ORIGINAL STUDY

acta orthopaedica belgica, 2023, 89, 651-658

doi.org/10.52628/89.4.12193

# Papineau-irrigation technique: an alternative treatment of fracture-related infectious soft tissue defects

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**The original Papineau technique described satisfactory results in treating infection-related pseudarthrosis and chronic osteomyelitis with chronic draining wounds. We described our experience in treating these soft tissue defects using the Papineau-irrigation technique.**

**We retrospectively reviewed the records of patients that were treated with the Papineau-irrigation technique at UZ Leuven, Belgium, between January 2006 and January 2023. All surgical procedures were performed by one senior orthopedic surgeon. There were no exclusion criteria.**

**There was successful healing of the soft tissue defect in 27 out of 32 patients with serial drip irrigation. Additional debridement was often necessary.**

**The Papineau-irrigation technique may provide a useful alternative for treating fracture-related soft tissue defects. In addition, this technique is safe and feasible. Further comparative studies are necessary to validate its efficacy.**

**Keywords:** Papineau, drip irrigation, fracture related infection, soft tissue defect, Ilizarov.

## INTRODUCTION

Despite advances in surgical techniques and antibiotic treatment, delayed unions and non-unions are common and remain a challenge to treat accordingly. Especially infected non-unions and chronic osteomyelitis with persistent draining wounds remain difficult to treat[1-4]. In 1973, Papineau introduced open bone grafting to treat these injuries and described the three main challenges of treatment i.e. eradication of the infection, obtaining bony union, and establishing soft tissue coverage. He recommended a staged treatment consisting of radical excision of infected bone and soft tissue with repeated local debridement followed by topical rinsing with saline to promote the formation of granulation tissue. Papineau advocated the use of autogenous cancellous bone grafting to fill the bony defect[5-6]. This technique has been applied for almost five decades with satisfactory results.

The present study describes our experience with the original Papineau technique and a modified Papineau-irrigation technique for the successful treatment of infected soft tissue defects as well as wound problems due to fracture-related infections[7]. Infection control was achieved through radical debridement of infected osseous and soft tissue, skeletal stabilization using Ilizarov external fixation, and specific antibiotic treatment. We propose a local treatment consisting of serial irrigation of the soft tissue defect with saline to promote wound healing and progressive coverage of exposed bone, which can easily be managed in a patient's home setting.

Furthermore, we hypothesize this technique to be an inexpensive and effective alternative to vacuum assisted closure (VAC)-therapy or free-flap surgery.

## PATIENTS AND METHODS

We retrospectively reviewed the records of patients that received our modified Papineau-irrigation technique for treating chronic wounds resulting from fracture-related infections and infected wounds that occurred during the treatment of infected and non-infected pseudarthrosis. These patients were treated by our team and one surgeon between January 2006 and January 2023. We considered the progressive formation of granulation tissue as a favorable evolution. A fully epithelialized soft tissue defect was considered as successfully healed. There were no exclusion criteria. This study was approved by the KU Leuven Ethics Committee. We included 32 patients in this study. The Papineau-irrigation technique was used to treat all patients, including 10 females and 22 males, aged between 22 and 74 (mean age, 61 years). All patients

