THE SURGICAL TREATMENT OF SEPTIC PEDAL OSTEITIS IN THE HORSE: A REVIEW OF EIGHT CASES

by

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To My Wife Andria, whose hair turned darker and darker as my work progressed - In return for her patience, I give the best of my sympathy; in return for her love, I give the best of mine.

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DECLARATION

I, Edouard R.J. Cauvin, do hereby declare that the work in this dissertation is original, was carried out by myself or with due acknowledgement and has not been presented for the award of a degree at any other university.

signed: . . . .

date: 24/06/94

SUMMARY

Eight cases of septic pedal osteitis were diagnosed in horses at the Glasgow University Veterinary Hospital over a period of ten years (1982-1992). Most of them had a history of chronic lameness of several months duration. An accurate diagnosis could only be made with the aid of radiography in all the patients. Surgical debridement was undertaken in all the cases under general anaesthesia. The post-operative management was based mainly on hoof care, with an emphasis on keeping the wound clean and dry, and protected until healing was complete. One case was destroyed because of the spread of the infection into the navicular bursa. All remaining patients became sound, despite the development of a pathological fracture in two of them.

INTRODUCTION

Foot injuries are very frequent in horses. In fact, they are the most common problem that equine veterinary surgeons have to deal with (BEVA 1965). Looking back at the long history that horses and men have shared for millenia, it rapidly becomes obvious that much attention has been devoted towards the care of the foot. Sandals made of woven grass are thought to have been used by prehistoric peoples and the first "blacksmiths", who looked after the horses' feet, appeared in Assyria around 2000 B.C. (after Hickman, 1977). The first detailed description of hoof care was written by a Greek general, Xenophon, in the third century B.C. (after Hickman 1977). Despite this very old tradition, many pathological conditions that affect the equine foot still remain full of mystery. This is certainly due to the complex structure of the ungulates' digit, whose physiology is still not fully understood. Consequently, veterinarians are often faced with great difficulty in diagnosing and treating certain diseases. Laminitis and navicular syndrome have been well documented but other conditions are not as well known and too often underdiagnosed. Septic pedal osteitis, that is infection of the third phalanx, is undoubtedly one of them.

Septic affections of the bone are an important cause of morbidity in humans and animals alike. The advances in medicine in the last two decades, and in particular the release of extremely potent antibacterial drugs, have greatly reduced the mortality associated with it. Less than fifty years ago, the disease was fatal for over a third of the human patients affected, and children were particularly at risk (Blockey 1983, Dickie 1986). Amputation was then the only cure available. If bone infections only rarely prove lethal in humans nowadays, the sequelae still represent a very serious problem (Blockey 1983), especially in chronic cases which remain frequent in developing countries (Muir and Anderson 1985). In horses, and particularly so in the foot, these sequelae can be life-threatening and despite the availability of more efficient diagnostic and therapeutic methods, their management remains a challenge to today's veterinarians (Caywood 1983). Between 1982 and 1992, eight cases of septic pedal osteitis were diagnosed and treated at the Glasgow University veterinary hospital. The aim of this study is to discuss the observations obtained from the review of these cases and, if possible, to draw conclusions that may be useful to equine clinicians. After the literature has been reviewed, the techniques involved in dealing with the patients and the results of this investigation will be presented. These results will finally be discussed and interpreted in the light of the available literature on the subject.

CHAPTER ONE

REVIEW OF THE

LITERATURE

I. DEFINITIONS AND CLASSIFICATION

Osteitis is a general term used to describe inflammation of bone. The inflammation only involves the vascular tissues, contained within the haversian and Volkmann's canals, the medullary cavity and the periosteum (Jubb and Kennedy 1963, Jubb and others 1985, Cierny 1990).

Although it is nearly always caused by a septic process, infection need not be present for the inflammation to take place (Muir and Anderson 1985, Jubb and others 1985). Indeed, it can be caused by direct trauma or repeated minor injuries to the periosteum in the absence of any bacterial contamination (Jubb and others 1985). However, only septic osteitis will be considered here and the term "osteitis" will therefore be used to describe infection rather than inflammation of the bony structures.

Several classifications have been used to describe osteitis in relation to its aetiology, pathogenesis and pathology. Depending on the location of the infectious process, some pathologists distinguish **"superficial osteitis"**, involving the periosteum and cortex, from **"medullary"** infections where the medullary cavity and endosteum are affected. The condition can be further classified into **"localised"** and **"diffuse"** (Cierny 1990).

However, a classification into **"osteoperiostitis"**, or **"osteitis proper"**, and **"osteomyelitis"** is used by the majority of pathologists and clinicians. Osteitis proper (usually referred to as **"osteitis"**) is an inflammation of the cortical bone (Turner 1984) and does not involve the medullary cavity or the growth plates (Orsini 1990). It usually begins in the periosteum (Jubb and Kennedy 1963, Turner 1987). Osteomyelitis, on the other hand, describes an infection which originates in the medullary cavity of the long bones. It may only involve the latter (**"thalamic osteomyelitis"**) or can extend into the growth plates in growing animals (**"physeal osteomyelitis"**). It can secondarily affect the cortex (Harari 1984, Orsini 1990). Yet these expressions do not describe separate conditions: if the pathogenesis often follows different pathways, it is usually impossible to differentiate the two, either pathologically or clinically (Jubb and Kennedy 1963), especially in cases where the condition is rather advanced (Turner 1987).

In animals, osteitis proper is much more common and it often begins as periostitis. It is usually localised and only involves one bone (Jubb and others 1985). Osteomyelitis is however not a rare entity and is a dreaded potential complication of any bone surgery in humans and animals alike.

II. BONE INFECTIONS IN HORSES

Bone infection is a relatively common condition in the horse (Turner 1987). It can be a very serious problem indeed: in one survey, 10.6% of the fatalities associated with the locomotor system in this species were due to septic osteitis in general (Baker and Ellis 1981). The peculiar anatomy, in particular that of the limbs, and the physiology of the Equids certainly predispose them to skeletal injuries but also account for a number of differences in the clinical presentation of bone sepsis as compared to humans and other animals.

A. CAUSES

Microorganisms can be deposited into the bones by different routes: **haematogenous spread** from a distant infectious focus, **direct contamination**, or **contiguous extension** from a neighbouring septic process (Muir and Anderson 1985). Unlike in humans, where haematogenous bacterial spread is the most common aetiology, local contamination of the tissues is a far more frequent cause of bone infections in horses (Moens and others 1980, Clem and others 1986, Firth 1987, McDonald and others 1989, Carter 1991b).

Direct contamination secondary to trauma to the bones is implicated in most cases (McDonald and others 1989). In many of them, it is caused by sharp trauma, mainly skin lacerations (Clem and others 1986) or punctures (Carter 1991b). Fencing material, including barbed wire, is often considered to be the offending material (Firth 1987), however blunt trauma associated with kicks, falls or interference between the limbs are also involved (Kay and others 1976, Moens and others 1980, Stickle and others 1983, Orsini 1984). The large majority of bone infections are associated with the presence of a wound

(Firth 1987). Other infrequent causes of direct contamination of the bones include surgical trauma, as in the case of tooth repulsion (Firth 1987), and fractures where bacteria gain access to the tissues at the time of the injury (open fractures) or during open reduction and/or internal fixation (Kay and others 1976, McDonald and others 1989, Carter 1991b).

Contiguous spread from a focus of infection in the adjacent soft tissues is much more common in horses than it is in other species. Joint infections can easily spread into the adjacent epiphyses, whose vasculature is intimately related to that of the synovial membranes (Jubb and others 1985, Hanie 1989). This is particularly common in foals. In one survey, 75% of the foals presenting with septic arthritis had concurrent osteomyelitis (Martens and Auer 1980). Septic conditions of the tendon sheaths and synovial bursae can also lead to bone involvement as in the case of vertebral osteomyelitis secondary to supraspinous ("fistulous withers") or nuchal ligament ("poll evil") septic synovitis (Jubb and Kennedy 1963). Similarly, infection of the tarsal sheath or of the calcaneal bursae can spread into the tarsal bones (Edwards 1978, McDonald and others 1989). Finally, osteitis can result from sinusitis, periodontal disease (Jubb and others 1985), cellulitis related to pressure sores (Jubb and Kennedy 1963) and diffuse staphylococcal skin infections (Markel and others 1986a).

Septic material can be deposited into the bones from the bloodstream. The end result is nearly always osteomyelitis rather than osteitis proper and is usually named **"haematogenous osteomyelitis"** (Rains and Capper 1965, Blockey 1983, Muir and Anderson 1985). This is the most common route of infection in humans, but it is a rather uncommon condition in animals (Caywood 1983), and in horses in particular (Martens and others 1986). Whereas, in humans, infants are affected rather than babies, the condition is found mainly in new-born foals, usually less than 60 days of age (Martens and others 1986). This is related to the high incidence of failure of the passive transfer of colostral immunoglobulins in foals, which can lead to septicaemia and multifocal infection (Turner 1984). As in all domestic species, the bacteria are usually deposited in the metaphyses of the long bones, where the blood flow is substantially slowed by the presence of sharp vascular loops opening into dilated sinusoid vessels (Stickle and others 1983, Hanie 1989, Carter 1991a). Epiphyseal infection also occurs more commonly in horses than in humans. This is due to the presence of transphyseal vessels in the new-born animals (Hanie 1989) but also to the frequency of concurrent septic arthritis in this species (Blockey 1983, Turner 1984, Martens and others 1986).

While joint infection is often secondary to bacterial spread from the metaphyses in children (Muir and Anderson 1985), it is usually primary in foals (Martens and Auer 1980, Turner 1987). In the latter, infection of the epiphyses on either side of a joint is a relatively frequent finding (Morgan and others 1974, Turner 1984).

Haematogenous contamination is extremely rare in adults but has been implicated to explain the infection of areas of bone in the absence of any septic process in the surrounding soft tissues or any breach through the skin (Turner 1987, Gift and DeBowes 1989). Another form of haematogenous osteomyelitis has been described in the case of open fractures or surgical fracture repair that did not lead to infection of the fracture line or around the implants, but rather to the formation of an abscess in the metaphysis of the affected bone (Stickle and others 1983).

B. SITES

Most bone infections in horses occur in the limbs (Lewis and Heinze 1970), as shown in one survey where 87% of the cases were related to the appendicular skeleton (Clem and others 1986). Haematogenous osteomyelitis mainly occurs in long bones (Stickle and others 1983, Carter 1991a), although any part of the skeleton can be infected this way (Jubb and others 1985). In particular, vertebrae may be affected, but this is considered to be very rare in Equids (Markel and others 1986b, Carter 1991a).

Osteoperiostitis occurs in areas that are exposed to trauma, that is where the natural protection from the soft tissues is poor (Firth 1987, Turner 1987, Clem and others 1987, McDonald and others 1989). As a consequence, the extremities of the equine limbs, lacking muscle coverage, are most commonly affected (Rose 1978, Turner 1984, Carter 1991b), especially the third metatarsus and metacarpus (Lewis and Heinze 1970, Rose 1978, Clem and others 1986, Jann and others 1987, Orsini 1990). In one report, 57% of the cases of osteitis occurred in the "cannon bones" (Clem and others 1986), while the third metatarsus was much more frequently involved than the metacarpus in another study (Moens and others 1980), probably because the hind limbs are more prone to trauma than the fore limbs.

Osteitis and osteomyelitis have been described more infrequently in other limb bones, including the first and second phalanxes (Lewis and Heinze

1970, Gift and DeBowes 1989), the tibia (Moens and others 1980, Carter 1991a), the distal radius (Moens and others 1980, Firth 1987) and the humerus (Lewis and Heinze 1970, Moens and others 1980, Firth 1987). The condition is relatively common in the small metacarpal bones ("splint bones") (Turner 1984, Firth 1987). There have also been a few reports of infection of the tarsal bones (Lewis and Heinze 1970), in particular the sustentaculum tali (Edwards 1978, Tulleners and Reid 1981, McDonald and others 1989) and the tuber calcis (McDonald and others 1989) of the fibular tarsal bone. Areas prone to pressure sores such as the tibial malleoli, the radial styloid processes and the accessory carpal bone can also become secondarily infected (Jubb and Kennedy 1963).

C. CLINICAL FEATURES

Unlike in humans, chronic, superficial osteitis is more common than osteomyelitis in horses (Muir and Anderson 1985). In the absence of a prompt treatment, chronic suppurative osteitis develops both with haematogenous metaphyseal osteomyelitis (Stickle and others 1983) and osteoperiostitis (Jann and others 1987). It is characterised by the formation of an abscess subperiosteally and usually results in a chronically persistent or recurrent drainage through the soft tissues and the skin (Rose 1978, Moens and others 1980, McDonald and others 1989, Orsini 1990).

A very common feature of osteitis in the horse is the formation of sequestra. A sequestrum is nearly always infected (Turner 1987) and is usually caused by direct trauma (Turner 1984, Clem and others 1986, Carter 1991b). Some sequestra are observed in the absence of wounds (Jann and others 1987, McDonald and others 1989) but are often related to small chip fractures where the fragment has lost its blood supply (Moens and others 1980). In any case, it is felt that sequestra do not develop in the absence of infection (Gift and DeBowes 1989), and Moens and others (1980) showed experimentally that trauma and contamination were both necessary to induce the sequestration of bony fragments. It is possible that sequestra develop unrelated to wounds because bacteria reach devitalised bone haematogenously (Clem and others 1987, Gift and DeBowes 1989)

Diffuse osteomyelitis may infrequently occur in horses secondarily to haematogenous infection (Hanie 1989, Carter 1991a), open fractures or surgical contamination during internal fracture fixation (Kay and others 1976, Stickle and others 1983, Turner 1987).

III. SEPTIC OSTEITIS OF THE DISTAL PHALANX

Although relatively uncommon, osteitis of the third phalanx ("pedal bone") is a potential complication of any septic condition of the equine foot.

A. SEPTIC CONDITIONS OF THE EQUINE FOOT

Infections of the foot in horses have been described in detail (Adams 1974, Fessler 1989, Stashak 1989, DeBowes and Yovich 1989, Turner 1990, Moyer 1991). These infections are extremely frequent: they accounted for 22% of all digital disorders in a large survey conducted in The United Kingdom in 1962-63 (BEVA 1965) and are the most common disease not only of the foot, but also of the entire musculoskeletal system (BEVA 1965, Johnson 1972, Dyson 1986, Moyer 1991). Fessler (1989) stated that "most horses sustain a subsolar abscess at some time in their life". This is because the hoof lies continuously within a heavily contaminated environment (mud, litter etc.), and is directly exposed to aggressions from the ground surface (DeBowes and Yovich 1989).

All the tissues enclosed within the hoof can become infected and the nature and function of the structures affected, more than the actual extent of the septic process, determine the severity of the condition. This depends mainly upon the site and depth of the initial injury. The hoof is a strong structure which tightly encloses the tissues of the foot, thus isolating them from the environment. Contamination can only occur if there is a discontinuity of this natural seal.

Infection can be induced **iatrogenically** when a contaminated object is introduced through the cornified hoof. Improper placement of the nails at the time of shoeing is certainly the most common iatrogenic aetiology (Richter 1982). Nails can be driven directly into sensitive structures and cause infection, whether immediately withdrawn or remaining in place for some time

(Richter 1982, Steckel 1984). Occasionally they do not penetrate the deeper structures but cause local compression, leading to necrosis and secondary infection of the underlying tissues (Johnson 1972).

Infrequently, bacteria can be introduced during injections into the distal interphalangeal joint or the navicular bursa (Turner 1984), or during surgical procedures such as internal fixation of distal phalangeal fractures (Rose and others 1979).

The most common cause of foot sepsis, however, is **puncture wounds**, that is injuries to the ground surface of the foot, to the hoof wall or to the coronary band, that are caused by sharp, pointed objects (Johnson 1982, Richter 1982, Richardson and others 1986a). In the majority of cases, the offending object does not penetrate the corium, causing what is usually referred to as a **"superficial puncture wound"**. The usual result is an abscess beneath the sole (Johnson 1970, Johnson 1972, Steckel 1984). Because the anatomy of the foot prevents drainage (Richter 1982, Steckel 1984), the infected material undermines the sole, and sometimes the frog, between the stratum corneum and the stratum germinativum (Johnson 1982, Steckel 1984). It then follows the path of least resistance below the hoof wall between the stratum lamellatum and the stratum germinativum of the parietal epithelium (Hauser and others 1982, DeBowes and Yovich 1989, Turner 1990). Eventually, the purulent material bursts out at the coronary band, often at the bulbs of the heel (Hauser and others 1982). In some cases, the accumulation of exudate may lead to increased pressure and subsequent liquefaction of the deeper tissues (Richter 1982, Steckel and Fessler 1983, Turner 1984, Stashak 1987a, Gaughan and others 1989).

Deep puncture wounds which result from penetration of the corium are relatively less common (Fessler 1971, Stashak 1987a) but are associated with more serious complications, related to the structures involved. Richardson and others (1986a) have proposed a classification of deep puncture wounds into three types, depending upon the site of entrance of the offending object. **Type I puncture wounds** involve the solar corium. Reported complications include fractures of the distal phalanx (Johnson 1972, Steckel and Fessler 1983, Richardson and others 1986a, Honnas and others 1988a, Baird and others 1990), necrosis of the digital cushion (Adams 1974, Richardson and others 1986a, Stashak 1987a) and extension of the septic process into adjacent structures, including the distal interphalangeal joint, the deep digital flexor tendon etc. (Turner 1984). **Type II punctures** are related to a penetration through the frog or its sulci and may lead to septic arthritis of the distal interphalangeal joint (Adams 1974, Honnas and others 1992), fracture of the distal sesamoid bone (Richardson and others 1986a, Rick 1990b), abscess formation within the digital cushion (Richardson and others 1986a) and septic podotrochleitis (or septic synovitis of the navicular bursa), which is certainly the most common and most serious complication (Richardson and O'Brien 1985, Richardson and others 1986b, Stashak 1987a). This condition is associated with a very poor prognosis: it may cause septic distal interphalangeal arthritis (Richardson and O'Brien 1985) or, more frequently, osteomyelitis of the distal sesamoid bone and infection of the deep digital flexor tendon or of the distal sesamoidean ("impar") ligament (Steckel and Fessler 1983, Richardson and others 1986b). These two structures may rupture secondarily to their necrosis. Finally, **type III punctures** correspond to penetrations through the coronary band and consequences that have been reported include septic arthritis of the distal interphalangeal joint (Richardson and others 1986a) and infection of the collateral cartilages of the distal phalanx ("quittor") (Johnson 1982, Richter 1982, Honnas and others 1988b).

A condition not as frequently reported is a puncture wound through the white line, which is often referred to as "gravel". The abscess induced by the penetrating object undermines the hoof wall and tracks proximad between the laminae, before bursting out at the coronary band, proximally to the site of penetration (Johnson 1970, Hauser and others 1982, Richter 1982, Turner 1990).

All these conditions may lead to secondary infection of the distal phalanx (Steckel and Fessler 1983, Gaughan and others 1989). Primary contamination, however, is due to deep puncture wounds of all three types described above, although type I injuries are more frequently encountered (Richardson and others 1986a, DeBowes and Yovich 1989).

A very similar pathology affects the human finger. Both the anatomical structure and the function of the hand are very different from the equine digit, yet similar conditions exist: the human third phalanx is protected dorsally by the nail and palmarly by a thick layer of loose connective tissue called the *terminal pulp space* (Hooper and Pollen 1989). Like the horse's hoof, the hand is in nearly constant contact with the environment and is therefore subjected to frequent aggressions and contamination. The hand is indeed the most common site of infection in humans. Fifty-five percent of these sepses develop at the level of the distal finger (Rains and Capper 1965). The most common form, *paronychia*, is a purulent infection below and around the sides of the nail, similar to subsolar abscesses in horses. In some patients, the third phalanx becomes secondarily involved (Hooper and Pollen 1989). Another condition called *"felon"* represents the development of an abscess within the terminal pulp space. It is usually caused by a puncture wound. The pulp space is enclosed within a strong fascia that tends to prevent drainage of the pus and osteomyelitis of the phalanx often occurs, unless surgical debridement is performed (Rains and Capper 1965, Hooper and Pollen 1989, Linscheid and Dobyns 1990).

A number of other foot injuries can, less commonly, cause such infections. Severe bruising of the sole has been reported to cause subsolar abscessation (Steckel 1984, DeBowes and Yovich 1989) and submural pyogenic infections may be induced by the presence of wall cracks (Johnson 1972). Avulsions of the hoof and/or coronary band are very often complicated by septic osteitis of the pedal bone (Fessler 1971, Steckel and Fessler 1983, Fessler 1989). Another well-known cause of sepsis in the foot is chronic laminitis. Rotation of the third phalanx away from the dorsal hoof wall leads to widening of the white line ("seedy toe") which predisposes to contamination and pyogenic infection of the necrotic material accumulated between the wall and the bone (Quick and Rendano 1977, Johnson 1982, Firth 1987, Gaughan and others 1989). Severe infection also occurs in cases of perforation of the sole by the "sinking" distal phalanx (Johnson 1982, Stashak 1987a).

B. INFECTION OF THE THIRD PHALANX (SEPTIC PEDAL OSTEITIS)

Septic inflammation of the distal phalanx is often referred to as **"pedal osteomyelitis"** (Richter 1982, Mackey and Roy 1984, Steckel 1984, Chapman and Platt 1986, Richardson and others 1986a, Rook and Stickle 1987, Honnas and others 1988a, DeBowes and Yovich 1989, Fessler 1989, Turner 1990). However, there is no medullary cavity in the third phalanx of the horse (or "pedal bone") (Sisson and Grossman 1953, Dyce and others 1987, Gaughan and others 1989) and some authors prefer to use the term "osteitis" to describe infections of this bone (Fessler 1971, Stashak 1987a, Gaughan and others 1989, Pabst and Kaegi 1990). On the other hand, the expression **"pedal osteitis"** is generally used to describe a radiographic alteration of the image of the distal phalanx, related to various degrees of demineralisation (Moyer 1979, McColles 1985, Stashak 1987a). Although it is thought to be secondary to inflammation in most cases (Adams 1974, Johnson 1982, Honnas and others 1988a), whether or not related to a septic process, its pathogenesis is in fact not fully understood (Moyer 1979, McColles 1985). It may involve non-inflammatory processes such as decreased blood supply (Colles and others 1979), chronic disuse, poor conformation, old age etc. (Adams 1974, Johnson 1982, Turner 1987). "Pedal osteitis" is therefore a radiological sign rather than a true pathological condition.

The expression **"septic pedal osteitis"** should be used to describe inflammation of the distal phalanx in Equids, related to a septic process. It is characterised clinically by the presence of infected material associated with radiographic signs of bone lysis (Gaughan and others 1989, Pabst and Kaegi 1990).

Infection of the pedal bone has been mentioned in various textbooks and publications as a potential complication of foot injuries, chronic laminitis (Chapman and Platt 1986) or surgical interventions (Rose and others 1979). In fact, the number of clinical reports that describe this condition is fairly limited. There have been few reports of cases where septic pedal osteitis was one of the features observed (Rose and others 1979, Mackey and Roy 1984, Rook and Stickle 1987, Dart and Pascoe 1988, Baird and others 1990). A larger study (Steckel and Fessler 1983) described a few cases of distal phalangeal infection as a complication of hoof wounds. Only rarely however has the condition been considered as a clinical entity in itself: two recent studies presented a series of cases and emphasised the sparcity of detailed data available concerning this pathology (Gaughan and others 1989, Pabst and Kaegi 1990).

