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Management of open fractures in dogs and cats

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KEY POINTS

- Accurate open fracture classification and evaluation of the patient and the fracture can be used to make decisions about the fracture fixation.
- Early administration of broad-spectrum antibiotic therapy is the most effective way of preventing osteomyelitis after open fracture.
- Wet-to-dry bandaging techniques are effective for wound debridement and preserve the viable surrounding soft tissues.
- In most cases, contaminated open wounds are best handled by allowing them to heal by second intention.
- Early stabilization of the fracture allows easier treatment of the soft tissues and control of infection.
- Grade III open fractures are effectively treated with minimal invasion of the fracture site and bridging fixation techniques.

INTRODUCTION

Open fractures frequently occur in dogs and cats, particularly in the distal extremities where there is a paucity of soft tissue coverage. Because the protective barrier of the skin is compromised, the potential for bacterial contamination, infection, and ultimately osteomyelitis is higher than is the case with closed fractures (1–4). This is particularly of concern when the open fracture is severely comminuted with extensive associated soft tissue injury (2–4). However, with appropriate treatment, the infection rate for open fractures can be controlled (3, 4).

The veterinary surgeon must understand the implications of open fracture classifications for perioperative fracture management and the fracture treatment decision-making process. The occurrence of osteomyelitis and other complications in fracture healing can be minimized by using appropriate antibiotic protocols, protecting the adjacent soft tissues, and providing appropriate fracture stabilization.

CLASSIFYING OPEN FRACTURES

Open fractures are classified according to the mechanism of puncture and the severity of soft tissue injury (1–3). Open fractures may be classified in various ways, but the classification most often used in veterinary medicine (1) is as follows:

- Grade I open fractures have a small puncture hole located in the skin in the proximity of the fracture, caused by the bone penetrating to the outside. The bone may or may not be visible in the wound.
- Grade II open fractures have a variably-sized skin wound associated with the fracture, resulting from the external trauma. More damage to the soft tissues is generally associated with this grade of open fracture. Although the extent of the soft tissue damage may vary, the fracture is minimally comminuted.
- Grade III open fractures have severe bone fragmentation and/or bone loss, as in a shearing injury associated with extensive soft tissue injury with or without skin loss. These fractures are usually high energy comminuted fractures such as gunshot injuries or shearing-type injuries of the distal extremities **(Figure 1)**.

In one study of humans, the grade of open fracture correlated with the wound infection rate. The infection rates were 1.4% and 3.6%, respectively, in Grade I and II open fractures, and 22.7% in Grade III (4). Grade III open fractures are also the most problematic for veterinary surgeons to treat. Complications with Grade III open fractures include osteomyelitis, implant failure, delayed union, and nonunion.

PATHOGENESIS OF POSTTRAUMATIC OSTEOMYELITIS

Posttraumatic osteomyelitis occurs when there is spread of infection from adjacent soft tissue wounds or open fractures, or a lapse in aseptic surgical technique during fracture fixation (2, 5).

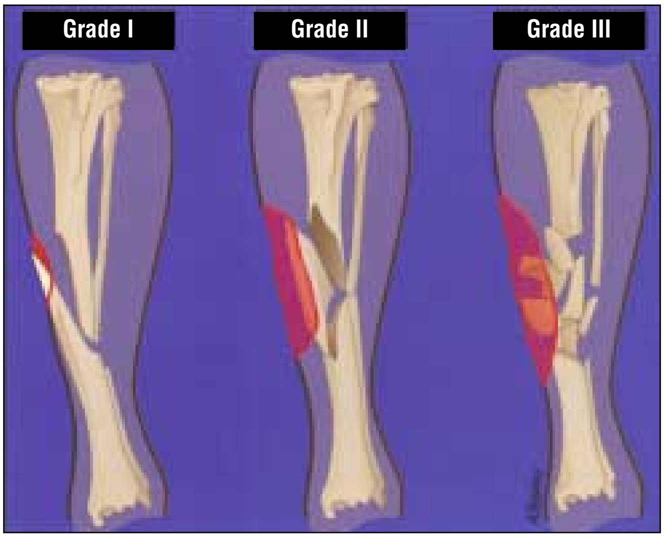

Figure 1 *Grade I open fractures are created by penetration of the skin by the bone. Grade II open fractures are created by an external force applied to the skin. The skin wounds are variably sized. Grade III open fractures are comminuted with extensive soft tissue damage.*