**Table I**. — Obtained data from patient records

| Case n° | Sex | Location | Interval | Cierny-Mader Type | Cierny-Mader Host | Cultures |
|---|---|---|---|---|---|---|
| 1 | M | Tibia/fibula | 33 | 3 | BS-BL | Proteus mirabilis, Enterococcus faecium, Bacillus cereus, Pseudomonas putida, Staphylococcus epidemidis, Enterocossus faecium |
| 2 | F | Tibia/fibula | 5 | 3 | A | Escherichia coli, Staphylococcus aureus |
| 3 | F | Tibia/fibula | 43 | 3 | BS | Staphylococcus epidemidis, Pseudomonas aruginosa, Streptococcus agalactiae |
| 4 | M | Tibia/fibula | 1 | 3 | BS-BL | Staphylococcus epidemidis, Staphylococcus aureus, Enterobacter cloacae |
| 5 | F | Proximal femur | 65 | 4 | BS-BL | Corynebacterium striatum, Staphylococcus aureus, Dermabacter hominis, Acetinomyces turicensis |
| 6 | M | Calcaneum | 84 | 3 | BS | Enterobacter cloacae |
| 7 | M | Tibia/fibula | 1 | 2 | A | Citrobacter kerosi, Staphylococcus haemolyticus |
| 8 | M | Tibia/fibula | 2 | 3 | BL | Staphylococcus aureus |
| 9 | M | Tibia/fibula | 10 | 2 | A | Escherichia coli |
| 10 | M | Tibia/fibula | 5 | 3 | BL | Escherichia coli, Enterococcus raff (fibula)/Escherichia coli (tibia) |
| 11 | M | Tibia/fibula | 5 | 3 | BL | Staphylococcus epidemidis/lugdunensis/aureus, Corynebacterium alycolatum/jeikeium |
| 12 | F | Tibia/fibula | 1 | N/A | N/A | Staphylococcus aureus |
| 13 | M | Tibia/fibula | 7 | 3 | BL | Staphylococcus aureus |
| 14 | F | Tibia/fibula | 3 | 3 | BS-BL | Staphylococcus capitis, Neisseria elongata, Peptostreptococcus anaerobius, Actinomyces turicensis |
| 15 | M | Tibia/fibula | 48 | 3 | BS-BL | Staphylococcus aureus, Streptococcus mitis, Streptococcus anginosus, Haemophylus parainfluenzae |
| 16 | F | Tibia/fibula | 2 | 3 | BS-BL | CNS Staphylococcus |
| 17 | M | Tibia/fibula | 63 | 2 | BS-BL | Streptococcus mitis, Serratia liquefaciens, Staphylococcus epidemidis |
| 18 | M | Tibia/fibula | 2 | 4 | BL | Enterobacter cloacae, Serratia liquefaciens, Bacillis species |
| 19 | M | Tibia/fibula | 144 | 2 | BL | Pseudomonas aeruginosa |
| 20 | M | Tibia/fibula | Unknow | 4 | BL | Escherichia coli, Streptococcus anginosus |
| 21 | M | Tibia/fibula | 1 | N/A | N/A | Klebsiella pneumoniae, Enterococcus caselliflavus/gallinarum, Clostridium sporogenes, Citrobacter braakii |
| 22 | M | Tibia/fibula | 1 | 4 | BS-BL | MRSA, Pseudomonas aeruginosa |
| 23 | M | Tibia/fibula | 1 | 4 | BS-BL | Enterobacter clocae, Enterococcus caselliflavus, Pseudomonas aeruginosa |
| 24 | M | Tibia/fibula | 1 | 4 | BS-BL | Enterobacter clocae, Acetinobacter baumanii, Stenotrophomonas maltofilia, Pseudomonas aeruginosa |
| 25 | F | Tibia/fibula | 18 | 4 | BS-BL | Staphylococcus aureus, Enterococcus faecalis, Escherichia coli |
| 26 | F | Tibia/fibula | 6 | N/A | N/A | Staphylococcus epidemidis, Staphylococcus capitis |
| 27 | M | Tibia/fibula | 2 | 2 | BS-BL | Staphylococcus epidemidis, Enterobacter cloacae, Staphylococcus aureus |
| 28 | M | Tibia/fibula | 2 | 3 | BS-BL | Morganella morganii, Enterobacter cloacae, Enterococcus faecalis |
| 29 | M | Tibia/fibula | 2 | 4 | BL | Enterobacter cloacae |
| 30 | M | Distal femur | 1 | 4 | BS-BL | Streptococcus oralis, Corynebacterium amycolatum, Staphylococcus aureus, Staphylococcus wamenri |
| 31 | F | Tibia/fibula | 3 | 3 | BL | Staphylococcus epidemidis, Staphylococcus aureus |
| 32 | F | Tibia/fibula | 1 | 2 | BL | Staphylococcus aureus, Pseudomonas aeruginosa |

DM, Diabetes Mellitus; Wound healing: '//' indicates simultaneous treatment of multiple wounds, '&' indicates treatment at different time.

