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Chronic osteomyelitis. Bases of surgical treatment

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Abstract: Chronic osteomyelitis is a progressive inflammatory process of the bone and surrounding soft tissues that mainly affects the tibia and is related to infection by *Staphylococcus Aureus.* Its management is complex and requires early diagnosis, proper staging and radical treatment, which will be based on 5 basic principles: remove infected tissue, identify the pathogen through samples of infected tissue, cover the remaining dead space, treat infection, either locally or systemically, and repair bone and soft tissue. There are many treatments proposed to carry out these principles, and the choice falls on the specialist based on his experience and the patient's commitment. Despite this, therapeutic success , and therefore prognosis, is clearly related to adherence to these five principles.

Keywords: chronic osteomyelitis; treatment; Cierny-Mader; dead space; reconstruction; injer- cough.

1. Introduction

Chronic osteomyelitis is a progressive inflammatory process, mediated by pathogens, that affects the bone, although it can also spread to the bone marrow, periosteum, and surrounding soft tissues, resulting in bone destruction and sequestrum formation (bone necrotic dead) and fistulous tracts [1,2]. The fundamental difference with acute osteomyelitis resides in the presence of necrosis and not in the pathochrony of the disease [3].

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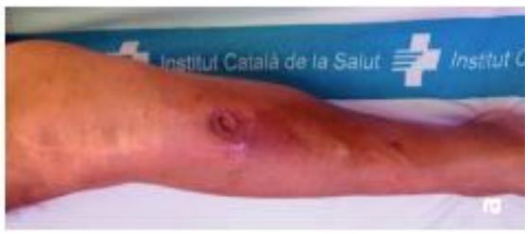
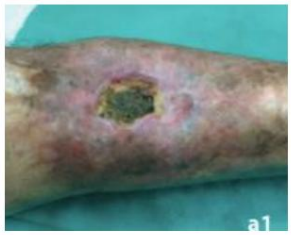
This entity, which most frequently affects the tibia [4], may be due to poorly treated acute osteomyelitis, but fundamentally it has a traumatic origin, mainly due to open fractures [1,3,4,5], although it also the role of post-surgical infection is noteworthy . There is a clear etiological predominance of gram positive cocci , the main agent being *Staphylococcus Aureus* [6], although agents such as *Staphylococcus epidermidis* can also be found within the family of gram positive cocci , or *Pseudomonas aeruginosa, Serratia marcensens, Escherichia coli* or fungi, the latter especially in immunocompromised patients [2,6]. These are capable of infecting injured bone and remaining attached to it through the formation of biofilms, quiescent bacterial structures and extremely resistant to systemic treatments, or remaining latent inside osteocytes, such as *S. Aureus* [1].

Chronic osteomyelitis presents not very specific clinical characteristics, which makes it difficult to recognize. It can present as a recurrent disease or

intermittent and its forms of manifestation are multiple (images 1 and 2), such as 40 alterations in the consolidation in the fractured bone, that is, delays in the 41 Infected consolidation or pseudarthrosis; chronic pain, ulcers and fistulous tracts, 42 general malaise, swelling or bone tenderness. 43





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Images 1 and 2. Macroscopic aspect of chronic ulcerated osteomyelitis. [3]

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Being an extremely difficult disease to recognize, it is essential in the 47 first place to know about it, and then to establish an early diagnosis 48 and aggressive treatment, in order to improve the patient's 49 vital and functional prognosis [1]. To do this, given clinical suspicion, we must use all available resources , 50 fundamentally simple radiography, computed tomography (CT) and 51 magnetic resonance imaging (MRI) as imaging tests, blood tests with 52 inflammatory markers such as sedimentation rate cell count (ESR), 53 C-reactive protein (CRP) and leukocytosis, and taking intraoperative cultures, the gold standard in the 54 diagnosis of chronic osteomyelitis [6].

