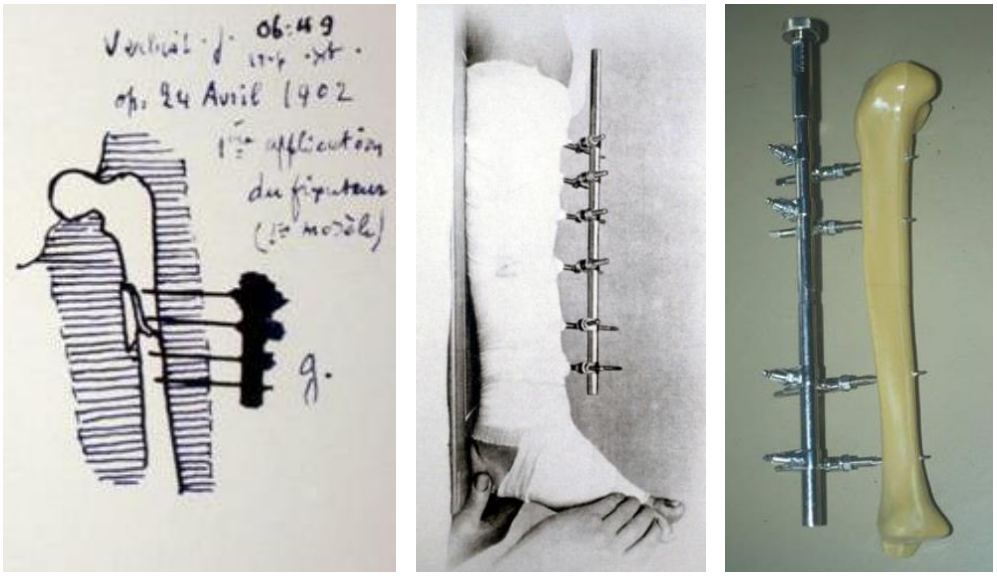
The external fixation created the possibility for bone fixation outside the wound area in open fractures. A first attempt was undertaken in 1847 by Joseph F. Malgaigne (1806-1866, Paris) with his "Claw of



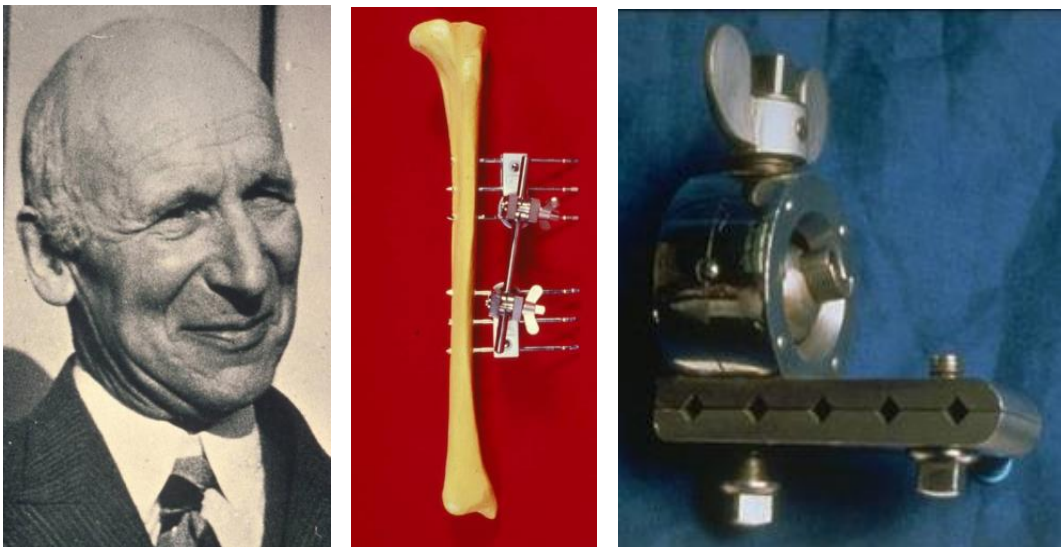
Joseph F. Malgaigne (1806-1866, Paris) developed in 1847 his "Claw of Malgaigne" (griffe métallique) for stabilization of open patellar fractures.