1. Causes

As mentioned earlier, septic injuries to the pedal bone are closely related to those of the foot in general. The cases described in the literature confirm that deep puncture wounds are the most common aetiology (Richter 1982, Mackey and Roy 1984, Steckel 1984, Firth 1987, Reeves and others 1989). Exposure of the bone to the environment is also frequently implicated and is usually associated with sloughing of the hoof wall in severe cases of laminitis (Crawley and others 1989), chemical trauma from excessive treatment of solar bruising with formalin (Dart and Pascoe 1988) or surgical debridement of subsolar abscesses (Baird and others 1990). Extension of neglected or mismanaged abscesses into the bone can also occur (Gaughan and others 1989), particularly in neurectomised horses that do not show any signs at the time of the injury or in the early stages of infection (Mackey and Roy 1984). The bone can also become infected in cases of "complicated" laminitis, that is when rotation of the distal phalanx allows the development of a submural abscess (Chapman and Platt 1986, Gaughan and others 1989). In one case report, the condition was due to iatrogenic contamination after internal fixation of a distal phalangeal fracture (Rose and others 1979).

2. Pathological features

Any part of the distal phalanx can be affected. Central parts of the body of the pedal bone seem to be frequently involved (Richter 1982, Rook and Stickle 1987), especially on its solar surface (Steckel and Fessler 1983, Dart and Pascoe 1988). The wings (palmar or plantar processes of the third phalanx) may also become infected (Mackey and Roy 1984, Honnas and others 1988b, Baird and others 1990).

The presence of **fractures** has been associated with these infections, including fractures of the palmar or plantar processes (Mackey and Roy 1984) or chip fractures of the solar margin of the bone (Richter 1982). These may, occasionally, have been produced before, or simultaneously to, the septic process, but they are usually secondary to inflammation and necrosis of the bone (**pathological fractures**) (Baird and others 1990). They are easily confused with sequestra.

Formation of a **sequestrum** is a relatively common feature of septic pedal osteitis in horses and has been studied as a separate entity (Firth 1987, Baird and others 1990). It is not quite clear whether sequestra represent fractured pieces of bone that have lost their blood supply and become secondarily infected (Mackey and Roy 1984) or whether the sequestration, that is the isolation of the bony fragment from the viable tissues, occurs before the necrotic bone actually becomes fractured (Dart and Pascoe 1988). In any case, sequestra are always infected (Firth 1987) and it is likely that they represent but a particular pathological feature of septic osteitis. It is indeed virtually impossible to distinguish the aetiology of sequestra from that of septic osteitis in the pedal bone (Firth 1987, Baird and others 1990).

Other complications of this condition include **progression of the septic process**, which may occur after treatment has been instituted (Pabst and Kaegi 1990). The infection may spread into the bone or into adjacent structures, in particular the distal interphalangeal joint (Mackey and Roy 1984), and the digital sheath of the deep digital flexor tendon (Rook and Stickle 1987).

Localisation of the sepsis into an **abscess** is another complication which has been infrequently reported (Rook and Stickle 1987, Pabst and Kaegi 1990). It may follow a course of antibiotics when proper debridement of the necrotic tissues has not been performed (Colles 1983), or in neglected chronic cases (Fessler 1971): the bacteria are hidden within the necrotic material and can therefore not be reached by natural defense mechanisms or antibacterial drugs. Very large cyst-like lesions can form within the body of the distal phalanx (Chapman and Platt 1986). **Laminitis** has also been reported as a complication to the surgical treatment of septic pedal osteitis in one case (Dart and Pascoe 1988).

3. Clinical Features

a. Clinical Signs

The clinical signs associated with septic pedal osteitis are often difficult to differentiate from those of other septic conditions of the equine foot. **Lameness** is certainly the one most consistent sign: it is observed in virtually all cases and is usually severe (Steckel and Fessler 1983, Gaughan and others 1989, Baird and others 1990). A **bounding digital pulse** can often be felt (Rook and Stickle 1987, Pabst and Kaegi 1990) and, in most patients, **pain** is obvious when pressure is applied to the foot with hoof testers (Baird and others 1990). In the majority of these animals, the entire sole is sensitive at the time of the examination (Johnson 1972), although it may be possible in some to observe a more pronounced reaction over the site of the initial puncture wound (Adams 1974, Richter 1982, Richardson and others 1986a).

Another consistent finding is the **presence of draining tracts** discharging purulent material (Rose and others 1979, Rook and Stickle 1987, Baird and others 1990). These have often been present for some time or have recurred after a course of antibiotics or local antiseptic treatment has been terminated (Turner 1990). There may be **soft tissue swelling** above the coronary band and up to the proximal cannon (Rook and Stickle 1987), but this is rarely observed (Pabst and Kaegi 1990).

b. Diagnosis

Because the clinical signs are not specific to this condition, it is not always easy to diagnose. An offending foreign body can sometimes be found (Turner 1990) or its site of penetration can be identified as a black dot or crack in the horn (Johnson 1970, Richter 1982, Richardson and others 1986a). Hoof testers may be helpful in locating the entrance portal (Richardson and others 1986a) but in many cases the sensitive area is very diffuse (Rook and Stickle 1987) and it is often impossible to detect a puncture wound (Dyson 1986). When a penetration site can be found, a sterile metal probe can be used to assess the direction and depth of the tract (Turner 1990).

Radiography is, however, the most effective method to confirm the involvement of the distal phalanx (Rose and others 1979, Steckel and Fessler 1983, Rook and Stickle 1987). Radiographic changes within the bone (Richardson and others 1986a, DeBowes and Yovich 1989), the presence of foreign bodies or gas (Turner 1990) and the identification of sequestra (Firth 1987, Baird and others 1990) are the most common findings and the introduction of a metal probe or contrast medium ("fistulography") have been useful in some cases (Richardson and others 1986a, DeBowes and Yovich 1989). However, radiographic changes related to bone sepsis are only obvious a minimum of two to three weeks after the injury (DeBowes and Yovich 1989, Turner 1990). The diagnosis is therefore often delayed, as is the treatment.

4. Treatment

The treatment of osteitis in the early, acute stages is based on the administration of antibiotics and local debridement to allow drainage of all purulent exudate (Hughes and Anderson 1985, McDonald and others 1989). In the large majority of cases, significant bony changes are already present by the time an accurate diagnosis can be obtained and treatment instituted. In these patients, medical therapy has invariably failed (Johnson 1982, Rook and Stickle 1987, Fessler 1989, Turner 1990).

Surgical treatment is the only alternative whenever there is radiographic evidence of bone necrosis (Firth 1987, Baird and others 1990). Generally, prompt surgery has given the best results in terms of return to normal function of the patients (Richardson and others 1986a, Gaughan and others 1989). The surgical techniques involved have been described in the literature (Turner 1990); their aim is to remove all damaged bone and necrotic tissues (Steckel and Fessler 1983, Turner 1984, Chapman and Platt 1986, Pabst and Kaegi 1990) and establish proper drainage (Fessler 1989, Moyer 1991). The procedure is sometimes performed in the standing animal, under sedation and local or regional analgesia (Fessler 1971, Dyson 1986), but general anaesthesia is recommended by most authors in order to perform a proper examination and debridement under aseptic conditions (Richardson and others 1986a, DeBowes and Yovich 1989, Gaughan and others 1989).

The **prognosis** associated with this condition varies considerably. It is often considered to be guarded (Johnson 1972) but early surgical treatment has given a good prognosis for return to normal function or intended use of the patients (Gaughan and others 1989, Pabst and Kaegi 1990), although a decreased level of performance has been observed in some animals (Steckel and Fessler 1983).

CHAPTER TWO

REVIEW OF CASES

I. MATERIAL AND METHODS

A. CASE SELECTION

The cases gathered in this study were chosen from the clinical records of the equine surgery unit of Glasgow University Veterinary School. The clinical records of all the horses seen between 1981 and 1991 were consulted. The radiology files and the theatre records, both kept in the form of a computerised database, were also used.

The criteria for selection of the cases were as follows: all records where sepsis involving the third phalanx was described or suspected were read carefully. Septic osteitis was characterised by the clinical evidence of infection, such as signs of inflammation or the presence of purulent material or necrotic tissues within the foot, combined with the radiographic and/or surgical evidence of bone lysis and necrosis. Cases of primary involvement of the navicular synovial bursa ("septic podotrochleitis") were not included in this study. A total of eight cases were thus recovered and found to match these criteria. Their records and radiographs were analysed and compared. They were also given a number from 1 to 8 at random. They will be quoted in this review under these numbers.

B. METHODS

1. Preliminary examination

All patients presented in this study received a complete physical examination when they were first admitted, regardless of what had been performed by the referring veterinarian. Where necessary, and as indicated by the results of that clinical assessment, regional anaesthesia and trimming of the hoof were carried out.

2. Radiographic examination

a. Techniques:

In all the cases, radiographs of the affected foot were taken with a large radiographic unit (SIEMENS RG125, Siemens, Munchen, Germany) or with a mobile radiographic unit (OMNIX N30, X-Ograph ltd, Malmesbury, U.K.). Cassettes equipped with **rare earth intensifying screens** were used (CRONEX Cassettes, Dupont Medical Imaging Products).

The patients were usually sedated using a combination of **detomidine hydrochloride** (*DOMOSEDAN*, Norden Laboratories) at a dose rate of 10 micrograms per kilogram of body weight (10 µg/kg) and **butorphanol tartrate** (*TORBUGESIC* Injection, C-Vet Ltd) at a dose of 0.025 mg/kg, both given simultaneously intravenously.

A standard lateral to medial view and a dorsoproximal to palmaro- or plantodistal 60° oblique view of the distal phalanx were always included. Other views were obtained as and when required: dorsoproximal to palmaro- or plantodistal 65° oblique view of the distal sesamoid bone, dorsopalmar or dorsoplantar view of the third phalanx and various oblique views used to "skyline" parts of the latter.

Contrast studies (fistulography and arthrography) using sterile metal probes and/or a **meglumine iothalamate** solution (*CONRAY 280 Injection*, May and Baker Ltd, Dagenham, U.K.) were performed in two cases to assess the extent of a fistula or abscess and the degree of involvement of the different structures within the foot. Fistulography was performed in one patient (Case 4). The animal was sedated using the combination described above and the affected foot was trimmed in order to remove the purulent material and necrotic horn around the discharging tract. The hoof was then thoroughly cleansed with a brush and surgical soap and rinsed with surgical spirit. A 14-gauge, 8mm teflon "over-the-needle" catheter sheath (*INTRAFLON 2*, Laboratoires Pharmaceutiques Vygon, Ecouen, France) was then introduced into the discharging tract and approximately 8 millilitres of contrast medium were injected. A dorsoproximal to palmarodistal 60° oblique radiograph was taken immediately after the injection, followed by a standard lateral to medial view of the affected foot. Arthrography was performed in another patient (case 8). This was undertaken at the time of surgery in order to confirm or rule out the extension of the septic process into the distal interphalangeal joint. The foot had been prepared aseptically for the surgical procedure and no further preparation was therefore necessary. An 18-gauge, 1.5 inch hypodermic needle was introduced into the dorsal pouch of the joint in a routine manner and 5 millilitres of contrast medium were injected. A standard latero-medial radiograph of the foot was taken immediately thereafter (Figure 1).

b. Radiographic analysis:

The radiographs were analysed and interpreted in a routine manner. The criteria used to propose a diagnosis of pedal osteitis were as follows: signs of sepsis were as evidenced by the physical examination, i.e. the presence of purulent material or draining tracts, inflammation of the affected foot and failure of the conservative management to improve the condition. The presence on radiographs of areas of radiolucency compatible with the presence of gas within the foot was considered to be a likely sign of infection. The contact of these "gas shadows" with the bone of the third phalanx, the evidence of bone lysis (focal decrease of radiodensity and widening of the vascular channels, marginal irregularity, obvious defects) and bone reaction (new bone formation, sclerosis indicated by a focal increase of radiodensity) were considered to be signs of osteitis.

The degree of damage to the bone was evaluated by assessing the relative quantity of bone tissue that had undergone lysis and that was removed surgically. Due to the difficulty in determining volumes with the available equipment, an approximation was obtained by measuring the surface area of the third phalanx as it appeared on dorso-proximal to palmaro- or planto-distal 60° oblique radiographic views. The image was reproduced on transparencies and the original shape of the bone was drawn by comparing the altered contour with that of undamaged parts and, when necessary, with the contralateral phalanx (opposite limb). The surface area of the images thus obtained was measured by using a graduated grid, and the percentage of the bone destroyed was calculated. The same method was then applied on post-operative radiographs.

3. Therapeutic procedures

In all the patients considered in this study, surgical exploration and debridement of the wound were carried out because it was felt that it was the most expedient method and the only treatment in the presence of necrotic bone. However, surgery was only considered after a thorough physical and radiographic examination had ascertained the likelihood of septic pedal osteitis and indicated fairly accurately the area involved. In several cases, this required the application of poultices (*ANIMALINTEX*, Robinson and Sons Ltd,

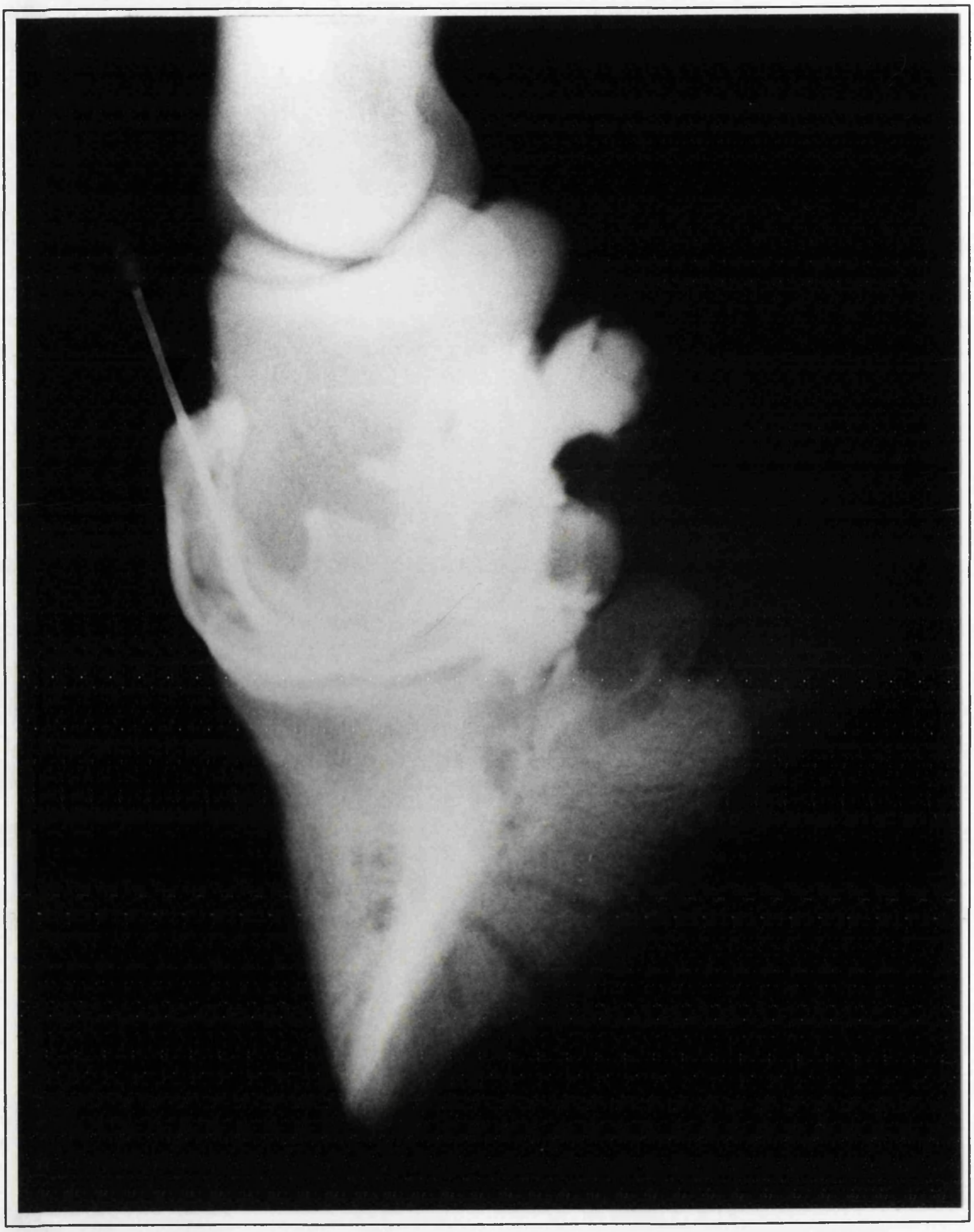


Figure 1.

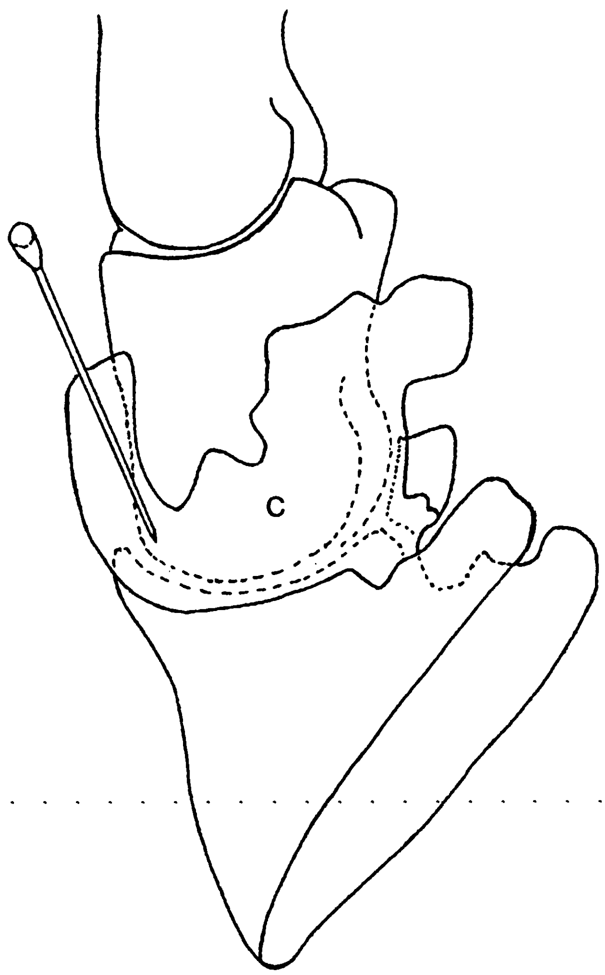


Figure 1: Distal interphalangeal arthrogram (Case 3)

The contrast fluid has filled the joint (c) and does not appear to leak into surrounding tissues or cavities.

Wheat Bridge, U.K.) and hot saturated sodium chloride solutions in order to detect the presence of a fistula.

a. Preoperative considerations

In all the patients, the foot to be operated on was trimmed with a hoof knife to eliminate grossly contaminated horn and then cleansed with a dilute **hexamidine based soap** (*HIBISCRUB* Skin Cleanser, ICI Pharmaceutical Division, Macklesfield, U.K.) the day before the operation. The hoof was kept overnight in a waterproof bandage soaked in **povidone-iodine solution** (*PEVIDINE* Antiseptic Solution, BK Veterinary Products Ltd, Bury St Edmunds, U.K.). Along with a complete physical examination, routine biochemical and haematological blood tests were performed to help assess the anaesthetic risk, before the animals were starved for twelve hours. Systemic antibacterial drugs were usually administered at least twenty-four hours prior to the operation, so that sufficient plasma levels were obtained before the wound debridement was performed. In the absence of results from bacterial sensitivity at that stage, a combination of **trimethoprim and sulfonamides** (*UNIPRIM* for Horses, Cheminex Laboratories Ltd, Corby, U.K.) was used because of its wide spectrum of activity, low toxicity and the possibility of oral administration

b. Surgical techniques (Figure 2a-e)

Anaesthesia was induced in all patients, after premedication with intramuscular acetylpromazine (ACP Injection 10 mg/ml, C-Vet Ltd, Corby, U.K.), with either a combination of intravenous xylazine hydrochloride (ROMPUN Dry Substance, Bayer U.K. Ltd, Bury St Edmunds, U.K.) and ketamine (KETASET Injection, Willows Francis Veterinery, Crawley, U.K.), or xylazine and thiopentone (INTRAVAL Sodium, RMB Animal Health Ltd, Dagenham, U.K.). After intubation, anaesthesia was maintained with a halothane/oxygen mixture and intravenous increments of ketamine. The horses were placed on lateral recumbency on an inflatable mattress and the affected limb was clipped from mid-cannon distally. **Regional anaesthesia** was performed in all the cases, by injecting 2.5 millilitres of 2% mepivacaine hydrochloride (INTRA-EPICAINE, Arnolds Veterinary Products, Romford, U.K.) near the palmar or plantar digital nerves on either side of the limb at the level of the proximal sesamoid bones. An Esmarch bandage was then applied proximally to the fetlock and the distal limb was cleansed and draped in a routine sterile manner.