55

56

Despite advances in surgery, the treatment of chronic osteomyelitis is still 57 challenging and complex [2,4,7,8], requiring multiple surgical interventions and 58 prolonged periods of antibiotic therapy. Furthermore, once treated, the incidence of relapse 59 after apparently successful treatment remains high [1]. 60

2. Classification of chronic osteomyelitis 61

A classification is useful when it allows us to design an adequate therapeutic strategy 62 and offers us an approximation to the prognosis of the disease under study [3]. 63 Based on these principles, the Cierny-Mader classification [9] was born in 1985 and remains the most 64 classification system used today, which combines anatomical and physiological 65 items to define 12 clinical stages (Table 1) and be able to define a 66 treatment according to the stage. 67

68

		functional class		
		TO	B.	**C.**
anatomical type	I (Intramedullary)	AI	IB	CI
	II (Superficial)	IIA	IIB	IIC
	III (Located)	IIIA	IIIB	IIIC
	IV (Diffuse)	VAT	BVI	CVI

Table 1: Cierny-Mader classification [9]. Depending on the functional class and the anatomical type 69 we can define 12 clinical stages. In addition, in functional class B we must distinguish if the 70

involvement is localized (Bl), systemic (Bs) or mixed (Bsl), which increases the number of stages to 71
24. 72

The anatomical types define bone involvement and are divided into four based on 73 the depth of bone involvement (Image 3). Type I (Image 4) affects the bone marrow 74 (for this reason called intramedullary osteomyelitis) and the primary lesion is endosteal. Type 75 II (Image 5) affects the surface of the bone (for this reason called superficial osteomyelitis) and 76 is mainly due to a lesion due to contiguity, in which an alteration of the 77 soft parts exposes the bone and it ends up becoming infected. . Type III (Image 6) is known 78 as localized osteomyelitis and its fundamental characteristic is the presence of a 79 full-thickness cortical sequestration, but that does not affect bone stability. Finally, type IV 80 (Image 7) is a diffuse osteomyelitis, and as its name suggests, it affects the entire 81 bone and adjacent soft tissues, and this, unlike its previous type, does affect 82 stability of the bone, either intrinsically (for example, due to a septic nonunion 83) or due to debridement performed to eradicate infection. 84

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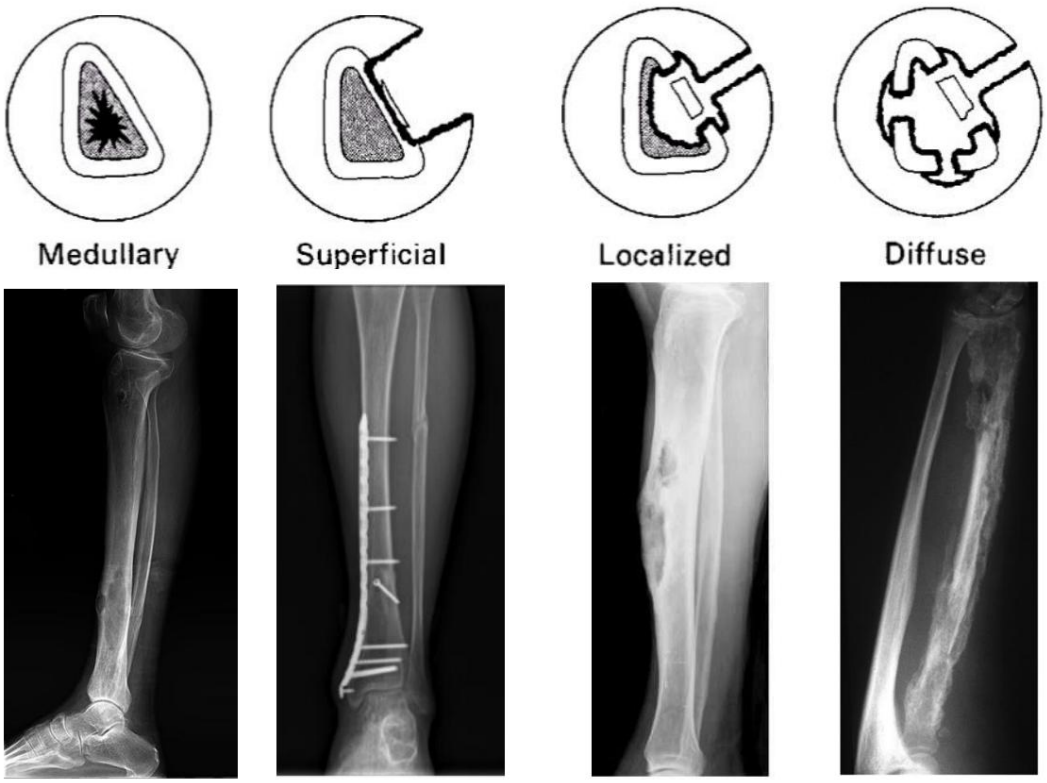

