

Chapter 1

Orthopedic Treatment of Lower Leg Open Fractures in Italy Before the Onset of Orthoplastic Surgery

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The explosion of motorization, which occurred in Italy during the economic booming of the postwar period, caused a huge increase of road traffic accidents and high velocity body impacts due to expulsion from vehicles, particularly motorbikes. The high energy lesions derived from this totally new mechanism of injury had rarely, or even exceptionally, been faced during previous peaceful historical periods.

During the last three centuries, open fractures were routinely considered absolute indications for amputation, if and when the patient was so lucky to survive, in particular, before the onset of asepsis, antisepsis and antibiotics in Europe. The patient was considered “too ill” to receive any type of treatment apart from an immediate and unconditioned decision to sacrifice the limb in order to (try to) save the patient’s life.

Two hundred years ago, the British orthopedic surgeon Percival Pott was unseated from his horse while riding in London and suffered a compound fracture of the tibia. Despite the shock and pain derived from the accident, he maintained his lucidity and self-control. He showed a far-sighted intuition when he decided to keep his injured leg accurately and firmly immobilized to prevent the spread of contamination. He improvised a makeshift tool, consisting of a door and two poles (a sort of a stretcher), on which he was taken to hospital, with minimal or no movement allowed to the injured leg. By doing this, he managed to save not only his life, but even his leg, which was an exceptional result for that time.

Nowadays, the incidence of open tibial fractures is far higher than at Pott’s time, due to the increase of road traffic accidents, high-intensity sports, mass calamities, and terrorism. The complexity of an open osteo-cutaneous lesion can be such that even the most expert trauma surgeon may struggle with diagnostic-prognostic evaluations and therapeutic decisions and procedures. The advent of these major injuries has determined the necessity of familiarization with a vast range of modern means of fixation and has involved the knowledge and improvement of many surgical techniques and, not rarely, the necessary capacity of improvisation.

The following paragraphs describe how a patient used to be approached in the Italian preorthoplastic era, a historical phase of medicine in which orthopedic surgeons used to limit the involvement of plastic surgeons, even when facing complex lesions with an enormous loss of soft tissue, at least in the first instance. This period

1 corresponds to the sixties, seventies and beginning of the eighties of the last century since, in later years, the average orthopedic surgeon gradually becomes more conscious about the importance of appropriate soft tissue management, in the wake of the Slovenian orthoplastic school and its pioneering clinical research works by Godina and Arnez.^{1,2} These watershed papers can be considered the milestones defining the date in which the practice of orthoplastic philosophy in medicine and surgery began.

In the preorthoplastic era, diagnostic-therapeutic recommendations were based strictly on orthopedic concepts.

At that time, a referral to a plastic surgeon used to occur in a fashion that was routinely SEQUENTIAL (after completion of orthopedic input) rather than SIMULTANEOUS, as is now in the modern, purely orthoplastic settings. In other words, the approach was piecemeal and not comprehensive towards the lesion in its entirety.

A thorough description of the surgical approach to open fractures of the leg in the preorthoplastic era follows, as described in the Italian translation by Merlo and Morlacchi of the Watson-Jones textbook on fractures and dislocations.³

Acute treatment

Although increased knowledge of microbiology and infectious diseases and the discovery of antibiotics have reduced the problem of infections, the principles pioneered by Percival Pott some centuries ago were and are still valid, and led to the development of the pre-orthoplastic approach in the acute phase. A key concept was that the movement of bone fragments or, even worse, clumsy attempts of fracture reduction by inexperienced personnel, favors penetration of external material, and thereby facilitates bone contamination.

This implies that the laceration has to be covered with any improvised means and the limb immobilized with anything available that can achieve that purpose. The patient has to be immediately transported to a hospital for optimal treatment conditions, i.e., within an operation theater.

Wound debridement

The injured leg is appropriately washed and a thorough trichotomy is carried out. The most common agent for the initial scrub is a skin antiseptic, such as Cetavlon.

A sterile field is prepared and no tourniquet is applied, in order to distinguish what is viable from what is nonviable, unless a frank hemorrhagic risk is present.

Radical excision of the wound margins has to be performed, until bleeding is noticed. Degloved tissues have to be partially debrided and reapplied as biological dressings. Serial dressings are then performed until the raw areas are covered with split-thickness skin grafts.⁴

Direct suture of the skin margins is possible if tension-free. Lacerations 1 cm long or less can routinely be closed directly. Larger wounds have to be carefully evaluated in each case, but as a general rule, the surgeon who is not familiar with compound fractures should avoid suturing the soft tissues. Fasciotomies of all compartments have to be performed to prevent compartmental pressure increase and muscular necrosis. All soft tissues appearing nonviable have to be excised and the approach is almost “oncological”, in the sense of a wide margin of excision into undoubtedly healthy tissue.

