Care and Management of Surgical Wounds, Wounds Dehiscence, and Scars

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1 Introduction

Although the skin is not the key issue in foot and ankle surgery, wound healing has a fundamental role for a successful outcome.

A wound that does not close properly can lead to severe problems with bone and/or osteosynthesis hardware exposure, leading to known consequences such as infections, delayed consolidation, and the need for reoperations, among others.

A defective scar, from either a functional or an aesthetic point of view, could be a nightmare for the surgeon. Even though the main problem may be resolved, a scar that is annoying for the patient could be related to multiple consultations and discrepancies with the result obtained.

Bearing these points in mind, it is essential to take serious precautions and manage surgical wounds with care, trying to procure the most effective results in the context of global treatments.

Anatomical considerations and the considerable mobility exerted at the ankle level make the management of wounds in this body segment even more challenging. A separate topic corresponds to traumatic wounds that add even more significant difficulties and usually require a plastic surgery specialist's assistance to achieve a suitable improvement.

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In this chapter, we will review practical recommendations to adequately treat surgical wounds performed during foot and ankle surgery, both in elective and trauma surgery, as well as advices to follow when complications such as dehiscences and pathological scars occur.

2 Relevant Anatomy

The lower limbs, especially the foot and ankle, are functionally very relevant and highly demanded areas for developing the human standing characteristic. By being upright, they support all body weight, generally for long periods, and, furthermore, are responsible for producing our displacements.

Despite this, it could be stated that the ankle and the foot are relatively unprotected areas highly exposed to trauma. The skin on the distal third of the leg and around the ankle is thin, with a little subcutaneous tissue layer; moreover, essential structures like bones and tendons are poorly covered and can be easily exposed in trauma.

Conversely, the glabrous skin of the sole possesses completely different characteristics, being thick and firm, designed to resist weight. Unfortunately, its characteristics are unique, and there are no similar structures that could replace it.

2.1 Irrigation

As in all the functioning of the human body and each surgical intervention, the blood supply is central for a favorable result.

The foot and ankle are supplied by arteries dependent on three main axes, the anterior tibial, posterior tibial, and peroneal arteries, each of which feeds specific segments interconnected by vessels of a smaller caliber.

To better understand how a body segment is irrigated, it is essential to keep in mind the concept of angiosome described by Ian Taylor [1]. An angiosome corresponds to a three-dimensional anatomical unit of tissue supplied by a source artery. In his experimental study, Taylor maps the whole body describing 40 territories or angiosomes, of which 6 correspond to the foot and ankle. These angiosomes are unrigid structures intercommunicated between adjacent angiosomes through a network of so-called shock vessels. Specifically, at the ankle and foot level, six angiosomes are described (Fig. 1).

- The posterior tibial artery originates three angiosomes that supply the medial ankle and the sole through the calcaneal branch (heel), the medial plantar artery (arch of the foot), and the lateral plantar artery (lateral midfoot and forefoot).
- The peroneal artery is the source of two angiosomes that supply the anterolateral ankle and the lateral hindfoot, thanks to the anterior perforating branch (superior anterolateral ankle) and the calcaneal branch (plantar heel).

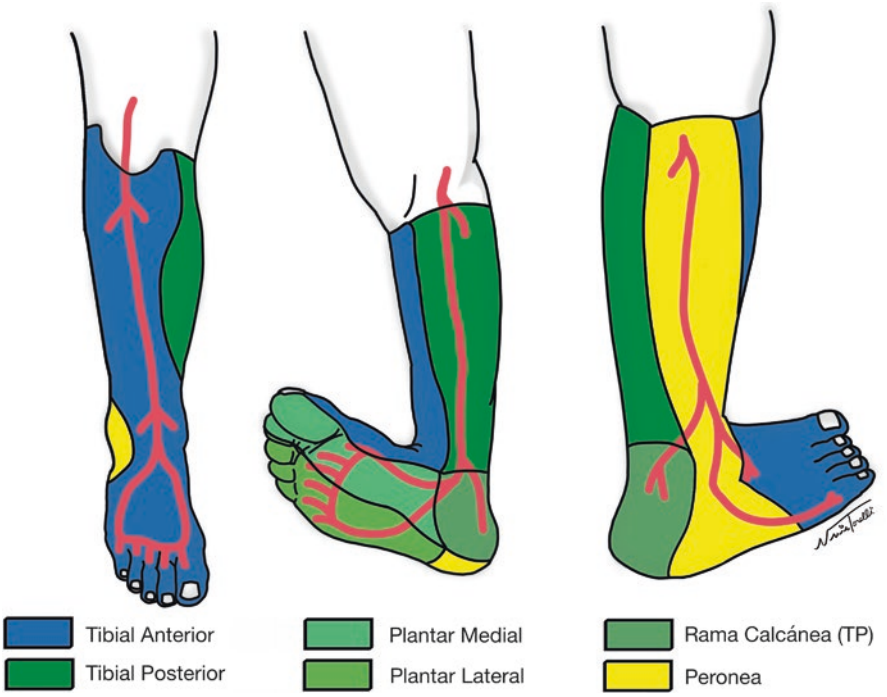

Fig. 1 A schematic representation of the angiosomes at the level of foot and ankle

- An angiosome that supplies the anterior ankle depends on the anterior tibial artery and then like the dorsal artery of the foot that feeds the entire foot dorsum [2].