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Images 3-7. Cierny-Mader anatomical types. Above is the anatomical classification (figure 3), from left to right, from smallest to largest. Correlation between the anatomical and radiological image (images 3-7). [7,8,9,10,11] 87 88 89

On the other hand, the physiological classes define the type of patient and will inform us about the ability of the patient's immune system to fight infection. Thus, 91 we define 3 states. Class A refers to a patient with a normal physiological response 92 and a correct state of the soft tissues; class B refers to a compromised patient , either systemically (Bs), localized (Bl) or combined (Bls); 94

finally, class C refers to those patients in whom the treatment or the result of the treatment turns out to be worse for him than the disease itself. This class C represents 96 a clear limitation of this classification, since assuming that the treatment is worse than 97 the disease implies a high degree of subjectivity [3]. To define the physiological classes 98 we base ourselves on some items represented in Table 2. 99

100

Systemic status (S)	Local Status (L)
protein malnutrition	chronic lymphedema
Chronic renal failure	Burns
Alcoholism	venous stasis
Immunodeficiency	Chronic arterial disease
chronic hypoxia	unstable skin
Malignant neoplasm	Multiple previous incisions
Mellitus diabetes	radiodermatitis
Advanced age	
Chronic corticosteroid therapy	
smoking	

Table 2. Adapted from [9]. Set of items that make us classify the functional class of patient 101 with chronic osteomyelitis. If it presents any of these, it will be classified as Bl or Bs, or Bsl if it combines 102 items from both functional classes. 103

3. Treatment 104

The cornerstone of chronic osteomyelitis treatment is surgical management 105 [1]. The treatment will seek to prevent the progression of the infection, control the damage 106 caused and repair it [12] through the use of five basic principles [2,3]: (1) management 107 of the infected tissue, (2) identification of the pathogen, (3) dead space management and 108 local anti-infective treatment, (4) systemic and targeted antibiotic treatment and (5) 109 bone and soft tissue reconstruction. Following these principles practically 110 ensures the success of the treatment, with recovery rates of at least 80% [2].

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112

Despite the fact that the principles of chronic osteomyelitis treatment are clearly established , 113 identifying the most beneficial treatment method for 114 patients is really challenging [2], due to the large number of therapeutic options 115 and the similar results among them. [2]. The choice of treatment is also 116 complicated by the difficulty in comparing techniques in the research setting 117 due to the lack of an internationally accepted definition, which means that the 118 evidence is not entirely conclusive [3].

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3.1. Management of infected tissue 120

The basis of this principle will be the removal of infected tissue, the removal of 121 exogenous materials such as prosthesis and osteosynthesis material, and irrigation. 122

123

Removing infected tissue is the fundamental pillar of chronic osteomyelitis 124 treatment , and the quality of this is a prognostic factor in therapeutic success [1, 125 3], since it will eliminate the bacterial biofilm and allow defenses and antibiotics 126

systemic access to the focus of infection [2]. However, despite being an unquestionable step 127 , it is incapable of resolving the infection by itself [4]. Likewise, we must 128 consider that in patients with functional type C, any type of surgery would be 129 contraindicated, and should be sustained only with systemic antibiotic therapy, with 130 expectations of poor resolution. 131

132

Within the techniques to remove infected tissue, we must distinguish according to the depth of the defect. If the defect exclusively affects the bone marrow (type I of 134 Cierny-Mader), we can resort to conventional drilling of the endomedullary canal and 135 intramedullary reaming, using the RIA or *Reamer-Irrigator-Aspirator technique;* while 136 if it affects beyond, we must resort to a conventional debridement, which 137 it will depend on the degree of involvement and should be radical and atraumatic [9, 13], not limited 138 by concern for the bone defect [1] and include all necrotic bone and ischemic soft tissues 139 but not bone involvement [13], since this is reactive bone and therefore healthy. In addition to considering the depth of the defect, we must consider the 141 presence of osteosynthesis or prosthetic material, which must always be removed. 142

