THE ELEPHANT'S FOOT

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Prevention and Care of Foot Conditions in Captive Asian and African Elephants

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INTRODUCTION

Foot problems are seen in 50 percent of captive Asian and African elephants at some time in their lives. Although many problems are treatable, they may result in serious disability or death. Information on possible causes, prevention, and treatment of these problems is critical to the health of captive elephants but has not been systematically collected or distributed. The First North American Conference on Elephant Foot Care and Pathology was held in Beaverton, Oregon, 19–21 March, 1998, bringing together experts on elephant husbandry and veterinary science in order to address commonly encountered foot problems in Asian and African elephants. The conference drew 117 individuals representing over 40 zoos, circuses, elephant sanctuaries, universities, and colleges of veterinary medicine from 23 states, Canada, India, and New Zealand.

The following chapters are based on some of the presentations given at the conference. Many individuals with valuable knowledge about the treatment of elephant foot problems were unable to attend the conference. We invited some of these experts to write chapters that appear in this book. The conclusions and recommendations of the conference (Chapter 27) are strongly seconded by these additional contributions.

There is general consensus that lack of exercise, long hours standing on hard substrates, and contamination resulting from standing in their own excreta are major contributors to elephant foot problems. Alleviating these contributing factors presents a major challenge to the husbandry of elephants maintained in confined environments. All contributors also agree that prevention of foot problems is preferable to treatment. Case studies of surgical intervention to treat bone infection underscore the high costs and risks associated with heroic treatment of late-stage foot disease. We hope this review will lead to a heightened appreciation of the serious implications of improper elephant husbandry and foot care and a reduction in the incidence of foot problems in these magnificent animals.

We caution the reader not to interpret this volume as a definitive guide to elephant foot care. The husbandry, prevention, and treatment regimens described in the chapters that follow were developed at different institutions to address their particular circumstances. They are not, alas, recipes that will solve all foot problems but should serve as points of discussion in the development of new strategies. Foot care practices vary widely among elephant holding facilities. The plethora of variables contributing to foot health, combined with small sample sizes, make controlled research on effective husbandry and treatment difficult. We hope the elephant management community will respond to the problems identified in this volume by developing cooperative, multi-institutional research programs that will lead to more effective foot care standards and treatments.

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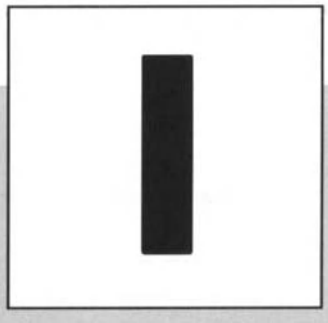

PART I
The Context of Elephant Foot Care

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1

AN OVERVIEW OF FOOT CONDITIONS IN ASIAN AND AFRICAN ELEPHANTS

MURRAY E. FOWLER

Elephant management has become a hotly debated issue. At one extreme are those who demand that no elephant should be maintained in captivity, and at the other are those who feel that they have all the answers regarding elephant management. Humans have had a long association with proboscideans. First, as food during the Ice Age, then as beasts of burden and objects of religious adoration, and more recently, for enjoyment. Asian elephants have been domesticated for over 5,000 years. The African elephant has also been tamed and trained to work for and on behalf of humans. Aside from the easily perceived danger of handling elephants, one of the major challenges of elephant managers is maintaining the health and function of the feet.

Foot problems constitute the single most important ailment of captive elephants. More caretaker time is spent caring for feet than on any other task, except feeding and cleaning. The purpose of the foot care conference was to address important issues and arrive at a consensus regarding the basic principles of foot management to be recommended to colleagues all over the world.

The foot of an elephant is a masterful piece of evolutionary development, designed to support the weight of the largest land mammal (Table 1.1). While standing, each foot of a large African male elephant (13,200 pounds) supports a weight of 3,300 pounds. That same elephant has an approximate slipper area of 254 square inches, which equals a pressure of 12.99 pounds/square inch (Table 1.2). While walking, with one foot swinging, the other feet support 4,400 pounds, for a pressure of 17.32 pounds/square inch. While ambling (modified pace), with only two feet supporting the body weight, each foot bears 6,600 pounds, for a pressure of 25.98 pounds/square inch (Table 1.2).

The anatomy of the elephant foot is unique. Chapter 2 provides details of what is known about the anatomy, but a few introductory remarks are pertinent. The elephant is semidigitigrade in the forefeet and semiplantigrade in the rear, with variable numbers of toenails (Figure 1.1). Each toenail is attached to the underlying third phalanx by a series of lamina (Figure 1.2), which interdigitate with corresponding groves in the corium, which, in turn, anchor to the bone. The external morphology of the front and hind feet differs (Figures 1.3–1.6); the front feet are rounded and the hind feet are an elongated oval. The digital cushion, interacting with the phalanges, provides an excellent cushion. The circumference of an elephant foot increases by 2.5 to 4.0 inches when weight bearing as contrasted with a nonweight-bearing circumference (Table 1.3, Figure 1.7). The compression and relaxation of the digital cushion serves an important function in pumping venous blood from the foot on its return to the central venous system. Lack of exercise has serious consequences on the foot of an elephant.

TABLE 1.2—Elephant weight distribution for an African elephant, weighing 13,200 pounds with a slipper area of 254 square inches.

Activity	Weight per Foot (pounds)	Pounds per Square Inch
Standing	3,300	12.99
Walking	4,400	17.32
Ambling	6,600	25.98

The following are suggestions of predisposing factors leading to foot problems based on the author's experience:

1. Lack of exercise.
2. Overgrowth of nail and/or sole.
3. Improper enclosure surface.
4. Excessive moisture.
5. Insufficient foot grooming.
6. Insanitary enclosures.

TABLE 1.1—Elephant measurements.

	Adult Female		Adult Male		Height	
Elephant	Pounds	Kilograms	Pounds	Kilograms	Feet	Meters
Asian	7,920	3,600	9,900	4,500	8.2–10.0	2.5–3.0
African	11,000	5,000	13,200	6,000	9.8–13.0	3.0–4.0

TABLE 1.3—Elephant foot circumference and slipper measurements for front feet (F) and hind feet (H).

Elephant	Age (Yrs)	Circumference of Foot [Inches (cm)] Relaxed	Weight Bearing	Increase [Inches (cm)]	Increase (%)	Length* [Inches (cm)]	Width** [Inches (cm)]
AFRICAN							
Mailika	11	F 35.25 (89.5)	F 38.25 (97.2)	F 3.00 (7.62)	F 8.0 H 8.3	F 12 (30.5)	F 9.75 (24.8)
		H 36.00 (91.4)	H 39.00 (99.1)	H 3.00 (7.62)		H 14 (35.6)	H 7.88 (20.0)
Tika	20	F 46.25 (117.5)	F 50.75 (128.9)	F 4.5 (11.4)	F 9.7 H 8.6	F 15.5 (39.4)	F 13.5 (34.3)
		H 46.50 (118.1)	H 50.50 (128.3)	H 4.0 (10.2)		H 18.25 (46.4)	H 11.25 (28.6)
ASIAN							
Taj	58	F 48.25 (122.6)	F 52.00 (132.1)	F 3.8 (9.7)	F 7.8 H 7.0	F 16.25 (14.3)	F 14.25 (36.2)
		H 44.00 (111.8)	H 48.50 (123.2)	H 4.5 (11.4)		H 17 (43.2)	H 11.25 (28.6)
Tina	42	F 47 (119.4)	F 50.50 (128.3)	F 3.5 (8.9)	F 7.4 H 4.4	F 5.25 (38.7)	F 14.25 (36.2)
		H 45 (114.3)	H 47.00 (119.4)	H 2.0 (5.1)		H 16.75 (42.5)	H 10.75 (27.3)
Range				F 2.0–4.5 H 5.1–11.4	F 7.0-9.7 H 4.4-8.6		

*Length—Measured from front to back of foot, including slipper and toenails.
**Width—Measured from side to side at widest point of the slipper.

FIG. 1.1—Toenails of an Asian elephant forefoot.

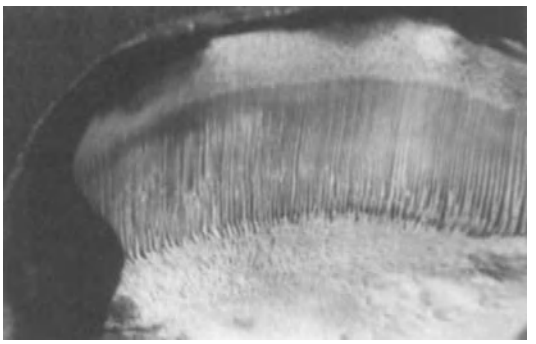

FIG. 1.2—Lamina on the inner surface of the toenail of an elephant.

FIG. 1.3—Lateral view of the right hind foot of an African elephant.

FIG. 1.4—Bottom of the right forefoot of an African elephant.

FIG. 1.5—Front view of the right forefoot of an African elephant.

FIG. 1.6—Bottom of the right hind foot of an African elephant.

FIG. 1.7—Measuring the maximum circumference of an elephant foot.

7. Inherited poor foot structure.
8. Malnutrition.
9. Skeletal disorders (arthritis).

MAGNITUDE OF ELEPHANT FOOT PROBLEMS

The records of the International Species Information System (ISIS) indicate that over 70 institutions in the United States and Canada exhibit a total of 328 elephants (Table 1.4). This doesn't include performing elephants or animals in private facilities. It is estimated that there are more than 600 elephants in the United States and Canada. Worldwide, 743 elephants are listed in ISIS records (Table 1.4).