Knowing these angiosomes allows for the correct planning of the location of the surgical incisions. The usual designs consider these angiosomes, reducing the risk of complications. In the case of traumatized feet or with chronic pathologies, such as diabetic foot [3], that can alter the vasculature, an easy-to-use tool is mapping these arteries with a portable Doppler pencil, noting alterations to the normal anatomy and allowing adjustment of surgical plans [2].

3 Wound Healing Process

To understand how to manage a wound, it is a prerequisite to have notions about the normal healing process and the factors that can alter it.

Every time a wound occurs, our body triggers a series of processes that lead to tissue repair and scar formation. This process has been divided into stages that help understand it better, yet these stages are intertwined in a dynamic process [4, 5].

3.1 Phases of Wound Healing Process

- Hemostasis: While it is not considered a stage in the healing process, it is the first to happen after any injury. Initially, vasoconstriction occurs, and the intrinsic and extrinsic coagulation pathways are triggered. This process culminating in the production of a clot acts as a bridge to the inflammatory phase.
- Inflammatory phase: Immediately after the injury, an inflammatory process begins cleaning the wound of microorganisms and foreign bodies. After the initial vasoconstriction occurs vasodilation, an increase in the blood vessels permeability, and an increased arrival of lymphocytes and macrophages releasing cytokines and other biologically active agents.
- Proliferative phase: From the second day and approximately until the third week, fibroblasts represent the predominant cells in the wound, producing collagen deposits, granulatory tissue formation, angiogenesis, and finally epithelialization.
- Maturation/remodeling phase: Finally, the repair process can be extended for up to 1 or even 2 years. Initially, the scar is mostly composed of type III collagen, achieving approximately 20% of healthy skin strength. This collagen predominantly changes to type I through remodeling, reaching 80% of the original strength after 2–3 months. Later the scar begins to contract and never reaches the initial strength of healthy tissue.

3.2 Factors Affecting Wound Healing

From a practical point of view, understanding the factors that can alter the wound healing process is more important than understanding the physiological process of wound repairs. Keeping these factors in mind is essential to avoid problems later.

- Oxygen: The cellular growth proper to the healing process is dependent on oxygen, and adequate arterial oxygen pressure and tissue perfusion are fundamental factors for tissue repair.
- Age: Age, by itself, affects healing. At an older age, the stages described previously begin late, occur more slowly, and generally do not obtain the same results as at younger ages.
- Nutrition: Healing requires an increased production of cells and their products, so a state of malnutrition will negatively affect the entire process. On the other hand, poor nutrition due to excess has also shown an increase in complications such as infections and dehiscences.

Ideally, a patient who will undergo elective surgery should arrive in good nutritional condition at the surgery. In trauma cases, the nutritional status should be evaluated, and the necessary corrections and supplements should be adjusted early.

- Tobacco: The deleterious effects of tobacco are multifactorial. Nicotine is a vasoconstrictor that decreases cell proliferation; carbon monoxide decreases oxygen transport capacity; and tobacco also increases platelet aggregation and blood viscosity. These and other facts explain why a single cigarette generates cutaneous vasoconstriction for about 90 minutes.

The recommendation for elective surgeries is to stop smoking at least 4 weeks before and 4 weeks after surgery.

- Infection: Infection prolongs the inflammatory phase, interfering with later phases, especially collagen deposition, epithelialization, and contraction. In addition, the granulatory tissue growing under local infection is of lower quality, therefore being more abundant, edematous, hemorrhagic, and fragile, not allowing an adequate closure of the wounds.
- In chronic wounds, attention should be paid to biofilm, although it does not imply an active infection, alters, and inhibits wounds healing. Actions must be taken to eliminate it.
- Radiation: Apart from the beneficial effects sought with radiotherapy, it also causes deleterious effects on the tissues, altering the DNA, and reduces the irrigation, the deposit of collagens, and the tensile strength obtained. Unfortunately, irradiated skin is chronically damaged, forever affecting the wound healing processes.
- Chronic diseases: A series of chronic diseases alter the overall state of health and wound healing. The classic example is diabetes mellitus, but others such as obesity, COPD, cancer, liver and kidney failure, connective tissue diseases, and venous and arterial failure, among others, are involved in alterations to the healing process and should be compensated as much as possible prior to any elective surgery.

4 Elective Surgical Wounds

As previously mentioned, the anatomical characteristics at the foot and ankle require the correct management of surgical incisions to achieve the best result.

4.1 Location of Incisions

The approach to be used will remain a fundamental matter for the orthopedic surgeon, who will consider anatomical factors, such as irrigation of the area and the need for adequate access to the element to be intervened.

When deciding on these approaches, it is crucial always to be concerned about the possible complications in the future and the soft tissue deficit existing at the time or that could develop in the expected evolution of the wound, paying

particular attention to signs of skin suffering. In these cases, being aware of the situation and the options to reconstruct later will always guide a fair decision-making process.

In complex cases, it is always advisable to discuss the case with the plastic surgery team if, in the future, the patient requires their assistance to reconstruct a skin coverage deficit.

4.2 Incisions

In general, the incision should be the smallest to achieve adequate exposure, limiting the scars' extension. However, it is inadvisable to save on the incision extension at the cost of having poor access and hindering subsequent repair and results.

