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The use of Papineau technique for the treatment of diabetic and non-diabetic lower extremity pseudoarthrosis and chronic osteomyelitis

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The treatment of 31 consecutive adult patients, ages 25–67 years with chronic draining osteomyelitis (12 cases) or infected pseudarthrosis (19 cases) by the Papineau technique was retrospectively reviewed. The initial injury was an open fracture in 24 patients and a closed fracture in 7 patients. In all cases an Ilizarov circular external fixation device was used for the stabilization of the fracture or for bone lengthening. Mean follow-up for the group was 20 months (range, 10 months to 5 years) and there was successful limb salvage in all cases with eradication of infection and bone consolidation was achieved. The Ilizarov circular external fixation was removed at a mean of 18 weeks (range, 14–24 weeks). The mean time to bone union was 5 months (range, 4–10 months). All patients returned to their pre-treatment activity levels or better.

Keywords: *papineau*; *osteomyelitis*; *diabetes*; *pseudoarthrosis*; *lower extremity*

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Despite modern surgical techniques and advanced antimicrobial therapy, osteomyelitis remains a difficult and challenging problem. Posttraumatic composite bone and soft tissue defects are usually the result of high-energy trauma and patients often have other injuries that must be addressed, making the reconstruction of these defects more difficult. Many protocols have been described to treat severe open lower extremity fractures. These include early aggressive and repeated debridement of necrotic tissue, fracture stabilization (usually with external fixation), early soft-tissue coverage with local muscle flaps or free muscle transfers (1–3), and staged skeletal reconstruction (4–8). For bone defect reconstruction, different techniques have been described including direct non-vascularized cancellous bone grafts (9, 10), open cancellous Papineau grafting (11), bone transport using the Ilizarov bone lengthening technique (12), and vascularized bone graft (13, 14).

Debridement with incomplete bone resection, followed by repeated local treatment, has been published by Papineau and has commonly been used (15–17). In this technique, after bone stabilization, repeated local debridements follow excision of the infected area with preservation of the posterior bone cortex (18–20). Topical treatments follow and consist of frequent moist dressing changes until granulation tissue is formed in the resected osseous and soft tissue recipient bed. Thereafter, cancellous bone grafting and delayed soft tissue closure may be added but are not necessary. Local radical debridement of the infected bone area is mandatory and cannot be overemphasized. Open cancellous bone grafting has been used to fill the resultant bone defect (20) following bone stabilization with either a cast or with an external fixation

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device. Both one-stage autogenous cancellous bone grafting of the defect and multiple-stage grafting procedures have been reported and recommended (21, 22).

The present study focuses in the use of a modified Papineau technique for the successful treatment of recurrent osteomyelitis following severe lower extremity trauma and the secondary reconstruction of bone and soft tissue defects without closing the skin when other procedures had already failed after, of course, a meticulous debridement and curettage (bone grafting, negative pressure wound therapy, local flap closure). While in the classical Papineau technique the surgeon uses corticocancellous chips, our modifications consist that we use almost exclusively cancellous bone harvested from the iliac crest by a special trocar using a minimal invasion technique.

In tibial osteomyelitis, we used the Papineau technique under three therapeutical aspects: (1) where we ensured a good immobilization and a satisfactory continuity at the dorsal cortex of the tibia; (2) after bone resection, acute shortening and docking combined with Ilizarov distraction-compression technique; and (3) as a final step after an adequate tibia distraction followed a large bone resection. In foot and ankle recurrent osteomyelitis we used the Papineau technique after a meticulous debridement of the osteomyelitic bone. In cases where the osteomyelitis was extended to the whole tarsal or metatarsal region, we performed a complete radical bone resection followed by the filling of cancellous bone and osseous external fixation stabilization.

Materials and methods

Between February 2000 to April 2004, the Papineau technique was used to treat 31 consecutive patients, all males ages 25–67 years, who had draining osteomyelitis (12 patients) or infected pseudoarthrosis (19 patients).