The precise prevalence of foot problems in elephants in North America is unknown. No centralized reporting system is in operation. However, based on personal experience, few institutions have been spared the grief and frustration of dealing with elephant foot problems. It is the author's opinion that nonresolvable foot infection and arthritis are the major reasons for euthanizing

TABLE 1.4—Elephants registered with the International Species Information System (ISIS).

Elephant Species	Males	Females	Total	Number of Institutions	Captive Born (%)	Wild Born (%)	Captive Births Last 6 Months
WORLD, ASIAN							
No subspecies	55	271	326	102	29	48	6
Sri Lankan	4	13	17	11	12	76	0
Indian	19	80	99	32	34	41	3
Malayasian	6	11	17	5	0	94	0
Total	**84**	**375**	**459**				
WORLD, AFRICAN							
No subspecies	22	153	175	69	6	87	0
S. African Bush	15	62	77	29	3	96	0
E. African Bush	4	25	29	11	40	60	1
W. African Bush	0	1	1	1	0	100	0
African Forest	2	0	2	2	0	100	0
Total	**43**	**241**	**284**				
WORLD FAMILY TOTAL	**127**	**616**	**743**				
U.S. & CANADA, ASIAN							
No subspecies	33	106	139	41			
Sri Lankan	1	9	10	6			
Indian	5	31	36	15			
Malayasian	2	1	3	2			
Total	**41**	**147**	**188**				
U.S. & CANADA, AFRICAN							
No subspecies	9	96	105	41			
S. African Bush	4	25	29	13			
E. African Bush	0	6	6	6			
Total	**13**	**127**	**140**				
US & CANADA FAMILY TOTAL	**54**	**274**	**328**				

elephants. It is unlikely that an elephant will progress through life without requiring periodic pedicures to keep the feet healthy. African elephants seem to have fewer foot problems than Asian elephants, but the reasons for the difference are unknown.

FOOT PROBLEMS IN FREE-RANGING ELEPHANTS One often hears the statement that foot problems don't occur in free-ranging elephants. That is not entirely true because wild elephants suffer from snare injuries, lacerations, fractures, and perhaps penetration of foreign bodies. Elephants in work camps in India and Southeast Asia seem to suffer from problems similar to those of Asian elephants located in North America. In one elephant camp, it was estimated that 50 percent of the elephants had one or more foot problems (personal communication, Professor D. K. Lahiri-Choudhury, Portland, Oregon, 20 March 1998). The true prevalence is unknown because of the difficulty in collecting data.

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2

ANATOMY OF THE ELEPHANT FOOT

EDWARD C. RAMSAY AND ROBERT W. HENRY

While elephants have played an important role in human ecology throughout recorded history, their anatomy has been the subject of relatively few studies, and these studies considered only a limited number of specimens. This is especially true for the elephants' feet, despite the common occurrence of foot disease in elephants (Evans 1961, Mikota et al. 1994). One study that surveyed North American captive elephants found that 50 percent had experienced foot problems (Mikota et al. 1994).

Despite their phylogenetic differences, the components of Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephants' feet are remarkably similar. The major differences are the shape of the rear foot and the number of phalanges and toenails. This is not to say that the feet of the two species are the same. The differences in their wild habitats and the more common occurrence of foot lesions in captive Asian elephants suggest that the biology of the two species' feet are quite different. The following describes anatomical characteristics common to both species unless otherwise identified.

THE LEGS The huge mass the elephant is required to maintain virtually defines the concept of a graviportal, skeletal-support system. Both forelimbs and hind limbs have little angulation, compared to other mammals. The legs are straight, and the articular surfaces are in line with the axis of the leg. The limbs avoid excess exertion by flexing minimally during locomotion (Hildebrand 1995).

The bones of the limbs are massive and lack a marrow cavity. The radius and ulna are fixed in a prone position (Eales 1928). The fibula is separate from the tibia.

The forelimb is longer than the hind leg. The increase in elephant leg length is accomplished by lengthening the proximal limb segments but not the distal limb segments (Eisenberg 1981). There is little exterior definition of leg segments, and there are no externally identifiable digits. The number of toenails varies depending on the species.

THE HIND FOOT The hind foot is smaller than the forefoot and laterally compressed, resulting in an ovoid sole. This compression is more pronounced in the African elephant.

FIG. 2.1—The skeletal structure of an African elephant's left hind foot, medial view. a = calcaneus, b = talus, c = os tarsale I, d = os metatarsale I. The cartilagenous rod or prehallux is shaded.(From Smut and Bezuidenhout 1994; reprinted by permission of the editor, *Onderstepoort Journal of Veterinary Research*).

The tarsus is composed of seven bones, arranged in three rows (Figure 2.1). The talus and calcaneus make up the proximal row, and there are two articular facets between them. The talus is disc-shaped and compressed dorsoplantarly. The tuber calcaneus points plantarly (Smuts and Bezuidenhout 1994).

The central tarsal bone is the sole bone of the second row of the tarsal bones. The four tarsal bones (T1-4) make up the distal row of tarsal bones and are wedge-shaped. Each tarsal bone articulates with its corresponding metatarsal bone, with T-4 also articulating with metatarsal five (MT-5) (Smuts and Bezuidenhout 1994). There are four separate synovial sacs in the tarsus of the African elephant (Smuts and Bezuidenhout 1994).

The metatarsal bones have an expanded distal extremity for articulation with the proximal phalanx. Metatarsal three (MT-3) is the largest metatarsal, while MT-1 is the smallest and somewhat triangular in shape.

The elephant possesses an unusual structure—the prehallux, a cartilaginous segment that extends distally from MT-1 and T-1. The prehallux attaches to the sole

medial to the midline. The prehallux's function is unknown, but it appears to assist in stabilizing the tarsus over the digital cushion.

The hind foot has five digits that radiate in a craniocaudal orientation. In the African elephant, digit one (D-1) is represented by only a single sesamoid bone (Smuts and Bezuidenhout 1994), where in the Asian elephant this digit is described as having one phalanx (P) without a sesamoid bone (Mariappa 1986). The other digits have paired sesamoid bones, plantar to the metatarsal-phalangeal articulation. In the African elephant, D-2 has two phalanges, and in the Asian elephant it has three (Mariappa 1986). Digits three and four are larger than the other digits in both species, and each has three phalanges. Digit five has two phalanges in each species. The proximal and intermediate phalanges are quadrilateral in shape. The third phalanges are slightly spindle-shaped with bilateral transverse processes and a single dorsal process. The third phalanx only loosely articulates with P-2 and appears to be buried in the tissue medial to the corresponding toenail. There is a slight but distinct axial angulation of digits two and four, toward the third digit.

The number of toenails is reported to vary between species and in the African elephant between subspecies. The African elephant is generally considered to have three subspecies (Grzimek 1975): the cape, *Loxodonta a. africana,* the savannah or steppe elephants, *L. a. oxyotis,* and the forest elephant, *L. a. cyclotis.* The cape and savannah elephants have three toenails on the hind foot, protecting the distal aspects of D-2 to D-4. The forest African elephant may have four toenails on the hind foot. The Asian elephant has four toenails on each hind foot, corresponding to D-2 to D-5.

The digital cushion, a mass of fibroelastic tissue, occupies the area under the tarsus and plantar to the digits. This cushion compresses and expands the foot during weight bearing, making the elephant foot a far more dynamic structure than might be assumed. The cushion also helps distribute the animal's weight over the entire sole. The foot structure is digitigrade despite the lack of externally identifiable digits; however, extension of the digits during weight bearing may cause the hind feet to become semiplantigrade. The digital cushion is poorly vascularized and there are numerous fatty masses enmeshed within it (Sikes 1971). In the Asian elephant, the digital cushion is supplied by the plantar digital arteries and palmar digital nerves (Mariappa 1986).

The foot sole, or slipper, is a flexible, 4 to 12 cm thick, keratinized (cornified) pad covering the plantar surfaces of the feet. Upon removing the slipper, numerous indentations are seen in the foot, which are projections of the sole that extend into the sensitive dermis of the foot (Evans 1961). These projections, or papillae, presumably join the cornified pad and the underlying sensitive structures.

The toenail is a plate-like cornification of the outer layers of the epidermis, corresponding to the distal ends of certain digits. The medial aspect of the nail contains vertical horny leaves, or laminae, that interdigitate with laminae on the distal digit (Evans 1961). A sparse number of sweat glands occur just above the toenail (Schmidt 1986).

There are only a few reports on the musculature of the elephant foot, and several of these are based on dissection of a single fetus. None of these reports describe clinical aspects of the anatomy. Because the most serious clinical foot problems involve the distal aspects of the digits, the following discussion is restricted to the muscles that insert on the phalanges.

In the African elephant hind foot, the lateral digital extensor inserts on the lateral aspect of MT-5; P-1 and P-2 of D-5; and P-1, P-2, and P-3 of D-4. The long digital extensor inserts on P-1, P-2, and P-3 of D-3 and D-2. These extensor tendons and the deep digital flexor tendons totally ensheath P-3 of D-3 and D-4 and insert into the nail. The short digital extensor inserts into the deep surface of the lateral and long, digital extensors in the metatarsal region. The abductor of D-3 inserts on the distomedial aspect of P-1 and the proximomedial aspect of P-2.

The deep digital flexor runs dorsal to the digital cushion. Its tendons insert on the distal ends of P-2 and P-3 or into the nail bed and fibrous surface of the sole of D-2 to D-4. The superficial digital flexor forms a manica for the deep digital flexor tendon on the plantar aspect of the carpus and splits to insert laterally and medially on the sesamoids of D-2 to D-5, the distal ends of P-1, and the proximal end of P-2 of each digit. The superficial digital flexor muscle runs plantar to the prehallux and the digital cushion. A fibrous manica courses plantardistally from D-3 and P-1 to the sole and separates the sole from the digital cushion.