The skin must be handled with care avoiding unnecessary traumatization, handling the skin with grasps pressing the dermis, and leaving the epidermis free is a way to protect it, especially with delicate skin like those of aged people. Using hooks to catch the skin, instead of grasps, is also an excellent alternative.

The use of skin retractors is recommended to avoid damage to the soft tissues. These could be self-retaining retractors or individual elastic retractors (Lone Star™ Cooper Surgical™/CooperSurgical Inc., USA), which, given their versatility, can be adjusted to any size and wound position.

The incision closure is presumably the most critical surgeon-dependent aspect to achieve the best possible scar, this means making it as unnoticeable as possible, not depressed, not raised, and similar in color to the surrounding skin [6]. With this, the core objective is to close in layers and avoid, whenever possible, a closure only in a single cutaneous plane. When facing deep planes, dead spaces are closed, avoiding scar depression and reducing skin tension. Ideally, before placing the last suture line over the skin, the wound margins should be seen practically closed, leaving minimal tension on this layer (Fig. 2).

Fig. 2 Skin suture: before performing the last suture plane, for example, with a running subcuticular suture, the wound edges have to be almost completely opposite without tension

4.3 Suture Materials

Absorbable suture materials are preferably used to target muscles, fascia, and subcutaneous tissues. Our preferred material is polydioxanone (PDS™, Ethicon Inc., Somerville, NJ, USA), a strand of easy maneuverability that, being monofilament, reduces trauma to tissues and risk of infection. Also, its durability profile allows maintaining extended support while healing occurs.

A valid and high-quality alternative corresponds to polyglactin (Vicryl™, Ethicon), probably the most used suture for deep planes. In very thin patients and incisions over areas with scarce subcutaneous tissue between the skin and the bone, it can be especially useful, since by being more flexible, it would be less noticeable by patients. The use of a colorless strand prevents it from showing through the skin.

For superficial layers, a continuous subdermal suture is recommended, avoiding the excessive accumulation of knots, with 3–0 or 4–0 material depending on the patient's wound location and characteristics.

Finally, for the last plane, non-absorbable materials should be used that causes the least possible inflammatory reaction. Nylon (Ethilon™, Ethicon) is usually the first alternative, and in general, a 4–0 size should be adequate. However, in less demanding areas such as the foot dorsum, smaller diameter sutures could be used. On the contrary, in greater demand areas such as the sole or closed with a certain degree of tension, larger sutures should be used. An alternative is polypropylene (Prolene™, Ethicon), which advantage is having a higher tensile strength, being useful when approaching tissues with some tension degree.

4.4 Suturing Technique

Before closing any wound, hemostasis should be appropriately checked in order to stop any active bleeding. It is ideal to coagulate promptly only at the bleeding sites and not aimlessly reducing the tissues' irrigation, with the risks that it entails in terms of infections and dehiscences.

For deep layers, inverted stitches are used in which the needle enters and exits through a deep plane, leaving the knots inwards, which reduce the chances of extrusion or even being felt by the patient, especially at the ankle in the case of very thin patients. The steps to perform an inverted suture are demonstrated in Fig. 3. When there is greater tension or risk of infection, it is advisable to use simple interrupted stitches. Once the tension has been decreased, a continuous suture could be used with the advantage of reducing time and resulting in fewer knots.

There are different options for suturing skin, always remembering that wound edges must be everted. The first corresponds to the simple interrupted stitches whose advantage lies in its ease of execution, ability to adapt the tissues' margins, and

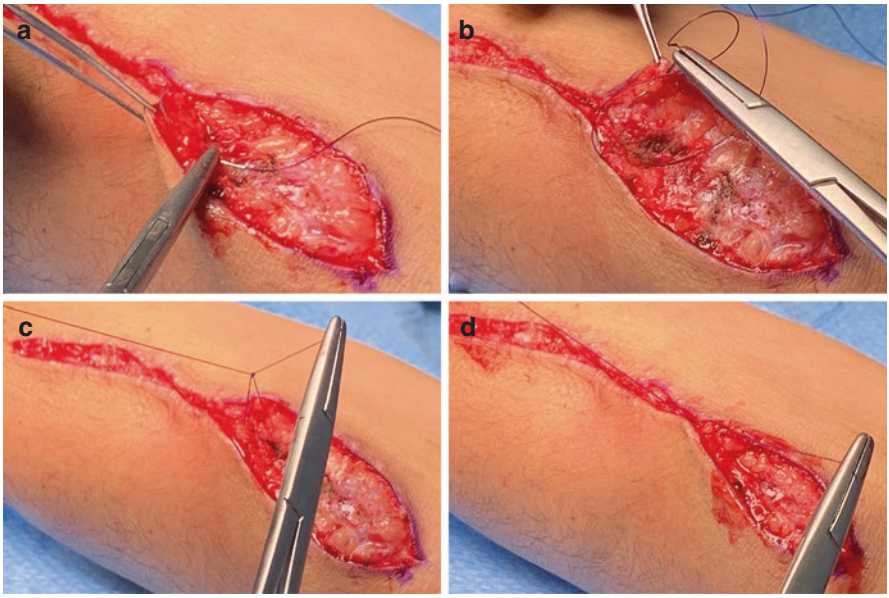

Fig. 3 Inverted stitches are used to suture deep planes. (**a**) The needle penetrates from a deep plane; (**b**) at the opposite edge, it enters from a superficial plane to a deep one; (**c**) edges are approaching; (**d**) the knot is hidden inward

speed. An excellent option is to perform an intradermal suture in wounds well faced in their deep layers, which generates a more aesthetic linear scar. It could be done with absorbable material avoiding the need to remove stitches or with a non-absorbable suture, in which case it can be removed deferred. It is important regarding long incisions, to leave intermediate exits of the strand, in order to be able to remove it easily.