Removal of bony fragments should instead be as conservative as possible. Only fragments that are completely detached from the soft tissues have to be removed.

Osteosynthesis

In case the reduction cannot be maintained by noninvasive methods, the necessity of bone fixation has to be considered. With increasingly complicated cases, the pressure of performing bone fixation rises, as the “mechanical quiet” obtained with the osteosynthesis facilitates soft tissue reconstruction as well.

A fracture complicated by an arterial lesion used to be an indication for bone fixation, but after the experiences of the Vietnam War, any fracture associated with vascular lesions were treated conservatively.⁵⁻⁷

As a general rule, compound fractures without complication can and should be treated by non-invasive technique. Those with complications may require surgical fixation. The choice of technique depends on the local conditions. A plate is certainly the most practical and safe method. The plate should always be covered by soft tissues; in case this is not possible, the plate can be left exposed until consolidation. With regard to this, the preorthoplastic view differs from the current approach to internal fixation, in which exposure is considered a real taboo, particularly when the fracture focus is overtly uncovered. In preorthoplastic philosophy, the reconstruction of the soft tissue cylinder is important, but not crucial, and not necessarily an immediate requirement in the first few days.

Another possibility for bone fixation is a combination of internal fixation and conservative approach; *i.e.*, application of two trans-osseous nails, which can be utilized when the conservative cast-based treatment is not contraindicated. A proximal nail is inserted just distally to the tibial tuberosity and a distal one is fixed distally, in close vicinity of the malleolus. The fracture is reduced and a cast incorporating the nails is applied.

External fixation

In 1954, Hoffmann⁸ pioneered the treatment of open fractures with the method of external fixation, which was then developed by Vidal and Adrey.⁹

In the preorthoplastic era, external fixation was NOT considered a standard, routine approach for open tibial fractures. This is different from the principles of the current orthoplastic period, in which external fixation is somewhat the default initial treatment of bone lesions. In the past, external fixation was deemed a second choice, or an indication for comminuted or already infected fractures, but not as an acute treatment. No specific indication is given with regard to the sites of pin insertion, in order to avoid vascular damage and interference with soft tissue reconstruction.

External fixation was brilliantly applied and developed by Lecco's school of orthopedics. Orthopedic surgeons from Lecco made a special contribution in the practice of circular framing and the Ilizarov method for leg osteodistraction.

Since Ilizarov's method was imported in 1981, this technique has been applied by orthopedic surgeons in Lecco in thousands of patients and taught to colleagues practicing it in many places, *i.e.*, Genoa, Bologna and Naples.

Ilizarov's method is based on the ability of bone to determine biologic regeneration through osteodistraction. Among the various indications of this technique, deep infection and osteomyelitis hampering or delaying bone consolidation have been considered to be ideal conditions for treatment with circular frames.

Intramedullary fixation

Infibulation of bony fragments is a possible option, but tends to be adopted after the patient has overcome the acute phase of the trauma. In case infection develops, the consequences are far worse if an endomedullary pin has been inserted.

Prominent personalities and precursors of the orthoplastic approach

Giorgio Brunelli certainly deserves to be mentioned as a pioneer of orthoplastic treatment during the preorthoplastic era. He introduced microsurgery in Italy at Brescia Hospital in the sixties, and soon became a director and professor of Orthopedics at the local institutions, teaching his novel approach to complicated fractures, among many other fields, based on accurate soft tissue management in terms of debridement and microsurgical reconstruction.

On the plastic surgery side of prophetic orthoplastic surgeons, Ezio Morelli and his contribution to complex limb reconstructions in Legnano merit citation. Morelli was a famous plastic surgeon and hand microsurgeon. He was the first in Italy to replant the feet of a child in the eighties.