The musculature of the Asian elephant foot seems similar to that of the African species with minor differences. Shindo and Mori (1956a) describe the long digital extensor, the extensor of D-5, and the peroneus tertius, which is fused to form one large muscle belly in the Asian elephant. The fused muscle divides into a medial and lateral portion. The medial portion divides and inserts medially into D-2 and laterally into D-3. The lateral portion divides into a superficial part, inserting into the dorsolateral surface of D-5, and a deeper part (corresponding to the peroneus tertius) that inserts on MT-4. In our dissection of the African elephant, the tendons arising from this complex have an attachment similar to the individual muscles.

There are few detailed reports on the vasculature and nervous tissues of the foot. In the African elephant, the cranial tibial vessels course down the medial aspect of the cranial tibial muscle but become small at the tarsus. The caudal tibial artery and paired veins course distally and divide into medial and lateral vessels at the calcaneus. The medial branch passes through the tarsal canal with the tibial nerve. The lateral branch of the caudal tibial artery passes craniomedially over MT-5, then divides into a large cutaneous branch and the abaxial and axial arteries for D-5. Paired large cranial tibial veins drain the dorsal digital vein of D-3 and a vein

from the plantar aspect of the foot that runs between MT-3 and MT-4. Mariappa (1986) describes the tibial artery in a fetal Asian elephant as running deep to the deep digital flexor at the level of the tuber calcis, where it divides into a medial and lateral branch. The medial branch passes with the medial plantar nerve to the digital cushion. The lateral branch also extends to the digital cushion. The deep peroneal nerve dispatches the dorsal digital nerves.

THE FOREFOOT The carpal bones are block-like and arranged in two rows of four (Smuts and Bezuidenhout 1993). The proximal row includes the radial, ulnar, intermediate, and accessory carpal bones (Figure 2.2). The distal row of bones is referred to as carpal bones one to four (C-1 to C-4). C-1 to C-4 articulate with their corresponding metacarpal (MC) bones, with C-4 also articulating with MC-5. Position and articulation of the elephant carpal bones are different than other ungulates, permitting very little abduction of the carpus (Miriappa 1986). In the Asian elephant, the three carpal joints (the radioulnar joint, the intercarpal joint, and the carpometacarpal joints) each contains its own synovial sac (Mariappa 1986).

The region distal to the carpus of the forefoot resembles the hind foot (Smuts and Bezuidenhout 1993). There is prepollux, extending distally from C-1 and MC-1 and attaching to the sole medial to the midline. All five digits are retained. In the African elephant, D-1 has one phalanx and a single sesamoid bone, but in the Asian elephant, D-1 has two phalanges and a single sesamoid bone. The other digits have paired sesamoid bones plantar to the metatarsal-phalangeal articulation. Digit five has two phalanges and digits two, three, and four have three phalanges. Similar to the hind foot, digit three is the largest, and the proximal and intermediate phalanges are quadrilateral in shape. The third phalanges are slightly spindle-shaped with bilateral transverse processes and a single dorsal process.

The cape and savannah African elephant have four toenails on the forefoot, protecting the distal aspects of D-2 to D-5. The forest African elephant and the Asian elephant have five toenails on the forefoot. The sole of the forefeet of both species is round.

In the Asian elephant, the extensor of D-5 (extensor carpi quinti [Eales 1928]) courses medial to the ulnar carpal extensor and then emerges to insert on the proximal and terminal phalanges of D-5. Miall and Greenwood (1878) report that it also attaches to the base of D-4. The common digital extensor (long digital extensor [Shindo and Mori 1956b] or communis digitorum [Mariappa 1986]) divides at the carpus into medial and lateral tendons, which further divide and attach to D-2 and D-3 and D-4 and D-5, respectively, and into P-3 and the nail. The palmaris longus passes palmar to the carpus and fans out over the digital cushion and diffusely inserts on D-1 to D-5. The long digital flexor arises from the humerus and divides to insert on the distal phalanx of each digit.

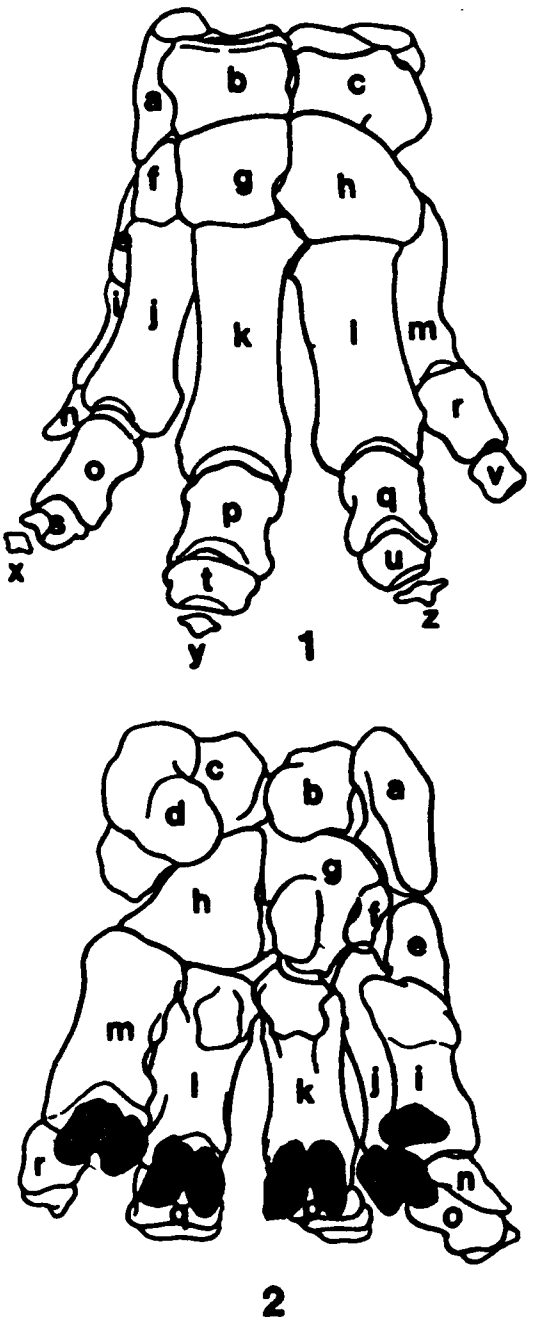

FIG. 2.2—The skeletal structure of an African elephant's left forefoot. 1 = dorsal view, 2 = palmar view, a = radial carpal bone, b = intermediate carpal bone, c = ulnar carpal bone, d = accessory carpal bone, e = os carpale I, f = os carpale II, g = os carpale III, h = os carpale IV, i-m = ossa metacarpalia I-V, n-r = proximal phanlanges of digits 1-5, s-v = middle phalanges of digits 1-5, x-z = distal phallanges of digits 2-4. Proximal sesamoid bones are shaded. (From Smut and Bezuidenhout 1993; reprinted by permission of the editor, *Onderstepoort Journal of Veterinary Research*).

In the Asian elephant, the median artery passes with the median vein and nerve down the medial aspect of the antebrachium to the carpus, where it becomes the metacarpal artery. Branches of the median artery include the interosseous artery, which descends to the lateral aspect of MC-5 and continues as the fifth digital artery (Mariappa 1986). The metacarpal artery then courses deep to the metacarpals, branching off the first dorsal digital artery before arching laterally and ventrally to become the deep palmar arch. From this arch branch the metacarpal arteries for D-2 to D-5, which become the palmar digital arteries, the recurrent branches, which supply the carpal joints, and the dorsal metacarpal arteries for D-2 to D-5, which continue on as the dorsal digital arteries.

The median nerve courses with the median artery and vein to the level of the carpus. Below the carpus, it divides into four terminal branches, becoming the palmar digital nerves for D-1 to D-4, which accompany the common digital flexor tendon to D-1 to D-4. The radial nerve supplies the dorsal digital nerves to D-1 to D-3. Dorsal digital nerves four and five are formed from the dorsal branch of the ulnar nerve, which has been joined with the radial nerve. The palmar branch of the ulnar nerve forms the palmar digital nerve of D-5 (Mariappa 1986).

CONCLUSION Considerably more information is needed on the anatomy of elephants' feet. Histological descriptions of the toenails and soles of both species should identify differences between the species and assist in our understanding of why the species' foot health differs in captivity. Further study of the relationship between the toenails and the distal phalanges would assist elephant managers and veterinarians to more intelligently trim toenails and care for nail lesions. Additionally, detailed descriptions of the interface between the sole and the underlying tissues should help our understanding of the pathogenesis of sole abscesses and separations.

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3

THE ROLE OF NUTRITION AND ITS POSSIBLE IMPACT ON ELEPHANT FOOT CARE

WILLIAM C. SADLER

INTRODUCTION Webster defines a nutrient as "something that nourishes or promotes growth and repairs the natural wastage of organic life." The key to sound nutrition is to provide the proper levels of many different nutrients. Rarely does providing one nutrient or family of nutrients solve a problem alone. The best analogy for proper health is still a chain. So it is with nutrition, all of the nutrients must serve as strong links to allow good overall health.

This chapter will discuss a number of key nutrients that are frequently related to the care of the feet and nails of elephants, but by no means will nutrients alone solve these problems.

ENERGY AND ITS ROLE IN WEIGHT CONTROL

One concern in managing foot health must be the weight supported by an elephant's feet. Increased weight certainly can exert additional pressure on the foot. This, combined with a hard surface and lack of exercise, does not present the best situation. Therefore, managing weight should be a primary focus to support proper foot care.

Energy or calories are basically fuel. When there is an excess of fuel, it is stored as fat, which increases the weight of the animal. For herbivores, calories arrive in many forms. The main sources are in the forage and feed provided. Although they may be balanced for protein, vitamins, and minerals, the total volume in a diet may provide more than the daily calorie requirement, resulting in added weight.