In the case of wounds closed at higher tension, it is ideal to use a stitch that provides greater firmness and a coapted surface. In this case, vertical or horizontal mattress points are the alternative of choice.

In the situation where one of the edges of the wound has borderline irrigation, it is advisable to use a less ischemic technique, such as Gillies' stitches in which the suture enters and exits the surface on only one side and passes through the other edge only by dermis (as in an intradermal suture). This same point is recommended to close flap wounds.

Regarding surgical staples, no evidence shows the superiority of one method over another [7–9] except for faster with stapling [10] and a trend towards better aesthetics with suturing [11]. In our practice, the use of staples is unusual, and we recommend always using them after correctly closing deep planes and removing them promptly, no later than 10 days, to avoid excess marks on the skin.

4.5 Wound Dressing

Once the suture is finished, the skin must be protected. The ideal dressing generates an environment with controlled humidity, which prevents desiccation and reduces edema, with an easy application and removal, painless, and inexpensive.

In simple wounds that do not have a higher risk of complication, our recommendation is to apply a skin protector and then cover with paper tape (Micropore™ 3 M, Ltd., USA), applying at least four tape layers.

In the case of bruised or traumatized skin, it is important to use a product for advanced wound management. At this point, the most used primary dressing is a *tulle gras*, applied to the wound and covered with a secondary dressing. The telfa has similar characteristics.

For highly exudative wounds, alginate or foam is the most suitable alternative.

In general, wound dressings should be changed every 3 to 5 days, depending on the product used. When healthy skin has been noticed, it can continue using paper tape.

Regarding the right time to wet a wound, we recommend not doing it for the first 48 to 72 hours, and then, for example, if using paper tape, it is possible to wet it with extreme caution in order to completely dry it later. Other dressings require keeping it dry until removal.

Other essential precautions are respecting rest, keeping the leg up, and evaluating the use of compression bandages [12], all measures that reduce edema and its negative consequences.

In the same way, it is crucial to maintain adequate glycemic and nutritional management and suspend the use of tobacco.

4.6 Incisional Negative Pressure Wound Therapy

Negative pressure wound therapy (NPWT) since its introduction in 1997 [13] has been a significant contribution to wound management. Traditionally it has been used in open wounds, being widely accepted as a bridging or even definitive therapy.

Its applications have gradually expanded, including its use in closed surgical wounds, known as incisional negative pressure wound therapy (iNPWT) described by Gomoll et al. in 2006 [14] precisely in patients undergoing ankle and foot surgery.

iNPWT refers to the application over closed wounds, acting as a dressing that transmits pressure on the suture line.

The advantages it provides are fundamentally an improvement in the microcirculation of the wound, a decrease in tension on the wound edges, a decrease in edema, and a more effective obliteration of dead spaces [15].

Its use is increasingly popular, thanks to a decrease in dehiscences and wounds infections [16–19]. Our group demonstrated a decrease in complications in the donor area of the anterolateral thigh flap, allowing large defects to be closed with minimal consequences [15]; however, systematic reviews have not been able to strongly demonstrate a global utility of this therapy nor its clear cost-effectiveness [20, 21].

We recommend the use of iNPWT in any high-risk injury:

- Closed with a certain degree of tension.
- Performed on traumatized tissues.
- Patients with risk factors for dehiscence (obese and smokers, among others).
- Presence of significant edema.
- Arthroplasty, considering that the consequences of a wound infection are so dire that any preventive measures seem reasonable.

Its application is straightforward. There are ready-to-use devices such as the VAC Prevena™ (KCI, San Antonio, Texas, USA). If this type of device is not available, it can be easily made with the material of a standard NPWT. Once the wound is closed, both sides of the lesion are covered with a transparent dressing, leaving only the suture line uncovered, and over this, the standard NPWT foam is placed covering the sutured area and then is connected to the suction motor (Fig. 4). In general, a pressure of −125 mm Hg continuously is the most suitable.