Another master of orthoplastic surgery was Simone Teich Alasia in Turin. He needs to be considered a very prominent pioneer, almost a prophet in defining the importance of the plastic-orthopedic collaboration. Graduated in 1940, he served as an intern at the INAIL (National Institute of Insurance for Work Accidents) Traumatology Department at San Vito Hospital in Turin, which was the main trauma reference in the city, and since 1949, he was a volunteer assistant in the Academic Department of Surgical Pathology. He was then the Assistant in Charge in the Department of Reconstructive Plastic Surgery of the Injury Institute at “Ospedale Maggiore” in Milan (Niguarda) from 1952–1953. He returned to Turin and between 1953–1966, he was Assistant and then became Consultant Plastic Surgeon in Traumatology at the San Vito Hospital in Turin. Dating to this period, there are publications focused on the topic of treatment of complex fractures of the lower limbs and chronic osteomyelitis.^{10, 11}

According to Teich Alasia, the bases of correct treatment are identified in the synergistic, collaborative relationship between orthopedic and plastic surgeons; this approach emphasizes how early skin repair in open fractures plays a decisive role in containing infections of the skeletal system, reducing the incidence of osteomyelitis and secondary pseudarthrosis.

In those years, these concepts were innovative and what now seems well established was the subject of passionate debates. In 1953, Teich Alasia was in Paris as a clinical fellow of Merle D'Aubigne, a convinced advocate of the importance of early integumentary repair versus prolonged open treatment.

Among the various techniques, the dermo-epidermal graft was proposed as a temporary solution in the management of vast cutaneous and soft tissue defects, but also as an alternative to closure by primary intention with margins under tension, or of uncertain vascularity, or still widely apart.

In addition, in the treatment of osteomyelitis outbreaks, the graft was used after extensive debridement as a temporary closure.

Since then, the ideal soft tissue repair was that carried out with flaps, particularly in areas subject to mechanical or load stresses, and intended to protect the skeletal planes and vascular-nerve bundles.

The function of the flap, however, was not merely a cover, but decisive in the healing process of old osteomyelitis or pseudarthrosis, thanks to its contribution to the local circulation and the recruitment and stimulation of osteoblasts.

Similarly, when bone grafting operations were performed, the cover with a flap promoted revascularization and therefore, engraftment and skeletal integration.

Finally, through the use of flaps, it was possible to improve the results of amputations, creating more trophic and resistant stumps.

At the time, the notions of vascular anatomy of the skin being much less in-depth, the length/base ratio of a flap was located between 1-1.5, and very often, a preventive autonomization procedure was used a week before the transfer.

Local flaps, generally cutaneous, flat and proximally pedicled, could only solve some situations. In other cases, distant flaps were used, either flat or tubular (Figure 1.1).



Figure 1.1

A 37 year-old woman who sustained an open tibial fracture 20 years prior and then developed an ulcer overlying an osteomyelitic process (A). Bone and soft tissue debridement was performed, followed by reconstruction through a tubular abdominal flap (B) transferred to the raw area after an intermediate surgical step in which the flap was based on the wrist (C-E).

Among the distant flaps, the “cross-leg” played the most important role. Although it required meticulous preparation and forced the patient into uncomfortable postures with four-week immobilizations with considerable sacrifice, it saved time and procedures compared to the abdominal tubular flaps transferred in several stages (Figure 1.2).

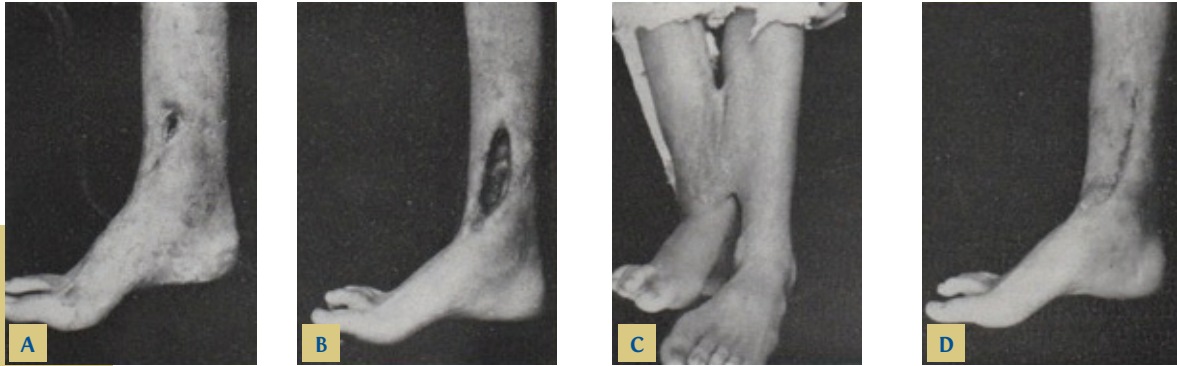


Figure 1.2

Chronic ulcer overlying osteomyelitis following an open tibial fracture in a 24 year-old man (A). Result after bone and soft tissue debridement and split-thickness skin graft of the defect (B). Immediate result after iliac crest bone graft and cross-leg flap (C). Final result (D).