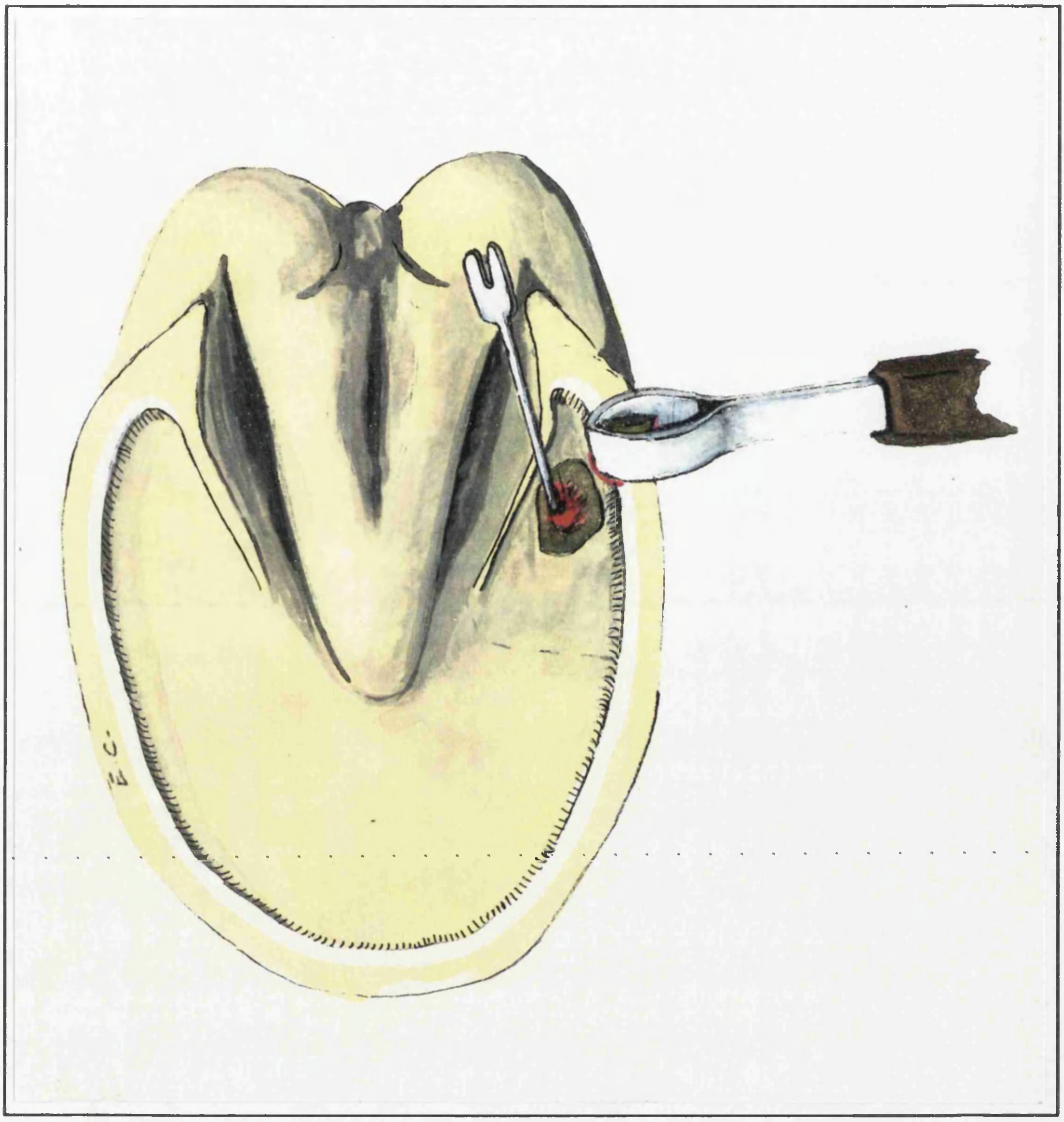


Figure 2a: A probe is introduced into the sinus tract. A sterile "quittor" knife is used to pare out the horn progressively around the probe.

Figure 2: Surgical treatment of septic pedal osteitis: Example of an infected palmar process

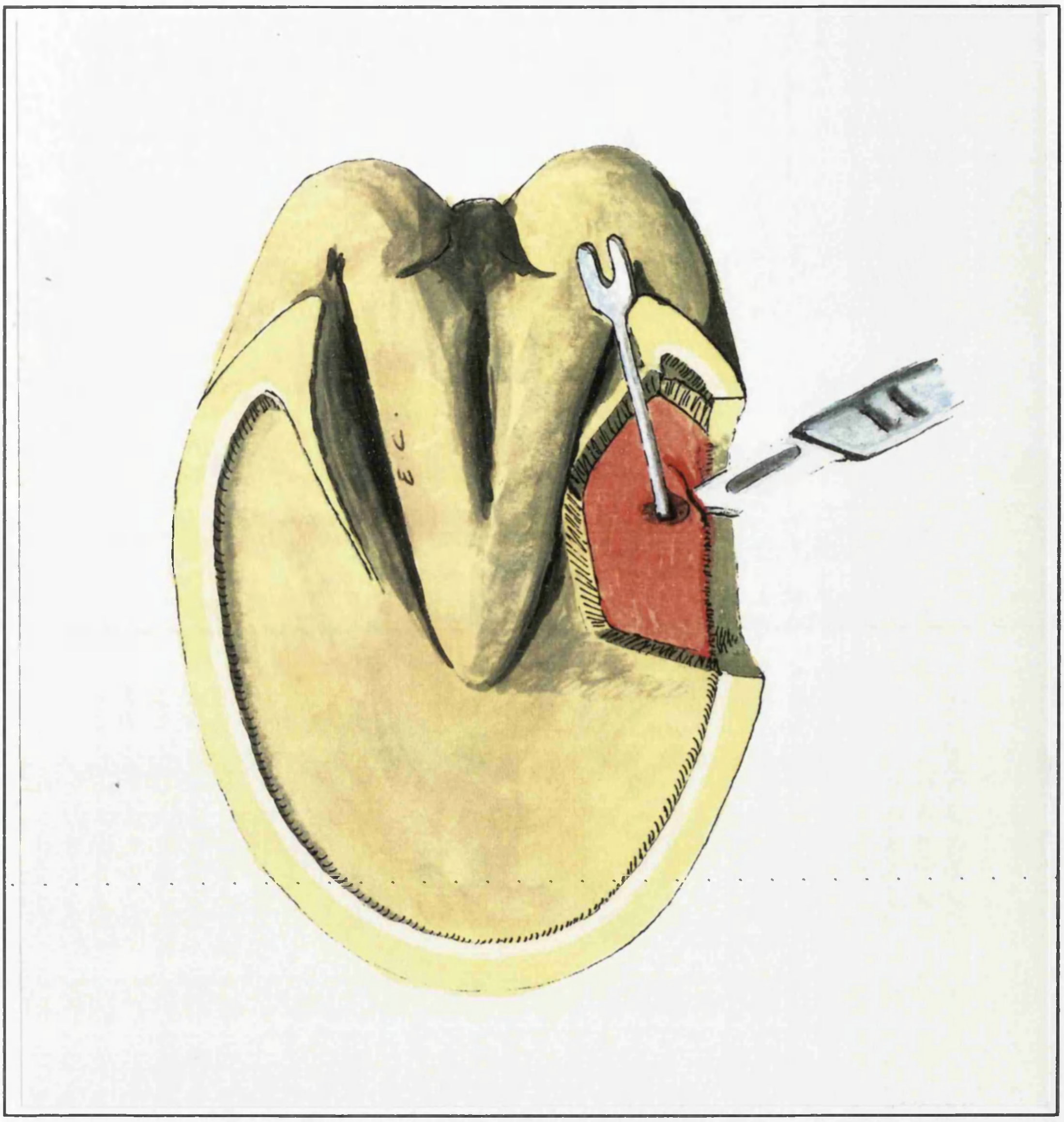


Figure 2b: Once all underrun horn has been removed, the soft tissues are excised with a scalpel around the probe, each tissue layer being removed separately

Figure 2: Surgical treatment of septic pedal osteitis: Example of an infected palmar process

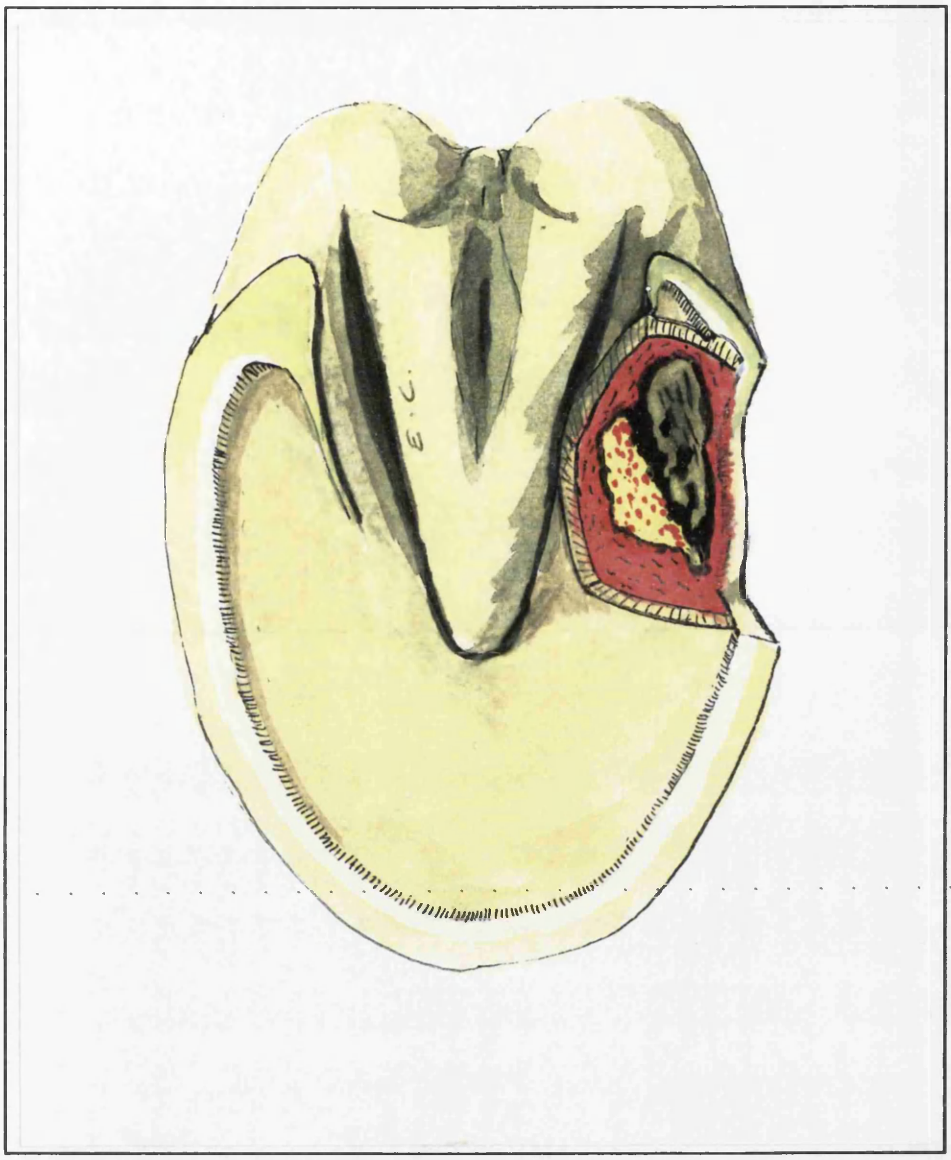


Figure 2c: All abnormal bone, plus a margin of healthy bone, is exposed. The wound can be increased in size if required, always ensuring that the edges flare outwards.

Figure 2: Surgical treatment of septic pedal osteitis: Example of an infected palmar process

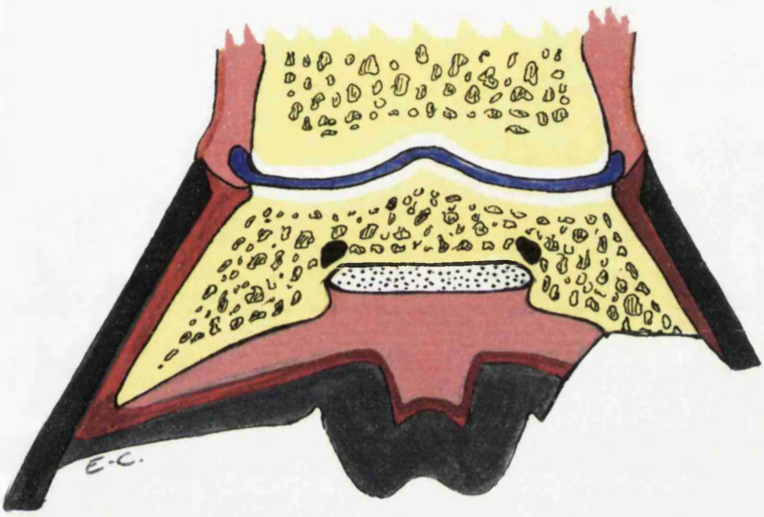


Figure 2d: Longitudinal section through the surgical wound, showing the conical shape of the defect.

Figure 2: Surgical treatment of septic pedal osteitis: Example of an infected palmar process

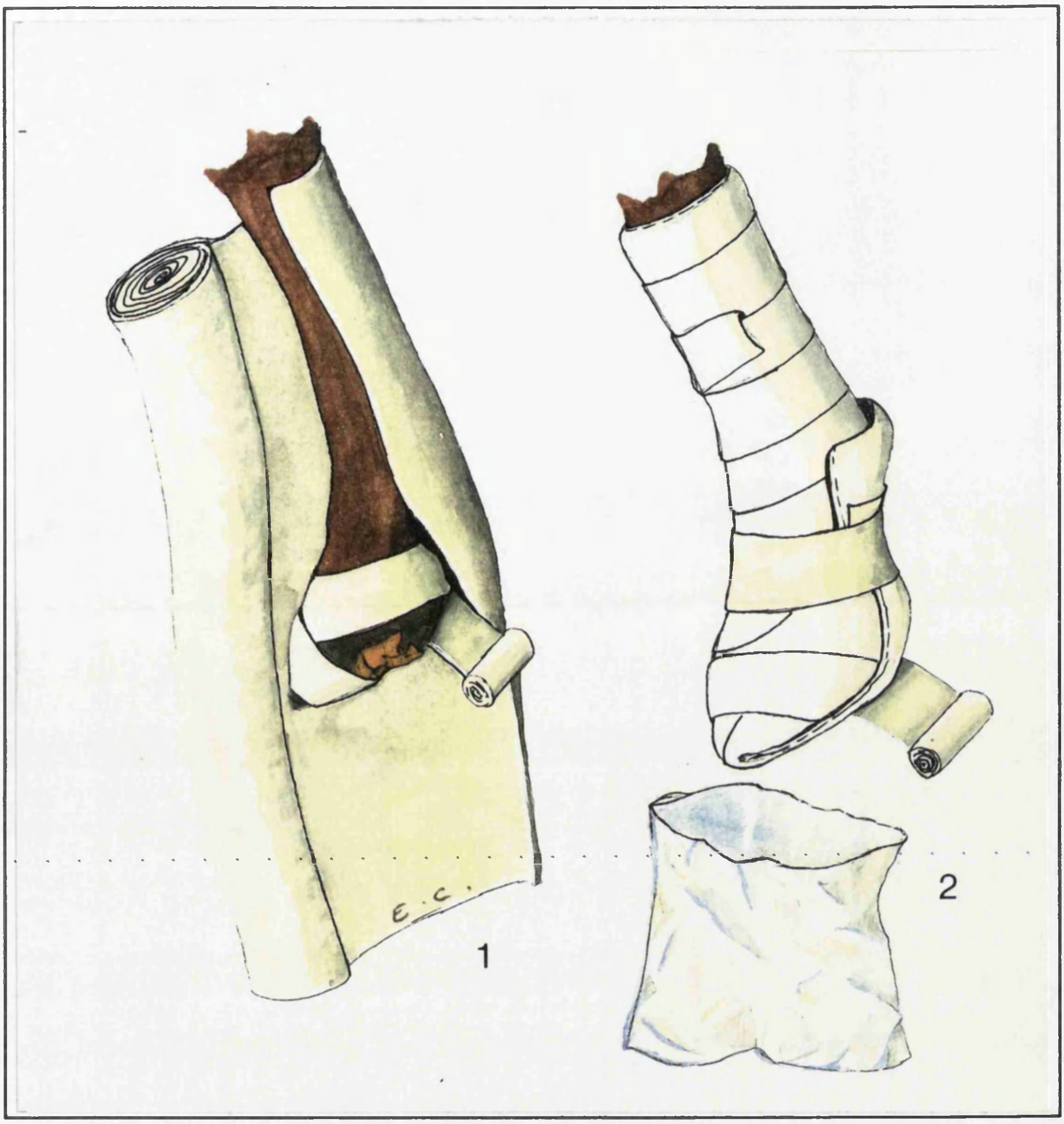


Figure 2e: After the debridement and lavage, the defect is tightly packed with swabs soaked in a povidone-iodine solution, and kept in place with gauze bandages (1). A thick layer of cotton is then applied to the foot and up to the proximal metacarpus.
The bandage is finally covered with a polythene bag, protected by a strong, adhesive bandage (2).

Figure 2: Surgical treatment of septic pedal osteitis: Example of an infected palmar process

A sterile, flexible **metal probe** was introduced into the fistulous tract whenever possible and the horn around the entrance of this tract was pared away with a sterile quittor knife. All abnormal horn was removed. Using the probe as a guide, the deeper structures were exposed and debrided with scissors and a scalpel until the bone was reached and exposed. Care was taken to ensure that all the abnormal, necrotic tissue was debrided and that the hole was large enough to expose all the affected bone.

The quality of the bone was assessed on the basis of its colour, consistency, smell and tendency to bleed. In all the cases presented here, the necrotic bone was grossly discoloured, that is pale grey to black, and usually had a foul smell. It was always friable and soft, and did not bleed when being scraped. All the abnormal bone that could be identified was debrided with bone curettes and rongeurs, until only healthy, bleeding bone was left (Figure 3).

The wound was then flushed with a 0.5% povidone-iodine solution and then with solutions of **metronidazole** (*TORGYL* Solution, RMB Animal Health Ltd, Dagenham, U.K.) and either **sodium benzylpenicillin** (*CRYSTAPEN* 5-Mega for Injection, Pitman-Moore Ltd, Uxbridge, U.K.) or **ampicillin** (*PENBRITIN* Injectable Suspension, Beecham Animal Health, Brentford, U.K.). The wound was packed with gauze swabs soaked in povidone-iodine and a waterproof sterile bandage was applied over the entire foot and up to the carpal or tarsal area after the tourniquet had been released. The horses received an injection of **tetanus antitoxin** (*TETANUS ANTITOXIN*, The Welcome Foundation Ltd, London, U.K.) and non steroidal antiinflammatories before the end of the anaesthetic and were injected intramuscularly with **potentiated sulfonamides** (*TRIBRISSEN 485* Injection, Coopers Animal Health Ltd, Crewe, U.K.) once they were standing.

4. Postoperative treatments

Analgesic drugs were administered for several days. Most patients were given oral **phenylbutazone** (*EQUIPALAZONE*, Arnolds Veterinary Products, Romford, U.K.) at a dose of 4.4 milligrams per kilogram of body weight twice daily, decreased to 2.2 mg/kg twice daily once the horses started to increasingly weightbear on the affected foot. In small ponies, **meclofenamic acid** (*ARQUEL* Granules, Parke, Davis and Co., Pontypool, U.K.) at a dose of 2.2 milligrams per kilogram, given orally twice daily, was preferred to phenylbutazone because of its decreased toxicity. **Potentiated**

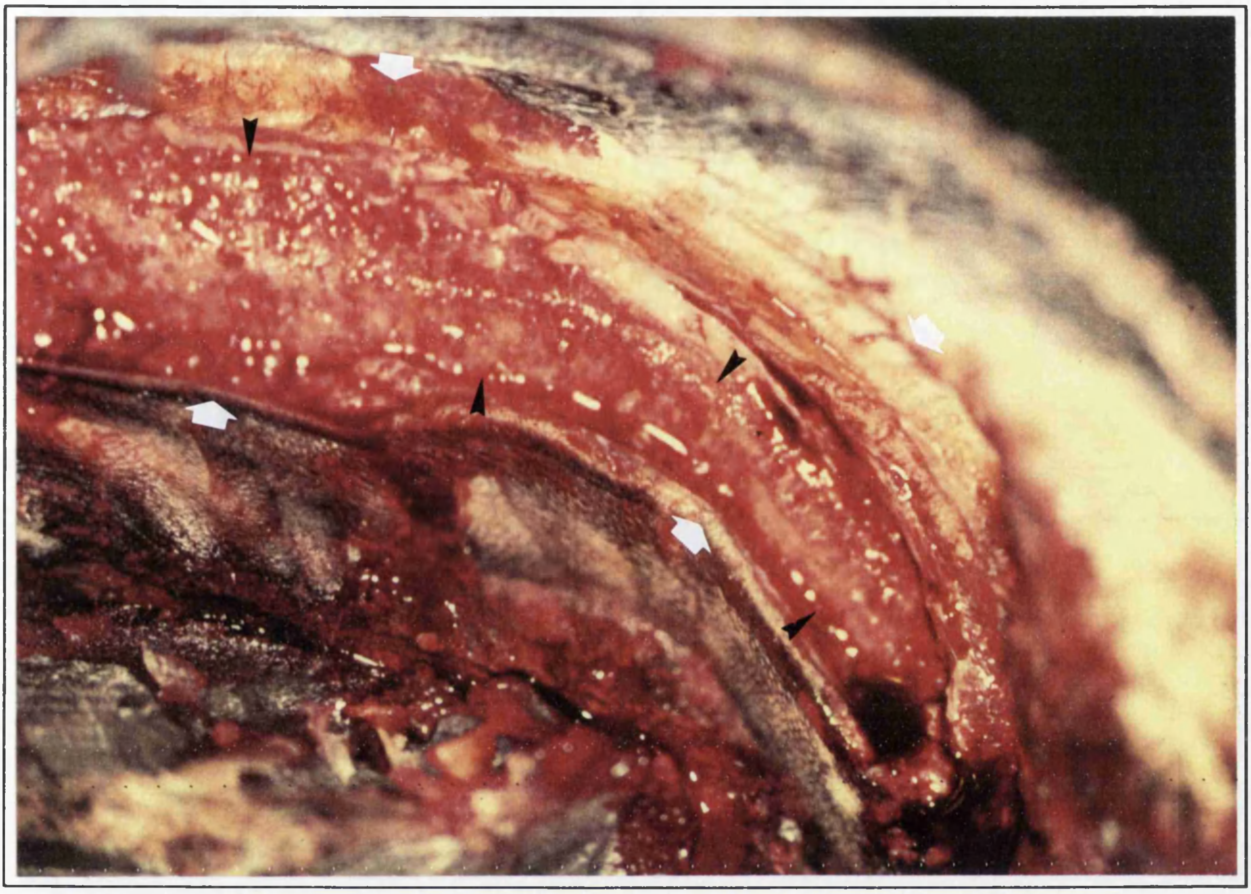


Figure 3: Photograph taken during surgery in case 3

The solar horn has been pared out (white arrows). All necrotic bone has been debrided, leaving a bed of healthy, bleeding bone (black arrows).

sulfonamides were also administered orally for several days, unless results of bacterial sensitivity made it necessary to use another antibiotic drug.

The **post-operative care** consisted mainly in changing the bandage and flushing the wound with a 0.5% povidone-iodine solution. This was performed daily for the first few days, until the wound was clean and dry, and then every other day, until a sufficiently thick layer of healthy granulation tissue completely covered the bone. At that stage, a metal shoe with a removable metal plate, that covered the entire ground surface of the foot was applied. The wound and sole were packed with gauze swabs soaked in povidone-iodine before placement of the plate to prevent contamination. This procedure was repeated at increasingly wider intervals. The patients were discharged from the hospital once the lameness was receding and the wound was sufficiently filled with healthy granulation tissue. In some cases, once the superficial epithelial layer of tissue in the former wound was cornified, the remaining defect was filled with a hard synthetic polymere (acrylic or *DEMOTEC 90 resin*, Siegfried Demel, Nidderau, Germany) (Figure 4).

II. RESULTS

The data obtained from the study of these eight cases has been compiled in tables I to VIII. Although as much of the information that could be recovered from the records has been used, some details were not available in some cases and this is indicated in the tables by a question mark in the relevant boxes.

A. HISTORY

The data for each case as regards the description of the patients and the history of the pathology has been summarised in tables I and II. Although none of the patients were stallions, there was no significant difference between the proportion of females and males (geldings). The age ranged between one year and seventeen years, with a mean of 7.9 years of age. The animals weighed from 270 kilograms to 470 kilograms preoperatively and three horses weighed less than 400 kilograms.