The original injury was an open fracture in 24 patients (Figs. 1a, 2a) and a closed fracture in seven patients. The mechanism of injury included 20 motorcycle accidents, three falls, four crush work related injuries, two pedestrian–automobile, and two spontaneous infections. The tibia was involved in 21 cases, while the midfoot and forefoot in eight cases, and the calcaneus in two cases. Associated risk factors were smoking and diabetes mellitus. According to the classification of Cierny and Mader (23) and Cierny (24), the site of osteomyelitis was diffuse in 17 cases, localized in six, medullary in five, and superficial in three.

The initial management included external fixation in 19 cases, intramedullary nailing or pin fixation in nine, and internal fixation with plating in three. These patients had received conventional surgical debridement and antibiotic treatment at their primary hospitals. The mean time from injury was 18 months (range, 10–25 months). When they were addressed in our center, all had local signs of infection including a discharging sinus or skin septic necrosis (Figs. 1b, 2b). The infection and osteomyelitis were located in the proximal third of the tibia in three patients, the middle third in seven patients, and the distal third in 11 patients. The size of the soft-tissue defects were measured in all patients. The donor site for the cancellous bone harvesting was the contralateral iliac crest in 20 cases, the ipsilateral iliac crest in five cases since the contralateral side was already operated, and bilateral iliac crests in six cases.

Plain radiography and a bone scan were performed on every patient. The initial reports were then reviewed by an experienced musculoskeletal radiologist and further medical imaging including computed tomography, magnetic resonance imaging or indium-labeled white cell scanning was performed depending on the clinical assessment. Diagnosis was made based on clinical presentation and medical imaging with further confirmation of intra-operative soft tissue, bone cultures, and biopsies.

A complete blood count, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were also ordered for each patient. Antibiotic therapy was initiated and based on the intra-operative results and culture of organisms at our center. After the definitive surgery, patients were treated with 6 weeks of intravenous antibiotics selected by an infectious disease specialist. Thereafter, patients received appropriate oral antibiotics for approximately 6 months or until the end of surgical treatment.

Surgical technique

Our protocol was divided into three stages. Stage I involved removal of non-viable infected soft tissue and bone or any retained internal or external fixation (Figs. 1c, 2c). Avascular sclerotic bone was debrided with a bone burr to produce a saucerized defect, which was expanded until healthy bleeding margins could be noted on the osseous bed. Intra-operative culture specimens of the area were obtained and the extremity was stabilized by an Ilizarov external fixation device. The saucerized defect was dressed with fine-mesh gauze soaked in povidone iodine solution. The original dressing was changed aseptically at 2–5-day intervals with new cultures taken at each interval. Positive cultures were treated by appropriate parenteral antibiotics from the time of surgery until granulation tissue covered the defect and the white blood cell, ESR and CRP had returned to normal limits. Two to 3 weeks after surgery, a treatment decision was made. If the wound showed areas of non-viable sclerotic bone, surgical debridement was then repeated. If the wound demonstrated healthy granulation tissue over the saucerized osseous bed, we proceeded to Stage II of the protocol. In a few previous cases, we had performed fasciocutaneous reversed vascularized flaps (Fig. 1d, 2d) and after flap failure for radical osteomyelitis management, we partially exposed the flap and continued with the next stage of the protocol.