**Table I**. — Obtained data from patient records (continuation)

| Smo-king | DM | Origial Papi-neau | Wound healing | Duration Papi-neau irrigation (months) | Union | Complication | Frequency of debridement (+ repeat Papineau) | Follow-up (months) |
|---|---|---|---|---|---|---|---|---|
| - | + | Yes | Yes | 9 | Yes | - | 0 | 9 |
| - | - | Yes | Yes | 6 | Yes | - | 0 | 15 |
| + | - | Yes | Yes | 15 | Yes | - | 1 | 15 |
| + | - | No | No//No | 20 | Yes | Persistent fibula | 1 | 35 |
| - | + | No | No | 25 | No | Persistent non union | 0 | 39 |
| + | + | No | No (Flap) | 7 | Yes | Persistent fibula | 2 | 37 |
| - | - | Yes | Yes | 5 | Yes | Open fracture GA gr2 | 0 | 28 |
| - | - | No | Yes | 15 | Yes | Persistent osteomyelitis | 2 | 15 |
| - | - | No | Yes | 3 | Yes | - | 0 | 3 |
| - | - | No | 1/Yes 2 (No (Flap) | 8//1 | Yes | No healing proximal tibia | 1 | 21 |
| - | - | No | Yes// Yes | 14 | Yes | - | 1 | 14 |
| + | - | Yes | Yes | 5 | Yes | Pin loosening | 0 | 16 |
| - | - | No | Yes// Yes | 7//3 | Yes | Pin tract infection | 0 | 22 |
| + | - | Yes & No | Yes & Yes | 5 & 3 | Yes | Recurrence wound after 11 years | 2 & 0 | 131 |
| + | - | Yes | Yes | 9 | Yes | - | 0 | 9 |
| + | - | Yes | Yes | 39 | Yes | Pin tract infection | 4 (repeat Papineau with 4th debridement) | 39 |
| + | + | Yes | Yes | 28 | Yes | Pin tract infection | 2 | 28 |
| - | - | No | Yes | 4 | Yes | - | 0 | 89 |
| - | - | No | Yes | 11 | Yes | - | 0 | 93 |
| + | - | No | No (Flap) | 2 | Yes | - | 0 | 75 |
| - | - | No | Yes | 1 | Yes | - | 2 | 71 |
| + | - | No | Yes | 3 | Yes | - | 5 | 62 |
| + | - | No | Yes// Yes | 4//9 | Yes | - | 1 | 113 |
| + | - | No | Yes | 4 | No | - | 2 | 40 |
| + | - | Yes | Yes | 39 | Yes | Stress fracture | 3 (repeat Papineau with 2nd debridement) | 106 |
| - | - | No | Yes | 5 | Yes | - | 0 | 46 |
| + | - | No | Yes | 13 | Yes | - | 0 | 18 |
| + | - | No | Yes | 5 | Yes | - | 2 | 23 |
| - | - | No | Yes// Yes | 2 | Yes | - | 0 | 74 |
| + | - | No | Yes | 9 | No | - | 0 | 16 |
| - | - | No | Yes | 9 | Yes | - | 0 | 57 |
| - | - | No | Yes | 14 | Yes | - | 3 | 14 |

had an open wound or discharging sinus, and required Ilizarov treatment for pseudarthrosis. Most patients had received multiple courses of antibiotics and several surgical procedures before being referred to our center. In seven patients, a soft tissue defect occurred during their treatment of infection-related pseudarthrosis. Six patients received Papineau-irrigation of multiple wounds simultaneously. The original Papineau bone grafting technique was performed on 10 cases. When present, the Cierny-Mader classification was used to classify the site of osteomyelitis, and the host type[8-9]. Patient history of smoking and diabetes mellitus was also recorded. In three patients, there was an infection of the wound in absence of infected bone. Nine patients had Cierny-Mader stage IV, fourteen had stage III, and five patients had stage II. Three patients were classified as Cierny-Mader type A hosts, while twenty-six patients were classified as type B hosts. Patient history of smoking during treatment was present in 16 patients. Diabetes mellitus was present in 4 patients. Bacterial cultures were positive in all patients. The time from the origin of the soft tissue defect to the start of Papineau-irrigation was questioned. Other data recorded included location of the soft tissue defect, time to complete full soft tissue coverage, presence of bony union, frequency of debridement, complications, and duration of follow-up. All obtained data was summarized in Table I.