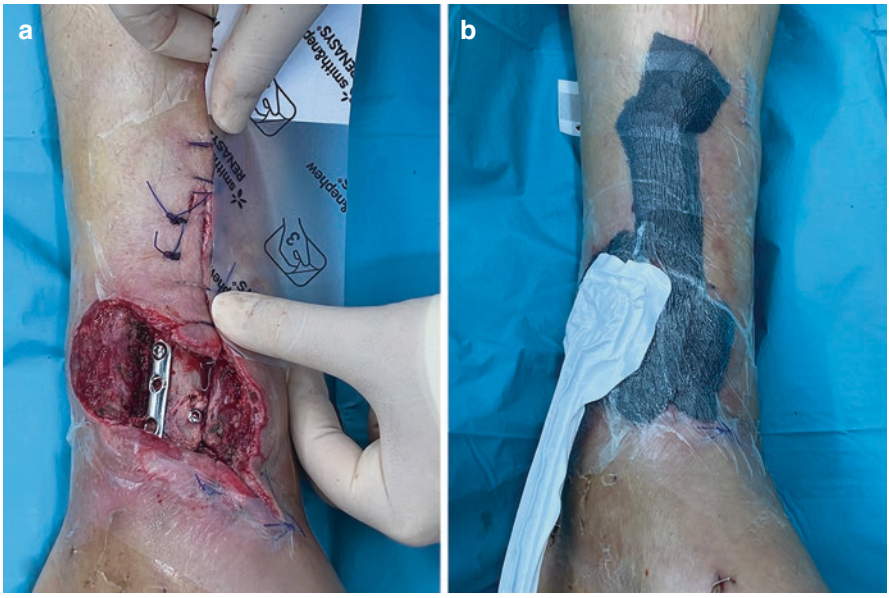

Fig. 4 An incisional negative pressure wound therapy (NPWT) can be assembled using a traditional one. (**a**) Start protecting the edges of the wound with a transparent dressing, (**b**) cover with foam over protected areas. In this case, a traditional NPWT is used to cover an open wound and an incisional segment over a closed one

Its removal is recommended between 5 and 7 days later, being earlier in the case of doubts about infection or other complications. A second cycle can then be applied if the wound is not yet completely closed or if there are reasonable doubts of subsequent favorable evolution. If the wound is seen to be in good condition, it will be possible to continue with the usual care.

4.7 Suture Removal

A frequent question for patients, and surgeons, is when to remove sutures.

The first thing to point out is that there is no standard recipe applicable to every case, but rather, it will be customized according to the characteristics of the injury, the quality of the tissues, and the technique used.

In general, at the ankle, they should remain in place for 10 to 14 days for young patients and up to 21 days for older patients or in case of high-risk wounds (fracture cases, limb with more edema, greater risk of dehiscence). On the dorsum, they could be removed between 7 and 10 days. On the contrary, those located on the sole should be removed deferred, especially if the patient has the authorization to support. In these circumstances we recommend not to do so, before 21 days.

A suture that remains on the wound for a long time will leave more imprints, especially marking each site where the suture passes through the skin. If a useful, aesthetically result is sought, the sutures should be removed early; however, it should never be done before ensuring that the wound will not become dehiscent. A good alternative is to make partial removals, which reduce the areas where there could be marks of the suture material in the scar but maintains adequate support. After removal, reinforce the wound with paper tape or adhesive skin suture (Steri-Strip™, 3 M).

4.8 Wound and Scar Care Management

Once the wound is closed and the stitches have been removed, it is still essential to continue with the scar's management in order to obtain the best possible result.

In this sense, there are three significant actions to develop:

- Adequate moistening, keeping the scar moisturized properly, promotes better healing and a better aesthetic result. Simply use any moisturizer to achieve this effect, to be used two to three times a day.
- Compression: It has been shown that a scar's compression improves their quality and prevents the appearance of complications such as hypertrophic scars. In case of a normal scar, it is enough to cover it with a few layers of paper tape [22, 23] that needs to be changed each 3 to 4 days.

- Of better quality is the use of the silicone sheet, which, due to its characteristics, has been demonstrated as an excellent tool for the improvement of the quality of scars [6]. It has the advantage of being self-adhesive and transparent.
- In both cases, we recommend its use for 2 to 3 months after surgery.
- Sun protection: One key point when looking for the least noticeable scar possible is to protect it adequately from the sun. During all wound healing process, the skin is much more vulnerable to the sun's damaging effects and may become hyperpigmented. We recommend the daily use of sunscreen, ideally SPF 50, reapplying to the scar, at least three times a day and ideally every 2–3 hours if are extensively exposed to the sun.

In the circumstance of presenting a pathological scar, this care should be reinforced, which will be reviewed later in this chapter.

5 Traumatic Wounds

A particular situation occurs with injuries originating after trauma. Open fractures, ulcers, and degloving are common in this body segment. Any soft tissue injury could complicate the orthopedic surgeons work and could be a risk factor for future complications.

In general terms, the treatment is similar and follows the same rules previously presented, with some necessary adaptations to remember:

- They should undergo surgical debridement, removing all necrotic tissue. If there are tissues with borderline vitality, it is appropriate to keep it until the following intervention.
- The ideal surgical incision could be located over injured areas and therefore not available, needing to adjust in an individual approach.
- Avoid using braided sutures.
- Perform advanced wound care that protects and allows damaged skin to recover.

5.1 I Cannot Close the Wound

Unfortunately, a wholly unpleasant and not uncommon circumstance occurs when the surgeon has finished performing the central actions of the surgery and proceeds to close the wound, which is not possible or has to do it with extreme tension or with injured tissues.

Faced with this situation, we recommend three actions:

- Try closing the wound with few single total stitches, separated and away from the edges. Doing this makes possible to approximate the wound margins gener-

ously or even close it completely, avoiding future surgeries. An example is presented in Fig. 5.

- If there are not enough tissues to close, the ideal method is to try to cope the tissues as much as possible and not leave them in a relaxed position, as they will quickly retract and will be unavailable for future closures leaving a larger defect and requiring the use of other reconstructive techniques.
- Ultimately, we recommend using NPWT or iNPWT, which helps to improve the condition of the tissues, and in a future intervention, try a definitive closure or request the plastic surgeon's assistance for this.