Figure 2 *The initial presentation of a Grade III open fracture of the radius in a two-year-old Labrador retriever.*

Figure 3 *Appearance of the Grade III open fracture of the radius after limited debridement, closed reduction, and external fixation.*

Infections become established when there are bacteria present or when avascular bone and soft tissue injury compromise the development of extra-osseous vascularity to the fracture site (2, 5). Unstable fractures and loose implants perpetuate an environment conducive to osteomyelitis (5–7). Fractures that are adequately stabilized, either with internal implants or external fixators, will heal despite bacterial infection (8). However, inadequate fracture fixation with internal implants, resulting in unstable fractures, causes significantly higher infection rates compared with stable fractures with internal implants (6, 7).

In addition, the type of metal implant used may affect the rate of infection. Titanium, a biologically inert metal, has been associated with significantly lower infection rates than stainless steel in experimental studies (9). Infective bacteria are capable of producing a polysaccharide mucoid peri-bacterial film, called biofilm or glycocalyx, which promotes bacterial growth and adherence to foreign material such as metal implants (5, 10). The result may be a cryptic infection which causes few clinical signs but persists until the implant is removed despite an effective immune system and appropriate antimicrobial therapy (10).

ANTIBIOTIC THERAPY FOR OPEN FRACTURES

It is generally accepted that open fractures must be treated early and aggressively with broad-spectrum antibiotics. Early (within three hours of injury) administration of antibiotics with antibacterial activity against both Gram-positive and Gram-negative microorganisms was the single most important factor in reducing the infection rate in humans with open fractures (4). In experimental conditions, animals receiving antibiotics four hours after insult with *Staphylococcus aureus* had an infection rate of 51%, compared with 91% in animals not treated with antibiotics and 30% in animals treated with antibiotics one hour before insult (11).

Dogs and cats presenting with open fractures should be treated immediately with a broad-spectrum antibiotic. The antibiotic should be administered intravenously, be active against staphylococci, resist β-lactamase, and have a bactericidal action. Antibiotic therapy should be continued during the surgical procedure. If there is no evidence of infection at surgery, therapy may be discontinued early in the postoperative regimen. Animals with open wounds are treated with antibiotics until healthy granulation tissue covers the wound. Antibiotic therapy is stopped at that time if there is no evidence of systemic infection. Animals with established infections and osteomyelitis may require prolonged treatment for six to eight weeks (2, 5).

MICROBIAL CULTURES

More controversial is the role of predebridement and postdebridement cultures. Predebridement cultures were determined to have no predictive value for infection in open fractures in humans, with only 8% of organisms grown eventually causing infection and 7% of the cases with negative cultures becoming infected (12). Postdebridement cultures were more accurate in predicting infection; however, the eventual infecting organism was present in only 42% of cultures (12). In one study of 110 fractures in small animals, 51 fractures had positive cultures made at surgery, but only nine fractures developed osteomyelitis. Four of the nine bones with osteomyelitis harbored the same organisms as were cultured at surgery (13).

When operative cultures were made for 20 dogs with gunshot fractures, 19 cultures were negative. Sixteen of these dogs received preoperative antibiotic therapy, and four dogs did not. Osteomyelitis occurred in three of the dogs, all of whom cultured negative at the time of surgery (14).

In practice, swabs for microbial culture and sensitivity should be made during surgery (that is, after debridement and irrigation) to check for presence of bacteria which may not be sensitive to the administered antibiotic. Antibiotic therapy can then be adjusted early in the course of therapy, as dictated by the sensitivity response if organisms are cultured.