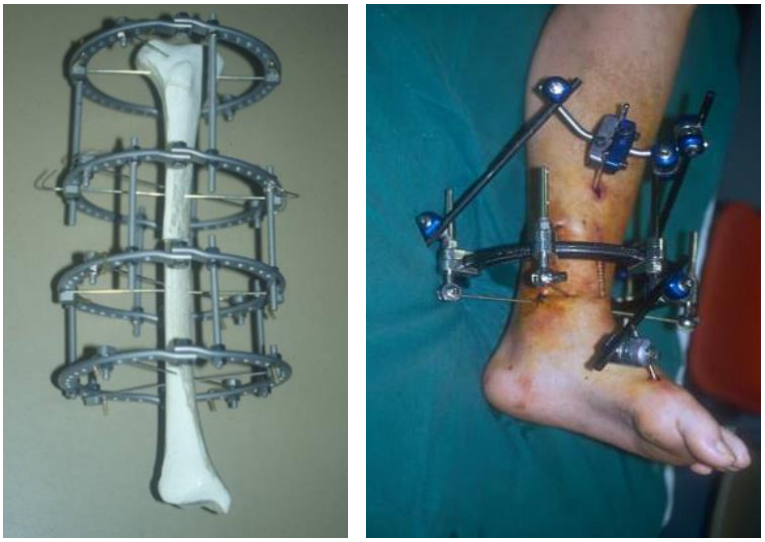
The first diaphyseal external fixator of Clayton Parkhill (1897).



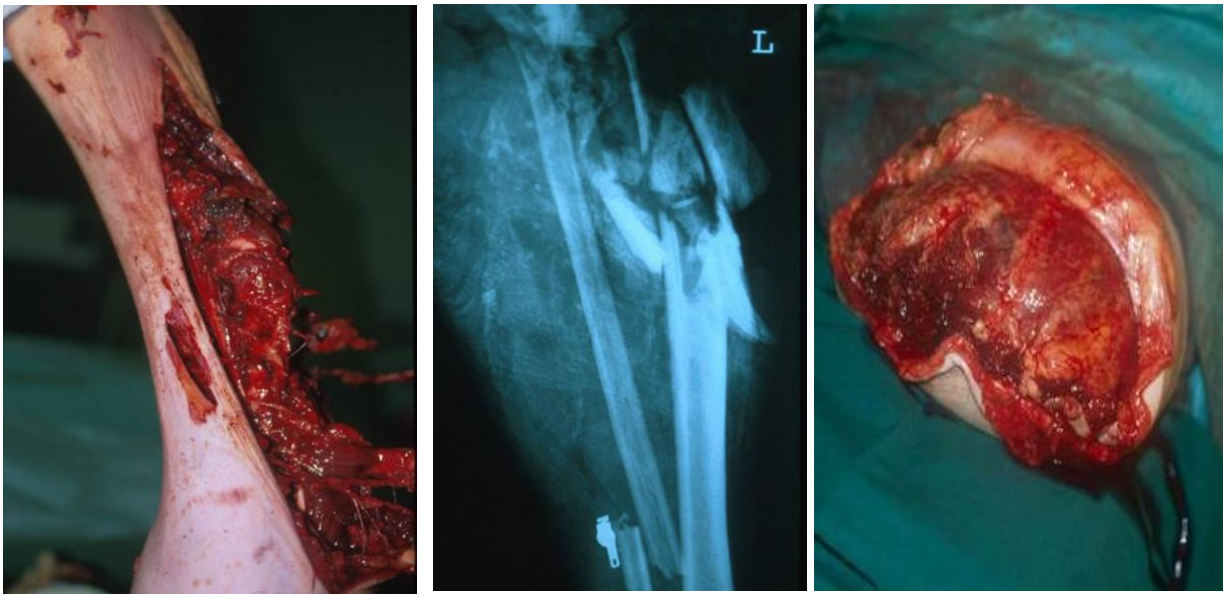
Already in 1902, Albin Lambotte developed a prototype (1) of his external fixator (2) and later on an external fixator with compression option.



Raoul Hoffmann (1) modified the rigid external fixator of Lambotte to the "fixateur simple elastique" (2), by the development of the universal ball joint in 1938 (3).



Out of the combination of the Ilizarov fixator (L) and the fixateur simple élastique, the Hoffmann II hybride fixator was developed (R).



"The enigma of the open fracture".
For some extreme open fractures – Gustilo IIIC - there are still indications for immediate amputation.

Malgaigne", the "griffe métallique" to stabilize open patellar fractures[27–38].

Next in 1897, Clayton Parkhill (1860-1902, Denver) was the first surgeon to develop an external fixator which was usable on diaphyseal bones[16].

But it was again Albin Lambotte who introduced the first high-performance external fixator system, to which he later added a compression system. However, the Lambotte exfix was a quite rigid and hard to applicate device.