In the case of having a soft tissue deficit and especially if it involves exposure of noble structures or any hardware, the limb's reconstruction should be performed as early as possible [24]. Management in conjunction with the plastic surgeon is an excellent alternative. If this is not possible, the NPWT gives a time window to schedule the reconstruction.

A practical recommendation is always to take pictures of the injury to discuss the case with the plastic surgeon and have reconstructive options planned for the next intervention.

Fig. 5 (**a**) Due to an accident, the patient develops an eschar on the lateral aspect of the foot. (**b**) After resection, it is closed advancing skin flaps on both sides of the wound that are sutured in a single plane with simple interrupted stitches. If a complete closure is not achieved, at least the skin edges are approximated, preventing their retraction

6 Wound Dehiscence

6.1 Definition and Classification

Wound dehiscence corresponds to the partial or total disruption or opening of a previously closed wound. A complication, with an incidence in the foot and ankle surgery difficult to estimate, both due to a lack of consensus in defining dehiscence and because of communications that use slightly broader expressions such as *problems of the wound*. Considering these factors, reports show an overall incidence of 4–6% [25], between 8.6% and 16.5% in fractures [18] up to values as high as 28% in ankle arthroplasty [26].

To standardize concepts in 2018, the World Union of Wound Healing Societies generates a consensus that defines dehiscence as the separation of the margins of a closed surgical incision that involves the skin with or without exposure or protrusion of underlying tissue, organs, or implants. It can occur at single or multiple regions or involve the entire length of the incision and one or all tissue layers [27]. In the same consensus, they adapt the Sandy Grading System for Surgical Wound Dehiscence Classification [28], generating a new classification that allows an efficient systematization and the treatment options suggested, which graduates surgical wound dehiscences into four levels according to the depth of affected tissues:

- Grade 1: Epidermis only.
- Grade 2: Exposed subcutaneous tissue.
- Grade 3: Exposed subcutaneous tissue and fascia.
- Grade 4: With exposure of organs, viscera, bones, or implants.
- A: In addition to each of these degrees, add the presence or absence of signs and symptoms of wound infection.

6.2 Risk Factors

There are several risk factors for the occurrence of operative wound dehiscence. These factors can be:

- Related to the patient and modifiable: Obesity considering that the higher the BMI, the greater the risk, malnutrition, especially protein deficit, anemia, diabetes mellitus, smoking, and alcohol consumption.
- Related to the patient and difficulty or non-modifiable: Age over 65 years, emergency surgery, and other comorbidities such as cancer, liver failure, kidney failure, use of steroids, and prior irradiation.
- Intraoperative: Prolonged duration of surgery, perioperative hypothermia, inadequate closure technique, non-obliteration of dead spaces, tension closure, and wide dissections.
- Postoperative: Wound infection, premature removal of sutures, edema, failure to rest, and other complications such as hematomas and seromas.

Managing these risk factors is essential to avoid complications. Optimizing the patient's global state prior to elective surgery, especially by stopping tobacco consumption 1 month prior, making nutritional corrections, and maintaining controlled comorbidities are unavoidable actions.

Similarly, after surgery, adequate care must be provided, generating a good follow-up plan, especially in patients undergoing outpatient surgeries, reinforcing the importance of complying with indications such as rest and wound care.

6.3 Treatment

If despite taking all possible safeguards a dehiscence occurs, which unfortunately is not unusual in ankle and foot surgery, an adequate treatment can help resolve it successfully.

Its management will depend on the extension and mainly on the depth of this and the presence or not of wound infection.

We will systematize its management in the following aspects:

6.3.1 Prevention

Already stated in the risk factors section, we cannot fail to reinforce these measures, which are by far the most important.

In addition to stopping tobacco consumption, optimizing nutritional status, and compensating for any chronic disease, there are some specific actions to be carried out by the medical team:

- Closure technique appropriate to the type of surgery and patient's characteristic. It is important to remember the closure by layers and avoid prolonged surgeries [29].
- Wound dressings: keep the wound closed, with dressings that maintain a controlled moist environment. In the case of traumatic wounds, they should also allow adequate recovery of the epidermis.
- Do not remove the dressing in the first 48 to 72 hours, at which time a re-epidermization should have already occurred, thus reducing the risk of wound infection.
- Use of iNPWT: its use on closed wounds is gradually gaining more acceptance; the cause has been shown to reduce the risk of infection and complications, like dehiscences. Its use is recommended in wounds or patients at high risk for dehiscence [18] [16].
- Prevention of edema: during the postoperative period through compression bandages [7] and the limb's elevation.
- Rest/immobilization: reinforcing the previous point, it is necessary to maintain rest and eventually use immobilizers to avoid excessive movements subjecting the wound to excessive stress.

6.3.2 Infection

In the case of wounds with local signs of infection, limited to the wound, the main treatment tool corresponds to advanced dressings adapted to each wound's needs. The use of topical antimicrobial and antibiotic dressings for a limited period should also be added [27].

In the case of systemic signs of infection or local signs that extend beyond the wound's limits, systemic antibiotic therapy is indicated.

Antibiotic therapy should be adjusted to the local epidemiological reality and, if possible, guided by cultures, ideally of tissues, since those with superficial exudate usually show cutaneous flora and do not represent accurately soft tissue infection status.

6.3.3 Superficial Dehiscence

Superficial dehiscences, grades 1 and 2, that is, that exposes even the subcutaneous tissue, can be effectively treated with advanced dressings.