The so-called “cross-leg” or hetero-hamstring flaps used to have multiple indications for coverage of extensive cutaneous defects of the lower limbs before the current predominance of microsurgical methods of reconstruction.

Originally described in 1854 by Hamilton,¹⁰ this reconstructive surgical technique can be applied to any kind of flap. Nevertheless, the most employed version is the hetero-hamstring fasciocutaneous flap, and in particular, the saphenous flap.

The theoretical basis of this procedure is simple. In cases of soft tissue defects regarding leg, ankle or foot, and in the absence of a homo-leg or microsurgical locoregional reconstructive option, it is possible to use a hamstring flap, which will require a secondary intervention.

This revision occurs after a period of approximately three weeks, during which a new vascular network forms from the receiving site into the flap. Immobilization with an external tibiotibial fixator is sometimes necessary during this period to avoid any traction on the flap. The application of this fixator also enables elevation of the two lower limbs, which avoids any point of attrition, and thereby, the risk of pressure sores, particularly around the heel. However, for compliant patients, some authors, including Teich Alasia, prefer a more flexible immobilization, by means of pancake or elastic adhesive bands.

After this three-week period, which may be prolonged in the case of poor vascularity, weaning of the flap is assessed through a test of pedicle clamping.

The technique has been practiced successfully for quite some time. In 1958, a series of 19 patients was published by Teich Alasia and his group.¹¹

A follow-up analysis in 1982,¹² when it had already become of lesser use in favor of more modern methods, included 183 cases with very high success rates.

The strengths of the method were very clear: short operating time, modest surgical trauma, and flap dimensions suitable for the purpose. Furthermore, immobilization, which was originally maintained with complex plaster casts, was then easily ensured by bandages and plasters.

It should also be added that originating in the 1960s, Papineau developed a three-stage technique for the treatment of chronic osteomyelitis that aimed to reduce the time needed to resolve this pathology. In his classic 1973 publication, he described the long timescales of the so-called traditional method, which he contrasted with the treatment he proposed as capable of reaching the definitive result in only 3-6 months.¹³

The first surgical phase of this technique was dedicated to the excision of infected tissues and possible osteosynthesis, followed by a second phase, in which the bone defect was filled with autologous cancellous bone

1 chips. In these two stages, no skin covering was envisaged, which was instead performed as a third stage, after the engraftment of the autotransplanted bone, using thin grafts or flaps.

The technique established itself and was widely practiced in the Trauma Orthopedic Center (CTO) of Turin, which opened in 1966, where Teich Alasia headed the Department of Plastic Surgery and the Large Burns Center until 1985.

The gradual decline of traditional reconstructive methods, due to flaps based on new anatomical knowledge and microsurgical technique, was accompanied by reflections of a somewhat nostalgic flavor that questioned the real superiority of these new options, as Teich Alasia wrote in 1980.¹⁴

In the current state of orthoplastic knowledge and surgical habits in this sector, the pages of Teich Alasia's works certainly appear to be linked to a distant time. However, the debates around the causes and remedies proposed and implemented can be read with pleasure and photos can still suggest historical as well as future development of this fascinating border territory between plastic and orthopedic surgery.

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Chapter 2

The Aims of Acute Orthoplastic Surgery

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Traumatic injuries are the sixth leading cause of death worldwide. They account for 10% of overall global mortality. Trauma is the leading cause of death among people aged less than 45 years.¹ Polytrauma is responsible for almost 40% of trauma admissions.^{2,3} Major trauma with several simultaneous injuries can lead to significant disability, delayed or impeded return to work, and high economic costs. Often affecting young, productive individuals, polytrauma is a financial and social burden to society.⁴

Major trauma is a perfect example of the importance of the multidisciplinary approach to management that can reduce post-traumatic mortality and morbidity at its core.^{5,6}

Orthopedic trauma is positioned high on the list of commonly encountered injuries. Lower limb open fractures (LLOF) often derive from motor vehicle accidents, falls from height and increasingly, fragility fractures in the elderly from falls less than two meters. LLOF are also associated with mass casualty incidents (MCI): earthquakes, landslides, crush and blast injuries from explosions caused by terrorists. Of the 54% of blast injuries and 60% of earthquake injuries that affect the extremities, 8-13% are LLOF.^{7,8} Limb salvage in MCI must be decided upon by plastic surgeons collaborating with orthopedic surgeons on the multidisciplinary trauma center orthoplastic team.⁹

After the first trauma center opened in Birmingham, the United Kingdom (UK) in 1941, trauma centers were built worldwide, principally to manage patients with multiple injuries in a multidisciplinary way to prevent death and reduce post-treatment morbidity. Trauma centers are equipped with all diagnostic and therapeutic tools (including intensive care facilities), knowledge and the 24/7 presence of emergency care physicians, anesthetists, and surgeons experienced in immediate life-saving procedures with availability to other specialties, who are called upon when their expertise is required.