Figure 4: Solar view of the hoof in case 4, 3 months post-operatively

The very large area of sole that was excised has keratinised (brown area). Note the large defect in the lateral and medial hoof walls (arrows). The defects were filled with acrylic at this stage, to protect the fragile new hoof.

TABLE I: History.

Case	1	2	3	4	5	6	7	8
Type	Eventer	Riding Pony	Broodmare	Riding Pony	Hunter	Trotter	Riding Pony	Hunter
Sex	Gelding	Gelding	Female	Gelding	Female	Female	Female	Female
Age (years)	10	11	Non Available	10	4	1	17	2.5
Weight (kg)	400	340	350	270	423	400	427	470
Affected Limb	RF	LF	RF	RF	LF	LF	LH	RH
Cause	Sharp stone	Metal spike	laminitis	Unknown	Unknown	Unknown	Shoe nail	Unknown
Duration of signs (weeks)	7.5	12	1	10	5	12	8	3.5
Site of wound	White line, Toe region	frog	sole	sole	lateral wall	sole	medial sulcus	sole

Note: RF=Right fore limb; LF=Left fore limb; RH=Right hind limb; LH=Left hind limb

TABLE II: Treatments Administered Prior To Referral.

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Drug/Duration	AB/3 AI/3	AB/1	AI/4	AI/?	AI/4	AI/5	AB/1	AB/7 AI/7
Local treatments	None	for 7 days	for 3 days	for 7 days	None	None	for 7 days	None
Hoof trimming	yes	no	yes	no	no	no	yes	yes

Note: AB=systemic antibacterial; AI=Antiinflammatory drugs (non steroidal)
Duration of treatments in days.

As regards the type of horses and their use, three patients were used for hacking and general riding, two were three-day-eventers and one was a broodmare. Two animals were still unbroken, but one was intended to be a trotter and the other one was to be a riding horse.

The duration of the signs prior to referral varied from one week to twelve weeks, with a mean of 7.4 weeks. All eight patients had been severely lame despite the administration of analgesic and antibiotic drugs at one stage or another.

All four limbs could be involved, but the fore limbs were found to be significantly more frequently affected than the hind limbs (75% versus 25% for the latter). There was no difference between the right and the left side. The cause of the injury was unknown in one half of the cases, laminitis was implicated in one case, although penetration by a foreign body could not be ruled out, and puncture wound from sharp objects was determined in three cases (75% of the known causes). The site of the wound was found on the solar surface in five patients, the frog in two of them and the dorsal hoof wall in one case . The weight-bearing surface of the foot was therefore affected in 87% of the animals.

B. PHYSICAL SIGNS (Table III)

The most consistent sign in this study was lameness, which was observed in all the cases; it was always severe, with a grading of 3 to 5 (mean of 4), at the walk, on a scale of 0 (no lameness) to 5 (non-weight-bearing). Two patients could not weight-bear on the affected foot and a total of five cases presented with a lameness graded 4.5 or over.

Pain on the application of hoof testers to the affected foot was also always present but in only three patients could a specific sensitive area be detected; all the other patients presented with diffuse foot pain. Heat was detected in the foot in seven cases (87.5%) and a bounding digital pulse could be felt in five of them (62.5%). Inflammation above the level of the coronary band was also observed in five cases.

The presence of a discharging tract within the foot was only detected in five patients at the time of the initial examination, but poulticing and trimming of the hoof allowed a fistula to be found in all the remaining animals. Rectal

TABLE III: Clinical Signs.

Case	1	2	3	4	5	6	7	8
Lameness*	4.5	3	3	5	3	4.5	4.5	5
Focal pain**	+	-	+	-	+	-	-	-
Diffuse pain**	-	+	-	+	-	+	+	+
Heat in foot	+	+	-	+	+	+	+	+
Swelling above coronet	-	+	++	+	-	-	++	+++
Bounding digital pulse	+	+	-	+	+	-	+	-
Dischar-ging tract	+	+	-	-	+	-	+	+
"Gravel"	-	+	-	-	-	-	+	+
Muscle waste	+	-	-	+	-	-	-	-
White Blood Cells***	9.8	N/A	9.8	9	9.6	14.2	7.7	8.4
% Neutro-phils	63	N/A	68	73	47	42	73	68

*lameness graded from 0 (no detectable lameness) to 5 (non-weight-bearing)
** upon application of hoof testers
*** in billion cells per litre ($.10^9/l$)
N/A = Data Not Available

temperatures, blood cell counts and biochemical figures were all within normal limits.

C. RADIOGRAPHIC FINDINGS (Figures 5 to 15)

The main radiographic findings are summarised in table IV. The presence of gas, as evidenced by focal areas of radiolucency, was observed on all the radiographs. A definite gas filled tract that communicated with the third phalanx could always be identified. The most consistent bony alteration visible radiographically was a definite irregularity or spikiness of the contours of the bone. This was observed in all but one patient (87.5%). In five cases, an obvious defect was present, indicating a more aggressive or advanced osteolytic action. Other less consistent findings included a focal decrease of radiodensity and widening of the vascular foramina ("vascular channels") around the area of lysis. This was evidence of focal demineralisation and was observed in five cases. In one of them, the whole third phalanx was involved.

Three cases (37.5%) presented with sequestra. Two of them were small, marginal fragments and the third one (case 8) was very large, involving the whole of one plantar process. It was separated from the body of the phalanx by an irregular, radiolucent fracture line. In a fourth case (case 4), a pathological fracture of the palmar process occured post-operatively. This large piece of bone certainly underwent sequestration but it disappeared on subsequent radiographs two months later, having been either resorbed or fragmented and eliminated with the exudate. Pathological fractures were observed in three cases altogether (37.5%), all of them involving a palmar or plantar phalangeal process. The percentage of bone resorbed by the lytic process, calculated as described before, varied from 1.1% to 5.02%, with a mean of 2.3%.

Contrast studies were carried out in only two patients. A fistulogram was used in case 4 to confirm that a sinus tract found on the solar surface was leading towards the third phalanx. The same procedure was used in case 8 to assess the depth and direction of a puncture wound. In the same animal, arthrography of the distal interphalangeal joint was also performed to rule out its involvement in the septic process.

TABLE IV: Radiographic Findings.

Findings\Case	1	2	3	4	5	6	7	8
Gas tracts	+	+	+	+	+	+	+	+
Irregular contours	+	-	+	+	+	+	-	+
Bony defect	+	+	-	+	-	-	+	+
Special findings	None	sequestrum	None	None	Sequestrum	None	None	P3 Fracture Sequestrum
Decreased radiodensity*	Focal	None	Focal	Generalised	Focal	Focal	None	None
% Bone lysis	2.72	5.02	1.64	2.54	1.73	1.10	2.46	1.33

*within the third phalanx (P3) and including widening of the vascular channels.

Note: +=present on radiographs; -=Not detected on radiographs.

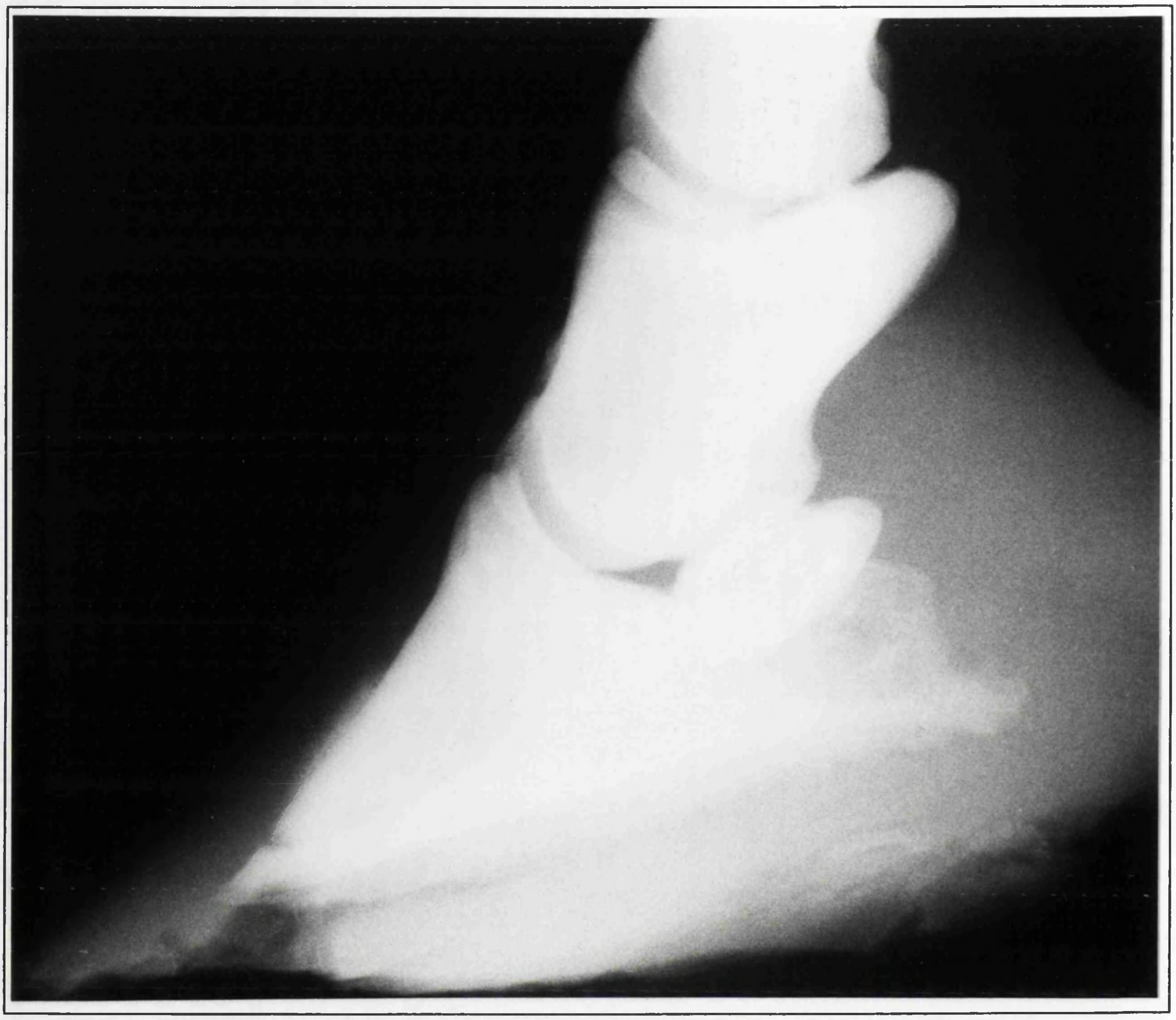


Figure 5: Preoperative radiographs of the right fore foot (case 1)

5a: Lateromedial radiograph

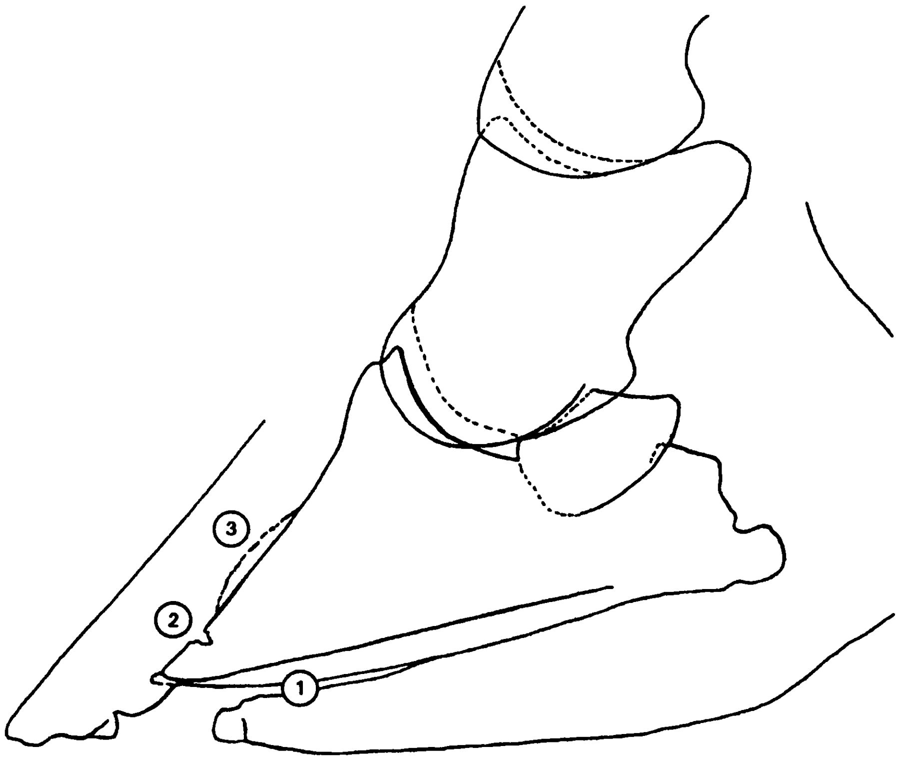


Figure 5a: Lateromedial radiograph of the right fore foot (case 1)

Note the radiolucent tract (1) between the sole and the third phalanx, the lytic area near the dorsodistal border of the phalanx (2), and the new bone reaction on its dorsal aspect (3)

Figure 5: Preoperative radiographs of the right fore foot (case 1)

5b: Dorsoproximal - palmarodistal 60° radiograph.

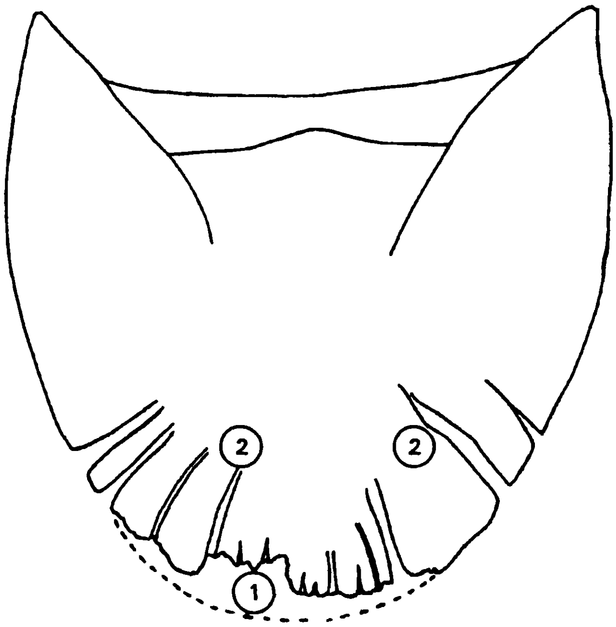


Figure 5b: Dorsoproximal - palmarodistal 60° radiograph of the third phalanx (Case 1)

There is a discrete defect at the dorsodistal margin of the phalanx (1), and widening of the vascular channels (2).

Figure 6: Dorsoproximal - palmarodistal 60° radiograph of the left fore foot (case 2)

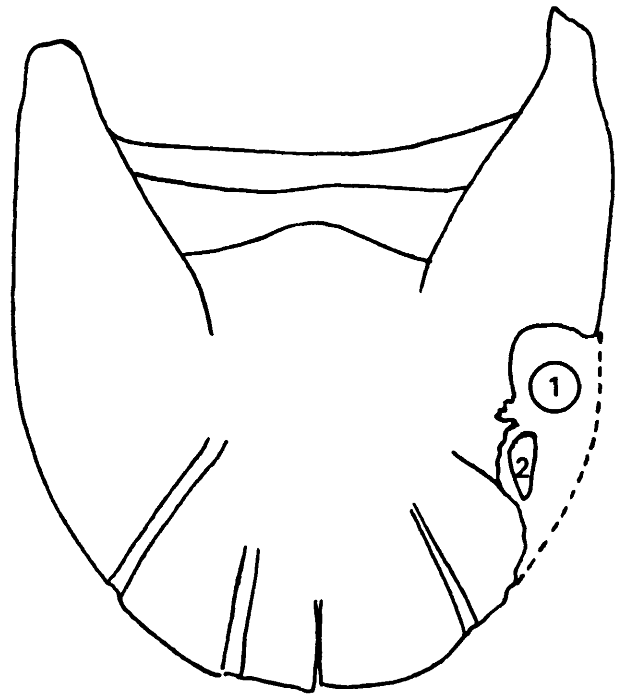


Figure 6: Dorsoproximal - Palmarodistal 60° radiograph of the left fore foot (case 2)

A large defect is visible in the lateral solar border of the third phalanx (1). There is a well circumscribed fragment (sequestrum) (2), and diffuse decrease of the radiodensity of the bone (osteoporosis).

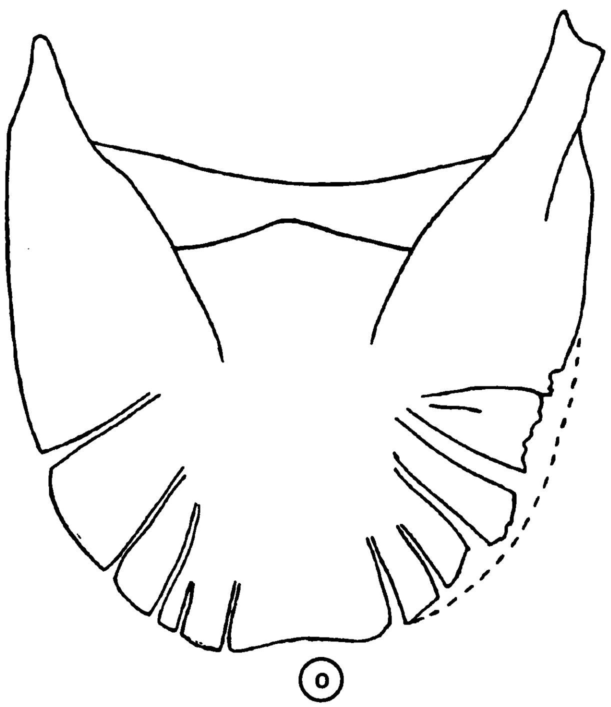


Figure 7: Tracing of a dorsoproximal - palmarodistal 60° radiograph of the right fore foot (case3)

It shows general widening of the vascular channels of the third phalanx, and a dicrete area of osteolysis in the medial solar border (o).

Figure 8: Preoperative radiographs of the right fore foot in case 4

8a: Dorsoproximal - palmarodistal 60^{o} radiograph

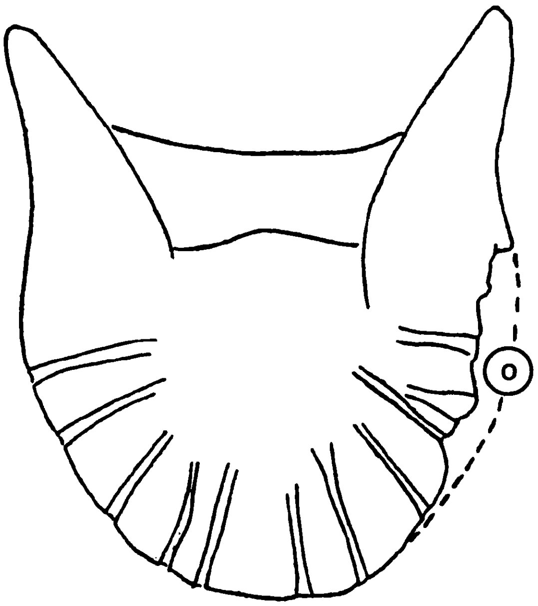


Figure 8a: Dorsoproximal - palmarodistal 60° preoperative radiograph of the right fore foot (case 4)

There is an irregular defect in the lateral solar border of the third phalanx (o), general decrease of radiodensity (osteoporosis), and widening of the vascular channels of the bone.

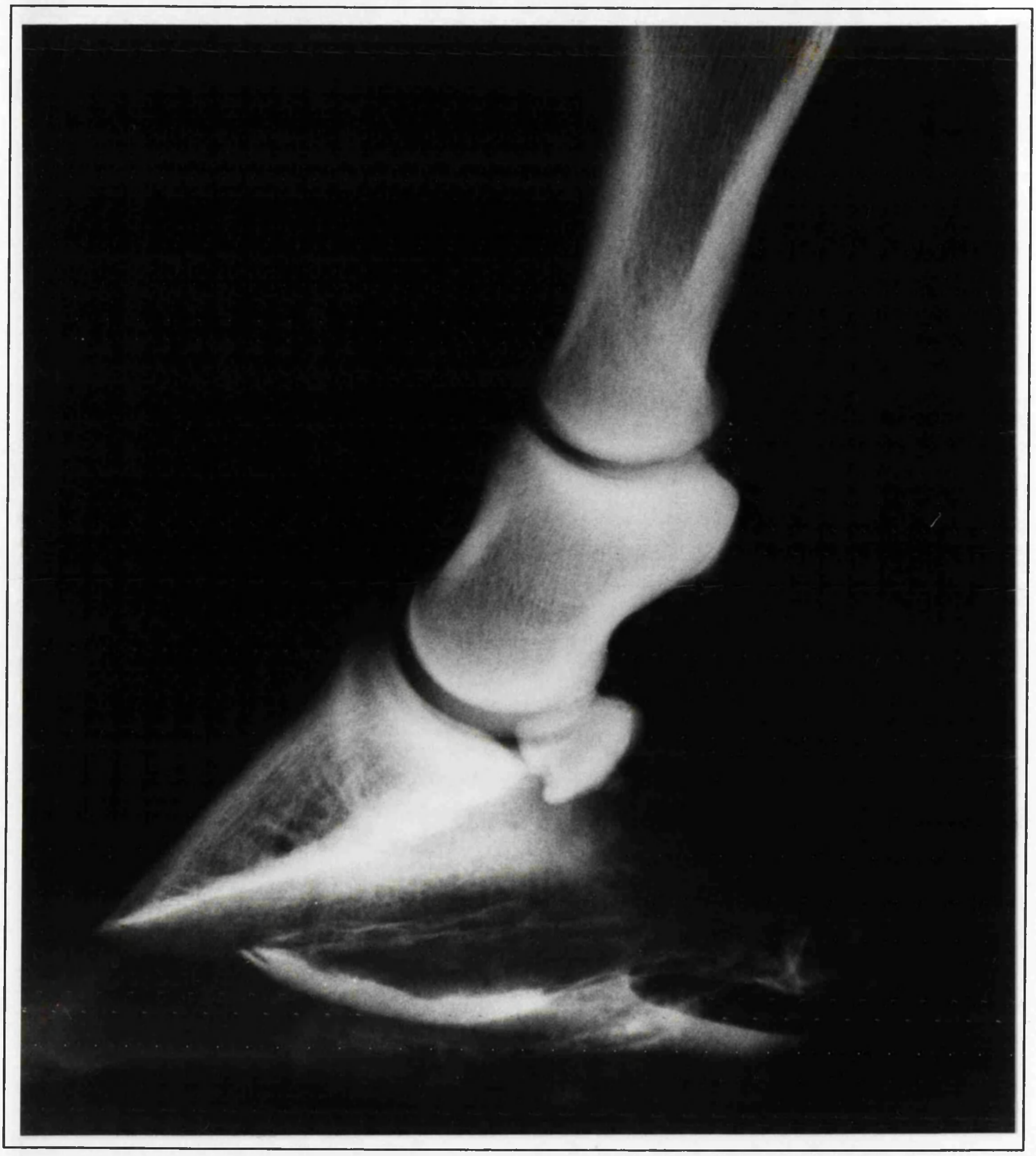


Figure 8: Preoperative radiographs of the right fore foot in case 4

8b: Latero-medial fistulogram

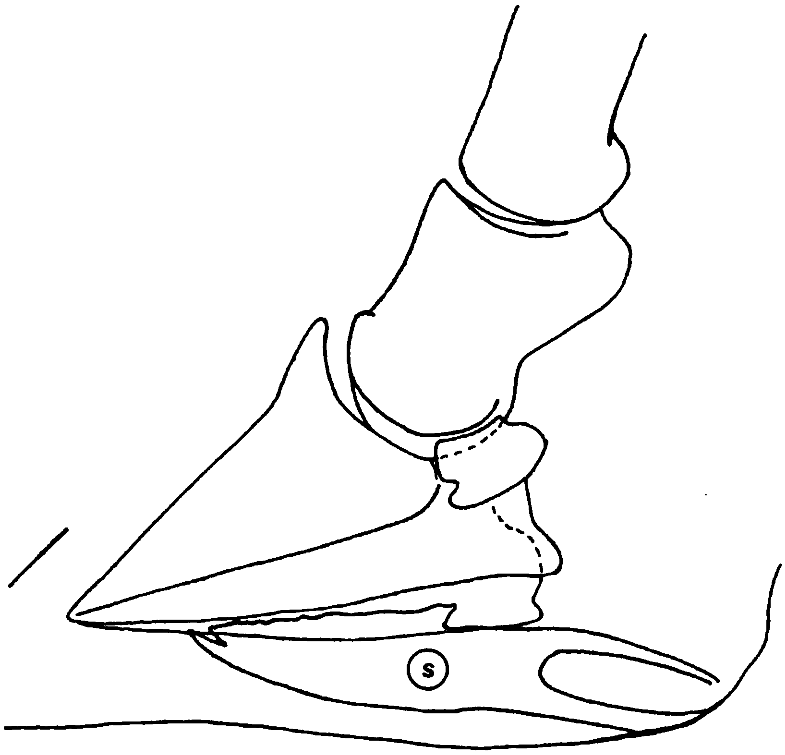


Figure 8b: Lateromedial fistulogram of the right fore foot (case 4)

The contrast fluid delineates a sinus tract (s), between the frog and the solar surface of the third phalanx.