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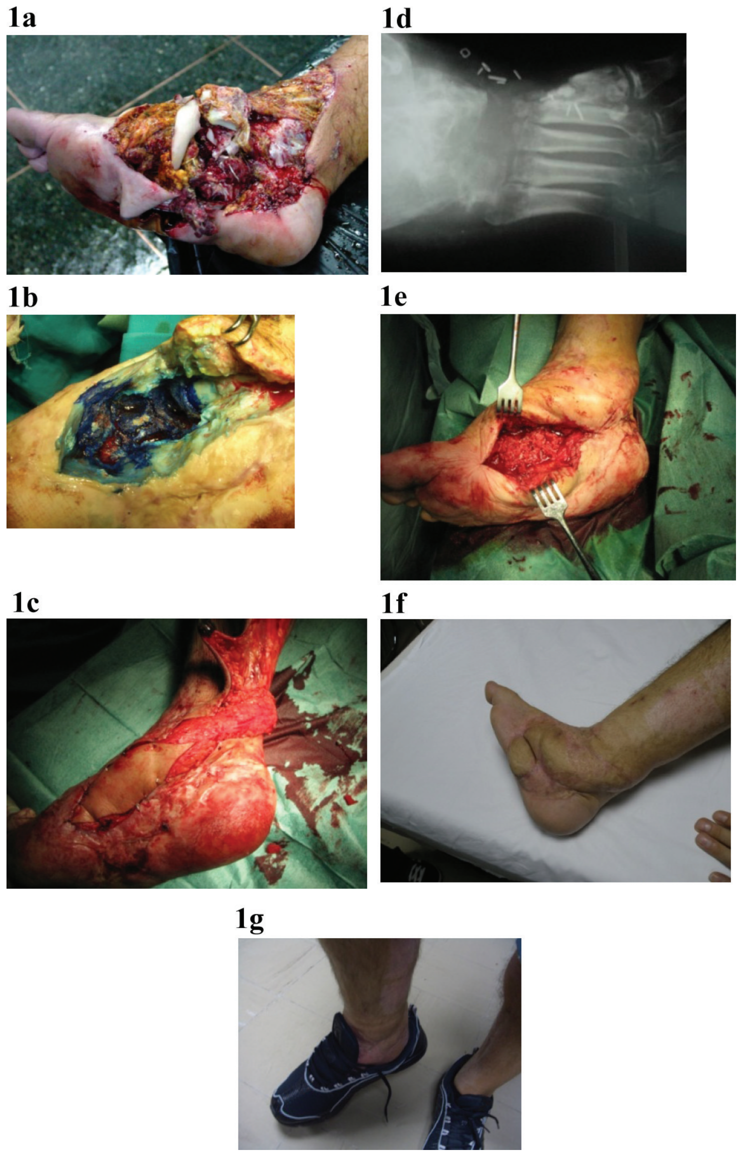

Fig. 1. (a) Initial presentation of a severely open fracture that was treated by multiple pin fixation and simple closure, (b) Postoperative multiple tarsal bones with osteomyelitis confirmed with methylene blue stain, (c) Soft tissue coverage attempt by a reverse sural neurofasciocutaneous flap, (d) Osteomyelitis confirmed by plain radiographs, (e) Example of the Papineau technique after meticulous bone resection, (f) Final clinical presentation of lower extremity, and (g) Final functional result.

Stage II involved the grafting of autogenous cancellous iliac bone to the recipient osseous and soft tissue defect. Autogenous bone obtained in the standard manner was packed firmly into the granulation bed (Figs. 1e, 2e). A petrolatum gauze dressing was applied and changed every 2–4 days, with intermittent debridement of necrotic bone from the surface. Another treatment decision was made after three or four dressing changes. If the remaining viable bone graft inadequately filled the defect, grafting was repeated. Stage II was continued until granulation tissue completely covered the grafted recipient area.

Stage III consisted of coverage of the wound. During this stage, one of four techniques were used: (1) the defect was allowed to be epithelialized from the wound edges, (2) a split-thickness skin graft was placed directly on the wound defect, or (3) a muscle transposition to the wound was followed by immediate split-thickness skin coverage, or (4) final closure of partially re-opened fasciocutaneous flaps following osteomyelitis eradication (Figs. 1f, 2f). Flap monitoring included clinical observation (capillary refill, venous congestion, color changes), surface temperature readings, and Doppler testing. If the clinical wound and plain radiographs demonstrated healing with no further evidence of infection, antibiotics were changed to sensitivity-appropriate oral antibiotics, which were continued for approximately 6 months at the discretion of the infectious disease team.