If wound infection or osteomyelitis occurs postoperatively, additional samples from the infected area are cultured and appropriate antibiotic therapy administered.

PERIOPERATIVE MANAGEMENT OF SOFT TISSUE INJURIES

Open fractures are initially managed by clipping the adjacent hair, thoroughly cleaning the wound, and applying a bandage to both protect the wound from further bacterial contamination and aid in debridement of necrotic soft tissues (1, 2). Appropriate analgesia should be administered and homeostasis attended to. After the initial

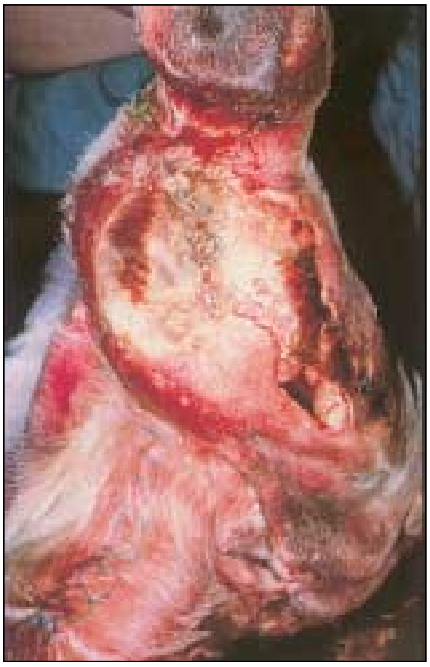

Figure 4
Severe open wound with deep tissue infection associated with a transverse distal femoral diaphysial fracture.

Figure 5
Dehiscence of the open wound which was prematurely sutured during fracture treatment. Note the healthy granulation tissue where the wound was treated as an open wound.

assessment and stabilization of the traumatized animal, a sedative is administered and the skin adjacent to the wound is clipped and scrubbed. Water-soluble petroleum jelly can be applied to the wound to prevent contamination with hair. The wound is gently cleaned with sterile, lactated ringers solution or a 0.5–1.0% chlorhexidine solution. Obviously, necrotic superficial tissues may be dissected and removed. Small puncture wounds are covered with nonadherent pads. Larger, cleanly lacerated skin wounds which are not overtly contaminated or infected may be closed primarily after flushing and debridement (2). Heavily traumatized wounds, such as the open wound in **Figure 2**, are cleaned and covered with gauze sponges soaked in lactated ringers or 0.5–1.0% chlorhexidine. The wound is then bandaged. The bandage is changed daily, reapplying the soaked gauze sponges, until there is minimal exudate in the bandage. The time period between bandage changes then can be extended (2).

A limb bandage is applied preoperatively to patients with fractures below the elbow or stifle. The bandage provides wound coverage, preventing further contamination, protects the soft tissues from additional injury and temporarily stabilizes the fracture, providing comfort to the patient. A splint may be used to maintain the position of the bandage and provide support to the limb. Wounds over femoral or humeral fractures are usually covered with a bandage incorporating a spica splint to support the fracture. Roll cotton can be used in a Robert Jones type bandage to compress the soft tissues and prevent or decrease preoperative swelling. Bone landmarks are more easily identified during closed reduction techniques if swelling is minimized.

Early surgical stabilization of the fracture enhances soft tissue healing and infection resolution. Open fractures which are obviously infected can be temporarily stabilized with external support, and the soft tissues treated with lavage and drainage before the definitive surgical procedure (2). During surgery, debridement is also limited to obviously necrotic tissues, which are easily visible on the external portion of the wound **(Figure 3)**. Deep tissue infections are treated with ingress–egress drainage and copious once or twice daily lavage of the wound until the drainage subsides **(Figure 4)**. These wounds are rarely sutured, to allow drainage into the bandage. Problems often occur after premature closure of a wound, with abscess formation and wound dehiscence being common sequelae **(Figure 5)**. Superficial wounds are treated postoperatively with wet-to-dry dressings changed daily to further debride unhealthy tissue.