Figure 9: Case 4 - Dorsoproximal - palmarodistal 60^{o} radiograph of the foot (10 days post-operatively)

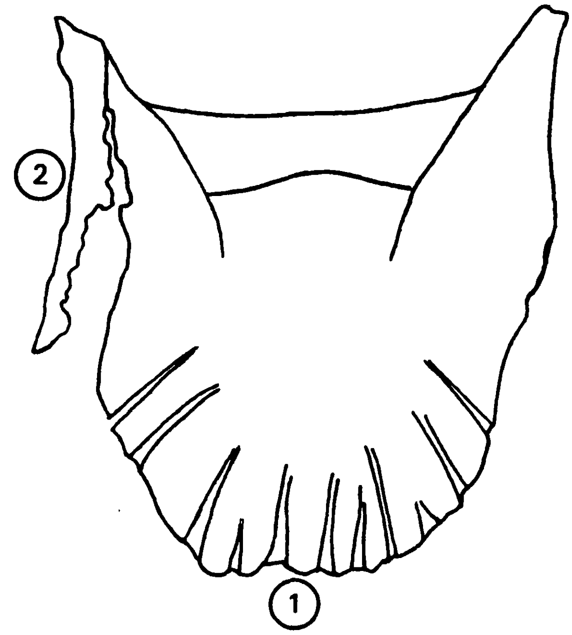


Figure 9: Case 4 - Dorsoproximal - palmarodistal 60° radiograph of the foot (10 days post-operatively)

The photograph has been reversed as compared to figure 8a. The whole solar margin has a ragged contour (1), due to severe osteoporosis. A large fragment, including the lateral palmar process, has been broken off the third phalanx (2).

Figure 10: Dorsoproximal - palmarodistal 60° radiograph of the left fore foot (case 5)

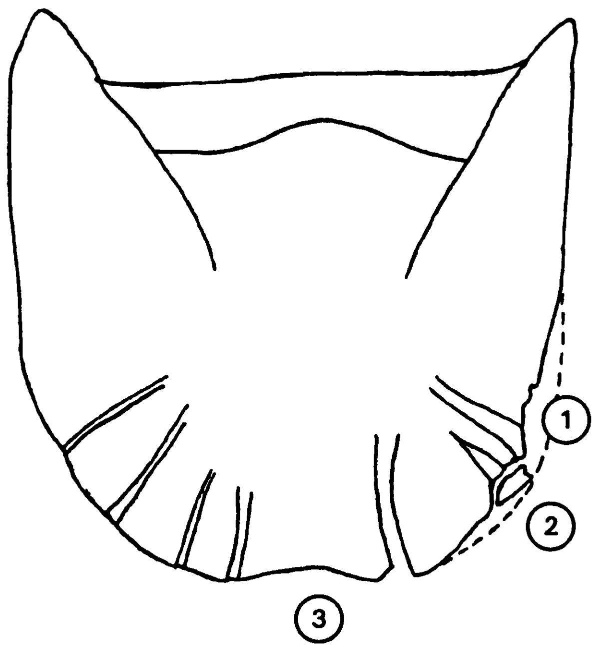


Figure 10: Dorsoproximal - palmarodistal 60° radiograph of the left fore foot (case 5)

There is a small area of lysis (1) and a small sequestrum (2) on the dorsomedial aspect of the third phalanx. The slight notch on the dorsal aspect of the phalanx (3) is a normal feature ("crena").

Figure 11: Case 5 - Post-operative radiograph of the foot

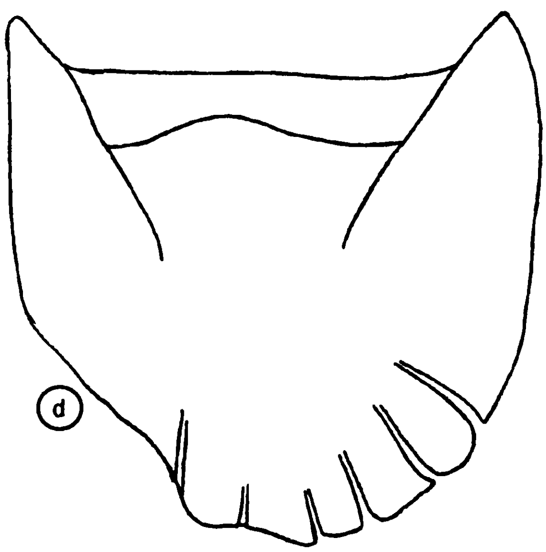


Figure 11: Case 5 - Post-operative radiograph of the foot

The photograph has been transposed as compared to figure 10. The bone has been debrided, leaving a large, smooth defect (d).

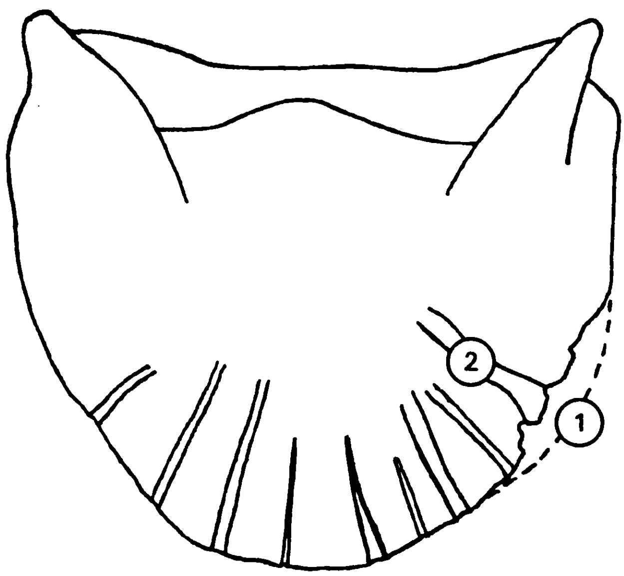


Figure 12: Tracing of a dorsoproximal - palmarodistal 60° radiograph of the left fore foot (case 6)

An irregular defect is visible in the medial border of the third phalanx (1). There is local widening of the vascular channels (2).

Figure 14: Case 7 - Dorsoplantar radiograph of the foot 10 days post-operatively

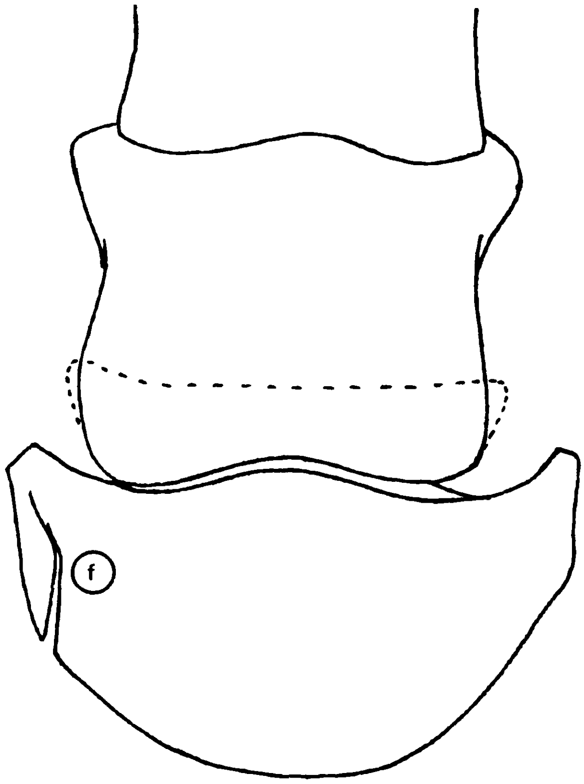


Figure 14: Case 7 - Dorsoplantar radiograph of the foot 10 days post-operatively

There is a discrete fracture line (f) through the **lateral** plantar process of the third phalanx.

Figure 15: Dorsoproximal - plantodistal 60° pre-operative radiograph of the right hind foot (case 8)

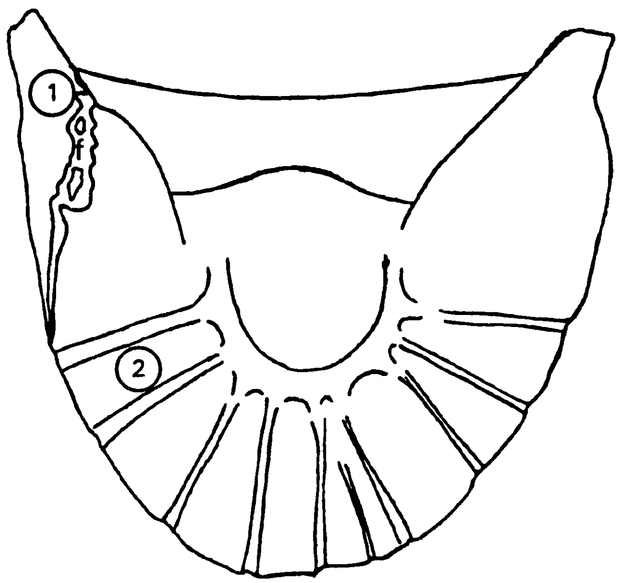


Figure 15: Dorsoproximal - plantomedial 60° pre-operative radiograph of the right hind foot (case 8)

A very irregular fracture line (f) separates most of the medial plantar process (1) from the body of the third phalanx. There is generalised widening of the vascular channels, most obvious on the medial side (2).

D. BACTERIOLOGY

Results of bacteriology tests were available in four cases. In case 1, a culture of several aerobes was obtained, including E. coli, Streptococcus spp and Proteus spp. All of them were sensitive in vitro to the combination of trimethoprim and sulfadiazine, but not to other antibiotics commonly used in horses. No anaerobes could be detected.

In case 3, a culture was obtained from a sample of discharging material collected from the wound. It revealed the presence of a mixed population of organisms including E. coli and Streptococcus sp., as well as a DNase-negative Staphylococcus and a Proteus sp. An anaerobe bacteria, Peptostreptococcus sp, was also isolated. All these organisms were very resistant to the usual antibacterials used in horses, except chloramphenicol. The latter was used topically to avoid its high systemic toxicity. Metronidazole was used to control the anaerobic organisms.

Two types of samples were collected from case 4. A bacteriological swab was used to collect necrotic material from the wound and a culture of E. coli and beta-haemolytic Streptococcus was obtained. They were both sensitive in vitro to trimethoprim/sulfadiazine, ampicillin and penicillin. A second sample consisted of necrotic bone scraped out during the surgical intervention. The same Streptococcus sp. was the only organism present. The E. coli was still isolated from another culture obtained from the wound one week later and appeared to be resistant in vitro to most antibacterials except apramycin and gentamycin. The latter was also used topically.

Finally, the same types of samples were obtained in case 8. The wound scraping yielded a mixed culture of Staphylococcus aureus , a non-haemolytic E.coli and Bacteroides melaninogenicus. This time, the same organisms were recovered from the bone sample and were all sensitive in vitro to potentiated sulfonamides.

E. SHORT TERM RESULTS OF THE TREATMENT

All the available data concerning the treatments given during the hospitalisation of each patient has been compiled in tables V to VII. The surgical findings confirmed those of the physical and radiographic

TABLE V: Surgical Findings And Immediate Outcome

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Affected area	solar margin toe region	solar margin quarter	solar margin quarter	solar margin quarter	solar margin quarter	solar margin quarter	plantar process	plantar process
Particular findings	None	sequestrum	None	None	sequestrum	None	None	Large sequestrum
Complications	None	None	"gravel"	recurrence; pathological fracture	None	None	septic podo-trochleitis; fracture	recurrence
Number of G.A.* required	1	1	1	2	1	1	1	2
Short term outcome	sound	sound	sound	slightly lame	slightly lame	sound	**destroyed**	sound
% bone lysed + excised	9.11	5.71	2.07	9.83	6.88	2.85	2.94	8.12

*G.A.=general anaesthesia.

TABLE VI: Duration Of Post-operative Treatments (in days)

Case	1	2	3	4	5	6	7	8
NSAIDS*	15	5	10	22	7	15	23	14
Antibacterials**	26	5	15	22	14	15	23	18
Bandaging	17	N/A	10	21	28	32	23	11
Stay at hospital	23	14	24	50	19	34	23	22

*NSAIDS=Non steroidal antiinflammatory drugs
**systemic antibiotics or sulfonamides
Note: N/A=data not available.

TABLE VII: Evolution Of The Wound (in days)

Case	1	2	3	4	5	6	7	8
Defect filled*	17	N/A	7	24	21	32	NAP	11
Keratinization starting	35	N/A	N/A	N/A	45	N/A	NAP	22
Keratinization complete	90	N/A	N/A	90	150	79	NAP	65

*Defect filled by healthy granulation tissue
Note: N/A=data not available
NAP=Not Applicable

examinations. Septic pedal osteitis was confirmed in all the cases. This was evidenced by the presence of soft, crumbly bone, with obvious discoloration and putrid smell. There was always some necrotic, purulent material around the affected bone. In case 8, the large portion of plantar process that had been fractured appeared to have lost its blood supply and had to be excised. The other two sequestra observed on radiographs in cases 2 and 5 were easily removed with bone curettes.

The parts of the bones affected by the septic process corresponded to the radiographic findings. In six cases (75%), the solar margin of the bone (angle between the solar and parietal surfaces of the third phalanx) was involved, one at the level of the toe, the other five on the medial or lateral side (quarter area). The remaining two cases involved the plantar processes of the phalanx.

One surgical intervention under general anaesthesia was sufficient to eliminate the infectious process in most patients (75%) but a **second anaesthetic** was required in two animals (25%). In these, the wounds failed to granulate after the first surgical intervention and discoloration of the bone became obvious once again.

Post-operative complications were observed in four patients (50%), including the two cases that required a second intervention because of further infection. The other two patients developed a pathological fracture. In one of them, septic podotrochleitis (infection of the navicular bursa) and subsequent osteomyelitis of the distal sesamoid bone also occured and the patient had to be humanely destroyed. In the second horse (case 4), the fractured fragment was left in place. Recheck radiographs taken two months later showed that the fragment had been eliminated completely.

The **proportion of bone that had been removed** both by the septic process and the surgical debridement ranged between 2.07% and 9.83% with a mean of 5.94%.

The **short term outcome**, that is the efficacy of the treatment as observed at the time the patients were sent home was favorable in 7 cases (87.5%) although two horses were still slightly lame. The eighth case is the one that had to be euthanised.

The **postoperative treatments** involved the administration of non-steroidal anti-inflammatory drugs orally for five to twenty-three days (mean 13.9) and antibacterials for five to twenty-six days (mean 17.25). Oral sulfonamide / trimethoprim combination was used in seven cases and intramuscular penicillin and streptomycin injections were used in one patient. In no cases did the antibacterial need to be changed because of lack of response or results of bacterial sensitivity. The bandages were changed daily or every other day until a shoe and plate could be fitted, ten to thirty-two days postoperatively (mean 19.83), and the patients were discharged from the hospital after a stay of fourteen to fifty days (mean 26.1).

It was possible in most animals to follow up the evolution of the wound by re-examining them at later stages or by contacting their owners or the veterinary surgeons looking after them. Immature granulation tissue had filled the horny defects within seven to thirty-two days (mean 18.6). Keratinization was first noticed twenty-two to fourty-five days postoperatively (mean 34) and was complete within sixty-five to one hundred and fifty days (mean 94.8), although this information was not available in two cases.

F. Outcome and Long-Term Follow-up

The **short term outcome**, as observed when the patients were discharged from the hospital, was favorable in seven cases (87.5%), although two of these horses were still slightly lame. The eighth animal developed incurable complications (septic navicular bursitis and osteomyelitis of the distal sesamoid bone) and had to be humanely destroyed after three weeks of treatment at the hospital. Among the seven surviving patients, a **long-term follow-up** could only be obtained in six of them. Two returned to their previous level of performance. Two were retired, although this was only a temporary measure in one of them; this latter case developed severe solar bruising nine months after the surgery, but became rapidly sound again. Case 8 was unbroken at the time of surgery and was subsequently used as a broodmare. She was however sound and the owners were planning to use her later as a riding horse. One patient returned to work but became lame a year after the operation; no obvious cause was found then and the condition improved progressively. She was later used for dressage. All the surviving horses were sound at the time of the follow-up investigation, that is between six months and ten years postoperatively. Deformation of the hoof was always minimal although two horses had contracted heels.

TABLE VIII: Long Term Results And Synthesis.

Case	1	2	3	4	5	6	7	8
Length of convalescence (months)	3	3	2	6	12	N/A	NAP	1
Hoof deformation	contracted heels	None	None	None	Contracted heels	N/A	NAP	None
Return to function	No	yes	yes	Retired for 12 months	At lower level	N/A	NAP	Unbroken
Soundness	yes	yes	yes	yes	yes	N/A	NAP	yes
Long term outcome	Retired	Return to work	Return to work	Retired	Return to work	N/A	NAP	Return to work
Complications	Unrelated laminitis	None	None	Sole bruising	Sole bruising	N/A	NAP	None
Duration of signs*	7.5	12	1	10	5	12	8	3.5
% bone lysed + excised	9.1	5.7	2	9.8	6.8	2.8	2.9	8.1

*duration of the signs prior to referral (in weeks)
Note: N/A=Data not available
NAP=Not Applicable

CHAPTER THREE

DISCUSSION

I. PATHOLOGICAL FEATURES

A. AETIOPATHOGENESIS

The general aspects of the aetiopathogenesis of septic pedal osteitis have been mentioned earlier on. Except in case 3, a sharp object was thought to have been involved in all the other cases. The actual cause of the injury was unknown in one half of the cases. The parietal surface of the third phalanx was only affected in one patient, whereas the infection developed on the ground surface of the foot in all the other horses, which points to the possibility of sharp objects being driven through the sole or frog during weight bearing. Penetrating foreign bodies were also considered to be the most common cause of septic pedal osteitis by other authors (Richter 1982, Steckel 1984, Gaughan and others 1989).

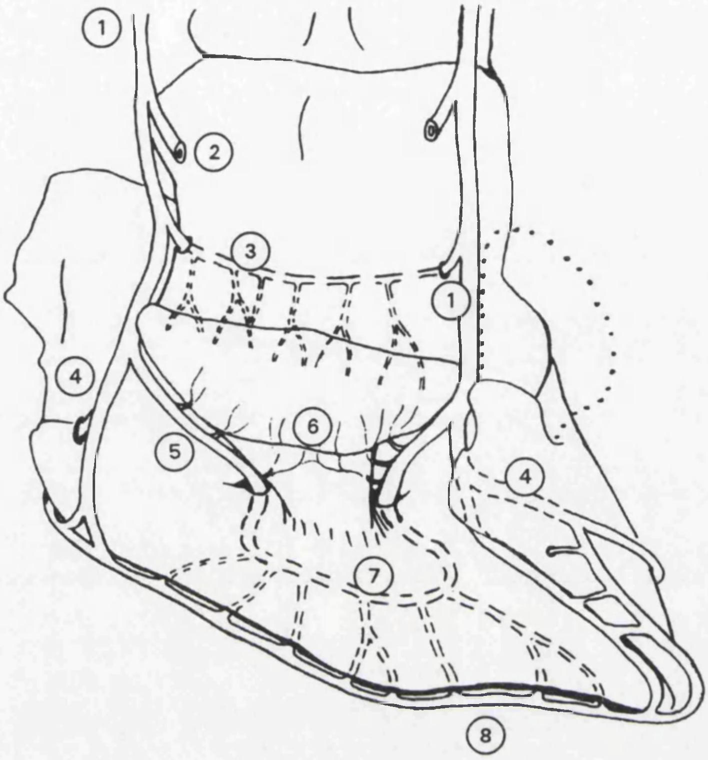
In case 3, on the other hand, chronic laminitic changes were present concurrently to the septic process. The history given by the owners, in this case, was unclear, and it was difficult to know which of the septic process and the laminitis had appeared first. Horses suffering from pedal inflammation are prone to laminitis (Colles and others 1979, Fessler 1989). This may be partly related to the peculiar vascular pattern of the equine foot: the laminar corium receives its vascular supply from the terminal arch via small foraminae. The blood flow in the laminae is in a distal to proximal direction, and it may therefore be affected by injuries to the phalanx or to the distal foot (Colles and others 1979). On the other hand, rotation of the third phalanx in chronic laminitis leaves a space filled with necrotic tissue on the dorsal aspect of the bone. The white line widens and allows contaminated material to track proximad into the dead space where an abscess can easily develop (Chapman and Platt 1986, Stashak 1987a, Gaughan and others 1989). Interestingly, in the same animal, formalin had been used to treat the submural abscess. A similar case of septic pedal osteitis caused by chemical trauma from formalin has been described elsewhere (Dart and Pascoe 1988), although there is no evidence of such an effect in this case.

The time elapsed between the onset of the signs or the injury and the admission to Glasgow University was variable but was rather long, the average time being 7.4 weeks. The pathology involved was, therefore, a very slow process, with bone infection occuring in one of two ways. Contamination was caused directly by the offending object, or the infection spread from the surrounding soft tissues. There was no evidence, in any of the cases, that the bone had actually been penetrated by foreign material and, in the author's opinion, the second pathogenesis was more likely to have been involved.