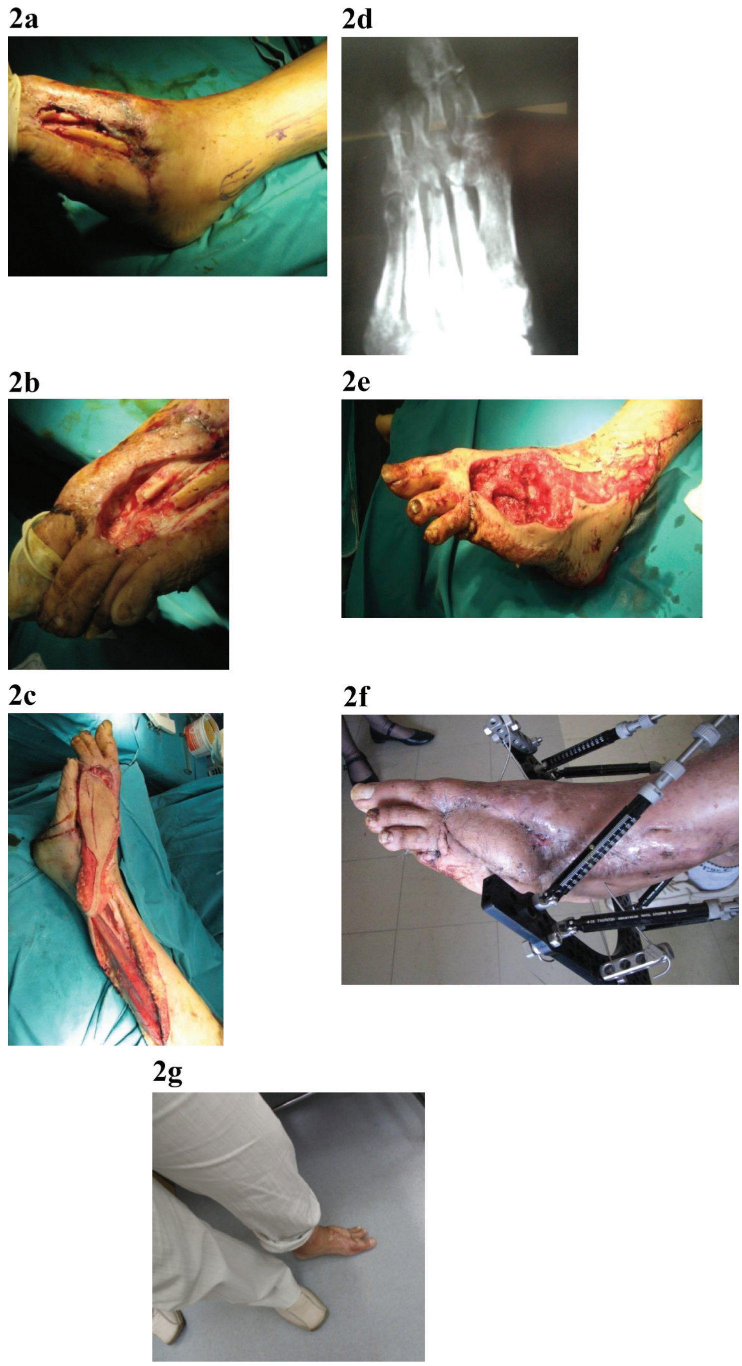

Fig. 2. (a) Posttraumatic skin necrosis and multiple metatarsal osteomyelitis, (b) Post-surgical debridement and appearance of metatarsal defects, (c) Soft tissue coverage attempt by a lateral peroneal distally based fasciocutaneous flap, (d) Osteomyelitis confirmed by plain radiographs, (e) Example of the Papineau technique after meticulous bone resection, (f) Clinical presentation of the lower extremity with the application of an external fixation device, and (g) Final functional result.

Results

Thirteen patients were chronic smokers and five had a history of diabetes mellitus complicated with peripheral neuropathy. Mean follow-up for the group was 20 months (range, 10 months to 5 years), and in all cases bony union and eradication of infection was achieved (Figs. 1g, 2g). Bony regeneration was followed by serial radiographs and there were no clinical or radiographic signs of bone infection in the last follow-up period. The Ilizarov circular external fixation was removed at a mean of 18 weeks (range, 14–24 weeks). All patients returned to their pre-treatment activity levels or better. One was older than 65 years, retired, and was active but not working. No patients required chronic pain medication treatment.