In 1938 (Geneva), the Swiss surgeon Raoul Hoffmann developed the functional solution with his "fixateur simple élastique". He developed a ball joint system with an extreme suppleness that allowed an easy fracture reduction. (Interestingly is that Raoul Hoffmann is another typical example of the traumatologist – multitasker: as a surgeon, theologian - minister and cabinetmaker)[38].

During the last quarter of the 20th century, new types of external fixators were presented such as the compression fixator of De Bastiani (1978) and the cylindrical Ilizarov fixator. This device was already introduced around 1950 by Gavriil Ilizarov (1921 – 1992, Kurgan) for leg lengthening, but found his indication in traumatology around 1980 in the treatment of septic non-unions[7].

Despite the perfection of wound cleaning, wound care and stable external fixator, along with the possibilities of the vascular - and especially the reconstructive surgery, the "enigma of the open fracture" still remains. Non-unions, septic non-unions and major trophic lesions are still observed. Currently there are still - although extremely minimal - indications for immediate or delayed amputation.

THE POLYTRAUMA CARE

The Poulton - Gloucester study showed that out of wartime multiple trauma rarely occurred in the Ancien Régime. In this situation the patient also rarely reached the hospital, where neither surgeon could provide adequate relief.

In the 19th century, Joseph Malgaigne reported that he included 2368 patients with a fracture at the Hôtel Dieu in Paris in a period of 11 years, of whom only 30 with multiple fractures[38].

During the great wars of the 19th and 20th century, there was obviously a major increase in the number of casualties with multiple injuries, for which progressively more performing evacuation - and stabilization systems were developed. But in civil society polytrauma remained a rarity.

With the densification of traffic in the 60s of the 20th century, together with the expansion of the heavy industry and the bikers phenomenon, an exponential increase of high-energy trauma was noted.

At the same time also the development of medical emergency teams was seen, who went from the hospital to the accident scene to perform the first aid. The aim was to bring the polytraumatized patient as quickly as possible to the hospital, where after proper resuscitation and control of the haemorrhage, final skeletal reconstruction could be started.

Where in the last quarter of the 20th century a fairly aggressive "all-in-one" procedure was chosen, currently a rational "damage control" approach is performed.

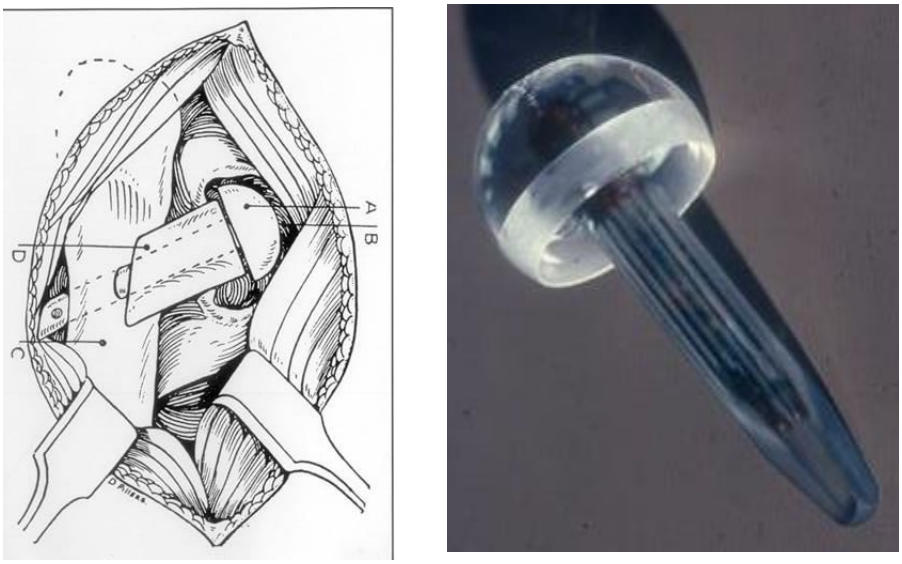
FRACTURE TREATMENT BY ARTHROPLASTY

Due to the aging of the population since the second half of the 20th century, there is an exponential increase of the number of osteoporotic fractures. For some of these fractures, particularly the Garden III and IV hip fractures and four-part subcapital shoulder fractures, an immediate partial joint replacement can provide better results.

Arthroplasty as treatment in hip fractures was initiated by Ernest Hey-Groves (1927, Bristol) with his ivory femoral head prosthesis[5] and later by the Judet acrylic prosthesis (Robert and Jean Judet, 1946, Paris)[38].