Puncture of the sole or frog always leads to the formation of an abscess. The corium, in the distal part of the equine foot, is richly vascularised via a complex network of venous sinuses, arising from the circumflex artery (Figure 16) (Colles and others 1979). Trauma to the distal foot can therefore lead to congestion and haematoma formation ("subsolar bruising"). The latter is an ideal medium for bacterial growth (Johnson 1970 and 1972, Orsini 1984), and large abscesses may form secondarily to contamination.

Large amounts of exudate were retrieved from the solar corium in most of our cases. In some patients, drainage had been provided by paring the sole prior to the referral and, in virtually all of them, we found sinus tracts on the ground surface of the hoof. These tracts probably formed at the site of the initial puncture. Yet these openings were never sufficient to eliminate the infection. In other parts of the animals' body, superficial abscesses progressively erode the skin, form fistulae and subsequently heal (Knight and others 1980, Muir and Anderson 1985). In the foot, on the other hand, drainage cannot occur and the exudate accumulates within the corium. There may be two reasons for this. Firstly the pressure exerted by the weight of the animals on the foot is such that any defect in the arched sole or on the frog tends to collapse rather than expand. Secondly, the corium offers less resistance against the progression of the septic process than both the bone and the horn.

The pressure within the abscess increases progressively as exudate accumulates. The combination of this pressure and the lytic action of the pus on the surrounding tissues forces the exudate along the path of least resistance, between the stratum germinativum and the stratum corneum (Johnson 1982, Steckel 1984). In cases 1 and 4, most of the sole had become separated from its "sensitive" layer in this way. When no drainage was provided, as in cases 7 and 8, the process continued until the pus reached the white line. There, for similar reasons and because the hoof expands more at the coronet than at ground level during weight-bearing (DeBowes and Yovich 1989, Turner 1990), the exudate was forced proximad between the strata lamellatum and germinativum of the epidermal laminae. It eventually broke out through the skin of the coronary band. This drainage is rarely sufficient, and the septic process evolves chronically, progressively undermining the sole, as noted by Richter (1982).



1. Palmar Digital Artery
2. Branch To The Digital Cushion
3. Proximal Navicular Plexus
4. Dorsal Third Phalangeal Branch
5. Palmar Third Phalangeal Branch
6. Distal Navicular Plexus
7. Terminal Arterial Arch
8. Circumflex Artery

Figure 16: The Arterial Supply To The Equine Foot (After Kainer 1987)

The corium and the periosteum are continuous and the infection can slowly progress towards the bone, leading to a low-grade bone lysis, as observed by Steckel and Fessler (1983) and Gaughan and others (1989). Despite the long duration and the presence of large abscesses, in our patients, the lytic process remained fairly limited, and was always localised. Bone is not particularly prone to infection, even after direct contamination, unless it becomes necrotic, or there is some alteration of its blood supply (Caywood 1983, Orsini 1984). Bones that are directly exposed to trauma, as in the case of the metacarpal and metatarsal bones, are more often involved in septic conditions. Injuries at that level cause contusion of the periosteum and/or microfractures as well as contamination of the surface of the bone. The local alteration of the blood supply decreases the defences of the tissue, thus allowing bacterial agents to grow (Harari 1984, Turner 1987). The third phalanx, on the other hand, is relatively well protected from the environment by the hoof, a thick and well vascularised dermis and a number of soft tissue structures (Figure17). Damage to this bone, in our cases, was probably caused by the local pressure from the exudate, thus leading to necrosis and low grade infection.

Tables I to IV show that the extent of the lytic process was in fact unrelated to the duration of the condition in this study. The severity of bone infections depends seemingly on a large number of factors, including the site and depth of the injury, the bacterial strains involved, the treatments administered and the associated complications. The development of osteoporosis (due to chronic hyperaemia), sequestrum formation and the occurence of pathological fractures, for example, greatly worsened the effects of the infection. This was obvious in the cases where pathological fractures caused whole palmar or plantar phalangeal processes to be destroyed (cases 4 and 8).

In two of the animals in this review (cases 2 and 7), the presence of a subsolar abscess was never obvious but deep sinus tracts had developed between the frog and the bulbs of the heel. Unlike the parietal and solar aspects of the third phalanx, the palmarodistal half of the foot contains large soft tissue formations, in particular the collateral cartilages of the third phalanx and the digital cushion. Both of these structures offer little resistance to infection. The blood supply to the cartilages is very limited and their contamination leads to necrosis (Johnson 1982, Honnas and others 1988b). Bacteria can become hidden from the body defences and may form abscesses or extend into the third phalanx, which is continuous with the cartilage. This was observed in cases 2 and 7. It was important, therefore, to remove any necrotic cartilage at the time of surgery. Wounds at the level of the frog are potentially more serious than those involving the solar surface, because of the presence of synovial structures on the palmar or plantar aspect of the third phalanx, in particular the podotrochlear (navicular) bursa (Richardson and O'Brien 1985, Richardson and others 1986b) and the digital tendon sheath (Richardson and others 1986a) (Figure 17).

B. Response to Injury and Complications

Once a septic process has started to evolve within the tissues, there is a constant interaction between the destructive effect of the microorganisms and the defence mechanisms developed by the invaded tissues. The initial trauma damages the connective tissue and contaminates it with bacteria, that release toxic chemicals. These toxins trigger an inflammatory response, leading to local venous congestion and accumulation of neutrophils. Vascular stasis causes ischaemia and degeneration of the cells, including the neutrophils. The latter release intracellular enzymes that add their lytic action to that of the bacterial toxins (Jubb and Kennedy 1963, Harari 1984, Rudd 1986). Thus in the majority of cases, the defence mechanisms are overwhelmed and the tissues are destroyed and replaced by purulent exudate (Orsini 1990).

The bones are not spared from this process, and since their interstitial matter is rigid, hyperaemia rapidly leads to a pressure increase that causes osteocytes to degenerate (Jubb and Kennedy 1963). It has also been shown that locally released prostaglandins lead to active bone resorption (Turner 1984, Norden 1988).

The tissues do, however, respond, by encircling the lytic area with granulation tissue, which stops or at least slows down the progression of the septic process (Harari 1984). If there is a balance between the lysis and the defence mechanisms, the surrounding bone becomes sclerotic, forming a shell (**involucrum**) around the pus (Caywood 1983). The abscess thus formed is called a **Brodie's abscess** (Muir and Anderson 1985). The administration of antimicrobials systemically may help the animal to control the septic process. Yet the involucrum not only protects the tissues from the bacteria, it also isolates them from the action of antibodies, white blood cells and antibacterial drugs. The microorganisms may remain alive this way for weeks or months. The involucrum eventually weakens, becomes perforated by **cloacae** through which the infection can spread (Caywood 1983, Harari 1984).

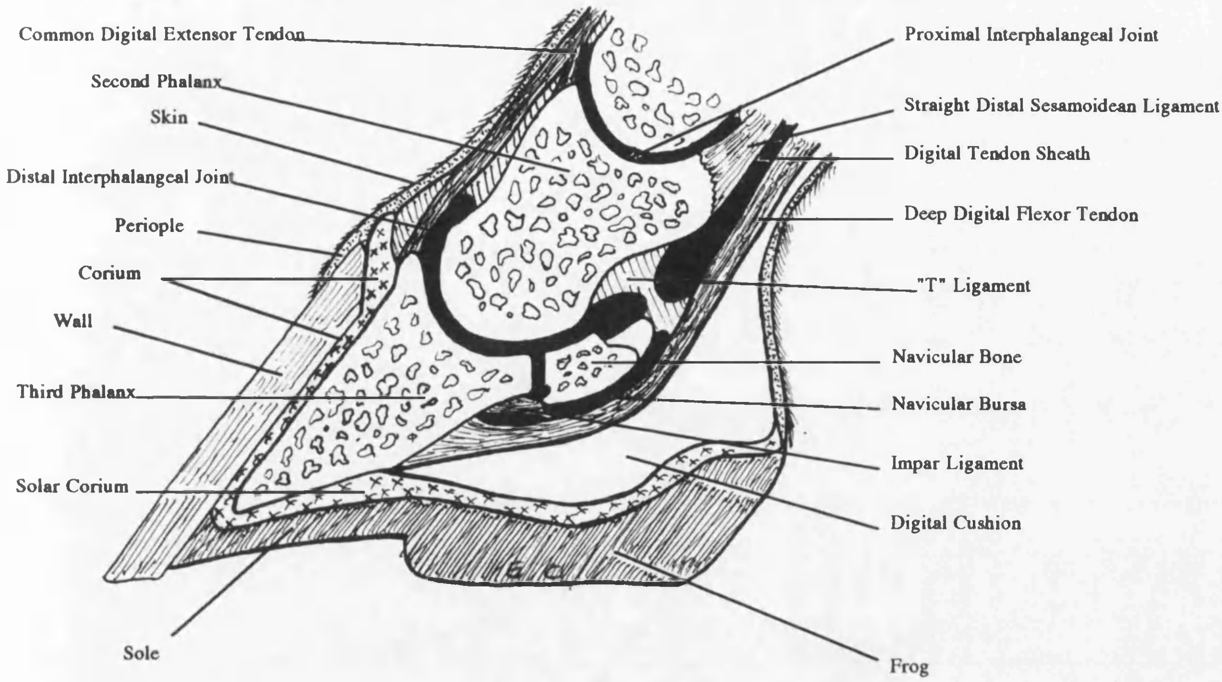


Figure 17: Diagram of a sagittal section of the equine foot (After Dyce and others 1987)

The third phalanx does not contain a medullary cavity and **osteitis** usually starts as a periosteal infection, or **periostitis** (Turner 1984). The periosteum of the third phalanx is however firmly attached to the bone in adult animals (Orsini 1984, Kainer1989) and the sepsis tends to corrode the bone by the combined effects of increased pressure and toxic action, rather than undermine the periosteum, as in the case of osteomyelitis in long bones (Jubb and Kennedy 1963). This might explain why, in the cases presented in this review, the osteolysis appeared marginal and irregular rather than in the form of large defects.

In some cases however, the lytic process isolates a whole area of bone which subsequently undergoes **sequestration** (Baird and others 1990), as observed in cases 2, 5 and 8. The mechanism through which **sequestra** are formed is not yet clear. In long bones such as the third metacarpus, the destruction of the periosteum leads to disruption of the blood supply to a superficial layer of cortex. That area undergoes necrosis and eventually becomes totally isolated from the healthy bone tissue (Turner 1987). Large sequestra can also be created when a large part of the medullary cavity is destroyed in severe osteomyelitis (Jubb and Kennedy 1963, Firth 1987). These mechanisms are unlikely in the third phalanx and sequestrum formation may be secondary to the fracture of a piece of bone (chip fractures) (Moens and others 1980). Another possible cause is the alteration of the blood supply of a fragment due to local thrombosis, which is known to be induced by sepsis (Jubb and others 1985). Many authors, in fact, believe that sequestra are formed by the lytic action of the septic process and are a different entity from fractures altogether (Moens and others 1980).

In a previous review, Baird and coworkers (1990) found that third phalangeal sequestra were relatively large and were well encapsulated by reactive bone. On the contrary, the sequestra observed in this study, appeared on radiographs as small fractured fragments and sclerosis was not obvious. They were found, however, to be necrotic and bathed in pus at the time of surgery. It is possible that the involucrum in these cases was not yet radiographically visible, but that sequestration had already occured. In case 8, a large fragment was separated from the body of the phalanx by a fracture at the base of one of the plantar processes. Although this fragment was also necrotic and isolated by infected material, sequestration in this case was most certainly secondary to the fracture and, in the author's opinion, sequestration may indeed occur because a fracture line becomes infected and destroys the vascular supply to the separated fragment.

Pathological fractures have been only rarely associated with septic pedal osteitis (Mackey and Roy 1984). They are however not uncommon in cases of chronic foot inflammation (Turner 1984, Honnas and others 1988a, Turner 1990). Chronic hyperaemia leads to an increased pressure and local hypoxaemia. The consequence is degeneration of the osteocytes and an increased osteoclastic activity (Jubb and others 1985). Demineralisation of the bone ensues and is often referred to as "**traumatic pedal osteitis**" (Moyer 1979, McColles 1985). This weakens the bone considerably, making it less resistant to trauma and infection alike (Honnas and others 1988a, Rick 1990a). The constant stress related to the accumulation of exudate, its lytic activity and the abnormal use of the limb may cause minor trauma to induce a fracture.

Three animals in this review presented with a non-articular fracture of a phalangeal palmar or plantar process. This type of fractures has been classified as type I phalangeal fractures (Scott and others 1979) and are the most common type (Scott and others 1979, Rick 1990a). Pathological fractures are usually comminuted and tend to involve the thinner part of the bone, that is the solar margin. They are usually classified as type V fractures (Rick1990a) but Honnas and others (1988a) have described them as a separate type (type VI), because of their common occurence. Pathological fractures of the palmar or plantar processes have only been described in one publication (Mackey and Roy 1984). The high occurence in this study (three cases) may be related to the long average duration of the septic condition.

Once a fragment of bone has been fractured in a contaminated environment, pus may protrude through the fracture line, thus enhancing the lytic activity. The fracture line widens and the presence of infected material prevents any bone healing (Kay and others 1976, Turner 1987, Carter 1991a). The broken fragment may become deprived of vascular supply, by the fracture itself, or because of the extension of the sepsis around the contours of the fragment. Sequestration is then induced, as demonstrated in case 8. In case 4, a pathological fracture of the palmar process occured after the surgical debridement. Surprisingly, this large fragment was no longer visible on repeat radiographs taken two months later. It is known that small sequestra can be resorbed either by the purulent exudate or by active osteoclastic activity (Jann and others 1987, Gift and DeBowes 1989). This particular one was, however, very large and it is more likely that it was partially resorbed and fragmented, and was then pushed out and eliminated by the granulation tissue filling the large solar wound.

In case 7, the septic process eventually extended into the podotrochlear (navicular) bursa. This led to destruction of the deep digital flexor tendon and osteomyelitis of the distal sesamoid bone, and the horse had to be eventually euthanised. This is a relatively common complication, particularly in puncture wounds affecting the palmar or plantar one half of the foot (Richardson and O'Brien 1985). The distal interphalangeal joint may also become involved if surrounding tissues are infected, including the collateral cartilages and palmar/plantar processes of the third phalanx (Mackey and Roy 1984). This complication did, however, not occur in the patients with infection of the palmar/plantar pedal bone in this series.

II. DIAGNOSIS

A. HISTORY

In this review of cases, no significant difference was observed in relation to the sex and age of the animals. The type of animals and their use did not seem to affect the incidence of the condition although one half of the patients were riding ponies. This is related to the type of horses present in the west of Scotland. Ponies are also often kept in paddocks, where they may be more exposed to various injuries.

The fore feet were significantly more affected than the hind feet. Although there is little difference in the anatomical structure of the fore and hind digits, the thoracic limb carries more weight than the pelvic limb. It is possible that deep penetration of sharp objects occurs more commonly in the fore feet, although no such evidence exists in the literature.

As regards the site of the injury, the hoof wall was only affected in one case. In a review of thirty cases including all types of hoof wounds (Steckel and Fessler 1983), the wall, sole and frog were affected with a similar incidence. The actual site of the initial injury is not well documented in other reviews of third phalangeal infections, but it seems, in this series, that the bone is more frequently involved after solar injuries. This may be related to the fact that the phalanx is more exposed to trauma on its solar surface.

The duration of the signs prior to referral was relatively variable but was always of several weeks to months (mean 7.4 weeks). Although a much shorter duration, ranging between one day and four weeks, was observed in another series of twelve cases (Pabst and Kaegi, 1990), a different review of similar injuries indicated that some horses had been lame for up to five years and the average duration of the signs was thirteen months (Gaughan and others 1989). This delay before a decision to refer the animal is made depends upon a number of factors. These include the severity and evolution of the signs, the response to the treatments administered by the referring veterinarian and the accuracy of the diagnosis obtained by the latter. In the cases gathered in this study, radiographs had been obtained prior to referral from only one patient A significantly shorter duration before admission to the referral center (3.5 weeks) was observed in that particular case. As far as the treatments and their effects are concerned (table II), various antibiotics and anti-inflammatory drugs had been administered. They seemed, however, to have little influence on both the outcome and the duration of the condition.

B. Clinical Features

The findings in this study are very similar to those described in other publications (Steckel and Fessler 1983, Gaughan and others 1989, Baird and others 1990, Pabst and Kaegi 1990). Pain was the most consistent sign: it manifested itself, in virtually all the patients, as severe lameness and pain on application of hoof-testers. It was rarely diminished by conservative management. Pain was usually very diffuse in the foot, and only rarely could the site of the injury be detected as an area of increased sensitivity upon the application of hoof-testers. This was probably due to chronic inflammation affecting the whole foot. Pain is a very common finding with any type of bone infection, especially in the acute stage (Harari 1984, Waldvogel 1988). The pain decreases however very significantly as the disease progresses (McDonald and others 1989) and may not be present with chronic limb sequestra in horses (Gift and DeBowes 1989). The lameness associated with septic pedal osteitis is, in fact, not a specific sign: pain is induced by many septic conditions of the foot and by pedal bone fractures (DeBowes and Yovich 1989, Turner 1990, Moyer 1991). The pain is increased if pus accumulates within the hoof and when synovial structures become involved (Richardson and others 1986b, Honnas and others 1992, Smith and Schramme 1992).

Heat within the foot and the presence of a very marked, "bounding" digital pulse in the affected limb appeared to be significant signs in this study as well as in another publication (Pabst and Kaegi 1990). It is, however, only an indication of local inflammation and, as a result, it tends to become less obvious as the disease evolves into the chronic phase. Indeed the digital pulse was found to be normal in three cases out of eight.

The presence of a purulent discharge was only observed in one half of the cases at the time of referral. Yet, after several days of poulticing, sinus tracts could be identified in all the remaining patients. Sinus tracts are always present in chronic septic osteitis (Rudd 1986, Waldvogel 1988, McDonald and others 1989). As mentioned before, sufficient drainage through the hoof does not occur naturally, even in the presence of puncture wounds, and the infection tends to spread into the surrounding soft tissues. In three cases, drainage was present at the coronary band. This does not usually occur for some time after the injury (McColles 1985, Richardson and others 1986a) and was an evidence of the existence of a deep, chronic infection.

Some authors believe that very few puncture wounds should be overlooked if a proper examination of the sole is performed (Johnson 1970, Dyson 1986). Yet, thorough examination did not allow puncture sites to be found in one half of our cases. It is likely that the puncture sites become much less obvious in long standing cases, especially if the foreign body was very thin and sharp, thus only leaving a very small portal which would collapse after removal of the object. Removal of the shoe was thought to be warranted at this time, as nail holes are commonly found to be infected (Hauser and others 1982), although this was not found in this series.

The application of hot poultices proved very efficient in helping to identify puncture sites that could not be found on the initial examination in four cases. Poultices soften the horn and draw fluids towards the surface by an osmotic effect (Stashak 1987b, Moyer 1991). Pus-like material, thus drawn out through the puncture wounds, revealed the opening on the surface of the horn.

Careful paring of the horn with hoof knives was used to follow the tracts. A probe was used in some cases to assess the direction and depth of the wound, as advocated by Fessler (1971) and Richardson and others (1986a). We were, however, very cautious in doing so, because this procedure could have caused more damage if the probe had accidentally penetrated and contaminated tissues that were initially not affected (Richter 1982). Probing was therefore always carried out in combination with radiography or at the time of surgery. For the same reason, aggressive trimming of the foot was not used in the absence of significant findings, to avoid damaging sensitive structures.

When nothing obvious was found, regional anaesthesia (nerve blocks) was found to be useful to confirm that the problem was located within the foot, as suggested by other authors (Johnson 1970, Richardson and others 1986b). This was performed after a complete physical examination, because the presence of a foreign body or the suspicion of a fracture would be contraindications to the exercising of the patient. The animals in this study were so lame that the effect of perineural anaesthesia could be easily assessed, even at a very slow walk.

Finally, both the temperature and the white blood cell counts were within normal limits in the eight cases presented in this study. Although systemic signs of infection are often present in bone infections in other species, including high body temperature and increased white blood cell counts (Rudd 1986, Waldvogel 1988), this is rarely observed in horses (DeBowes and Yovich 1989), particularly in chronic cases (Harari 1984).

The physical examination allowed to confirm the presence of chronic infection within the hoof, but there were no definite signs of bone sepsis. This could only have been diagnosed at this stage if the phalanx had been visually exposed (McColles 1985, Dart and Pascoe 1988). The clinical assessment was, nevertheless, very important to rule out other conditions and to lead logically to a correct diagnosis.

C. RADIOGRAPHY

The physical examination alone never provided a definitive diagnosis of septic pedal osteitis in this series, and radiography was always necessary to confirm the diagnosis. Radiology is, however, a diagnostic tool with its own limitations.

The response of bone tissue to inflammation is very restricted and slow because of the mineralised nature of the interstitial substance. Radiographs can only reveal gross alterations of shape and radiodensity that reflect modifications of the mineral content of the tissues. The alterations will therefore be related to new bone formation, osteolysis and general increase or decrease in the radiodensity of the bone (Park and Lebel 1987). Osteolysis only becomes obvious once approximately fifty percent of the minerals have been removed from the affected tissues (Dickie 1986, McDonald and others 1989). This may take several weeks (Waldvogel 1988). As a consequence, bony changes can only be detected radiographically after some delay from the onset of infection. This delay is in fact very variable and depends upon the type and age of the animal, the affected bone and the pathogens involved. The first changes have been reported to be visible on radiographs as early as after three days (Rudd 1986), especially in young animals (Martens and others 1986), but they may not appear before fourteen (DeBowes and Yovich 1989) to twenty-five days (Morgan and others 1974). The average figure usually reported is ten to fourteen days (Harari 1984, Martens and others 1986, Park and Lebel 1987, Orsini 1990). Radiography is therefore of little help in early cases (McDonald and others 1989). Because all the animals reviewed in this study, except case 3, were radiographed after several weeks, this was not really a concern. Case 3 was admitted after only a week. In the latter, the changes were extremely subtle in the bone, but widening of the vascular channels and a very slight roughening of the solar margin were already visible.

In the early stages of septic osteitis, the only changes seen on radiographs involve the soft tissues and represent acute inflammation. There may be soft tissue swelling (Morgan and others 1974) and loss of the visualisation of the fascial planes (Caywood 1983), although, in the equine foot, these are only apparent above the level of the coronary band. Radiographic signs of sepsis include areas of fluid density representing the accumulation of exudate (Moyer 1991) and the presence of gas within the hoof (Richardson and others 1986a, Turner 1990). It is essential, however, to make sure that the hoof is properly trimmed and packed before radiographs are taken, or that a "water bath" is used, in order to eliminate the artefacts induced by the presence of air between the hoof and the cassette (Quick and Rendano 1977).

Gas filled tracts were observed in all the patients and their extent was related to the long duration of the septic process. However subtle the radiographic signs were, a good indication of bone involvement was the presence of a radiolucent tract (*"gas shadow"*) partly overlying the image of the phalanx. It is important that this feature be observed on several views taken at different angles, to ensure that the gas is actually in continuity with the bone on all views.