All patients received extensive debridement of the infectious bony and soft tissues. Intraoperative cultures specimens were taken. Skeletal stabilization was achieved using an Ilizarov ring fixation, allowing concurrent treatment of the pseudarthrosis and the use of bone transport when necessary[10]. The wound bed was left open. The modified Papineau-irrigation technique consists of serial rinsing of the wound

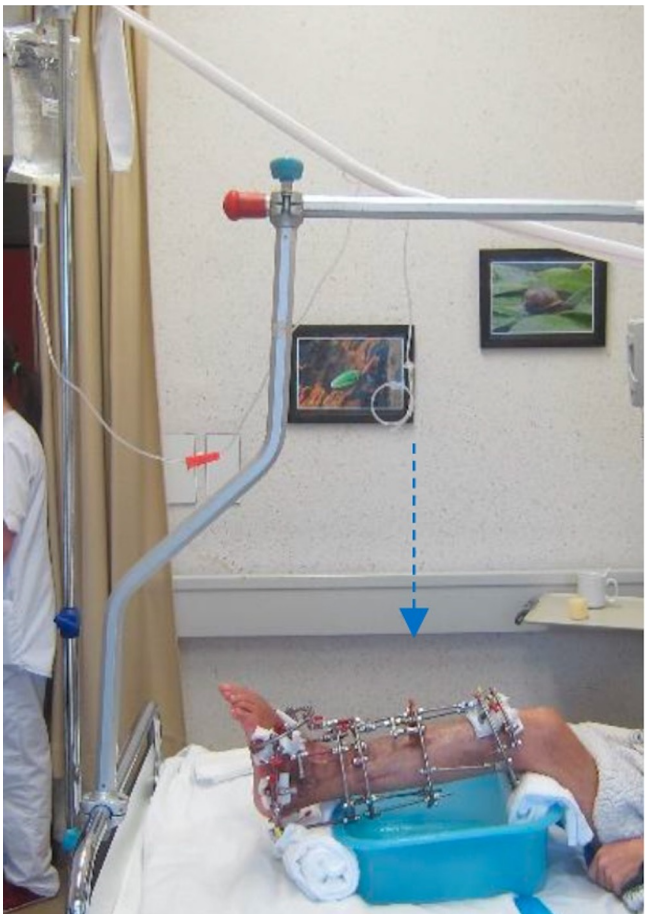

*Figure 1. — Illustration of the setup for the modified Papineau drip irrigation.*

with saline (NaCl 0.9%) fluids. To ensure thorough mechanical and therefore an antibacterial debridement, the saline drips onto the soft tissue defect from a height of approximately 60 cm, drip by drip. Once a day, one liter of saline should be used for about 45 minutes. (Figure 1) Afterwards the wound is dabbed