143

Specifically, regarding intramedullary osteomyelitis, currently the *gold* 144 *standard* for intramedullary debridement continues to be conventional reaming of the 145 intramedullary cavity [14]. However, this technique presents notable drawbacks 146 [14], which propose reaming using the RIA technique (images 8 and 9) as a more than viable 147 alternative, in which, by means of simultaneous reaming, irrigating and aspiration 148 of the intramedullary cavity, debridement can be accomplished more effectively 149 but with fewer risks [14,15]. The main advantages and 150 disadvantages are presented in Table 3. 151

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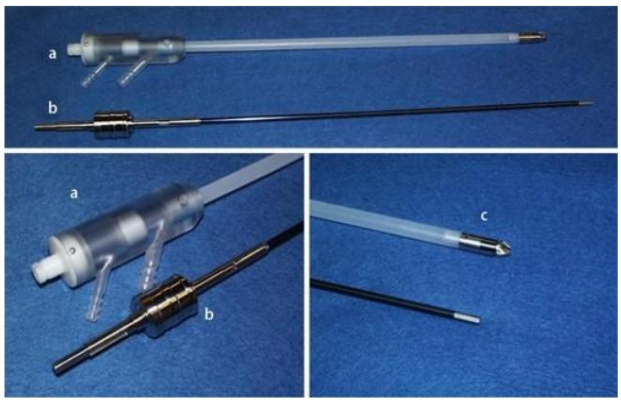

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Images 8 and 9 [15]. RIA system. In image 8 we can see the components of the system: drill head 155 (c), transmission shaft (b) and piping system (a); while in image 9 how 156 the system is introduced into the medullary cavity through the greater trochanter in a minimally 157 invasive way . 158

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	Advantages	Drawbacks
milling conventional		Need for diaphysis fenestration to drain irrigation fluids thermal necrosis Improper extraction of the content of the infected cavity Local and hematogenous iatrogenic spread
RIA reaming	Less traumatic and less complicated local tions Reduces intravasation of bone marrow components Drainage of irrigation fluids Prevents thermal damage by cooling without chronically medullary cavity and cor teat Possibility to extract the content medullary	Novelty Possibility to limit tor stability sional of the bone

163

Table 3. Advantages and disadvantages of medullary reaming and reaming using the *RIA technique.* 164 Both have the advantage of cleaning intramedullary infection and being minimally invasive , 165 while they have the risk of fracture and bleeding as drawbacks 166

3.2. Pathogen identification 167

When it comes to correctly diagnosing chronic osteomyelitis, the *gold standard* is the 168 culture of intraoperative samples [3]. For this reason, after the elimination of the infected bone tissue 169 and the removal, if any, of the prosthetic or osteosynthesis material, it is 170 essential to send samples to the laboratory of the remains of bone or material, of the 171 fistulous tract and of the surrounding tissues in order to determine the causative agent and 172 thus direct systemic antibiotic treatment, as well as rule out malignant changes [1]. 173

174

However, the presence of negative cultures does not rule out an infection, since, 175 as it could occur in a malignant disease, the infection may not be 176 homogeneous and may occur in the areas where we have not taken the 177 cultures . . For this reason, and to increase the profitability of the samples, it is essential to take the 178 correct intraoperative samples and the proper management of antibiotic therapy prior to 179 identification. When taking the samples, they should be multiple, 180 ideally six, deep, and include membranes or bone fragments with a necrotic 181 appearance [3,6]; if it includes infected osteosynthesis or prosthetic material, once removed, 182 it should be sent to the microbiology laboratory and processed by sonication and 183 subsequent culture, as well as taking cultures of samples from periprosthetic areas that are 184 macroscopically infected [6]. On the other hand, regarding antibiotic management, 185

Ideally, antibiotic treatment should be withdrawn up to three weeks before the 186

surgical procedure, and delay the administration of prophylaxis until the collection of 187 samples [3,6]. 188

3.3. Management of dead space and local anti-infective treatment

After the removal of the infected tissue, it is possible that we leave a bone defect: the dead space. This space will fill with blood, forming a hematoma that will eventually be replaced by avascular tissue [3,9] . The presence of avascular tissue is disastrous for treatment, since, being excluded from circulation, neither the immune defenses nor the systemic antibiotic have access, so that it can act as a perfect culture broth for the infection to perpetuate. [1,3], resulting in our first treatment completely useless. For this reason, this space needs proper management that allows to eradicate the infection, prevent new bacterial growth on the surface of the implant and, finally, bone regeneration [1,8].