Figure 6
Appearance of the wound associated with the Grade III open radial fracture (shown in Figure 2*) after two weeks of wet-to-dry dressing applications.*

Figure 7
Appearance of the wound associated with the Grade III open radial fracture (shown in Figure 2*) 12 weeks after surgery. The wound had completed contraction, and skin grafting was required to achieve a good outcome.*

Within one to two weeks, healthy granulation tissue will appear on the wound surface **(Figure 6)**. Nonadherent dressings are used after granulation tissue is present. In some cases where devascularized bone is visible in the wound, removal of the exposed bone is necessary before complete granulation of the wound can occur. The wound will eventually contract, with the remaining exposed surface being covered with a fibrous scar **(Figure 7)**. This scar may be prone to injury. Skin grafting after the granulation tissue is established may speed recovery and minimize scarring.

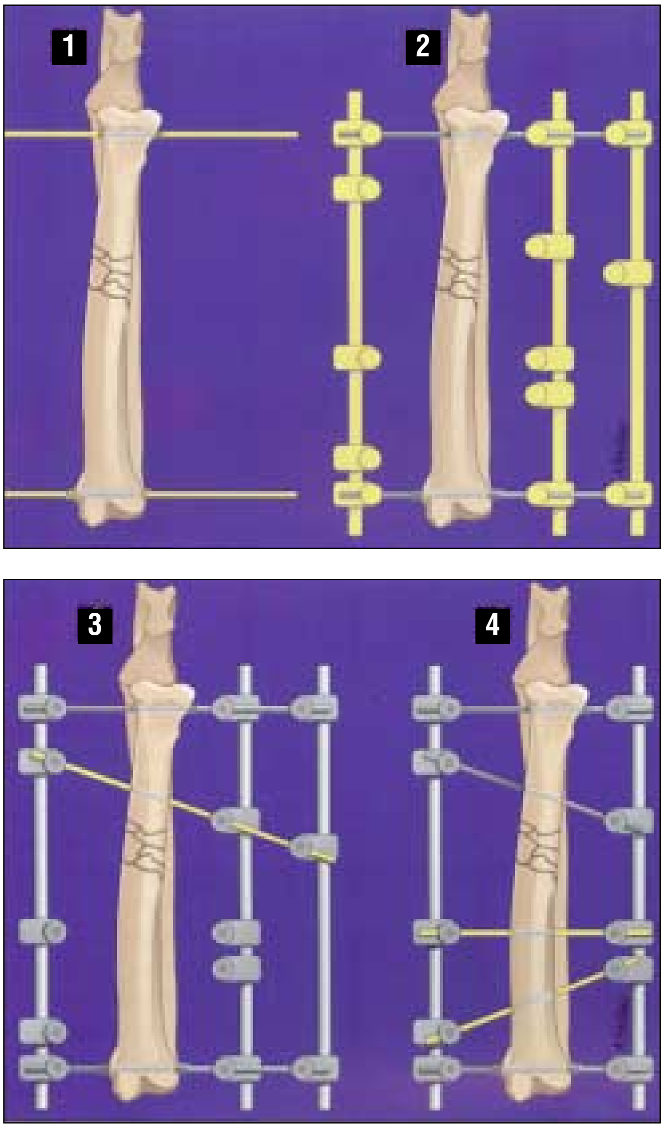

Figure 8 *Technique for applying a type II fixator to the radius.*
Illustrations courtesy of Biomedical Communications Center, College of Veterinary Medicine, UIUC.

TREATMENT OF OPEN FRACTURES

Decision making

A decision-making process based on assessment of the biological and mechanical status of the fracture is used to insure consistent and predictable results with open fracture management (15). Fracture fixation is a 'timing race' between implant failure and fracture healing. Rapid bone healing allows a rapid shift in relative load-bearing towards healing bone and away from orthopedic implants. However, slow bone healing means that implants must provide stability for a longer time and increases the likelihood of implant-related complications.