In most cases, products will be used to control the exudate and debride while there are detritus and then continue with another dressing type that allows better granulatory tissue growth.

In early dehiscence, generally linked to an inadequate closure technique, a primary delayed closure can be performed, as in totally clean wounds without other associated complications. In all other circumstances, which covers most cases, a closure by secondary intention is chosen.

6.3.4 Deep Dehiscence

For dehiscences of grades 3 and 4, that is, with exposure of fascia and other elements such as viscera, bones, and implants, in addition to what is exposed for those more superficial parts, management is usually more aggressive and involves surgeries. Surgical toilets will be performed, removing all the devitalized tissue present. The ideal situation in these circumstances is, when the wound is clean and without other complications, to try a new closure by re-advancing the skin flaps and applying iNPWT.

In wounds that cannot be closed, an attempt should be made to advance the flaps and approximate the tissues as much as possible to avoid their retraction. In a second intervention, they can be re-advanced again and eventually achieve closure.

We strongly recommend using NPWT as bridging therapy in these circumstances, especially in dehiscences of great extension and with abundant exudate. If bone or tendons are exposed, hydrophilic foam, VAC Whitefoam™ Dressing (KCI, San Antonio, Texas, USA), should be used to prevent drying out (Fig. 6).

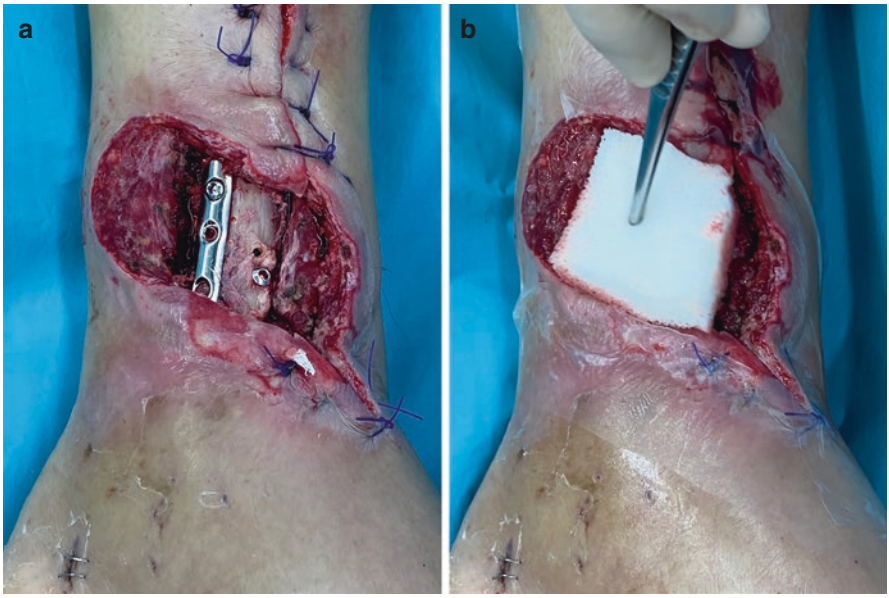

Fig. 6 (**a**) A traumatic injury with exposure of bone and osteosynthesis hardware is appreciated. (**b**) If it is not possible to close the wound, to avoid desiccation of the bone, a hydrophilic foam (VAC Whitefoam™) is used together with a traditional VAC

In the case of contaminated wounds, between any toilets, it is advisable to use NPWT with irrigation (VAC VERAFLO™ Therapy, KCI), which will help to clean the wound and promote the development of granulatory tissue [30].

Finally, in these cases, it is possible to continue treating with wound dressings or NPWT until a closure by second intention is achieved or when local conditions allow performing a closure by the third intention. If there are no tissues available to close the wound after extensive dehiscence, it will be necessary to work together with the plastic surgeon who will eventually require the use of grafts or flaps for definitive treatment [31].

7 When to Consult the Plastic Surgeon

By far, most of the wounds can be managed entirely and successfully by any orthopedic surgeon, being quite unlikely to need a reconstructive specialist for their management. Nonetheless, this may be necessary, especially in foot and ankle injuries due to the anatomical characteristics and frequently high-energy trauma.

A wound that does not close and has tendon, bone, or implants exposure can be a disaster if it is not promptly well managed.

Although the orthopedist can successfully execute the first steps, it is very likely that they will require a reconstructive plastic surgeon's support for the correct treatment. In these cases, we recommend that the consultation be as early as possible. Depending on the characteristics of each hospital, it can be immediately during the surgery. If this is not possible, a photograph will always be an excellent bridge to discuss the case with the plastic surgeon and plan actions to follow.

We highly recommended consulting the plastic surgeon in the following circumstances:

- Wide and deep dehiscences.
- Infected wounds.
- Traumatized surrounding tissues with signs of poor irrigation.
- Wounds with tendon, neurovascular structures, bone, or osteosynthesis materials exposure.
- Patients with a clear history of previous hypertrophic or keloid scars.

Working together to plan a reconstructive option, basically, grafts or flaps will give the best result for patients, minimizing the occurrence of significant complications such as osteomyelitis and its consequences.

8 Pathological Scar

Despite all care taken to manage wounds, some scars do not evolve favorably. Beyond a bad aesthetic result, which can generate high psychosocial stress in the patient, some scars transform into a new pathology, specifically hypertrophic and keloid scars.