Dead space can be handled in numerous ways, and there is no consensus as to which is best [4]. For this reason, we will make a distinction based on the number of interventions that need to be carried out to conclude the treatment, so that we find those techniques that require two times and those that require only one time. Despite the differences in management and times, both classes present a similar effectiveness [4]. In the same way, both seek to reduce this dead space and achieve the highest doses of antibiotic possible in the focus of infection, even exceeding the doses achievable through systemic administration, such as intravenous or oral route [3], further reducing systemic toxicity

derived from such high doses.

Currently, the most widely used treatment protocol is two-stage surgery, especially using polymethyl methacrylate (PMMA) cement spacers loaded with high-dose local antibiotics [16]. However, PMMA cement spheres also impregnated with antibiotics are also alternatives to the use of these spacers. Despite the fact that it is the most widely used treatment protocol, it does not stop presenting significant drawbacks [3,4,8,16], such as the difficulty in determining the time of antibiotic release, the creation of resistance to the antibiotic if it is maintained for too long due to the genesis of a bacterial biofilm and the appearance of sub-therapeutic levels, and the comorbidity derived from the second intervention, both due to the same and the difficulties derived from the removal of the PMMA cement, which can remain attached by the formation of granulation tissue around it.

On the other hand, surgeries that require only one procedure constitute both the present and the future of the surgical treatment of chronic osteomyelitis. There are many interests that accompany this type of technique, but, above all, the lower morbidity derived from a second intervention stands out. However, experience with this type of technique is less, therefore, even with similar effectiveness, it is still not the *gold standard* for dead space management surgery.

Among these techniques, we find those that use biological elements and 230 those that use non-biological elements [4]. Among those that use 231 biological elements, the use of muscle flaps and bone allografts loaded with 232 antibiotics stand out, which also allow the reconstruction of the surrounding soft tissues. On the 233 other hand, among those that use non-biological elements, also called 234 bone substitutes, we find antibiotic-impregnated calcium bone substitutes (image 10) 235 and bioactive glass.

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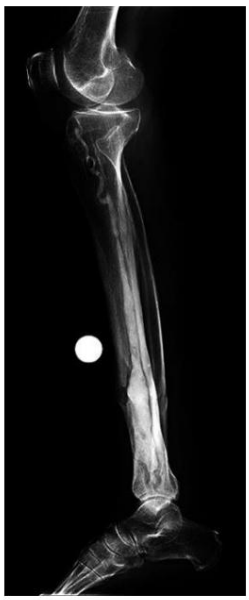

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Image 10. We found a medullary cavity covered with calcium sulfate two weeks after its 238 insertion, observing a slight reabsorption [7]. 239

Regarding bone substitutes, these are used to cover the surface of 240 implants due to their antimicrobial, osteoinductive and osteoconductive properties 241 [8], and have the advantage of being biodegradable [16], that is, they are resorbed *in situ,* therefore, 242 do not need a second extraction surgery as was the case with the spacers and the 243 PMMA cement spheres. Each of them works through different mechanisms: 244

On the one hand, in calcium bone substitutes, calcium sulfate being the most widely used, 245 the antimicrobial properties are conferred by the antibiotic impregnated with them [16] 246 and the osteoinductive and osteoconductive properties are conferred by the ability to 247 transform into hydroxyapatite, component of the inorganic matrix of normal bone [10]; 248 while in the case of bioglasses, the most notable being BAG S53P4 bioglass, 249 the antimicrobial properties are due to the alkalinization of the medium by contact with 250 the patient's body fluids and the increase in osmotic pressure in the medium by the 251 release of ions by the bioglass, on the one hand imposing an inviable 252 environment for bacterial growth and, on the other hand, the lysis by osmotic overload of the 253 infecting microorganisms [4,16], while the osteoinductive and 254 osteogenic properties are due to the release of more ions by contact with body fluids, 255 which will promote specific genes in osteogenic cells, favoring bone recruitment 256 and remodeling, and, like calcium bone substitutes, the formation of a natural hydroxyapatitite membrane 257 which promotes fixation and osteoinduction [16]. 258