Open fractures associated with severe soft tissue injury have a less favorable biological environment, which may delay healing. Other factors that may adversely affect the biological environment are increased patient age, poor general health, and the use of open anatomic reconstruction techniques for fracture fixation. Severely comminuted fractures are mechanically unstable and depend on the implants to buttress the fracture and withstand the load of weight-bearing during the healing process. Other factors that adversely affect the mechanical environment of the fracture are additional limb injuries or preexisting disease and large, active patients. Finally, uncooperative patients and owners can add to the difficulty of postoperative management.

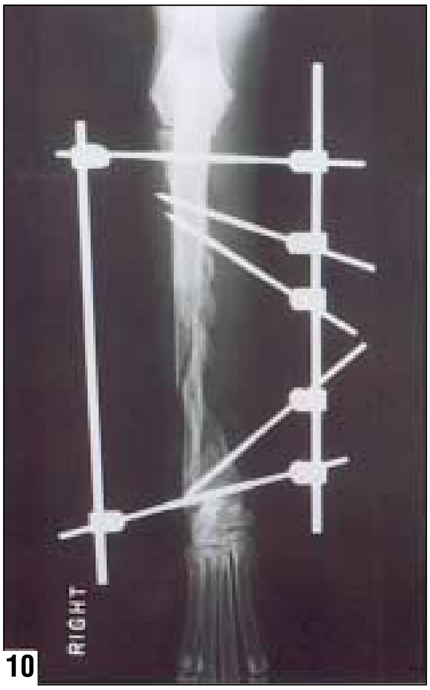

Figure 9
Preoperative cranial–caudal radiograph of the Grade III open fracture of the radius in a two-year-old Labrador.

Figure 10
Postoperative cranial–caudal radiograph of the Grade III open fracture of the radius in the two-year-old Labrador of Figure 9.

Figure 11
Twelve-week postoperative cranial–caudal radiograph of the Grade III open fracture of the radius in the two-year-old Labrador of Figure 9. *The fracture has bridged with bone.*

Treatment of Grade I and II open fractures

Grade I and II open fractures are generally single fracture lines or have large butterfly fragments. Choosing the appropriate fixation for these fractures generally depends more on the type of patient and the appearance and location of the fracture than on the fact that the fracture is open. In fractures where rapid bone union is expected and there is immediate load-sharing between the bone–implant construct, the strength and stiffness of the implant need not be extreme, nor does the implant need to function for a long time. In these cases, the suggested implants include type I external skeletal fixators, or intramedullary pins and cerclage wires. In fractures where the implant and bone will share the load, but healing may be delayed, more rigid fixations such as type II external fixators or plates and screws should be chosen (15).

Treatment of Grade III open fractures

In Grade III open fractures, the biology of the fracture site should be preserved by using minimally invasive techniques (15, 16).

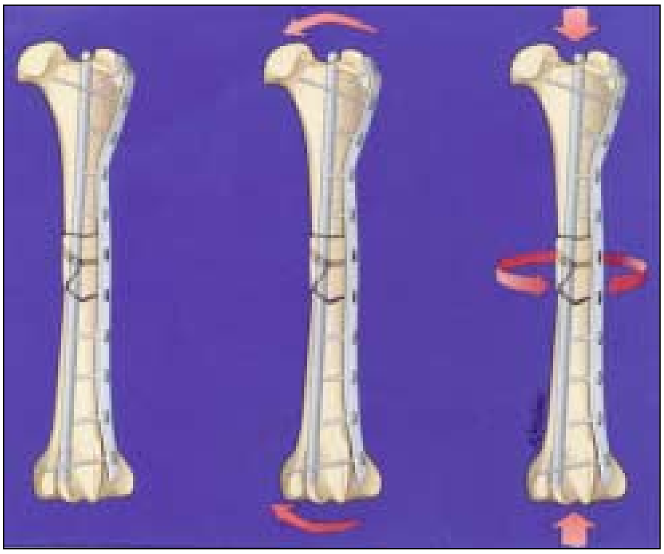

Figure 12 *The combination of a bone plate secured with bicortical and monocortical screws and an intramedullary pin which fills approximately 50% of the medullary canal to bridge the fracture. This combines the mechanical abilities of the two implant systems to counteract axial loading, rotation, and bending forces.*