8.1 Hypertrophic and Keloid Scars

One of the most feared problems is when a scar evolves into a hypertrophic one or, worse yet, to a keloid. Both carry a series of problems not only from an aesthetic point of view, but they can also be symptomatic.

Traditionally, both types of scars have been considered as distinct entities characterized by generating an excessive amount of scar. Hypertrophic scars are limited to the original margins of the wound, unlike keloids that grow beyond the limits of the initial wound; they also possess a genetic factor involved and can be symptomatic, mainly due to the pain and itching and, unfortunately, of very complex treatment. An example of a scar with both a hypertrophic segment and also a keloid part could be appreciated in Fig. 7.

In recent years, however, there is a tendency to consider both types of scars as a continuum on the same spectrum, in which the initial state would correspond to the

Fig. 7 A lateral foot surgical incision develops an excessive pathological scar of both types. (**a**) A hypertrophic scar respecting the original scar boundaries. (**b**) A keloid growing outside the borders of the original scar

hypertrophic scar and its most severe level to the keloid [32]. All this is based on physiopathological appraisals and histological findings.

Although there is still no complete understanding of these conditions, there are related factors, mainly the tension over the wound. Indeed, those sutured under tension or in areas of great mobility where the tissues are exposed to forces have a greater risk of progressing to hypertrophy in different degrees.

The treatment of these pathologies has several modalities. None of them are 100% effective. Among these, we can mention the infiltration with corticosteroids infiltration compression, use of silicone sheets, cryotherapy, and laser, among others, to reach the most effective keloid treatment that corresponds to the resection followed by radiotherapy. All of these generally have discrete results, with high recurrence rates, with radiotherapy being the most successful alternative in avoiding keloid recurrence, with success rates close to 90%.

8.2 Prevention

For the ankle and foot specialist, perhaps the most relevant action is prevention and, if one develops, its prompt referral to plastic surgery for definitive management. The prevention actions will be grouped into two areas: patient with no history and patient with a previous history.

8.2.1 Patient with No Previous History of Pathological Scars

This situation could occur in any patient and any scar; however, some risk factors such as wounds closed at high tension, in highly traumatized tissues, or with a slow healing process should make us suspect the appearance of problematic scars. In these cases, we recommend being very strict in the care of scars, with the elements

already exposed, namely, adequate lubrication of the skin and the fundamental compression of the scar with paper tape or silicone sheet [33].

If the problem is already established and a hypertrophic or keloid scar begins developing, the ideal step is to address it promptly, so it is essential to warn the patient to consult immediately if they notice that the scar begins to grow abnormally.

If a scar is evidently hypertrophic, it should be immediately compressed, ideally with a silicone sheet. After this, we believe the best course of action would be referring the patient to a specialist, generally plastic surgeons or dermatologists, to establish the appropriate treatment and perform a follow-up.

8.2.2 Patient with a Personal History of Hypertrophic/Keloid Scars

Although the ankle and foot are not among the most common areas of the body for the development of this type of scar, if a patient has already developed them elsewhere, especially a keloid previous history, they are at high risk of producing another keloid if they suffer any additional skin injuries.

For patients with hypertrophic scars, we recommend closing the wound, handling the tissues with care, avoiding over-trauma, achieving a tension-free closure, and immediately starting compression with a silicone sheet. If in the healing process it begins to hypertrophy, promptly refer to a plastic surgeon.

In terms of patients with keloids, extreme precautions must be taken. Even if it sounds like a truism, the first action is to warn the patient about the risk of developing a new keloid, owing to the way they cicatrize and mostly independent of the suture technique used.

At the time of surgery, we recommended using sutures that react as little as possible and that generate the minimum inflammatory effect on the wound. In this sense, an excellent option is to use nylon to close deep planes, although it is non-absorbable, since it avoids producing a reaction with tissues. It could be colorless for more superficial planes. For the final closure of the skin, ideally perform intradermal sutures avoiding multiple passes of the needle through the epidermis and dermis, as would occur with simple stitches or staples, since in each of these points a wound is produced with the risk of evolving into a keloid. Again, it is important to compress the wound initially with paper tape and, after removing the sutures, start using silicone.

All of the above can be accompanied by even more aggressive actions like infiltration of corticosteroids, generally triamcinolone, into the wound at the time of closure or the early use of tapes impregnated with corticosteroids [34] to avoid the appearance of a keloid; however, we recommend that under these circumstances refer the patient previously to the plastic surgeon, for a joint treatment planning. Once again, teamwork can deliver the best solutions for the patient.

9 Summary

The human being's ability to stand lies mainly on the foot and ankle, so on a daily basis, this body segment is overstressed and vulnerable to trauma. However, its anatomical characteristics leave it relatively unprotected. The skin at the ankle is very thin and bones and tendons can be easily exposed in any high-energy trauma or also in case of complications from elective surgery. Thus, correctly managing skin injuries is a skill to be developed by the foot and ankle surgeon.

The treatment of these wounds requires careful handling of the skin, making sutures by layers and posteriorly with adequate wound healing dressings, in which the use of negative pressure wound therapy plays an increasingly relevant role. The early recognition of complications such as dehiscences is essential to treat them successfully.

In the case of complex wounds and skin coverage deficits, working together with the plastic surgeon is essential.

If, despite everything, the patient develops hypertrophic or keloid scars, nowadays, there are a series of treatments that allow them to be treated with good results.

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