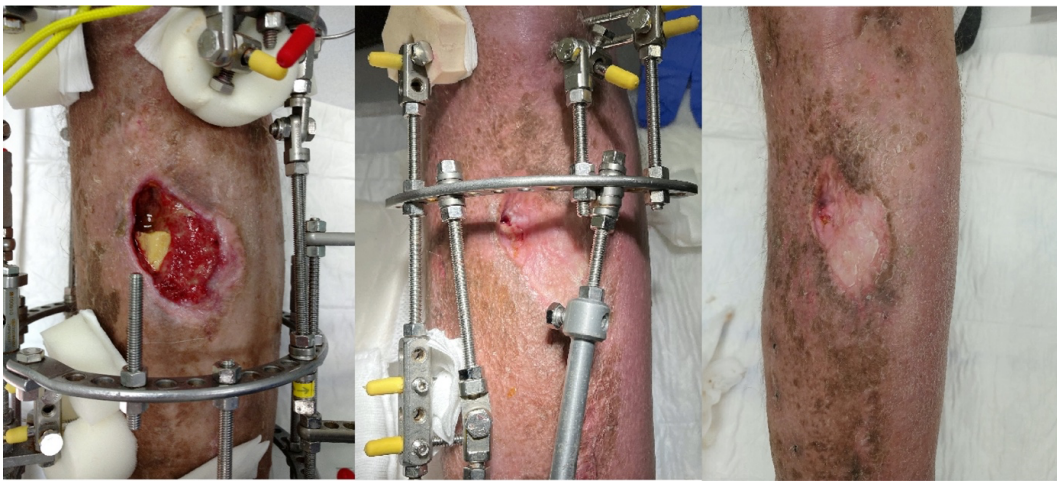

*Figure 2. — Progressive healing of a soft tissue defect at the tibia that occurred during treatment of infected non-union with Ilizarov-bone transport.*