After years of efforts and the British Orthopaedic Association (BOA) and British Association of Plastic Reconstructive and Aesthetic Surgeons (BAPRAS) providing ample evidence on superior outcomes of LLOF care when treated by multidisciplinary teams consisting of orthopedic and plastic surgeons (orthoplastic teams), LLOF were acknowledged as major trauma requiring admission to major trauma centers. LLOF, when managed in a

2 multidisciplinary, orthoplastic manner according to the 2016 National Institute for Clinical Excellence (NICE) guidelines, were financed better than conventional, non-orthoplastic treatment. Allocated resources were used to build around-the-clock plastic surgery services, which became an integral part of trauma centers in the UK, finally enabling the institutionalized, multidisciplinary orthoplastic treatment of complex extremity trauma.¹⁰

Trauma cannot be planned, in contrast to oncologic limb reconstructions, composite, elective microsurgical limb reconstructions or even limb transplantations, requiring the involvement and collaboration of different surgical teams, including orthopedic and plastic, but not the existence of 24/7 orthopedic and plastic services. The obligatory existence of around-the-clock orthoplastic services is the main difference between acute orthoplastic surgery, which is usually available only in trauma/specialist centers, or, in Italy, in university hospitals and elective orthoplastic surgery. Elective orthoplastic surgery has been sporadically reported since the birth of plastic surgery, and acute orthoplastic surgery can be traced back to Marko Godina in Ljubljana (Slovenia) in the 1970s. Although it was not called orthoplastic surgery, it consisted of around-the-clock interdisciplinary service involving trauma and plastic surgeons dealing with acute trauma and limb salvage.¹¹ Godina reported the outcomes of such treatment in his landmark paper which served as the basis for the BOA and BAPRAS working party's 1997 report on the management of LLOF.^{12, 13} In 1993, Levin defined orthoplastic surgery as "the principles and practice of orthopedic and plastic surgery applied to a clinical problem, either by a single provider or a team of providers, working in concert for the benefit of the patient".¹⁴ This definition does not differentiate between interdisciplinary surgery (single provider/single team of providers applying techniques of both specialities) and multidisciplinary surgery (multiple teams of providers, each applying techniques of his/her surgical speciality). It does not define the provider, as the providers are orthopedic and plastic surgeons. It does not differentiate between acute and elective orthoplastic surgery, as acute orthoplastic surgery deals with limb salvage and acute limb trauma management. In the mid-1990s, the term orthoplastic surgery was introduced in the UK. It was understood to be the acute multidisciplinary management of LLOF by the orchestrated, side-by-side work of orthopedic and plastic surgeons.

Orthoplastic surgery in 2021 is considered an organized, multidisciplinary collaboration between orthopedic and plastic surgery services, inclusive of allied health care professionals. This collaboration obviates delays in the treatment of acute LLOF by ensuring 24/7 limb salvage, as well as early timely wound excision, fracture fixation and well-vascularized coverage of soft tissue defects in lower limbs, according to the 2016 NICE guidelines and the 2020 Standards, by dedicated expert staff, to optimize the care of severe limb injuries.^{6, 15, 16} The multidisciplinary orthoplastic approach to acute LLOF offers superior outcomes, shortens treatment and lowers cost.

It is the aim of this book, a joint effort of many excellent Italian orthopedic and plastic surgeons, to inform the public about acute orthoplastic surgery in a step-by-step way, from the site of trauma to the completion of recovery from reconstruction.

This text offers evidence which could serve as the basis for promoting multidisciplinary work in acute trauma in Italy and elsewhere. The interested national societies, SIOT (Societa Italiana di Ortopedia e Traumatologia), SICPRE (Societa Italiana di Chirurgia Plastica, Ricostruttiva ed Estetica) and SIM (Societa Italiana di Microchirurgia) are currently working on providing national guidelines for the multidisciplinary treatment of LLOF in Italy.