Regarding cement spacers, in addition to lower morbidity due to the absence of a second surgery, they present a predictable elution profile. However, calcium bone substitutes, despite being resorbed in a short time, generally in 6 weeks, do not provide adequate structural support due to rapid hydrolysis [10]; In addition, do not solve the problem of resistance to antibiotics. These problems could be solved with bioglass, which, thanks to its slow reabsorption, does provide adequate structural support, and, in addition, can eradicate even highly resistant microorganisms such as methicillin-resistant *S. aureus* (MRSA) [16]. In fact, Ortega et al in 2022 observed an eradication of osteomyelitis in 80% of patients, after 43-month follow-up, with a complication rate of 27%, and without exacerbations of infection after placement of bioglass. [16]

The advantages and disadvantages of different dead space management techniques they are discussed in Table 4 [1].

Title 1	Advantages	Drawbacks
PMMA	*gold standard* Slow release of high concentrates tions of antibiotics, with minors systemic effects easy to mix	Two times, with difficulty to withdraw Antibiotic Resistance Risk
bone substitutes	Biodegradable (1 time) Osteoinductive, osteoconductive and antimicrobial	Depends on good soft tissue coverage
simple bone graft	Osteoinductive and osteoconductive	Limited to small defects Risk of early resorption Donor site morbidity rejection of infection
Prosthesis	Quick to restore the function No need to collect bone 1 time	Risk of infection and dislocation Need for soft tissue reconstruction surgery periodic reviews
Amputation	early mobilization One-shot surgery	

Table 4. Advantages and disadvantages of the techniques used to manage dead space. Although not discussed in the review, amputation and the use of prostheses are possible alternatives in the treatment of chronic osteomyelitis. Today they are rarely raised.

3.4. Systemic and targeted antibiotic treatment

In association with local treatment of the infection, antibiotic treatment systemic is another of the mainstays of the treatment of chronic osteomyelitis [3]. Ideally, this should be directed at the pathogen causing the infection, determined by the cultures obtained in previous steps and guided by antibiotic therapy, as well as in a multidisciplinary way with specialists in infectious diseases in the musculoskeletal system.

This antibiotic treatment should be started as soon as the culture samples are extracted [1], except in stable patients [17], in which it may be suspended until the microbiological diagnosis is obtained. Despite this, the duration and route of administration are still controversial to this day.

With respect to treatment, the consensus is that the duration of treatment should be prolonged, although it has been shown that there is no evidence that prolonged antibiotic treatment reduces the recurrence rate [17]. Some authors propose a treatment lasting at least 6-8 weeks, in which the bone has been covered by well-vascularized soft tissues [3,17], while others state that it is sufficient to maintain it until markers are normalized. of inflammation such as erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) [2].

On the other hand, the administration route of choice, also by consensus, is the intravenous route . However, a Cochrane review speaks of no differences between the oral route and the parenteral route, with the oral route prevailing as the most attractive option [18].

Initially, if the causative agent is unknown, treatment will be empirical with a combination of two drugs. However, if we know the causative agent, it must be directed at that microorganism and, once the results of the antibiogram are obtained, it will be de-escalated . The proposed treatments are summarized in Table 5 [17].

empirical therapy	Vancomycin + Cephalosporin 3rd-4th generation
SASM	Cefazolin, Oxacillin, Nafcillin, Fuxacillin, or Ceftriaxone
MRSA	Vancomycin, Daptomycin or Teicoplanin Alternatives: Rifampicin and Fusidic Acid
gram negative	Aminoglycosides: ciprofloxacin and levofloxacin; Cephalosporins: ceftri axone, ceftazidime, cefepime; o Carbapenems: ertapenem, meropenem

Table 5. Targeted antibiotic therapy in the treatment of chronic osteomyelitis [17]. The treatment will be intravenous, initially empirical based on suspicion and later directed according to the results of the cultures and antibiogram.

3.5. Bone and soft tissue reconstruction

Soft tissue reconstruction is another fundamental part of the treatment of chronic osteomyelitis [3]. This will make it possible to create a bunker that will isolate the debrided area from external pathogens, facilitate its revascularization and obliteration of the dead space [3]. This can be carried out in the same debridement surgery (immediate reconstruction) or delayed for a few days (delayed reconstruction).