Additionally, implants must generally bridge the fracture and have sufficient strength to prevent permanent bending or breakage. The chosen implants must also deter excessive motion at the implant–bone interface. Closed reduction and type II or III external fixators using positive profile threaded fixation pins is an excellent method of stabilizing Grade III open fractures of the radius or tibia while preserving the biological environment (17–19). Grade III open fractures of the humerus or femur are often more easily managed with 'open but do not touch' surgical approaches and bridging plate techniques (20).

Closed reduction and external fixation is ideal for Grade III open fractures of the radius and tibia **(Figures 8, 9, 10** and **11)**. This is because the distal limb can be easily manipulated, the bone landmarks are easily palpated, and the relatively rigid type II or type III external fixator is mechanically strong enough to support the full load of weight-bearing applied. In these cases, considerable attention must be given to accurate alignment of the joint surfaces to insure that the fractured bone is correctly aligned.

The animal is positioned with the affected leg securely suspended from the ceiling. The initial transfixation pins are placed in the proximal and distal metaphyses of the bone. These pins are centered in the bone on the medial-to-lateral plane and parallel to their respective joint surfaces. The operating table is lowered, causing the dog or cat to be suspended by the fractured limb. The weight of the animal both distracts the fracture and aligns the joint surfaces. The table is raised after the connecting bars are attached. The medial and lateral connecting bars containing the predetermined number of clamps are secured to the transfixation pins. A third connecting bar with three clamps is secured to the transfixation pins on one side of the limb, or a modified type II construct can be used, as in **Figures 10** and **11**. The remaining transfixation pins are placed using the guide bar to insure proper alignment of the pins with the clamps. There should be at least two, and preferably three, pins placed proximally and distally to the fracture. If the additional stiffness of the type III external fixator is needed, it is constructed at this time.

In several case series of comminuted radial and tibial fractures treated with closed reduction and external fixation, open fractures did not appear to adversely affect the outcome (17–19).

Grade III open fractures of the femur and humerus are not as easily manipulated during a closed reduction, and not as well suited to external fixation. When internal implants are chosen as the method of fixation, an 'open but do not touch' philosophy is used in the surgical approach. A standard approach is used to expose the major segments of the bone. A plate is contoured to reflect the bone anatomy by matching the contour of the plate to the appropriate radiographic view of the contralateral bone. Spatial realignment of the bone is assisted by inserting an intramedullary pin. The pin may be retrograded or normograded through the proximal intact bone segment, passed through the fragments, and seated into the distal intact bone segment. Driving the pin into the distal intact bone segment while restricting movement of the proximal bone segment with a bone-holding forceps allows the pin to distract the distal bone segment to regain femoral length. The rotational relationship of bone landmarks is noted, and the rotation alignment corrected. In keeping with the concept of minimally invasive fixation, the bone fragments in the comminuted area are not disturbed. Once spatial alignment of the bone is achieved, the bone plate is attached to the bone with plate screws at the most proximal and distal plate holes. If the alignment pin is removed, bicortical plate screws (screws which engage both cortices) are used to fill the remaining plate holes. Alternatively, the alignment pin can be left in place to achieve a plate–pin buttress of the fracture. In this case, bicortical screws are used proximally and distally while monocortical screws are used centrally. More bone screws will be needed if the pin is left in, since the screws cannot anchor into both cortices. The plate–pin combination **(Figure 12)** increases the strength and fatigue life of the fixation and, thereby, protects the plate from premature breakage (21). The plate–pin system can be destabilized between six and eight weeks by removing the pin.

In a case series comparing comminuted femoral fractures treated using bridging plates with similar fractures treated using fragment reconstruction and plating, the bridging plate techniques were associated with faster operating times and healing times (20). Again, open fractures did not appear to affect the outcome.