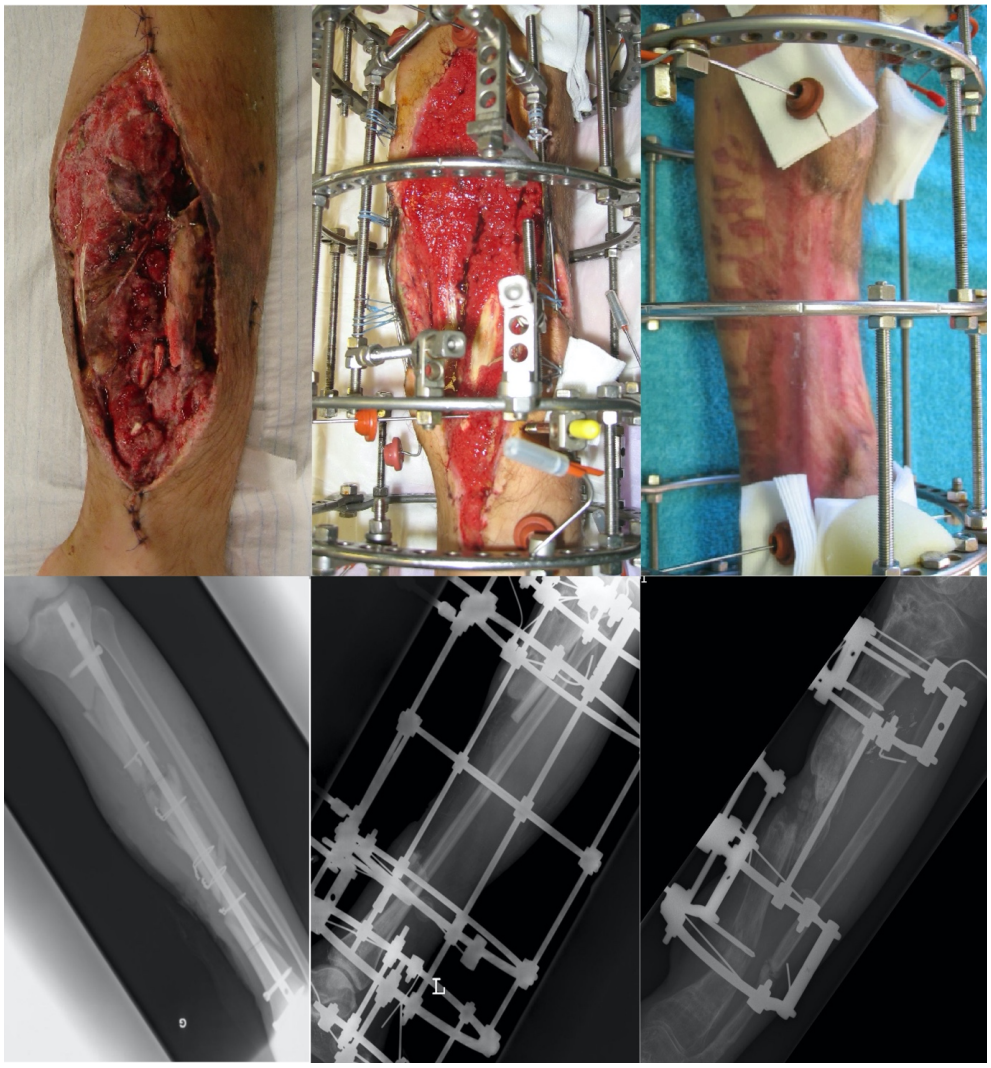

*Figure 3. — Segmental tibia fracture with a severe soft tissue defect was treated through radical debridement of the infected bone and soft tissue. An Ilizarov frame was utilized for bone transport, and during the bone transport process, the modified Papineau drip irrigation was performed.*

dry, and a fat gauze is applied as topical dressing. This process is repeated daily until the wound is fully healed, or until there is enough granulation tissue and spontaneous epithelialization, or until conditions are favorable for secondary closure or skin grafting. Moreover, this irrigation can be easily performed in a patient's home setting. A local debridement was performed when there was an unsatisfactory healing of the bony or soft tissue defect. When there was a severe bone defect, the original Papineau open bone grafting was used, and autografts were taken from the iliac crest. After obtaining intraoperative cultures, broad-spectrum antibiotics were administered and changed to an antibiotic specific to the antibiogram. Antibiotics were continued based on the evolution of C-reactive protein (CRP) levels and wound cultures. Routine follow-up was done regularly. Clinical examinations included evaluation of the wound healing. Imaging examination included radiographs to evaluate the bony union. Patients were followed up until successful soft tissue and bony healing. Two cases are illustrated in Figure 2 and 3.

## RESULTS

Twenty-seven patients experienced successful healing of the wound with Papineau-irrigation. Bony union was present in 25 of these patients. In one case who received Papineau-irrigation for multiple wounds simultaneously, there was successful healing of one wound, while the other wound persisted. This patient, along with two others received free-flap surgery due to a persistent fistula. In two patients who had previously undergone free-flap surgery, satisfactory results were

not achieved: one patient experienced recurrent wound problems and a persistent non-union with loosening of the external fixator pins, while the other had a persistent fistula. In all successful cases, there was no recurrence of infection during the follow-up period. All patients who received the original Papineau technique with osseous grafting achieved successful results of the bony and soft tissue defect. Twenty-nine patients had a soft tissue defect at the tibia or fibula. One patient had a persistent fistula at the proximal femur, another at the calcaneus, and one had a soft tissue defect of the distal femur. The mean time from the origin of the soft tissue defect to the start of Papineau-irrigation technique was 15 months (range, 1-144 months), excluding one patient where this was unknown. The mean Papineau-irrigation duration was 10 months (range, 1-39 months). The mean follow-up after starting the Papineau-irrigation technique was 44 months (range, 3-131 months). In 16 patients, one or more additional debridement was necessary. In two patients who had undergone the original Papineau technique, grafting was repeated once. One patient had a Gustilo-Anderson type 2 open fracture just after the wound had healed. The new wound was closed primarily. One case with persistent osteomyelitis received chronic suppressive antibiotics. Another patient had a recurrent wound problem nearly 11 years after earlier successful Papineau-irrigation treatment. A successful outcome was obtained after repeating the local debridement and Papineau-irrigation technique. Three patients experienced pin tract infection, and one patient experienced loosening of the pins. These issues were successfully treated with antibiotics, pin site dressing changes, and replacement of the pins, respectively. One patient had a stress fracture with wound drainage after removal of the external fixator, and a new external fixator was applied.