Another source of calories can be treats, such as apples, bread, carrots, etc. As individual items, these treats are not a concern and can provide enrichment. But when the volume of these items exceeds a guideline of greater than 5 percent of daily intake by weight, care should be taken to reduce the amount.

Forage quality should also be monitored. High-quality hay may have too much energy. Therefore, hay sources may have to be mixed to prevent excessive dietary energy, which may lead to weight control problems.

BIOTIN

Supplementation Biotin supplementation has been used by a number of zoological parks to improve elephant foot and nail health. To date, no definitive study of elephants has been conducted to confirm or deny the value of this practice. This section will provide current, relevant information to assist individuals in making an educated decision regarding the use of biotin in elephants. Foot health is certainly a function of management, and no nutritional supplement can take the place of proper foot trimming, appropriate substrate and flooring, and regular general hygiene.

Biotin: The Vitamin Biotin is one of the water-soluble B vitamins. Its main function is fixation of carbon dioxide in cells, which is required in a number of critical metabolic pathways, such as fatty acid and energy metabolism. Like many vitamins, biotin acts as a co-enzyme or "helper" in metabolism by enhancing cellular function, similar to oil in an automobile. Because biotin is by definition a vitamin, an animal cannot produce enough to meet normal metabolic needs. However, gastrointestinal bacteria are an excellent source of biotin because they can produce it from simple nutrients. The role this process may play in the nutrition of elephants will be discussed later.

Natural forms of biotin (e.g., alfalfa, soybeans, rice, liver, yeast) are linked to a protein. An enzyme is required to release it for absorption, which generally occurs in the small intestine, especially the jejunum. Elephants can receive biotin from three sources: 1) injected; 2) oral supplements; or 3) absorbed from hindgut bacteria. The bacterial source is the least known or understood. Though no acid digestion or active absorption system exists in the hindgut, it is generally accepted that nutrients produced by the hindgut bacteria do enter the body. This has been confirmed with antibiotic studies where vitamin deficiencies result when the hindgut bacteria have been killed or significantly reduced. However, the amount of biotin an elephant receives from this source is still not known.

The quantity of biotin consumed by elephants in the wild is also not known. Although some grasses and browse have been analyzed, other sources, such as water, which can contain bacteria, have not been analyzed. The practice of coprophagy (consumption of fecal material) can certainly impact the levels of many nutrients, including biotin.

Biotin deficiency results in a variety of general symptoms, including scaly dermatitis, skin dryness, graying mucous membranes, depression, and muscle pain. Symptoms have been alleviated in humans with

daily doses of 150 to 300 mg over 3 to 5 days. Excess biotin is excreted through the urine and some is stored in the liver. Large amounts of biotin (e.g., 5 to 10 mg injected) have been given to infants with no adverse effects. Therefore, it appears that biotin is relatively safe.

Dose Studies Because the horse has a similar digestion system to the elephant, it is frequently used as a model. Ullrey et al. (1988) conducted trials to measure the absorption of biotin in horses and elephants. In both species, an oral dose of biotin increased its blood concentration, but only for a short time. In the horse, levels of biotin return to baseline in approximately 12 hours and in the elephant in about 16 hours. Although urine was not collected from the elephants, it was collected from the horses. The urine contained a high level of biotin, matching the blood profile, and confirmed the general hypothesis that excess biotin is excreted through the urine. In the horse study, it was estimated that the animal retained less than 1 percent of the dose (50 mg per 500 kg of body weight).

The difficulty and unfortunate problem of using blood values to indicate nutrient status is that they are frequently inaccurate. Generally, it is only in severe cases that they reasonably predict a problem or a cure. The key to determining the status of any nutrient in the body is to quantify tissue concentrations. But these are frequently difficult to obtain in animals housed in zoological institutions because they involve either a biopsy or sacrifice of the animal.

These dose studies support the idea that elephants do not store high levels of biotin. It is speculated that an increase in blood concentration of biotin lasting 12 to 16 hours using a dosing frequency of 24 hours may increase tissue levels of this vitamin.

The Hoof Study A double-blind study of a large number of elephants all receiving common foot care is clearly an ideal study design. To date, no such study has been conducted in elephants, but it has been done in horses. Ninety-seven horses in Switzerland were studied over 1 to 6 years to determine if oral biotin supplementation would improve health and strength of the hoof. The study concluded that oral supplementation of biotin (5 mg per 100 to 150 kg of body weight) did improve hoof strength and reduce cracking.

The study was conducted using 11 control and 86 treatment horses. Hoof strength was measured and histological evaluations were made every three months. Definite improvements were seen in 8 to 15 months. A number of animals were removed from oral supplementation and hoof condition was monitored. In 7 out of 10 cases, the hoof deteriorated after the oral supplementation was removed. An additional case study in England shows similar findings.

PROTEIN The skin and nails of any animal are primarily composed of protein. Human skin represents 6.9 percent of the total body weight, making it the fifth largest organ in the body. Therefore, a considerable quantity of nutrients is required to keep this organ functioning correctly.

It does not appear (based on diets typically fed in zoos) that protein deficiencies are likely. Dierenfeld (1994) suggests that a maintenance level of 8 percent protein is marginally adequate. Data from Nepal indicate forage consumed by elephants has a protein level of 3.94 percent to 4.63 percent on a dry matter basis with animals in healthy condition. A comparative review of many elephant diets in zoos in North America indicates protein requirements have always been met or exceeded.

TRACE MINERALS Providing the proper level of each required trace mineral can become a challenge in any diet because of mineral interactions. Three trace elements that deserve some discussion because of their importance in skin and foot care are zinc (Zn), selenium (Se), and arsenic (As).

Zinc plays a vital role in skin and nail growth. The Greeks were among the first to notice the healing properties of Zn through the use of calamine lotion ($ZnCO_3$). Two studies in humans on wound healing demonstrated that a dose of 50 mg of Zn (as $ZnSO_4$) enhanced the rate of wound closure.

Deficiencies of Zn in humans have been linked to severe skin lesions, diarrhea, and hair loss (alopecia). Increased Zn loss has also occurred in burn victims and patients with kidney damage, supporting the role of Zn in the maintenance of skin health.

Data regarding trace element requirements in elephants are limited, but some do exist. Elephants in Nepal consumed forage with Zn levels ranging from 20 to 52 parts per million (ppm). The recognized Zn requirement for horses is 40 ppm for all life stages (National Research Council [NRC] 1989). Blood Zn concentrations in African elephants (*Loxodonta africana*) are around 15.1 to 18.4 µmol/l.

Because of zinc's important role in the maintenance of skin, a prudent evaluation of diet, blood status, and the form of Zn in the diet may prove useful in cases where foot and/or nail concerns are evident. Zinc appears to be among the least toxic of minerals; therefore, providing additional amounts above the NRC-suggested level should pose no immediate concern. However, Zn can interfere with copper uptake, so excessive amounts might be detrimental.

Arsenic has been recognized as an essential trace element in a number of studies of rats, goats, mini-pigs, and chickens. Little is actually known about the role of As, but it has a high affinity for keratin. Keratin is the protein that makes up the horny layers of skin, hair, and nails. It appears that most natural diets have sufficient quantities of As and do not need supplementation; however, Se competes with As for absorption.

With the recent focus on vitamin E and its role in elephant nutrition and interactions with Se, additional

amounts of Se are now frequently added to diets. If foot and nail problems occur in an institution, determining Se concentrations, both dietary and supplemental, may be valuable. Remember, Se has a very narrow range between its requirement and its toxic level, and an excess dose can easily be given if not properly managed. It should be stressed that no data exist to indicate that high Se may cause nail and foot concerns. However, providing a balanced level of all trace minerals should certainly be a goal of any diet.

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4

RECORD KEEPING AS AN AID TO FOOT CARE IN THE ASIAN ELEPHANT

CHARLIE RUTKOWSKI, RAY HOPPER, AND FRED MARION

INTRODUCTION Foot care is a major husbandry component for keeping Asian elephants in captivity. In order to track problems, which may take a long time to resolve, and to maintain a schedule of foot trimming, adequate and accurate records are needed. There are several ways to keep good records. The first and foremost is a written record-keeping system. The second is by incorporating still photographs to augment the written records. Finally, a videotape of the actual trimming process can show what was done to the foot.

COMPUTERIZED DATABASE SYSTEMS With the advent of the computer, record keeping has become a very simple process. Using a Windows-based database system, it's easy to keep daily records and to extract foot care information from them. After a foot has been trimmed, a note in the daily record is made. For example, it may state that nail number five on the right front foot was shaped or a maintenance trim was started. The database's "Find" feature can be used to locate all those records where nails were shaped or a maintenance trim was done. The "Find" feature should show a list, sorted by date, of all the foot trimmings that were done over a specified time period. Printing out the data to see a history of what was done and how often is a few keystrokes away.

An important point in using a computerized record system is that everyone uses the same terminology. The "Find" or "Search" command looks for a selected keyword. If that word does not appear in the record, then no records will be found. There are two ways to get around this. First, multiple-search requests can be made, or second, everyone entering data into the database must be familiar with a defined set of keywords.

Problems often arise in the care of elephants' feet, so keeping track of medications and treatments and their results, or lack of results, is a valuable tool. Again, the database is of great use. The data entered in the database can include when a certain treatment regime began, when it ended, and any important comments concerning the results of a treatment. As in the keyword search for foot trimming, all this information can be easily retrieved. For example, an elephant's foot was soaked in a Nolvasan solution. Type in the word "Nolvasan" in the appropriate field using the "Find" feature and all the records containing the word "Nolvasan" will appear. A complete record that shows the date of treatment initiation, completion, and any results can then be printed out. This information can then be filed in that elephant's separate foot care book. We feel that foot care is of such a major concern that each elephant should have its own foot care binder, containing all records and photos.