CANCELLOUS BONE AUTOGRAFT

A cancellous bone autograft is used to enhance the biological healing of the fracture site and to promote rapid bone bridging across the fracture. A cancellous bone autograft may be used in contaminated or infected fractures to promote healing without concerns of rejection or sequestration (22). Graft survival depends on adequate vascularization of the surrounding soft tissues. The cancellous bone autograft is implanted at the end of the stabilization procedure in all open fractures which have adequate soft tissue coverage. Caution is exercised to prevent bacterial contamination of the donor site, by harvesting the graft prior to exposing the fracture or using uncontaminated instruments and new gloves while harvesting the graft after the fracture is stabilized (22). When there is massive soft tissue loss and evidence of established infection, it may be prudent to stabilize the fracture and treat the wound for five to seven days to obtain healthy granulation tissue before proceeding with the cancellous bone autograft (23).

POSTOPERATIVE CARE OF OPEN FRACTURES

Postoperative wound care is similar to the open wound care described earlier. Postoperative radiographs are made to evaluate fracture reduction or limb alignment and the position of the implants. Sequential follow-up radiographs are made to evaluate bone healing. Deep tissue infections are treated with ingress–egress drainage and copious once- or twice-daily lavage of the wound until the drainage subsides. Care must be taken to accurately interpret

Figure 13 *Preoperative radiographs of an infected Grade III open femoral fracture in a one-year-old German Shepherd Dog. The wound was treated with lavage for five days before surgery.*

Figure 14 *Postoperative radiographs of the Grade III open fracture in the German Shepherd Dog* (Figure 13) *stabilized with a plate and pin combination.*

Figure 15
Photograph of the German Shepherd Dog (of Figures 13 *and* 14*) six weeks after fracture treatment. Although there was radiographic evidence of periosteal bone proliferation, there were no clinical signs of osteomyelitis.*

Figure 16 *Twelve-week postoperative radiographs of the Grade III open fracture with evidence of fracture bridging and smoothing of the periosteal new bone margins.*

the healing patterns observed with biological techniques for comminuted fractures and to differentiate them from signs of osteomyelitis **(Figures 13, 14, 15** and **16)**. In general, fractures stabilized in this manner have less periosteal callus formation and more endosteal and bridging callus **(Figure 11)**. There is usually increased mineral density throughout the fracture area, with minimal formation of periosteal callus observed radiographically by one month after surgery. Bone formation is noted within the fracture area by two months with remodeling of the callus evident in many cases by three months after fixation.

Radiographic evidence of osteomyelitis includes aggressive periosteal and endosteal bone formation, the presence of radio-dense bone fragments surrounded by radiolucent areas, and possibly soft tissue swelling (5). A radiographic diagnosis of osteomyelitis must be correlated with clinical evidence of osteomyelitis, including lameness and drainage from the fracture site, to institute aggressive treatment **(Figures 15** and **16)**. Osteomyelitis in the presence of stable implants and the absence of sequestered bone is treated with appropriate long-term antibiotics (5). Osteomyelitis associated with

Table 1

Management of the patient with an open fracture

- Assess and stabilize the patient
- Establish hemostasis, if necessary
- Administer broad-spectrum antibiotics immediately
- Clean and bandage the wound
- Decide on appropriate method for fracture treatment
- Operative fracture treatment
- Intra-operative culture and sensitivity, adjusting antibiotics if necessary
- Postoperative wound care
- Sequential radiographic evaluation

loose implants or sequestered bone fragments must be treated surgically to remove the affected implants and bone fragments, stabilize the fracture and apply a cancellous bone autograft, either immediately or as a delayed procedure (5, 23). Appropriate long-term antibiotics are also administered.

Implants are usually removed after the bone has healed, to avoid long-term complications at the fracture site. Implants cultured after removal from healed complex fractures had evidence of bacterial growth in 53% of the cases in one study (10). Chronic cryptic infection causing altered cellular activity in complex fractures with prolonged fracture healing or osteomyelitis has been suggested as a contributing factor in the development of fracture-associated sarcoma (24).

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