Osteolysis was the most consistent radiographic feature in this review. In seven patients out of eight, it was indicated by a roughening and spikiness of the solar margin. An obvious defect was visible in five of them. This reaction was an indication that the infection had spread secondarily from the corium, as observed by Gaughan and others (1989). These lytic defects were easily differenciated from the normal notch, or "crena marginis solearis", which often occurs on the most dorsal part of the solar margin of the pedal bone (Kainer 1987, Park and Lebel 1987): the latter was very smooth and was not surrounded by sclerosis or osteopaenic bone.

Osteolysis is the first bony alteration to become visible radiographically (McDonald and others 1989, Orsini 1990). It usually begins within two or three weeks as a focal, punctuate demineralisation in the bone margins (Park and Lebel 1987). Larger defects, such as those observed in five of our cases, only appear at a later stage (Morgan and others 1974). Bone sclerosis usually develops around the infected area (Park and Lebel 1987, Orsini 1990), but this feature was not noted in this review, despite the long duration of the condition. It may have been present, but concurrent osteoporosis, due to limb disuse and chronic inflammation, probably masked the bone reaction.

As a consequence, the osteitis appeared radiographically as a rather diffuse, irregular lysis at the solar margin of the phalanx. In some cases, abscesses may be visible in the body of the bone (Richardson and others 1986a). *Brodie's abscesses* appear as cyst-like radiolucent areas with a smooth edge, surrounded by sclerotic bone (increased radiodensity) (Colles 1983, Orsini 1990). These were not found in this series

One of the cases (case 8) presented with a different finding: there was a diffuse area of decreased radiodensity within a plantar process of the third phalanx, indicating that severe lysis was taking place within the bone. This was associated with an ill-defined fracture line. It is difficult to know whether the fracture was due to the initial trauma or whether it was secondary to the infection, but the absence of lysis on the solar border seems to indicate that a foreign body actually penetrated the bone. In a review of pedal bone fractures (Honnas and others 1988a), it was observed that fractures related to puncture wounds were usually at the edge of the bone and were comminuted. There is seemingly only one other report of a pathological fracture involving a palmar process secondarily to a puncture wound (Mackey and Roy 1984).

Diffuse decrease of the radiodensity of the bone was observed around the areas of lysis in five cases and there was widening of the vascular foramina in virtually all the cases. These changes are consistent with local demineralisation (osteoporosis) and are certainly related to chronic inflammation of the third phalanx (Gaughan and others 1989). It is a very common finding in septic pedal osteitis (Richardson and others 1986a). It is also possible that the common occurrence of pathological fractures (three cases out of eight) as compared to other reports (Gaughan and others 1989, Baird and others 1990, Pabst and Kaegi 1990) was due to weakening of the bone after a relatively long delay before surgical treatment was carried out.

It was difficult to differentiate the sequestrum from a pathological fracture in case 8. In fact, the separated fragment obviously underwent necrosis and sequestration after a fracture had occured. In two other patients, sequestra appeared as small fragments off the solar margin of the phalanx. Sequestra are not always easy to detect on radiographs (Caywood 1983) but radiography is the only way of confirming their presence preoperatively (Gift and DeBowes 1989). They usually appear as radiodense areas within the bone (Blockey 1983), sometimes surrounded by a radiolucent zone (osteolysis) (Clem and others 1987). There may also be some sclerosis (involucrum) separating it from the viable bone (Moens and others 1980, Baird and others 1990). Typical findings are only found in long standing cases and early signs are limited to thin, coalescing lines (Moens and others 1980). They become visible ten to twelve days after the injury. Periosteal reaction only rarely develops (Baird and others 1990) and was not observed in any of the three cases. When it occurs, it tends to encase the sequestrum within the new bone (Moens and others 1980). In the three cases included in this study, the sclerosis was only very limited. It was therefore difficult to differenciate sequestra from non sequestated fractures. In some cases, small radiolucent tracts may be seen crossing the involucrum and represent cloaca, that is migration of pus through the sclerotic tissue (Clem and others 1987). Cloaca were, however, not observed in this series. It may be important, clinically, to differentiate sequestra from non-infected fractures, because, unlike the former, the latter may be managed conservatively. Nonetheless, in this series, surgical treatment was always considered in the presence of such complications and all the fractures or sequestra appeared to be infected.

A fracture occured postoperatively in case 4 at the base of a palmar process and was managed conservatively. Less than two months later, the fragment had disappeared on control radiographs. Although the resorption of small sequestra has been observed elsewhere (Jann and others 1987, Baird and others 1990), the fragment in case 4 was very large (4.5 x 0.7 cm). It was probably partly destroyed by the exudate, but could not be totally reabsorbed. It is more likely that the sequestrum thus formed became fragmented and was progressively pushed out of the wound by the granulation tissue.

In summary, the radiographic findings that helped to detect septic pedal osteitis in this review were the combination of gas shadows or tracts overlying the phalanx on several views and the evidence of osteolysis. A number of normal features that may be mistaken for osteolysis include the existence of a notch on the dorsal part of the solar margin (crena) as well as the radiolucent lines formed by the semilunar (or solar) vascular groove and the dorsal (parietal) arterial grooves (Quick and Rendano, Gaughan and others 1989). The solar margin of the phalanx often appears irregular, especially at the level of the palmar or plantar processes (Gaughan and others 1989). It may be useful to compare the radiographs of the affected foot with those of the opposite leg.

D. Other Imaging Techniques

Because of the inability of conventional radiographs to detect subtle changes in bones, especially early in the course of the disease, other diagnostic techniques have been used to diagnose osteitis in humans with a higher specificity and sensitivity. Radiography with the aid of contrast media has been used in horses for some time, but other techniques that have been more recently introduced into the pool of diagnostic methods in human medicine are becoming or may become available to equine practitioners. More accurate information can thus be obtained by combining the results of several of these techniques (O'Callaghan 1991a).

1. Contrast radiography

Contrast media are used to better define lesions or structures that are not clearly visible on plain radiographs (Park and Lebel 1987). They are therefore useful to examine formations that have the same radiodensity as the soft tissues, in particular fluid filled cavities or tracts.

a. Fistulograms

A fistulogram is obtained by taking a radiograph after contrast medium has been introduced into a fistula, that is "an abnormal passage from a hollow organ to another or between two organs" (Lamb 1991a). The term "*sinogram*" can be used when sinus tracts are delineated, but it would not describe potential communications with cavities or the bone.

In case 8, a sterile, flexible and blunt metal probe was introduced into the sinus tract to assess its direction and depth. It was found to lead towards the third phalanx. This technique is often performed with a metal probe to explore wounds and fistulae (DeBowes and Yovich 1989, Smith and Schramme 1992) and some authors feel that it should be carried out whenever a sinus tract is found (Fessler 1971, Richardson and others 1986a). The use of a malleable probe, made of lead for example, reduces the risk of accidentally penetrating or damaging deeper areas that were previously not contaminated (Hauser and others 1982). The risk is however always present (Richter 1982) and care was taken, in case 8, to ensure that the tract had been adequately cleaned and that a sterile probe was used.

In case 4, contrast fluid was used rather than a probe. This was technically more difficult because it involved injecting the fluid under some pressure without letting it flow out. The conical plastic sheath of a teflon catheter was used in this study but other authors have preferred to use teat cannulae (DeBowes and Yovich 1989). Water soluble positive contrast fluids, such as sodium or meglumine diatrizoate (Rook and Stickle 1987, Smith and Schramme 1992) are less viscous and easier to use than oily preparations (Park and Lebel 1987). Meglumine iothalamate was used undiluted in case 4 and was found to be very efficient. This contrast study revealed a fistula coursing between the opening on the solar surface and the third phalanx. Fistulography has helped to confirm bone involvement in other wounds (Lamb 1991a) and has been found useful to delineate foreign bodies (Turner 1990), although these can never be ruled out with this technique (DeBowes and Yovich 1989).

b. Contrast Radiography of Synovial Cavities

Because of the presence of three synovial cavities in the foot, their involvement in septic conditions is always a serious potential complication, particularly when the palmar/plantar third phalanx is affected, as in case 8. Fistulograms may occasionally show communications between sinus tracts and joints or synovial sheaths (Hauser and others 1982, Rook and Stickle 1987). Communications are, however, more easily delineated after contrast fluid is injected under pressure into the synovial cavity itself (Park and Lebel 1987, Smith and Schramme 1992). Arthrography of the distal interphalangeal joint was therefore performed in case 8, preoperatively, to rule out extension of the septic process from the axial side of the plantar process. Arthrography helps to rule out the presence of fistulae communicating with the joint, but also the absence of cartilage or subchondral bone lesions (Park and Lebel 1987, Lamb 1991a). This technique can also be applied to the digital sheath or to the podotrochlear bursa (Smith and Schramme 1992).

Synovial fluid was collected for cytological and bacteriological examination in case 8, just before the contrast fluid was injected. Although the arthrogram failed to show any communication with the sinus tract, a negative finding does not rule out infection of the joint: contamination of synovial structures has been found to occur without any obvious physical communications (Smith and Schramme 1992). This could be explained by local spread of the microorganisms through the synovial membrane or via blood vessels. For this reason, it was felt that joint lavage was indicated in this case.

2. Alternative Imaging Techniques

More advanced imaging techniques are becoming available to the veterinarians, allowing better and more sensitive assessment of the tissues, including the soft tissue structures. Their potential in the diagnosis of septic pedal osteitis has yet to be determined. None of these techniques were used in this series of cases, but it is likely that some of them would be extremely useful, particularly in cases that are difficult to diagnose on radiographs.

Ultrasonography is a commonly used tool to assess soft tissue structures in the equine (Genovese and others 1987) and could therefore have been useful to determine the presence of abscesses, sinus tracts or damage to the soft tissues of the foot (Dik 1990). Because of its high acoustic impedance, the hoof forms a barrier to the penetration of ultrasound waves, thus preventing imaging of the tissues enclosed within. Hauser and others (1982) have nevertheless described the ultrasonographic examination of the palmar soft tissue structures of the foot and it may be interesting to use the technique they describe in potential foot infections in the future.

Gamma-scintigraphy is a sensitive means of detection of local inflammation, including at the level of the foot (Lamb and Koblik 1988, Steckel 1991). Septic processes can be diagnosed as early as forty-eight hours after the onset of the condition (Dickie 1986, Lamb 1991b), and early cases of septic pedal osteitis have been detected this way (Steckel 1991). Gamma-cameras also allow imaging of sequestra, that appear as "cold" spots on the scans (Lamb 1987). Although Technetium 99m-MDP lacks specificity to bone infections, excellent results can be obtained if other isotopes are used in combination, in particular Indium 111 (Raptopoulos and others 1982, Lamb and Koblik 1988, Cierny 1990). This technique was not found to be necessary in the relatively long-standing cases presented in this series, but would probably be an accurate tool in early cases.

Thermography is a non-invasive technique which allows to detect focal areas of inflammation (Stromberg 1974, Purohit and McCoy 1980, Turner 1991), but it offers very little specificity and may not be very reliable at the level of the foot.

Computed Tomography and Magnetic Resonance Imaging are certainly the most accurate imaging techniques available to date and they would be extremely useful to determine the exact extent of digital wounds and involvement of various structures (Barbee and others 1987, Park and others 1987, Denoix and others 1989, O'Callaghan 1991b). They are, however, very expensive tools and are not currently available for use in horses.

E. ANCILLARY DIAGNOSTIC TESTS

Serological tests seem to be of little value in osteomyelitis and osteitis alike, although white cell counts have been reported to be slightly increased in acute osteomyelitis (Waldvogel 1988). White blood cell counts were normal in all the patients in this study and no significant alteration has been associated with septic pedal osteitis elsewhere (Pabst and Kaegi 1990). Two types of laboratory tests may yet be helpful : bacteriology and synovial fluid analysis.

1. Synovial Fluid Analysis

Synovial fluid analysis is a well recognised method of diagnosing septic synovitis and arthritis. Cytology is the most useful test: white cell counts of over 20 or 30×10^9/litre (normal figure: less than 0.2) are usually associated with infection and there is often a predominance of neutrophils (McIlwraith 1987, Turner 1990, Smith and Schramme 1992). Degenerative changes may be observed in the neutrophils (DeBowes and Yovich 1989), but this is rare (McIlwraith 1987). Counts over 50×10^9/l are considered to be pathognomonic of sepsis (McIlwraith 1987). Normal figures were observed in the distal interphalangeal joint fluid in case 8 in this study and this was used to rule out joint involvement.

Protein concentration is sometimes assessed but it is increased (>2.5 g/dl) in any inflammatory conditions of the synovium (McIlwraith 1987) or secondarily to inflammations outwith the synovial structures ("sympathetic effusion") (Smith and Schramme 1992).

2. Bacteriology

Bacteriological tests are relatively easy and inexpensive to perform and can be useful for the diagnosis and treatment of septic osteitis (Dickie 1986).

Samples were submitted to bacteriology in one half of the cases in this series: necrotic material was collected from the deeper parts of the wounds in all of them and necrotic bone was otained in two patients. Unfortunately, there are no bacteriological findings to compare this with in similar case reviews (Steckel and Fessler 1983, Gaughan and others 1989, Pabst and Kaegi 1990).

Bacteriological examination can be difficult to interpret because of the high level of contamination and the wide variety of bacteria in the horse's environment (Hanie 1989). Purulent material from the sinus tracts is always heavily contaminated (Hanie 1989) and thus not reliable to determine which organisms are involved in the bone infection (Orsini 1990). Mackowiak and others (1978) showed that there is very little correlation between cultures obtained from fistulae and from infected bone in the same patients. However, if Staphylococcus aureus is present in the exudate, it is likely to be one of the pathogens in the bone. Similar observations were reported by Rudd (1986). In this study, Staphylococcus was found in both samples in only one case, but several organisms were present both in the wound and in the dead bone in another patient. In the author's opinion, the long duration of the condition and heavy contamination allowed less pathogenic bacteria to invade the bone. This shows, however, that the only reliable sample is necrotic bone, as reported by other authors (Mackowiak and others 1978, McDonald and others 1989, Orsini 1990).

Because of the heavy contamination of distal limb wounds, many bacterial strains can be involved in osteitis, even if they are not very pathogenic. Not all of them can, however, destroy bone. The most common pathogen isolated in human cases of osteitis (Mackowiak and others 1978, Hughes and Anderson 1985, Dickie 1986) and in animals (Caywood and others 1978, Hirsh and Smith 1978, Caywood 1983) is Staphylococcus aureus. This bacteria has a high affinity for bone and is able to inactivate chemotactic locomotion of leucocytes (Norden 1988). Its presence in sinus tracts is therefore a good indication of its involvement in the condition (Mackowiak and others 1978, Knight and others 1980).

Gram positive bacteria are more common than gram negative species in bone samples (Hirsh and Smith 1978, Walker and others 1983b, Harari 1984). Besides Staphylococcus, Streptococcus spp are often present (Caywood 1983) and were isolated in three cases out of four in this study. **Gram negative organisms** are often found in wounds and fistulae (Rudd 1986) and may also be isolated from the bone (Dickie 1986, Orsini 1990), in particular Escherichia coli (Coffman and Finocchio 1969, McDonald and others 1989). The latter was found in all the cultures in this review. A very resistant strain of E. coli was isolated from the bone in one case, indicating that this bacteria can also be a serious pathogen.

Anaerobes are seldom observed (Hirsh and Smith 1978). However, they are difficult to culture and a negative growth does not rule out their involvement (Jann and others 1987). They are very abundant in the animals' environment and should therefore always be looked for (Coffman and Finocchio 1969, Walker and others 1983a, Rudd 1986). Although abscesses elsewhere rarely contain anaerobes in horses (Knight and others 1980), most foot abscesses do (McColles 1985, Dyson 1986, Richardson and others 1986a). Anaerobes were isolated in two cases in this study. Metronidazole was therefore used routinely, usually as local instillations.

Although most samples contain only one pathogen in humans (Mackowiak and others 1978, Hughes and Anderson 1985), **polymicrobial cultures** are often obtained in animals (Caywood 1983, Walker and others 1983a and b). The fact that most cases of osteitis in animals are related to limb wounds might account for this difference. This is particularly obvious in the equine foot. This study does not gather enough cases to give significant observations, but it does emphasise the unreliability of sinus tract cultures. **Sensitivity tests** were used to assess the efficiency of the systemic treatment and local instillation of broad spectrum antimicrobial drugs was found to be sufficient to control the contamination of the wound. **Gram stains** may give some information concerning the bacteria involved, but it is best that results from in vitro sensitivity tests be awaited, so that appropriate drugs can be used. In this series of cases, potentiated sulfonamides were effective, systemically, in all the patients.

III. TREATMENT

A. CONSERVATIVE MANAGEMENT

All the patients presented in this review received surgical treatment. All the cases had received some sort of conservative management without success (table II). The lack of response to medical therapy was also observed by Gaughan and others (1989) in septic pedal osteitis. Most bacterial infections can nowadays be treated medically, thanks to the availability of many effective antibacterial drugs. Bone infections are no exceptions and human cases of osteitis requiring surgery have become very rare (Dickie 1986, Waldvogel 1988). This is in total contrast with the results of this study or that of Gaughan and others (1989). In general, antibiotic therapy is associated with a limited success in animal septic osteitis, because patients are usually presented to the veterinary surgeon at an advanced stage of the disease (Rudd 1986).

Infections in the foot are considered to be the most common pathology encountered by equine practitioners (Finocchio and others 1984). Most of them are very superficial and appropriate paring of the hoof with a hoof knife, along with topical antibacterial treatment, is often all that is required (Richter 1982, Steckel 1984). In this review, all the patients had been treated for some time before referral was considered. Yet, trimming of the sole or wall was only carried out in one half of them, even though the problem was always suspected to be localised in the foot (Table II).

Paring out the damaged horn allows the pus to drain out of the abscess. It is the first and most important step in the management of puncture wounds. In the cases where this had been performed, the owners had noticed an improvement of the signs for a short time. The sudden drop in the pressure of the exudate often provides immediate pain relief (DeBowes and Yovich 1989, Turner 1990). The signs, however, deteriorated again rapidly, and large amounts of exudate were found in all the cases by the time of referral, indicating that the drainage had not been adequate. Moreover, large areas of sole were usually severely undermined. It is important that all abnormal or separated horn be removed (Johnson 1982, Dyson 1986). In case 4, more than one half of the sole and parts of the wall had to be excised (figure 4). It is likely that a more thorough debridement should have been attempted prior to referral. Very large portions of the sole can be removed (Steckel 1984), even if it requires progressive paring over several days (Johnson 1972, Johnson 1982). In some of our cases, relatively small holes had been created for drainage. Larger openings would have been less likely to become obstructed, thus entrapping contaminated material again (Moyer 1991). **Tapering** the edges of the wound also helps in preventing this (Adams 1974, Steckel 1984).

Paring the hoof may not be sufficient in deep foot injuries (Richter 1982, DeBowes and Yovich 1989), but it might provide temporary pain relief and, more importantly, slow down the evolution of the septic process. In some cases, it may also prevent the spread of infection into sensitive structures. In some of our patients, it is likely that appropriate local management at an early stage could have helped to make an earlier decision regarding referral, particularly in the absence of response to the conservative therapy.

Antibacterial drugs were used by the referring veterinarians in all the cases in this series. In humans as in small animals, systemic antibiotics can be very effective to eliminate bone infections (Hughes and Anderson 1985, Orsini 1990), providing they are administered at high doses (Dickie 1986). A minimal duration of over four weeks is usually required (Harari 1984, Orsini 1984), which is in total contrast with the very short durations of treatment in our cases (Table II). Antibiotic therapy alone has proved to be sufficient to cure osteitis in horses, but only during the acute stage of infection and before any changes become apparent on radiographs (Caywood 1983, McDonald and others 1989). A number of factors rapidly decrease the efficacy of the drugs. The presence of dead tissue, which is no longer vascularised, does not allow diffusion of drugs in sufficient quantity (Knight and others 1980, Blockey 1983). The accumulation of pus (Knight and others 1980, Richter 1982) or the presence of necrotic material, or sequestra, act therefore as physical barriers against antibacterial substances and promote bacterial growth in a "protected environment" (Rudd 1986, Jann and others 1987). As tissues react against the septic process, a shell of thick fibrous tissue encircles the infected area. This protects unaffected tissues from the toxic action of pathogens but in the same time it also protects the bacteria (Harari 1984, Hanie 1989, Carter 1991a). This is possibly why the conservative treatment was always unsuccessful in this series (Caywood 1983, Gaughan and others 1989). Surgical removal of all necrotic **and** sclerotic tissue was therefore warranted. If diagnostic and surgical facilities were not available, referral should have been considered at an earlier stage in most cases (Steckel 1984, Turner 1990).

Systemic antibacterial drugs were used in combination with the surgical management. Firstly, they would protect healthy tissues against bacterial spread (Dickie 1986). Secondly, some bacteria always remain after the debridement. All physical barriers against the diffusion of drugs having then disappeared, the presence of antibiotics would keep microbial growth down post-operatively (Cierny 1990).

Coffman and Finocchio reported in 1969 the successful use of **autogenous bacterins** for the treatment of bone infections in horses, and three cases of third phalangeal osteitis were included in their trial. Although the patients had been affected for over a month, the bacterins lead to a complete remission. This was not considered in our cases, partly because of the lack of experimental evidence, partly because of the restriction to the diffusion of systemic drugs

B. SURGICAL MANAGEMENT

After the failure of the conservative treatment, surgical removal of necrotic tissue was necessary to eliminate the septic process. The aim of the procedure was not only to remove infected and devitalised material, but also to provide appropriate drainage. Any remaining exudate would otherwise have impaired healing. The surgical intervention was always very prompt after a diagnosis was reached, that is within twenty-four hours. Although delaying the intervention may, in some cases, facilitate the identification of the affected areas (Firth 1987), the risk of further bacterial spread made any delay unacceptable.

Because of the high level of contamination of the equine foot, thorough cleansing of the hoof was thought to be important prior to surgery. The hoof was trimmed and rasped down until a smooth surface of fresh horn was exposed. A concentrated (10%) solution of povidone-iodine was applied to the foot overnight, under a waterproof bandage, to allow the solution to penetrate the microscopic recesses that conceal bacteria within the horn (Richardson and others 1986a).

General anaesthesia was used in all our cases. The surgery could have been performed in the standing animal, under sedation and local anaesthesia (Fessler 1989, Gaughan and others 1989), but the procedure is painful, and may be prolonged if extensive curettage or joint lavage, for example, are required. It may be difficult to restrain the animal for long periods of time and this also puts the persons involved at risk. Absolute immobilisation of the patient is also warranted for proper exploration of the wound (DeBowes and Yovich 1989). General anaesthesia provided not only proper immobilisation of the patient, but also allowed us to work under adequate, aseptic conditions, that are required for any type of deep hoof wounds (Steckel and Fessler 1983, Turner 1984, Moyer 1991).

Regional anaesthesia (abaxial sesamoid nerve blocks) was performed in combination with general anaesthesia. This has been associated, in orthopaedic interventions, with a better recovery and a lower concentration of inhalant anaesthetic gas is required to provide an acceptable degree of narcosis. This is thought to be related to decreased nociceptive stimulation of the central nervous system (Munroe, 1992). This technique has been used for several years at Glasgow University Veterinary School and, in the author's opinion, provides a better quality of anaesthesia.