PHOTO DOCUMENTATION One of the more helpful tools in record keeping for elephants' feet is photo documentation. Often when we entered foot care information into our record-keeping system, we used words to describe what we found, but words leave a lot to the imagination. We have tried to use drawings or coloring on a predrawn foot template to show what is occurring, but each of these is susceptible to individual interpretation. Also, it often took a long time to fill in the template or to make a drawing. We have found that the simpler, the better. Presently, we try to take pictures of each foot before and after each foot trimming. For those elephants that have no problems, we try at least twice a year to use photos to document baseline conditions. It is helpful if the camera has a feature that puts the date on each photo. This lessens the need to keep auxiliary records of when photographs were taken.

VIDEO A third way to maintain foot records is through videotaping the foot care session and describing what is being done to the foot and why. Video footage can record important visual information, such as the elephant's gait. One disadvantage to this approach is the time involved in searching through the tapes to find an exact date or specific footage. It is not nearly as handy as a binder filled with dated photographs and an accompanying printed record.

CONCLUSION The combination of a written record generated from a computerized database and photo documentation has proven to be a valuable tool. Together they can show conclusively when a treatment for a problem has yielded good results or when it has failed. This record-keeping system has also helped us keep to a schedule of preventative foot maintenance and has shown us the results over time.

PART II

Approaches to Routine Foot Care

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5

FOOT CARE FOR CAPTIVE ELEPHANTS

ALAN ROOCROFT AND JAMES OOSTERHUIS

INTRODUCTION Elephant foot care has been practiced for hundreds of years-ever since elephants have been kept in captivity. Foot problems are frequently encountered in captive elephants and are treated in a variety of ways. The solutions chosen to correct these problems and the measures that are taken to prevent them can influence the overall health of captive elephants.

There are numerous approaches to keeping elephants in captivity and an equal number of opinions as to what constitutes proper elephant foot care. The following is a brief look at what we consider to be the factors that influence elephant foot problems, what constitutes good foot care practice, how to deal with problems when they develop, and what to do to prevent them from occurring.

We believe that no matter how good a foot care program is, eventually foot problems will be seen because they are the result of keeping elephants in captivity. We also believe that whatever the type of elephant contact allowed at an institution, proper foot care can be accomplished.

GENERAL FACTORS INFLUENCING FOOT CARE PROGRAMS

Philosophy of Institution Elephants are kept in captivity in many different ways. This is the direct result of the diverse background of the people involved in managing captive elephants and the equally diverse number of opinions on how captive elephants should be managed. Ultimately, elephant care follows a philosophy that is developed by each institution and is implemented through the knowledge and experience of each institution's handlers.

Type of Contact Allowed There are a number of factors that determine the type of contact that each institution allows its elephant handlers to have. These include: the elephant knowledge of upper management and the staff directly responsible for elephant care; the degree of liability the institution is willing to assume; the disposition of the elephants; and any past employee injuries sustained while handling elephants.

The different types of elephant contact allowed would require different tactics for proper foot care. But no matter what kind of contact is utilized, elephants' feet can be successfully cared for with proper training.

Competence of Personnel Staff experience is a direct result of either a well-established training program, the initial hiring of knowledgeable elephant personnel, or a combination of the two. In any event, the competence of the staff will be the guiding factor of a well-organized elephant foot care program.

Behavioral Disposition of Elephants The character, temperament, and disposition of the elephants will affect the overall outcome of any program. The more tractable the elephants, the easier the program will be to implement. Also, individual differences between elephants may require different types of approaches within the same herd. A progressive elephant program plots the course of each individual elephant over its lifetime, with regular reviews along the way.

HUSBANDRY PRACTICES NECESSARY FOR HEALTHY FEET

Sufficient Exercise Adequate exercise is one of the most important aspects of proper elephant husbandry (Figure 5.1). Healthy feet require exercise of all joints, tendons, and ligaments. Anything less predisposes an elephant to foot problems, especially later in an elephant's life. Too often, however, the need for adequate exercise is overlooked or ignored. As a consequence, captive elephants become overweight and are less likely to exercise or move at all.

One to two hours of walking each day should be considered the minimum amount of time an elephant needs for cardiovascular activity. This should be keeper-supervised exercise, not just strolling around the exhibit.

Proper Hygiene Elephants in the wild visit water holes twice a day to drink and socialize. During these hours they swim, roll in the mud, throw dirt on themselves, and rub their massive bodies against large objects. This process cleans and scrubs their bodies and rejuvenates their skin. Also, by digging with their feet in wet sand around the water source, they clean and scrub between their nails and around their cuticles. Although the wild elephants' feet are not typically considered pretty or well pedicured, they are healthy and functional.

FIG. 5.1—Elephants being exercised.

In captivity, elephants' feet are constantly exposed to their own feces and urine, which results from long hours of confinement in their stalls, up to 16 hours a day in some situations. Therefore, in order to reduce the corrosive nature of urine and the infective components of the feces that get on their feet and legs, proper hygiene practices must be followed. This includes the daily scrubbing of feet and legs, using soap and water and a hard bristle brush (Figure 5.2).

Regular Pedicures Elephants in captivity need to have their feet trimmed on a regular schedule. Unlike their wild counterparts, who tend to walk for up to 18 hours every day over different substrates, relatively sedentary captive elephants wear their pads down very little. The pads become overgrown and cracked, which provides an environment for infection. The nails also need periodic attention so they don't become overgrown and crowd one another. Crowding reduces the space between the individual nails and leads to the entrapment of fecal material and moisture, creating an environment for infection (Figure 5.3). Correct, well-implemented pedicures on a regular, 90-day schedule will lessen the possibility of foot problems.

Natural Substrates Unfortunately, most captive elephants spend the majority of their time standing on concrete or asphalt floors. Elephants should be housed for the majority of the day on resilient, interactive, yielding surfaces. Substrates allowing an elephant to dig will exercise and strengthen leg and foot muscles, tendons, and joints. This exercise and activity directly supports healthy feet throughout the elephant's life (Figure 5.4).

COMPONENTS FOR APPROPRIATE FOOT CARE PROGRAMS

Experienced Staff The experience of the staff is a critical component of proper elephant foot care. However, very few staff people become totally competent with the process of elephant foot care. Reaching a level of complete comprehension can only be achieved if the staff has the opportunity to interact with elephants of many different ages and under different management situations. Only then will they be able to see the wide variety of foot problems that can develop and learn the proper ways to deal with them.

Trained Elephants In order to trim an elephant's feet properly, the elephant must be trained to present its feet to the trainer for a length of time that allows for a complete pedicure. If the elephant is not trained to do this, the whole foot care program is doomed. The trained elephant must also present its feet to the person doing the trimming in such a way that allows access to all areas and surfaces of each foot.

Reliable Equipment A complete set of correctly sharpened pedicure tools is necessary for proper foot

FIG. 5.2—A keeper scrubbing the legs of an elephant.

FIG. 5.3—A healthy elephant foot with sufficient space between the nails.

FIG. 5.4—Elephant digging, which exercises the legs and joints.

care. Equally important is the use of tubs and other foot supports. It is sometimes necessary to elevate the elephant's foot to a height that is suitable for trimming and is comfortable for both the elephant and the person doing the trimming. In Figure 5.5 a tire is being used to increase the height of the leg and provide comfort to the elephant during the cleaning procedure.

Facility Design Proper facility design for pedicures is especially important for institutions utilizing remote handling or protected contact-management practices. In these circumstances, the facilities must be designed so that an elephant can present its feet to the trainer in positions that allow all surfaces of the foot to be accessed in a safe and comfortable manner for the elephant and the trainer (Figures 5.6–5.8).

Sufficient Time Having sufficient time to implement a foot care program is probably the most important component for proper foot care. Good equipment in the hands of experienced people, trained elephants, and a well-designed facility are useless and doomed to failure unless adequate time is available for proper, regular pedicures.

THE PEDICURE

Species Differences The ability to perform a correct pedicure is enhanced if staff people have some knowledge of elephant foot anatomy, especially its surface structures. It is also important to know how an elephant uses its feet during its daily activities and the function of each activity.

Captive African and Asian elephants generally have two distinctly different foot care needs, which probably result from differences between their natural environments and their relatively sedate lifestyles in captivity.

African elephants need little nail care. Most foot care attention is directed towards pad trimming. Proliferate pad growth is probably an adaptation of the wild African elephant's daily need to travel many miles on relatively hard, dry surfaces looking for food and water. On the other hand, the Asian elephant, whose natural environment is generally more moist and lush, needs considerable nail and cuticle work and relatively little pad care.

In general, both species need more foot care as they grow older, especially elephants in a nonworking environment. The consequences of captivity slowly catch up with an older elephant, with the lack of exercise being the most important factor contributing to the need for increased foot care.