The size of soft-tissue defects ranged from 4 × 9 cm to 16 × 22 cm. The average length of the preoperative bony defect was 10 cm (range, 5–16 cm). Staphylococcus aureus was cultured from the wounds of 26 patients either before or after the transfer to our institution. Most patients had received multiple courses of antibiotics and several surgical procedures before referral to our center; therefore, it was not surprising that Staphylococcus aureus was found in only 43% of initial surgical wound cultures and after the referral. Subsequent cultures were often polymicrobic. Most of the aerobic gram-negative bacilli were sensitive to ciprofloxacin and responded to a prolonged course of that drug. In our series, post-operative cultures had been found positive in 10 cases. Staphylococcus aureus was isolated in six out of those 10 cases. Despite this prevalence, antibiotics were given empirically as the choice also depended on availability. Many patients (56%) received ampicillin, 22% chloramphenicol, 9.8% amoxicillin, 9.8% tetracycline, and 2.4% received anti-tuberculous treatment.

Ten patients had a draining osteomyelitis; tibial in four cases, midfoot in four, and calcaneal in two. Two patients with localized osteomyelitis in intact tibias were treated by one local debridement while in the remaining two patients, after the initial debridement, coverage with local muscle flap was needed. In cases with tarso-metatarsal bone osteomyelitis, a radical excision was performed with preservation of the toes and soft-tissue envelope. The patients with the calcaneal osteomyelitis had a cavitary lesion and were treated by multiple debridements until a viable bony recipient area was present and then followed by the Papineau technique of open cancellous autogenous graft. The cancellous graft sites were allowed to heal without skin grafting. These patients remained non-weight bearing with a removable cast boot for approximately 4 months. In 21 patients an infected non-union was observed; proximal third in three patients, middle third in seven, and distal third in 11. At the proximal tibial third, the defect was treated by wide debridement and also had a gastrocnemius muscle flap in addition to cancellous grafting. The patients with defect in the tibia middle third were treated with wide excisional debridement, application of an Ilizarov circular external fixation, and bone transport averaging approximately 10 cm. Finally, in the distal tibial third after the debridement and the application of the Ilizarov circular external fixation, coverage with local muscle flap (soleus) was needed.

A total of 20 muscle and fasciocutaneous flap procedures including 13 soleus, three gastrocnemius, one tibialis anterior, two distal peroneal fasciocutaneous, and one abductor hallucis muscle flap were performed in conjunction with the application of the Ilizarov external fixation in these series. Adequate coverage of the bone defect was achieved in every case, and all flaps showed great healing after a mean period of 10 days.

Time from the beginning of stage I to the beginning of stage II ranged from 2 to 6 weeks (mean, 4 weeks). Five patients underwent more than one debridement, while two patients had three or more procedures performed. The time from bone grafting in stage II to a definitive coverage procedure was noted for five patients. This stage was repeated more than once in two patients. One patient in the study had three separate bone grafting operations and another had two procedures. During stage III, the mean period from iliac bone grafting to skin coverage was 4 weeks. In all patients, except the flap cases, complete epithelial coverage was developed. Bone consolidation as the final visit was confirmed radiographically by the presence of new bone formation and clinically by a return to weight-bearing without any assistant external devices for support. The time to bony union was 5 months (range, 4–10 months).

Pin or wire tract infections were observed in five patients and were managed successfully by conservative measures. Three patients under bone transport had stress fractures after the Ilizarov external fixation removal. The treatment of stress fractures included re-application of an external fixator in three cases. Bone healing was finally achieved by an average period of 10 months after the stress fracture. Infection recurrence noted in two cases and was treated by a successful repeated excision and grafting. There was also one case of tuberculous infection superimposed by Staphylococcus aureus. In eight of the muscle or fasciocutaneous flaps, superficial localized infection, hematoma, seroma, and wound dehiscence were observed and eventually healed by secondary intention and local wound care.

Discussion

This retrospective analysis of 31 cases managed with the Papineau protocol showed that if severe lower extremity injuries are treated promptly and in an appropriate fashion, favorable outcomes can result in terms of function without significant complications. The surgeon faces two distinct problems in the management of these patients: wound care and achievement of bony union. The treatment choice must appropriately address each of these problems.

The management of chronic osteomyelitis or an infected non-union is complicated by the presence of necrotic bone in a scarred soft-tissue envelope with a poor blood supply (23). The criteria for treatment of chronic osteomyelitis include adequate debridement of necrotic, infected soft tissue, and osseous structures (25–28); the preservation or creation of osseous stability (29); the ablation of dead space by packing and change of dressings, the use of methylmethacrylate, bone graft, closed suction irrigation, or muscle insertion (23, 24, 29, 30); adequate antibiotic therapy (26, 31); and appropriate soft-tissue coverage (30, 32, 33).