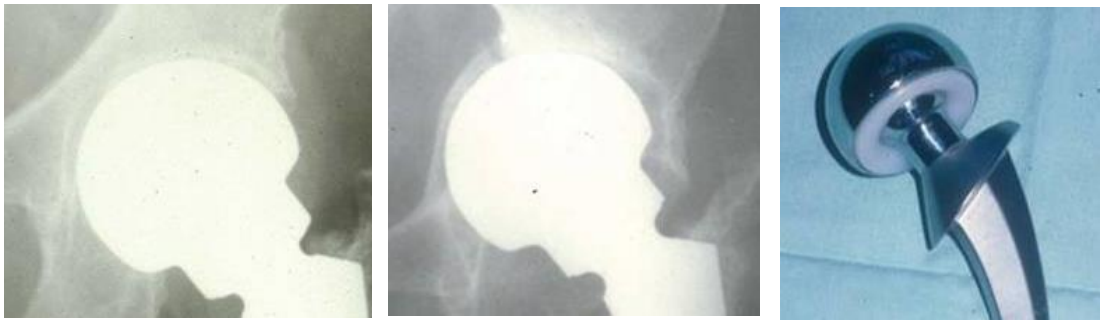
From the fifties onwards, especially the Thompson-Moore hemi-arthroplasty[20,14], with its stem fixation in the medullary canal, provided the first adequate solution for osteoporotic femoral neck fractures. However, the problem with the first generation arthroplasties was the insufficient metaphyseal anchoring on the one hand and the acetabular protrusion phenomenon on the other hand.

The first problem found its solution in the development of the total hip arthroplasty (especially



The ivory Hey-Groves femoral head prosthesis from 1927 (L) and the acryl Judet prosthesis from 1946 (R) for the treatment of femoral neck fractures.

De Austin Moore hemi-arthroplasty (L) for cementless diaphyseal stemfixation and the Thompson hemi-arthroplasty (R) for cemented stem fixation.



The problem of the protrusio acetabuli by the femoral head hemiarthroplasty,was solved by the bipolar head prosthesis.

the Charnley-Müller stemmed total hip prosthesis), with its better stem design and a more optimal cement fixation. The second problem was managed with the use of a double cup. This bipolar hip arthroplasty is currently commonly used in the osteoporotic femoral neck fractures of the 4th age group.

WHAT BRINGS THE 21ST CENTURY?

In the 21st century, an evolution towards the replacement of the metallic implants by bio absorbable fixations, together with a more intensive biological fracture treatment, based on stem cell therapy can be expected. Navigation can also provide a solution to the X-ray radiation exposure for the trauma surgeons. However, the sword of Damocles over the implant surgery in the 21st century is the increase in the number of nosocomial infections. The question will be whether certain population groups who are potentially contaminated (such as those in the biopharming industry, nursing homes and diabetic patients with foot ulcers) will not need an alternative treatment (Exfix), or will be treated on an alternative location outside the traditional hospital.

CONCLUSION

Globally we can state that fracture care has evolved over the centuries from the external splint to the internal stabilization.

The various osteosynthesis systems have gone through a similar evolution, from unstable implant to a rigid - and later an elastic fixation and finally to the biological osteosynthesis (MIS - Mipo). So today the most complex fractures can be stabilized and reconstructed.

The final question is which country introduced the most essential ideas in the evolution of osteosynthesis? Is this “Little Belgium”, created in 1830??? Probably!!! Indeed, With Louis Jean Seutin, with the first “inamovible” cast and the stimulator of early mobilization, Robert Danis, the initiator of the

Louis-Jean Seutin, Albin Lambotte en Robert Danis, the Belgian pioneers of modern traumatology!

interfragmental compression, and especially Albin Lambotte, the "genius of osteosynthesis", father of the plate osteosynthesis, the external fixation and the intramedullary nailing, this country offered a very important contribution to the evolution of traumatology. Seutin, Lambotte and Danis can certainly be considered as *"the founding fathers of modern traumatology"*.