Temporary treatment of the defect can be accomplished effectively through the use of negative pressure therapy or the *bead pouch technique,* in which using antibiotic-loaded beads the dead space is obliterated and then sealed with a *Opsite* type semipermeable membrane [19]; while definitive reconstruction may involve pedicled or not pedicled muscle and myocutaneous flaps, it should not take more than a week and should be accompanied by further debridement and removal of dead space coverage systems, if any, used in the first time [3].

On the other hand, bone reconstruction is also vital. Within the systems of bone reconstruction that we will use, in increasing order of complexity, will be: simple bone graft , induced membrane technique or Masquelet technique, Ilizarov technique and vascularized bone flaps, such as the free or pedicled fibula. To date, there is no evidence of the superiority of one technique over another [3], so the choice will fall on the preference of the surgeon. However, the use of vascularized bone flaps to treat bone defects in the upper limb and the techniques of Masquelet and Ilizarov to treat defects of the lower limb are generally preferred, using simple bone grafts in either technique, if necessary. , to reinforce the structure or fill in the dead space [9]. The advantages and disadvantages are gathered in Table 6 [3].

	Need perfect graft	Size of	Donor zone morbidity	correction of formities	Time	Bone quality	Difficulty	Evidence
autologous graft	Yeah	Little	Yeah	No	Short	high	Low	high
masquelet	Yeah	Big	Yeah	No	Intermediate	Low	Low	Intermediate
vascularized fibula	Yeah	Big	Yes (and high)	No	Intermediate	high	high	high
bone transport	No	Big	No	Yeah	Dragged on	high	high	high

Table 6. Advantages and disadvantages of bone reconstruction techniques. It should be noted that the correction of deformities is only possible with the Ilizarov bone transport, and that the techniques that achieve remodeling in large defects are the fibula bone flap, the Masquelet technique and the Ilizarov bone transport .

The technique of choice to fill in dead spaces and facilitate bone reconstruction 347 is bone marrow-derived bone grafts [12]. These can come from the same 348 patient (autologous) or from donated and frozen bone (autologous), and contain significant osteoconductive, 349 osteoinductive, and osteogenic capacity (the latter only in 350 autografts). However, due to inconveniences such as postoperative pain, clicking noises 351 when walking, gait disturbances, nerve pain, bruising, and acute rejection 352 as a consequence of infection, a recent study [17], 353 has successfully studied the autologous fat graft obtained by liposuction, which, by containing a large number of 354 mesenchymal stromal cells, is capable of differentiating into bone cells. 355

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The Masquelet induced membrane technique [20,21,22,23] (images 11 and 12) 357 is a two-stage bone reconstruction technique in which a pseudosynovial 358 membrane is formed , with osteoinductive properties and rich in vascularization and collagen, 359 as a consequence of an inflammatory reaction to the PMMA 360 cement spacer placed in the first stage. In the second stage, and by removing the cement spacer, 361 the aim is to maintain that pseudomembrane and fill it with an autologous bone graft, 362 which will end up anchoring and growing around that membrane, also reducing the 363 dead space. However, being probably the main method of treating 364 bone defects due to infection, it has its drawbacks, such as the absorption of the 365 graft, the inability to cover defects that are too large, the formation of 366 pseudo-articulations, cracking of the wound and that it may not correct the 367 discrepancies in limb length, as well as that it requires two times [21,22] 368

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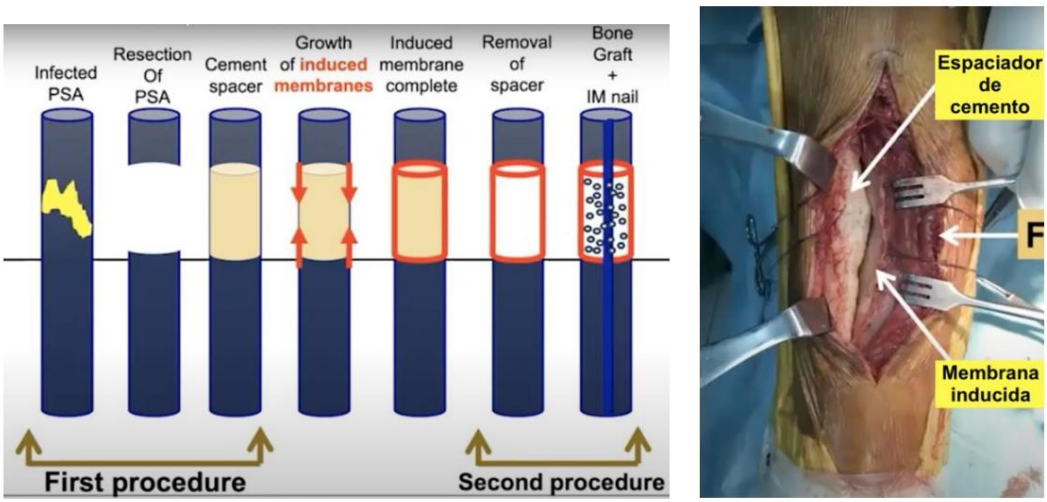