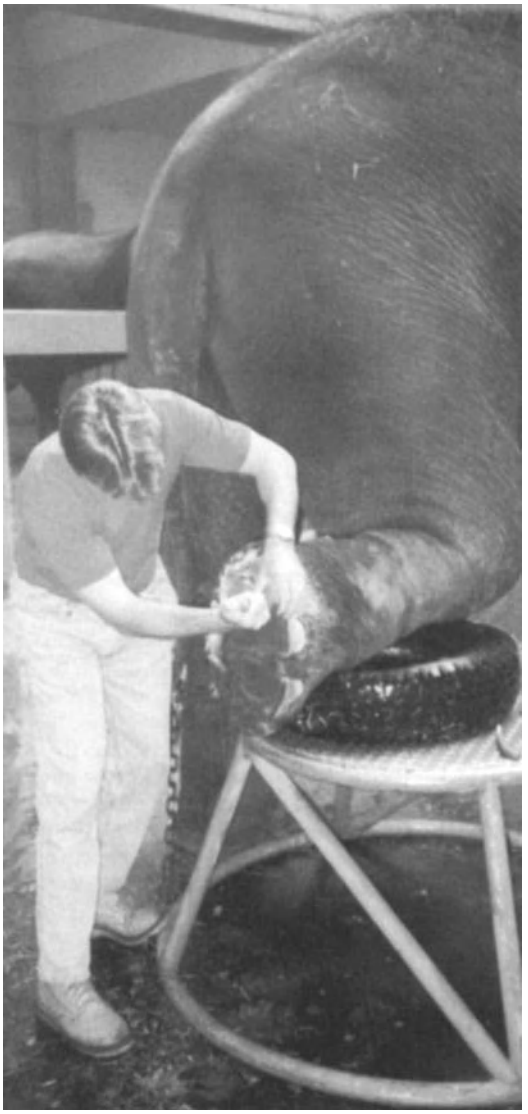

FIG. 5.5—A keeper uses a tire to increase the height of the leg and to provide comfort to the elephant during the foot care procedure.

FIG. 5.6—Front foot presentation for pad and nail access.

Correct Equipment Having the correct equipment is essential for a productive elephant pedicure. Staff people also need to know how to sharpen and care for pedicure tools. A properly sharpened hoof knife is of the utmost importance because it is used to remove nail, pad, and cuticle material quickly and efficiently, especially in the sensitive areas of the foot. Proper and well-maintained tools decrease the amount of time the elephant has to position its foot, reduces the stress on the elephant, and leads to a more cooperative elephant during future trims.

The basic tools needed are quite simple: two sizes of hoof knives with appropriate hones for sharpening and a hoof rasp. These are readily available through most farm supply stores and catalogs (Figures 5.9–5.13b).

As with other husbandry procedures, individual preferences, special needs, and experience result in the use of other types of pedicure tools, such as hobby

FIG. 5.7—Rear foot presentation for pad access.

knives, tree grafting loops, and woodworking draw knives and rasps. Some individuals utilize power tools when performing pedicures (Figure 5.13b). However, the use of power tools is strongly discouraged because it is too easy to remove too much material too fast, which can cause serious damage to an elephant's foot. Also, power tools are noisy and generate intense vibration and heat. It is generally accepted that the hoof knife and rasp are the best tools to use for trimming.

It is important to avoid frequent exposure of sensitive tissue when trimming an elephant's foot. Cutting too deep and drawing blood will cause the elephant to be less relaxed and unwilling to cooperate during the procedure.

Another important tool is the standard elephant tub, which helps correctly position the foot for trimming (Figures 5.14–5.17). A normal-sized elephant tub is comfortable for the average elephant for long periods of time. For older elephants that may need to shift positions during the pedicure, use of a car or trailer tire as a cushion on the tub is very helpful, especially for the rear foot position. It will provide comfort for the foot and will help to reduce pressure on the knee, thus making the process more acceptable to the elephant. For those elephants managed in a protected contact-management system, different types of stirrups and foot cradles have been developed to accomplish the same goals (Figure 5.18).

Positioning of Feet In order to perform a routine pedicure, the elephant must be trained to position its feet into four normal positions (Figure 5.19). Alternative positions for special circumstances are illustrated in Figures 5.20–5.22.

Correct training techniques are imperative. Training techniques include a sequence of actions where the elephant is exposed to every tool and procedure that will be used for the foot trim. It is important to proceed slowly, introducing the different tools and equipment in stages. This allows the elephant sufficient time to build confidence and comfort with the process and to understand what is expected of it during the procedure. The elephant will become desensitized to the process and will understand and accept the pedicure. If the process is a "hump and thump" exchange of ineffective techniques, the elephant will be less likely to cooperate, and consequently, the pedicure will be unproductive.

Approach and Time Frames The interval between pedicures in an "employed," adult Asian elephant (i.e., an elephant with regular, supervised exercise or activity) is three months. Elephants standing in a zoo exhibit and moving little generally need foot work more often, especially if they are fed like an employed elephant. Allow one hour per foot for elephants that are on a regular pedicure schedule.

For institutions that have elevated foot work to the highest priority, setting time frames may have little importance. (But even under normal circumstances, foot care is no more important than facility hygiene, daily elephant washings, or keeping your tools clean and sharp.) In other institutions with time constraints or institutions implementing elephant environmental enrichment programs, providing the best possible pedicure in the shortest possible time is highly desirable.

Frequently, however, foot work seems to be an area of elephant care that doesn't receive the full attention from management. We believe this is partly due to a lack of one institution that tests and explores foot care procedures or the availability of instructional classes that teach comprehensive foot care.

FIG. 5.8—Rear foot presentation for nail access (uncommon in many protected contact-management systems).

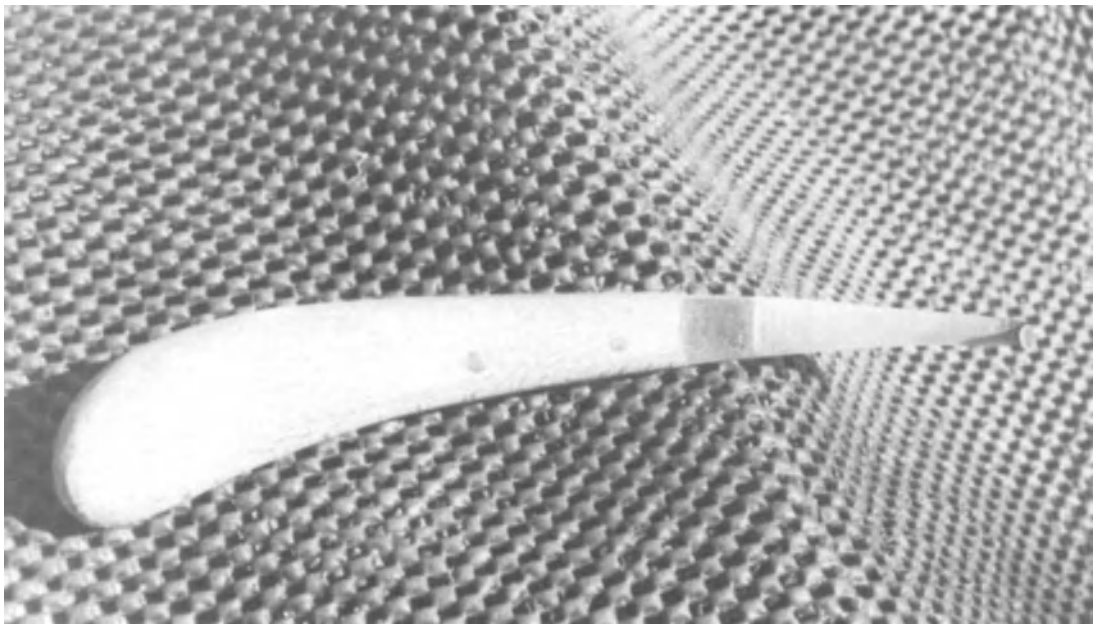

FIG. 5.9—Small knife (blade size 2.25 inches long and 0.15 inches wide).

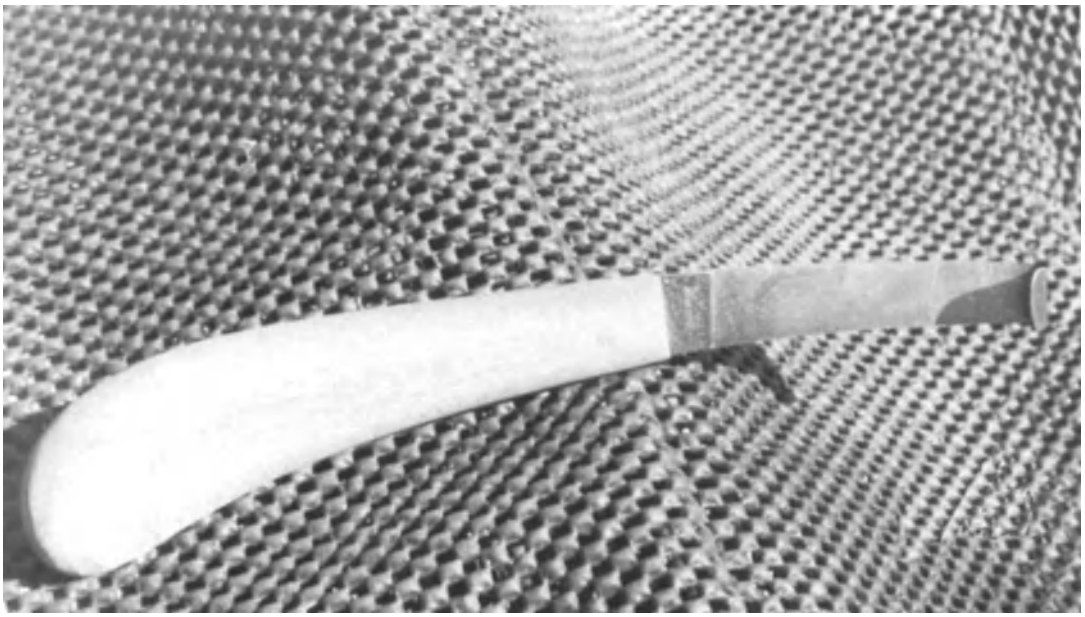

FIG. 5.10—Large knife (blade size 2.75 inches long and 0.50 inches wide).