REFERENCES

1. Bagby GW: Compression bone plating: Historical considerations. J Bone Jt Surg Am 1977, 59A, 625-631.
2. Böhler, Lorenz: Peltier LF (1995) The Classic. Clin Orthop 315:5.
3. Colles, Abraham: Jones AR (1950) Abraham Colles. J Bone Joint Surg [Br] 32- B :126-130
4. Danis, Robert: Peltier LF (1993) The Classic. Clin Orthop 292:10.
5. Hey Groves, Ernest William: J Bone Joint Surg (1945) 27(2):340-1.
6. Hippocrates: Peltier LF (2002) The Classic. Clin Orthop 400:19.
7. Ilizarov, Gavriil Abramovich: VHF (1993) Obituary. J Bone Joint Surg [Br] 75-B:333.
8. Küntscher, Gerhard: MS (1974) Fischer S. Obituary. J Bone Joint Surg [Am] 56-A208-209.
9. Lambotte, Albin: Obituary (1956) J Bone Joint Surg [Am] 38-A:464-466.
10. Lane, Sir William Arbuthnot: Jones AR (1952) Sir William Arbuthnot Lane. J Bone Soint Surg [Br] 34-B:478-482.
11. Lister, Joseph: Jones AR (1948) Lister. J Bone Joint Surg [Br] 30-B:196-199.
12. Lorenz, Adolf: Platt H (1950) Orthopedics in Continental Europe 1900-1950. J Bone Joint Surg [Br] 32-B:582-583.
13. Mathijsen, Antonius: Van Assen J; Meyerding HW (1948) Antonius Mathijsen, the Discoverer of the Plaster Bandage. J Bone Joint Surg [Am] 30-A:1018-1019.
14. Moore, Austin Talley: CJF (1964) Obituary. J Bone Joint Surg [Am] 46-A:465-466.
15. Paré, Ambroise: Peltier LF (1983) The Classic. Clin Orthop 179:3.
16. Parkhill C: A new apparatus for the fixation of bones. Trans Am Surg Assoc 1897, 15, 251. Reprinted in Clin Orthop Rel Res 1983, 180, 3.
17. Rush, Leslie V: Peltier LF (1986) The Classic. Clin Orthop 212:4.
18. Senn, Nicholas: Peltier LF (1987) The Classic. Clin Orthop 218:4.
19. Steinmann, Fritz: EMB (1966) A new traction method in the treatment of fractures. Clin Orthop 43:8.
20. Thompson, Frederick Roeck: REZ (1983) Obituary. J Bone Joint Surg [Am] 65-A:873.
21. Verbrugge, Jean: Van der Elst E : (1964) Obituary. J Bone Joint Surg [Am] 46-A:924-926.
22. Book references.
23. Battum Carolum – De chirurgie en de opera van de werken van Ambrosius Paré – 1566.
24. Böhler Lorenz – Die technik der knockenbruchbehandlung - Wilheim Maudrich - Wien 1957.
25. Broos Paul – Over geneeskundigen en geneeskunst – Davidsfonds Leuven 2011.
26. Broos Paul – Meesters met het ontleedmes - Davidsfonds Leuven 2014.
27. Burrell Carla L. – fracture patterns in the medieval period – Liverpool John Moores university.

28. Colton Christopher L. – The history of fracture treatment - Skeletal trauma – Browner et al. – Saunders 2009.
29. Eilis Harold – The Cambridge illustrated history of surgery – Cambridge university press 2009.
30. Evrard E. - Asklepios onder de wapens – Militaire medische dienst België 1997.
31. Harrison Mark – The medical war – Oxford university press 2010.
32. Kemph I. – Leung K.S. – Grosse A. – Practice of intramedullary locked nails – Springer verlag 2002.
33. Küntscher Gerhard – The marrow nailing method – Strycker trauma – Schönkirchen 2006.
34. Lambotte Albin – Les débuts de l'osteosynthèse en Belgique – AOB Bruxelles 1977.
35. Letournel, Emile – Robert Judet : Fractures of the acetabulum – Berlin Springer verlag 1981.
36. Loudon Irvine - Western Medicine – Oxford university press - Oxford 1997.
37. M.E. Müller, M.Allgöwer, R. Schneider, H Willenegger - manual of internal fixation – Springer verlag 1969.
38. Mostofi Seyed Behrooz – Who's who in orthopedics – Springer 2004.
39. Peltier Leonard F. – Fractures a history and iconography – Norman publishing – San Francisco 1990.
40. Peltier Leonard F. – Orthopedics a history and iconography – Norman publishing – San Francisco 1993.
41. Rang Mercer – The story of orthopedics – WB.. Saunders compagny 2000.
42. Rutkow Ira M. – Surgery an illustrated history – Mosby 1993.
43. Van Hee R. – Heelkunde in Vlaanderen – Gemeentekrediet 1990.
44. Van Hee R. Ziek of gezond ten tijde van Keizer Karel - Academia press 2000.
45. Van der Elst E. - Histoire de l'Orthopedie et de la Traumatologie - Histoire de la Médecine - Tome 5 - DIMP Paris 1977.