Several approaches have been described to reduce the dead space including open (15, 16, 18) or closed bone grafting (32), a local or free muscle flap (33), and closed wound irrigation with suction (34). The Papineau technique was developed to assist the management of difficult bony defects and posttraumatic osteomyelitis. Papineau and others have reported high rates of success in eradicating chronic bone infection and addressing significant bone deficits (15, 16, 18, 35, 36).

This old but revolutionary technique is not contra-indicated in the bone transport or muscle flap procedures. Whereas the duration of the Ilizarov technique takes a long time to complete (longer than 10 months) and requires adequate training to reduce the overall complication rate, external fixation is still very encouraging because it allows the simultaneous correction of axial, angular, and translational deformities while maintaining extreme mobility and weight-bearing capability. Tissue dissection and periosteal stripping associated with internal fixation are also avoided (12, 17, 37).

In the present study, we have reviewed our clinical results in traumatic lower extremity fractures or infections in 31 patients who had combined bone and soft-tissue defects.

When first seen at our center, the wounds were in the acute, subacute, or in the chronic phase. In all cases, our staged Papineau protocol was used. The first stage was managed by aggressive, repeated debridement of necrotic tissues and obtaining of wound cultures. The wounds in the subacute or the chronic phase were managed with culture-specific antibiotics and meticulous local wound care for eradication of infection. In some chronic wounds, biological dressings were used to protect underlying exposed structures, to improve the wounds, and to test whether the wounds were suitable for reconstruction. In addition, all patient reconstructions were performed when preoperative wound cultures were negative and the wounds appeared grossly clean and healthy. This treatment protocol minimized on a large scale the risk of infection and flap failure. Different types of local or muscle flaps were needed depending on the size, nature, and location of the defect for coverage.

A recent study by Archdeacon and Messerschmitt (38) suggested a modification of the Papineau technique by implementing a vacuum assisted closure device in lieu of moist-to-dry dressing changes. This protocol also included an aggressive excisional debridement of infected or necrotic bone, open bone grafting with cancellous autograft, and eradication of chronic infection with concomitant parenteral antibiotics.

In our series, major complications were not observed. Flap complications (superficial infection or wound dehiscence) were observed mostly in patients with history of smoking or diabetes mellitus; both of which had been recognized as host factors for complication (33, 39–41). Furthermore in cases of tarso-metatarsal osteomyelitis with diabetes mellitus, the method of radical resection or 'internal amputation' was performed. According to the literature, this method of pedal amputation consists of resection of the metatarsals, midtarsal bones, or talus with preservation of the toes and soft-tissue envelope. Following internal pedal amputations of a diabetic patient, the foot undergoes significant contracture that results in a stable, functional, foreshortened residual foot capable of being protected in custom-molded shoe gear with external or in-shoe orthoses (42).

All patients in our series had established chronic osteomyelitis or infected pseudoarthrosis and all had previous failed operations with wound debridements and antibiotics. Our modified Papineau technique and staged protocol was effective in salvaging difficult case scenarios where amputation was suggested as another option.

Conclusion

The Papineau technique is a useful tool in the surgeon's armamentarium and is performed in difficult cases of recurrent osteomyelitis and failed soft tissue coverage by direct skin closure or vascularized flaps. The technique can also be combined with distraction osteogenesis (before or after distraction) and with any soft tissue reconstructive surgery. In our experience, extensive bone surgical debridement is the most important part of the operation and needs to be performed regardless to the size of the resulting defect. Removal of necrotic bone and soft tissue, avascular periosteum, and scarred subcutaneous tissue and muscle is absolutely necessary for the success of further treatment. The principle of debridement has to be incision through healthy soft tissue and bone to save only well-perfused and absolutely intact tissue. Patient compliance and understanding of the overall plan are imperative for the patient's overall success rate.

Conflict of interest and funding

The authors have not received any funding or benefits from industry to conduct this study.

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