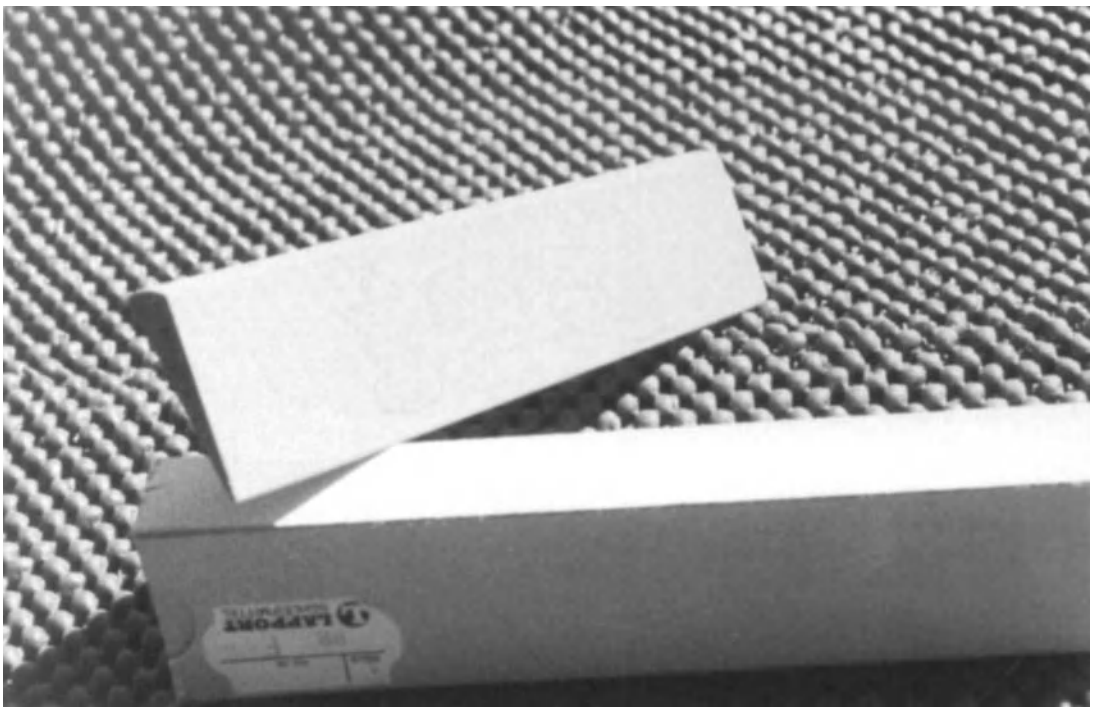

FIG. 5.11—Small hone (6 inches).

FIG. 5.12—Large hone (8 inches).

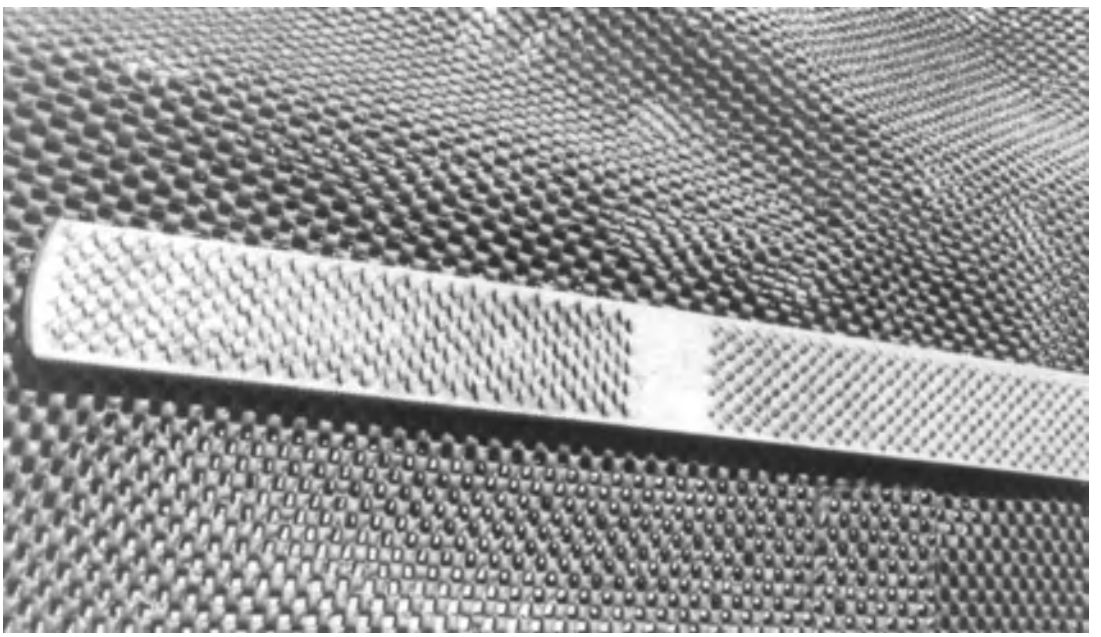

FIG. 5.13a—Rasp (11 inches).

FIG. 5.13b—The use of an electric grinder, if used inappropriately, may have severe consequences on elephants' feet.

FIG. 5.14—Positioning the foot for trimming using a tub.

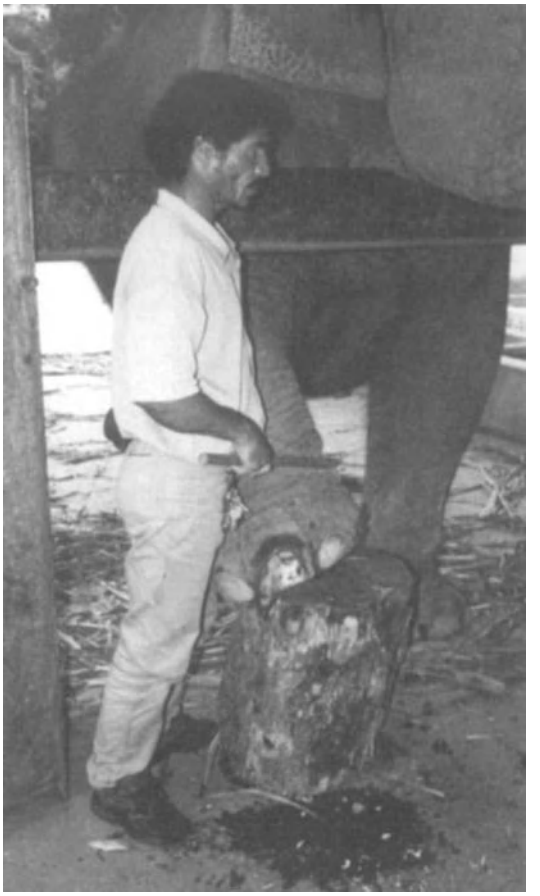

FIG. 5.15—When no conventional equipment is available, a tree stump works very well to position the foot for trimming.

Another rule, which is not often adhered to, is the timely completion of a pedicure. A completed procedure is an important priority for maintaining the well-being of an elephant. Once a pedicure is started, sufficient time should be allotted for its completion. When the person who began a pedicure is unable to complete it, thus leaving a foot partially finished, the next person responsible for foot care may be confused. Knowing where to start on an elephant's foot and knowing when the pedicure is complete is a skill that can only be learned through experience.

Nails African and Asian elephants occur in different types of habitat and have evolved different types of foraging habits. The African elephant has evolved as a browser, as is indicated by the shape of its trunk tip, which has opposing "fingers," and by its tremendous, flexible trunk, which amazes zoo and circus visitors. The feet of African elephants are subject to less stress because of their predisposition to browsing and

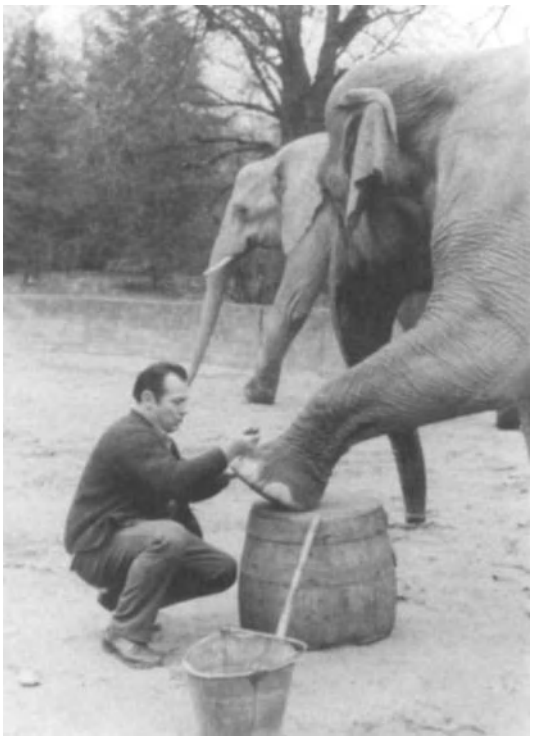

FIG. 5.16—The use of an old beer barrel for a pedicure at an old, established elephant facility.

FIG. 5.17—Another type of foot rest; they come in all shapes and sizes.

FIG. 5.18—A stirrup used in a protective contact-management system.

because they use their trunk more than their feet when foraging. It is commonly recognized that in captivity the African elephant needs less foot care than the Asian elephant, even among older elephants.

In contrast, the Asian elephant has a more robust foot structure that is assumed to have evolved because of its methods of grazing. The trunk of the Asian elephant is less flexible than the African. The tip of the trunk possesses one finger and a large palm-like appendage that opposes it. The structure and strength of the trunk allows the Asian elephant to graze by grasping large clumps of grass and pulling them out of the earth, while making a raking motion with its foot. The large nails of Asian elephants' feet act like chisels, digging deep into the soil and assisting the trunk in excavating grass and roots.