A **tourniquet** was used in all the patients, because it decreases the amount of bleeding which obscures the visual field in areas that are already difficult to visualise. Esmarch bandages were placed proximally to the fetlock, so that the pastern area could be kept sterile, in case arthrocentesis of the distal interphalangeal joint was required. Nevertheless Gaughan and others (1989) placed it at the pastern level without causing any inconvenience.

The surgical technique has been described in the preceding chapter. The technique used was very similar to that described elsewhere (Richardson and others 1986a, Fessler 1989, Turner 1990), proceeding layer by layer until the bone was reached. We were rather more conservative than these authors during the initial dissection around the draining tract. The hole was then progressively enlarged until all the affected bone was exposed. The use of a probe was found to be sufficient to identify the extent of the tract in this study but others prefer to inject methylene blue into the wound. It specifically stains dead tissues, but live cells eliminate the dye and remain unstained (Rudd 1986, Orsini 1990). The defect thus made was in the shape of a cone, with the base at the solar surface. This would prevent the granulation tissue at the most superficial level of the wound to develop too fast and entrap contaminated material (Adams 1974, Turner 1990). It also improved the visualisation of deeper structures.

Identification of the necrotic bone was sometimes difficult. The visual appearance was used as a criteria of viability: normal bone was considered to be hard, white, and to bleed homogenously when it was scraped. In all our patients, the affected bone appeared grey to black, it was soft and friable, and did not bleed. Similar findings have been observed by other authors (Gaughan and others 1989, Moyer 1991). Specific dyes, such as methylene blue or Disulphine blue, might have provided a more accurate assessment of viability (Rudd 1986, Orsini 1990). These techniques might have prevented recurrence of the infection and the need for a second anaesthetic in two of our patients. It is also possible that a larger margin of healthy tissue should have been removed.

Sequestra can be difficult to identify, because they remain hard (Turner 1984). They were nevertheless very loose in this study, and were always easy to remove. After all the dead bone had been eliminated, the sclerotic areas were also scraped because, as mentioned earlier, they would impair the diffusion of antibacterials and cells, hence preventing healing. A burr would have allowed easier and more rapid debridement (Cierny 1990).

We ensured that all debris was eliminated to remove it as a nidus for infection (Blockey 1983, Caywood 1983). A suction device could have been used, but lavage with large amounts of sterile polyionic fluid was found very effective by itself. Ringer's solution was preferred to sodium chloride solution, because it is less toxic to cells and has a buffered pH that will not inactivate antibacterial drugs (Caywood 1983). Povidone-iodine and antibiotics were used in our lavage solutions, but it is often felt that the mechanical effect of lavage is the main element of decontamination (Fessler 1971, Harari 1984).

A two stage technique is often carried out in humans to treat chronic osteitis (Cierny 1990). A first operation aims at debriding the wound which is then sterilised over several days with the aid of systemic and local antibacterials. A second operation is performed thereafter to fill the bone defect with autologous cancellous bone grafts or bone cement. This technique has been associated with better results and a faster recovery than a single intervention (Cierny 1990). Cancellous bone grafting is usually preferred in humans and in small animals (Caywood, 1983, Harari 1984) because the implants are rapidly revascularised and lead to faster healing and better control of bacterial contamination (Kold 1990). It is difficult to obtain sufficient stability of the graft bed in large animals and the technique has given poor results (Orsini 1984, Turner 1984). Bone cement on the other hand has been successfully used in horses to pack defects in the distal sesamoid bone after bone infection (Hickman and others 1984). This may be useful in the third phalanx as well and the bone cement can be impregnated with antibiotics, usually gentamycin, to prevent reoccurence of infection (Fitzgerald 1983, Hughes and Anderson 1985, Rudd 1986). Bone grafts could also be used in the equine foot by using a technique described by Cierny (1990): the wound is left to granulate for several days until a regular layer of granulation tissue covers the defect. Pieces of cancellous bone can then be inserted into the tissue bed. These techniques may decrease the healing time of the wound and, since the post-operative management is certainly the most costly part of the treatment of septic pedal osteitis, they could lead to reduced patient costs.

The size of the defect in the bone, created by osteolysis and surgical debridement, did not influence the outcome significantly. Up to 9.8% of the third phalanx was removed, without impairing the function of the bone. How much of the pedal bone can be amputated, or what the exact consequences of excessive debridement would be, are not well known. It is likely that a certain percentage of the parietal surface must be preserved to provide normal laminar function. Postoperative laminitis, in the affected foot, was not a problem in this study, as in other case reviews (Gaughan and others 1989, Pabst and Kaegi 1990). Gaughan and others (1989) removed up to 24% of the bone, and did not observe any subsequent alteration in the level of performance of the animals. These authors also reported two cases where the whole phalanx had been excised; a functional phalanx was later regenerated. These are probably extreme cases, but they show that large parts of the pedal bone can be resected. This review suggests that 10% of the bone is a safe limit, but one should take other factors into account. The anatomical part of the phalanx involved is very important to consider: there is more risk in debriding the parietal surface than the solar surface, and care must be taken not to damage the joint or the insertion of the deep digital flexor tendon.

At the end of the surgical procedure, the wounds were **packed** tightly with sterile surgical swabs impregnated with an antiseptic solution and a pressure bandage was applied to the lower limb. The pressure was used to prevent haemorrhage and haematoma formation, because it is impossible to ligate vessels in the rigid tissues of the foot (Jann and others 1987). Accumulation of blood might have allowed contaminating microbes to colonise the wound. Water-proof bandages were used to protect the debrided area from the moisture and heavy contamination of the environment: a layer of polythene was found satisfactory. A dry, clean stall was provided and the litter was kept thick to prevent the occurence of laminitis (Adams 1974, Johnson 1982).

C. POSTOPERATIVE MANAGEMENT

The postoperative care is always a lengthy procedure in severe hoof wounds. The patients had to stay at Glasgow University for fourteen to fifty days, but more care was always to be provided for some time after the animals were discharged from the hospital. Complete healing of large hoof defects has been reported to take from eight to twelve months (Fessler 1971). In any case, it is a costly and time-consuming treatment (Hamilton 1976, Kay and others 1976, Perry 1976).

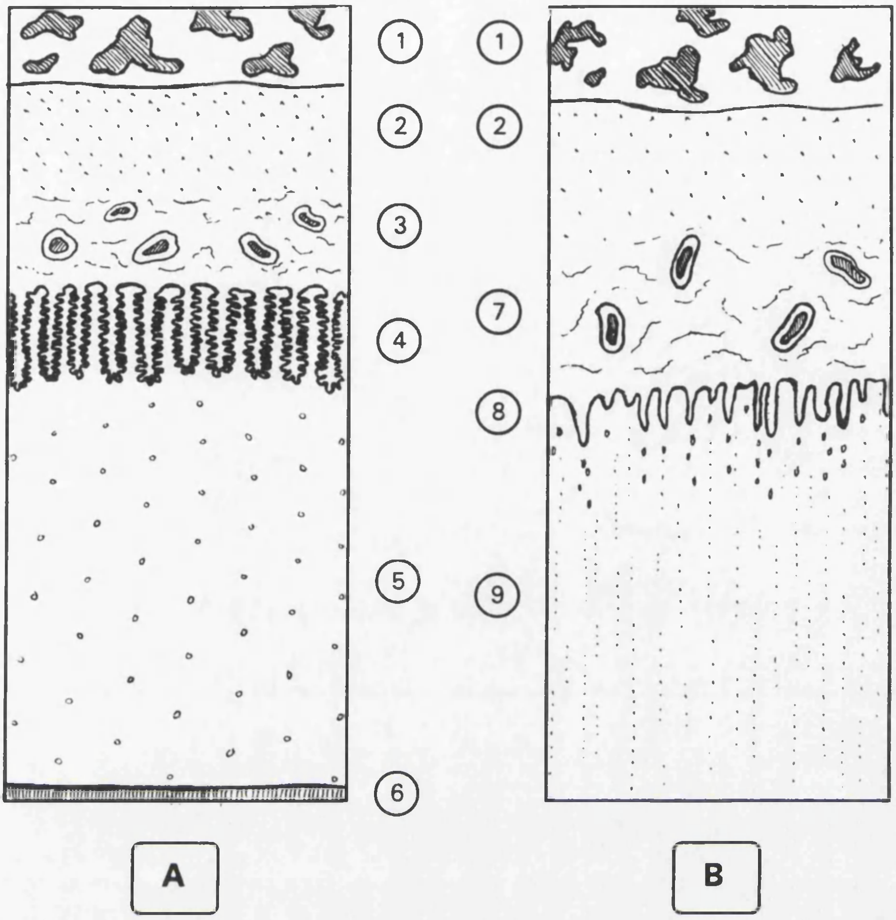
The bandages were changed after two days and then once daily, at which time the wound was flushed with bactericidal solutions. Some authors have advocated the use of hot, saturated salt solutions (Turner 1990, Moyer

1991) but the hypertonic nature of these solutions dries the granulation tissue and slows the healing process. Metronidazole was instilled into the wound for several days, because it was difficult to rule out the presence of anaerobic bacteria, for which the thick bandages provided ideal growing conditions. Other antibiotics were also used until the bone was covered by granulation tissue. Penicillin was usually used, unless in vitro sensitivity tests indicated the need for more specific antibacterials, such as chloramphenicol or gentamycin. These were used topically, because of their high systemic toxicity, and were found to be as effective.

A **shoe and removable plate** was applied as soon as the defect was completely covered by granulation tissue. This technique makes it much simpler to look after the patients, while still allowing regular monitoring of the wound. Pine tar and oakum are often used to pack the space between the plate and the sole (Johnson 1972) but povidone soaked swabs were used in this series of cases because they are easy to change. In one patient (case 8), the solar defect extended up the hoof wall and it was impossible to cover the hole properly with a shoe and plate. A waterproof PVC horse boot was used and was found to be very effective.

Fessler (1989) recommends the use of short limb casts rather than bandages. Casts provide appropriate protection and waterproofing and give a better immobilisation of the foot. The casts are left for ten to thirty days and are then either changed or replaced with a normal bandage. Immobilisation of the limb was not found to be necessary in this study. On the contrary the animals were encouraged to use the affected foot as early as possible to decrease the risk of laminitis in the opposite leg. Besides, regular bandage change made it possible on two occasions to detect the recurrence of infection that warranted further debridement. The use of a cast may be indicated in some patients whose struggle during the bandage changes make this procedure very difficult.

Healing of the equine hoof is known to be much slower than that of the skin. Figure 18 shows the basic structure of the equine hoof. Superficial defects left by the debridement of subsolar abscesses heal rapidly by epithelial proliferation from the stratum germinativum and subsequent keratinisation. This only takes eight to ten days (Richardson and others 1986a, Fessler 1989). If, on the other hand, the corium has been damaged and removed, granulation tissue fills in the defect (Steckel 1984). The hoof is a rigid structure in which wound contraction cannot occur. Healing depends therefore upon the migration of epithelial cells across the surface of the granulation tissue (Figure 19). These cells are formed at the margins of the wound and the larger the



A. HOOF WALL

1. Third Phalanx
2. Periosteum
3. Laminar Corium
4. Dermal and Epidermal Laminae
5. Stratum Medium of Epidermis
6. Stratum Externum of Epidermis

B. SOLE

1. Third Phalanx
2. Periosteum
7. Solar Corium
8. Papillae of Corium
9. Epidermis

Figure 18: Histological Structure Of The Equine Hoof

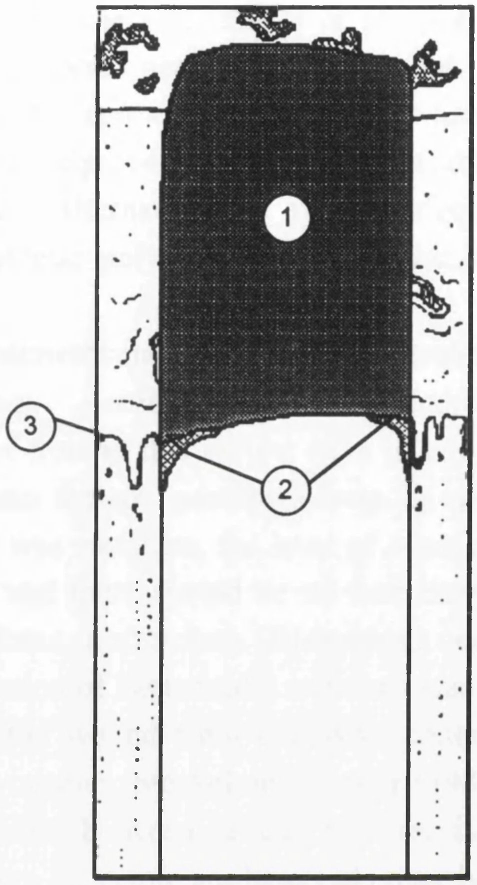


Figure 19: Healing process in a deep solar wound

The defects in the bone and corium are filled with granulation tissue (1). Epithelialisation progresses from the margins of the wound towards the center (2), by migration of epithelial cells from the germinal layer of the epidermis (3).

defect, the longer the process takes. The immature epithelium thus formed progressively thickens and keratinises. The whole process took an average of three months to be completed in this study. Steckel and Fessler (1983) reported a mean healing time of 3.3 months. Until that stage, the epithelium remains extremely vulnerable to chemical or physical trauma (Steckel 1984, Fessler 1989) and the horses need to be box-rested. Contamination is no longer a concern when the epithelium has started to keratinise. Since bandage changes are no longer required, a full sole pad (rubber or leather) (Moyer 1991) can be applied. Alternatively, if a large defect remains, the latter can be filled with a synthetic polymer such as acrylic, which was found very effective in case 4.

Adjunctive treatments included the administration of anti-inflammatory and antibacterial drugs. **Antibacterials** were administered systemically for rather long periods of time in this review (five to twenty-six days). In fact, the need for antibiotic therapy postoperatively is open to debate. If the surgical debridement was complete, the level of contamination should be very low postoperatively, and there should be no barriers against the diffusion of the animal's own defense mechanisms (Richardson and others 1986a, Fessler 1989). Local application of bactericidal solutions was therefore thought to be sufficient to protect the wound from excessive contamination. In a large review of septic foot injuries, Steckel and Fessler (1983) found no significant difference in the outcome between patients who received systemic antibiotics and those that did not. Systemic antibacterials may be useful in some cases, especially when there is a risk of recurrence of the infection.

Non steroidal anti-inflammatory drugs are certainly more useful. They provide pain relief and help in the prevention of laminitis (Dart and Pascoe 1988). Most horses appeared to increasingly weight-bear on the affected foot soon after the surgery and the doses could be reduced after a few days.

IV. COMPLICATIONS AND THEIR MANAGEMENT

As mentioned at the beginning of this chapter, complications are always a potential problem in severe foot infections. The long duration of the sepsis and the presence of extensive sinus tracts, in our cases, made infection of other sensitive structures a major threat. It was sometimes impossible to determine the exact extent of the problem, even at surgery. In case 3, a submural abscess was only noticed several days post-operatively, when it broke out at the coronary band. Spread of the septic process was more serious in case 7, as it involved the navicular apparatus. This latter condition is always associated with a very poor prognosis (Steckel and Fessler 1983, Fessler 1989), unless surgical debridement and exposure of the bursa are performed within a few days (Richardson and others 1986b). The most common consequence of this condition is necrosis of the deep digital flexor tendon, which adheres to the distal sesamoid bone or may even rupture, thus leading to the subluxation of the distal interphalangeal joint (Stashak 1987a, Honnas and others 1992). This did not occur in case 7, but the animal was destroyed after a diagnosis of navicular osteomyelitis was made. At post-mortem, the cartilage appeared to be entirely destroyed, and the deep digital flexor tendon was severely damaged. Arthrodesis of the distal interphalangeal joint has ben described as a salvage procedure in such cases (Richardson and others 1986b, Honnas and others 1992). It was not considered in our case, because of financial reasons and because of the extent of the infection into the surrouding tissues. In extreme cases, distal limb amputation has been performed (Koger 1982, Krpan and others 1986, Crawley and others 1989). Both trauma and fractures due to severe falls, and laminitis in the opposite foot are common fatal complications of these extreme treatments. The after care is extremely time-consuming and costly and amputation is very rarely indicated in horses. Euthanasia is therefore the only humane alternative that can be considered in many cases (Richardson and others 1986b, Honnas and others 1992).

The frequent occurrence of pathological fractures in this study was discussed earlier. It would seem that a fractured piece of bone, in an infected environment, tends to undergo sequestration, however large the fragment. Due to the underlying cause, that is demineralisation, pathological fractures are always very difficult to treat (Honnas and others 1988a). It is advisable, when they occur secondarily to infections, that the fractured bone be removed whenever possible, as indicated by the results of this case review. In case 4, the fracture happened postoperatively and it was decided against a surgical intervention for financial reasons. The broken fragment disappeared on radiographs during the healing, indicating that it became necrotic and was resorbed. There is, however, a risk of sequestration and entrapment of bacteria in the necrotic bone. Surgical removal of infected fragments would therefore be the safest alternative in other cases.

Pedal infections predispose to laminitis, either in the opposite limb because of increased loading (Richardson and others 1986a), or in the affected foot, subsequent to vascular alterations and the toxic effects of the bacteria (Dart and Pascoe 1988). Laminitis did not occur in any of our cases. An effort was made, however, to provide adequate support to the opposite limb with frog pads, support bandages and a thick, soft litter, and anti-inflammatories were administered systemically for several days after the horses had started to bear weight on the affected leg. Early return to full weight-bearing on the injured limb, in all surviving horses, was thought to have been paramount in preventing this complication.

Finally the bone infection recurred in two cases, despite the surgical debridement. This became rapidly obvious, because the granulation tissue failed to cover the infected bone and appeared darker, as mentioned by Richardson and others (1986a). Careful inspection of the wound on a regular basis is therefore warranted. It may be possible to debride the wound in the standing animal but a second general anaesthetic was favoured in our two patients, because it was felt that thorough exploration was once again necessary. Both horses made a successful recovery thereafter.

V. PROGNOSIS AND OUTCOME

The outcome of the surgical treatment of septic pedal osteitis appears very encouraging, since seven horses out of eight survived and became sound after a variable length of time. Yet the results need to be interpreted with caution. No horses included in this study were treated conservatively and it is impossible to compare the efficiency of medical and surgical managements. Failure of the care provided before the patients were referred gives little indication to that regard. General experience in human and small animal cases of septic osteitis indicates that systemic antibiotics need to be administered for periods of over six weeks (Blockey 1983, Harari 1984). Only four horses in this review received antibacterial drugs; only one injection was given in two of them and the longest treatment was of one week duration. It is possible that early aggressive medical therapy could have cured some of the patients. In chronic osteitis, however, surgical debridement has proved to be the most successful therapy, in particular in the third phalanx (Steckel and Fessler 1983, Gaughan and others 1989, Pabst and Kaegi 1990). Surgery was associated here with a very favourable prognosis for survival and for return to soundness (87.5%) and similar results were obtained by Gaughan and others (1989) (77%) and by Pabst and Kaegi (1990) (100%).

The final outcome is generally difficult to forecast, especially before the wound is surgically explored. It is often considered that the chances for recovery decrease as the surgical debridement is delayed (Johnson 1982, Steckel 1984, Richardson and others 1986a), but this was not observed in this review. In fact the prognosis is seemingly related to a large number of factors, among which the structures involved and the extent of tissue damage are the most prominent ones (Steckel and Fessler 1983, Richardson and others 1986a). It is obvious that any delay increases the chances of complication due to bacterial spread. Yet the nature and extent of the complications is totally unpredictable. The occurrence of pathological fractures and the extent of the septic process into the collateral phalangeal cartilages or into the digital cushion did not significantly alter the prognosis in this study, whereas septic navicular bursitis proved lethal. Similar observations were made by Steckel and Fessler (1983). As a consequence, it is advisable to perform surgery as early as possible to decrease the risk of life threatening complications. Nevertheless, horses that have been affected for a relatively long time may still have a fair chance for complete recovery.

The proportion of bone that was lysed or surgically removed did not influence the outcome in a previous study (Gaughan and others 1989). In this review on the other hand, all the patients in which over eight percent of the phalanx had to be excised were retired from work for a year or more, whereas a satisfactory outcome was associated with figures less than seven percent. This does not necessarily mean that the higher the proportion of bone damaged, the worse the outcome. In fact, all these animals were sound at the time of the follow-up investigation. The reason for temporary retirement was actually based on problems with shoeing of the affected foot in the two horses with the larger bone defects.

Whenever large areas of bone were involved, a more extensive debridement was necessary and this left very large defects in the sole and wall. Large wounds take a long time to heal in the foot and may need over a year to do so (Richter 1982, Fessler 1989). Until healing and keratinisation are complete, the patients remain prone to solar bruising (cases 4 and 5). Eventually, only one patient was definitively retired and seventy-five percent of the cases actually returned to work. Little information is available as regards the effects of loss of bone in the third phalanx and subsequent decrease in the level of performance. No significant difference was observed elsewhere (Gaughan and others 1989, Pabst and Kaegi 1990) but there have been reports of poor performance in racehorses (after Fessler 1989). In one of the cases in this study (cases 5), the foot remained fragile several years after the injury and the owner only used the mare for dressage and slow hacking.

Generally speaking, this case review indicates that the prognosis for return to soundness after surgical debridement is usually good but may be altered by the development of serious complications, in particular if synovial structures become involved. As in other bone infections (McDonald and others 1989), it is difficult to predict the severity of the condition on the sole basis of physical and radiographic examinations and more precise information is often obtained during the surgical procedure. It may take months however before an accurate prognosis as regards return to function and level of performance can be given to the owner.

CONCLUSION

The results of this review of cases indicate that, despite popular belief to the contrary, septic pedal osteitis is not a desperate condition and can carry a reasonably good prognosis. It is not quite clear whether or not aggressive medical therapy would be effective if it was initiated rapidly in the course of the septic process. It is, however, obvious that the problem is generally brought to the attention of practitioners in a chronic form. At that stage, physical barriers prevent drugs from penetrating infected areas. Medical management becomes fruitless, although it may seem to settle the problem for a time. This study confirms that surgical management is usually the only option in these patients and is highly effective. Above all, the conclusion to be drawn is that such cases need to be detected more frequently and at a much earlier stage. As new, more sensitive diagnostic methods progressively become available, very subtle changes can be detected in the third phalanx. The main limitation to prompt treatment is in fact the time of referral. It can be argued that the costs involved in the patient's hospitalisation are a strong limiting factor and many practitioners try to treat the problem empirically and at a "low cost" before considering referral as a last resort. This delay involves a lot of time and unnecessary expenses and as more complications develop, more expensive treatments and lengthy aftercare become involved. In the meantime, the chances of a successful outcome are decreased. With the development of new technologies and the growing demand from clients of a higher level of service, referral hospitals are becoming a necessary tool which general practitioners will increasingly have to use. In septic pedal osteitis as in many other conditions, the combined efforts of specialists and surgeons in general practice are the key to better results.

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