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Images 11 and 12 [23]. We observe the steps that make up this technique in image 11. A 371 highlight the macroscopic aspect of the membrane induced in a real patient, represented in 372 image 12, which at the time of intervention we must be careful not to remove it and accompany it with 373 autologous bone to stimulate osteogenesis. 374

375

On the other hand, the Ilizarov technique [22] is a minimally invasive 376 technique that, through slow and continuous traction of the bone, and based on the principle of 377 traction stress, allows osteogenesis and bone transport that allows the 378

bone lengthening, thus being ideal for repairing bone defects that 379 accompany debridement of infected bone tissue. This technique employs an annular external fixator 380 with tension wires drilled through the bone and fixed under tension 381 (image 13) whose main advantages are that the wires pierce healthy bone and therefore 382 spare the infected bone tract , therefore it does not facilitate the spread of 383 infection as other techniques would, and it can be individually assembled according to 384 treatment needs and bone characteristics, allowing the device to be adjusted 385 to the therapist's taste and correctly modulate the elongation . However, the 386 duration of treatment is usually prolonged, it is usually associated with pain due to distraction and 387 it entails great discomfort for patients, as well as other consequences such as 388 nail infections or stiffness in nearby joints due to immobility. In general, 389 interventions are used in a single stage and are accompanied by simple bone transport 390 if the defect is small, or bone grafting if the defect is larger, with the aim of 391 filling that dead space.

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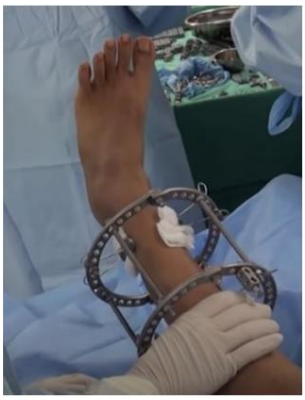

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Image 13 [24]. Ilizarov's device 394

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Maintaining the principles and results of these techniques, and mitigating their drawbacks, 396 alternatives have been postulated such as the piston technique [21], a technique that 397 combines the Masquelet membrane and the Ilizarov technique, in which the first 398 time is similar to the Masquelet technique, but in a second time, removing the 399 bone cement, an external fixator is placed like the one that accompanies the Ilizarov technique, 400 in a way that has been shown to reduce the time of external fixation and complications 401 derived from this, with similar results, as well as avoiding bone grafting. 402

403

Finally, as a bone reconstruction technique, there are 404 vascularized bone flaps [23]. Among them we highlight the fibula flap. This flap is accompanied 405 by the peroneal or anterior tibial vessels, and even by a skin flap, and allows 406 to cover defects of up to 22-26 centimeters, which is why they are very useful, as already mentioned, 407 for treating in single-time bone defects resulting from chronic 408 osteomyelitis of the upper limbs [3], although these are generally 409 in the minority. However, since they are autologous, we run the risk of non-attachment in 410 patients with peripheral vascular disease, since their vascularization will be 411 compromised [25].

412

4. Conclusions

There are many possibilities in the surgical treatment of chronic osteomyelitis. However, the resolution expectations can be improved and we await the appearance of new procedures that allow us to achieve a complete resolution and that do not show the drawbacks that current techniques present. Thus, there are many patients who, with current procedures, live with functional sequelae that greatly limit their quality of life. Therefore, it is essential to establish a common definition of the disease in order to be able to carry out standardized tests, and thus improve the results of these interventions, with the benefit of the system, but above all of the patient.

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