## DISCUSSION

The classic Papineau technique was developed to treat challenging bone defects, chronic osteomyelitis, and fracture-related infected pseudarthrosis[5]. It describes a staged treatment involving extensive debridement of bone and soft tissue, bony stabilization, appropriate antibiotics, and postoperative wet-to-dry dressing changes. Frequent moist dressing changes promote granulation tissue. Once healthy granulation tissue has formed, the bony defect was packed with osseous autograft, which has shown high success rates[5-6,11-14]. Unlike the original proposed dressing changes, we advocate a serial drip irrigation of the wound, which aims to remove cellular debris and surface pathogens contained in wound exudates. In our series, there were good results with both the original Papineau technique and serial drip irrigation. More recent literature has reported positive outcomes for patients through the combination of vacuum-assisted closure (VAC) and the Papineau technique[15-18]. Similar to VAC-therapy, we hypothesize that serial drip irrigation accelerates the growth of granulation tissue by promoting fibroblast proliferation through mechanical stress and by facilitating microcirculation within the wound. This creates an environment that minimizes the risk of infection, thus promoting growth of granulation tissue and wound healing[19-20]. Compared with VAC and free-flap surgery, the Papineau-irrigation technique does not require trained personnel or specialized technical equipment, and can be easily used in a patient's home setting[4]. It serves as an inexpensive and safe alternative that can be utilized in developed countries as well as in regions where VAC and microsurgery are not available. Furthermore, it can be applied regardless of local and systemic host factors, unlike free-flap surgery, which may have a higher incidence of complications in patients with a history of smoking or diabetes mellitus, or those with unstable soft-tissue reconstructions after the induced-membrane technique within a limited-resource setting[21-23]. We believe that extensive resection of septic, non-viable bony and soft tissue is crucial for eradicating the infection, in addition to administering culture-specific antibiotics. Revision debridements are necessary when the previous debridement is deemed insufficient. This creates an environment conducive to promoting bony union, healthy granulation tissue formation, and epithelialization. Skeletal stabilization is beneficial in the treatment of infected bone and soft tissues. By utilizing an Ilizarov external fixator, we can simultaneously address the axial, angular and translational deformities, non-unions, and bony defects[10]. The use of an Ilizarov frame has been reported to decrease the need for bone grafts and free flaps, and it is considered a less expensive alternative to other techniques[17, 24-26]. This case series demonstrates that the irrigation technique can be employed for soft tissue defects of all sizes. It also allows for the simultaneous treatment of multiple wounds and is easily applicable with the Ilizarov frame. Furthermore, this case series showcases the efficacy of our technique in salvaging challenging cases where amputation was considered as an alternative treatment. Nevertheless, the modified irrigation technique may result in delayed wound healing, which can progress slowly. We also observed increased scar formation, as described in the original Papineau technique. It is worth noting that the traditional Papineau technique has been associated with a relatively high nosocomial infection rate[18]. However, this was not

observed in our case series. We also did not observe an emergence of resistant pathogenic bacteria, despite the utilization of long-term antibiotics. This could be attributed to the serial drip irrigation, promoting an environment that minimizes the risk of infection and contamination with more resistant bacteria.

Bezstarosti et al. described an 8% recurrence rate of infection in the management of bone defects related to fractures[27]. In our successfully treated cases, there was no recurrence of infection. This could be attributed to the relatively small patient group, the challenges in comparing a heterogeneous patient population, and the short follow-up period for some patients. Moreover, we observed a persistent infection unresponsive to treatment in cases where serial drip irrigation was not successful.

More surgical revisions were observed with bone grafting and bone transport compared to alternative techniques[27]. In our case series, additional debridement, original Papineau grafting or bone transport was performed based on specific clinical scenarios and the senior surgeon's experience. The primary limitations of this study are its retrospective analysis and the heterogeneity of the cases. The measurements related to the size of the bony and soft tissue defects were not adequately documented, preventing us from demonstrating a correlation between defect size and treatment duration. Given the scarcity in the literature, it is necessary to conduct randomized, prospective studies to compare the efficacy of the drip irrigation technique with VAC and free flap surgery.

## CONCLUSION

Our series demonstrates that the Papineau-irrigation technique is an effective and safe method for treating soft tissue defects resulting from fracture-related infections that can be used in a patient's home setting. However, infection control through proper debridement and specific antibiotic treatment, as well as skeletal stabilization using Ilizarov, are equally important. In this regard, our technique can be easily used in conjunction with an Ilizarov frame. Further studies are required to investigate the efficacy of this modified irrigation technique in the treatment of soft tissue defects compared to vacuum-assisted closure and free-flap surgery. Moreover, this technique is limited by delayed wound healing, and scar formation.

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