The Asian elephant will also browse when the opportunity arises, and the African elephant is frequently observed eating grass on the savannah. But

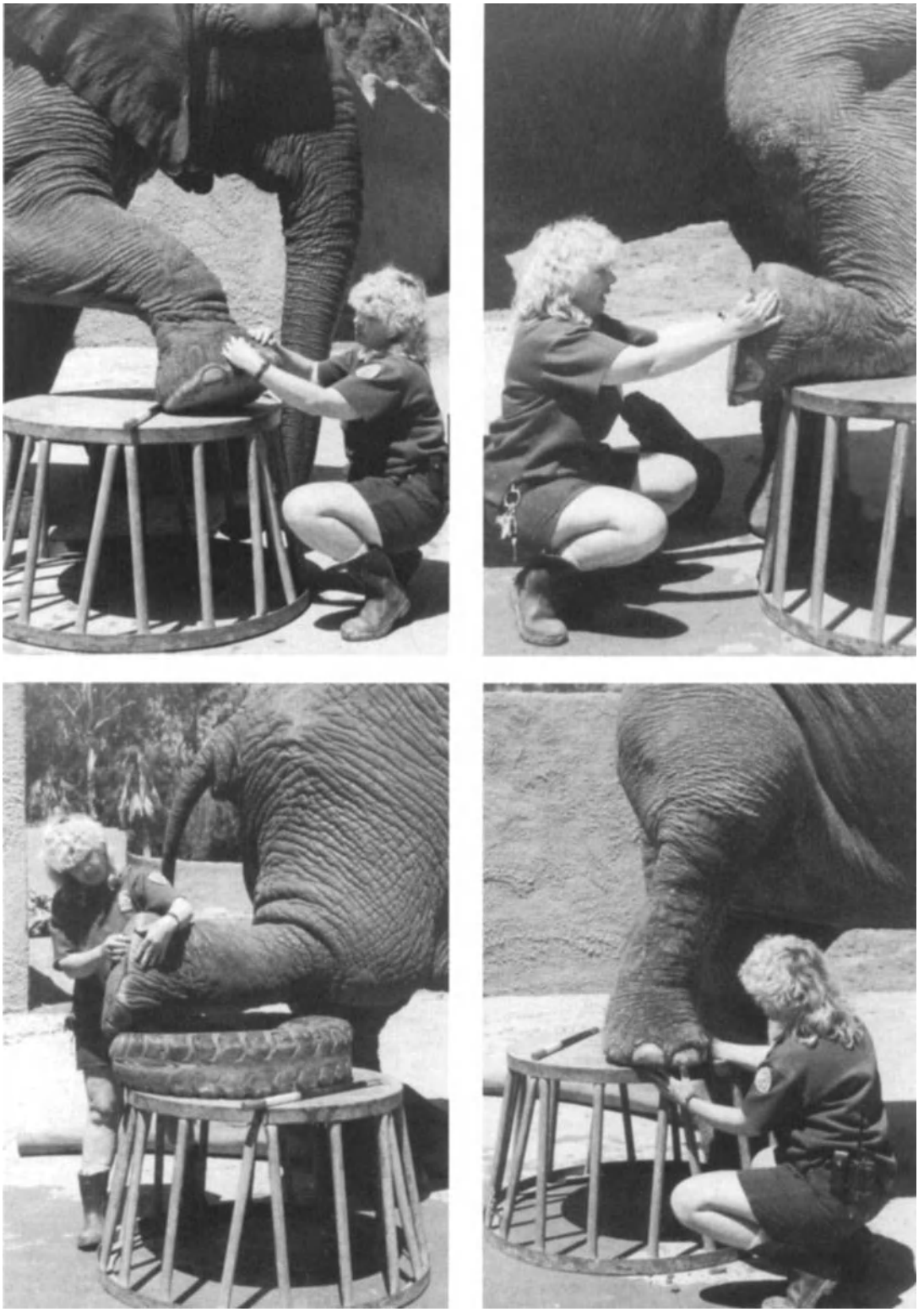

FIG. 5.19—Standard foot positions.

FIG. 5.20—Foot trimming position used in a circus.

FIG. 5.21—Elephant lying down for pedicure.

FIG. 5.22—Restraint chute utilized for a foot trim.

FIG. 5.23—Extreme nail overgrowth in an Asian Elephant.

these are secondary feeding adaptations resulting from the destruction of their primary grazing habitat.

We assume that the grazing habits of the wild Asian elephant explain the need for more continuous nail growth than is seen in the African elephant. Consequently, more nail care is needed for captive Asian elephants. Even so, there are a number of different approaches to nail and pad care for each species that have probably resulted from differences in their captive environments (i.e., substrate, diet, amount of exercise).

Because many circus trainers have had bad experiences with elephants hitting their feet on tent posts or stakes, filing the face of the nail has been frowned upon for many years. Filing may weaken or compromise the strength of the nail. The excessive removal of pad would also be a mistake for circus elephants, considering the type of substrate they must negotiate when offloading at stony train sidings or when walking on hot asphalt in the summer. We tend to share the opinion of circus trainers; a little extra pad and nail thickness might save an elephant's feet from a lot of damage.

Filing the surface of an elephant's nails requires an awareness of the thickness of the nail and the anatomy of the tissue behind it. If the nail is filed too thin, it will expose the sensitive laminar tissue, which will then dry and crack and possibly develop into an abscess. Each nail has a specific shape and is independent from its neighbor. The general rule of thumb when dealing with an adult Asian elephant is to create, without compromising the nail's strength, a finger's width distance between the second, third, and fourth nails on the front feet; and between the first, second, and third nails on the rear feet. (The nails are numbered from the inner to the outer edge on each foot.) This distance allows the tissue between the nails to dry sufficiently after washing,

FIG. 5.24—A well-maintained elephant foot.

bathing, or in the case of the rear feet, urinating (Figures 5.23–5.25). Since African elephants generally need little nail trimming this rule doesn't apply to them.

Cuticles Overgrowth is the most common problem associated with the cuticles of an elephant's foot. Some

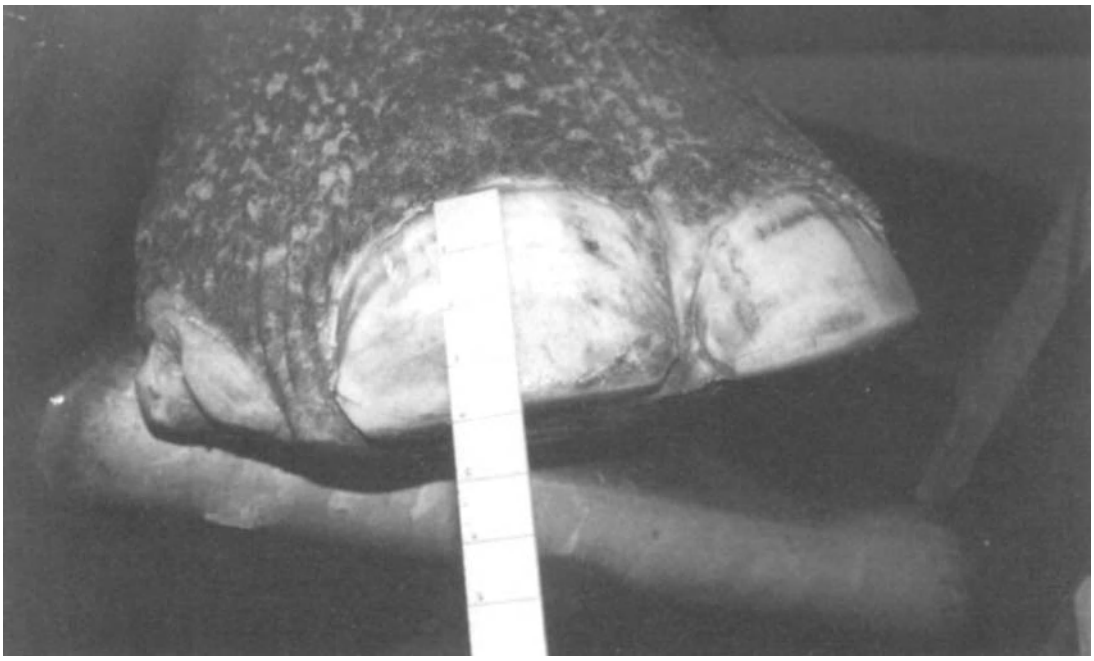

FIG. 5.25—Allowing the nails to grow too large can cause pressure distribution issues elsewhere on the foot.

overgrowth takes on the appearance of feathering and removal is very difficult and painful to the elephant.

Another condition we have seen, particularly in mature elephants that have had little or no cuticle trimming, is the development of fluid pockets behind the overgrown cuticles. It appears that when the sweat glands, which sit around the curve of the nail, are covered by an untrimmed cuticle they become blocked, causing small pockets of clear fluid to accumulate. This creates pressure and pain when the elephant walks, which causes the elephant to adopt a more flat-footed gait that avoids rolling on the front of the nail. After the excess cuticle has been removed and the pockets opened and drained, the elephant will revert back to a more normal, flexible gait. These pockets will reoccur if the cuticles are not kept properly trimmed (Figures 5.26–5.28).

FIG. 5.26—Normal cuticle growth.

Pads An elephant in the wild traverses many different types of substrates and terrain. Most often the Asian elephant walks on soft, yielding surfaces like the leafy jungle floor, while the African elephant walks on the grass and sand of the savannah and the hard dry surfaces of semiarid deserts.

The pads of an elephant in the wild are not smooth or well manicured; rather, they have deep grooves and cracks that give an impression of disrepair. However, this is not the case, as they are able to maintain their feet by walking great distances each day for feeding, bathing, digging, and dusting. In the process they wear their pads and nails sufficiently and maintain healthy feet. This daily exercise also strengthens the tendons, ligaments, and muscles of their feet and legs and promotes good blood flow to the feet, which the average

FIG. 5.27—Cuticle feathering.

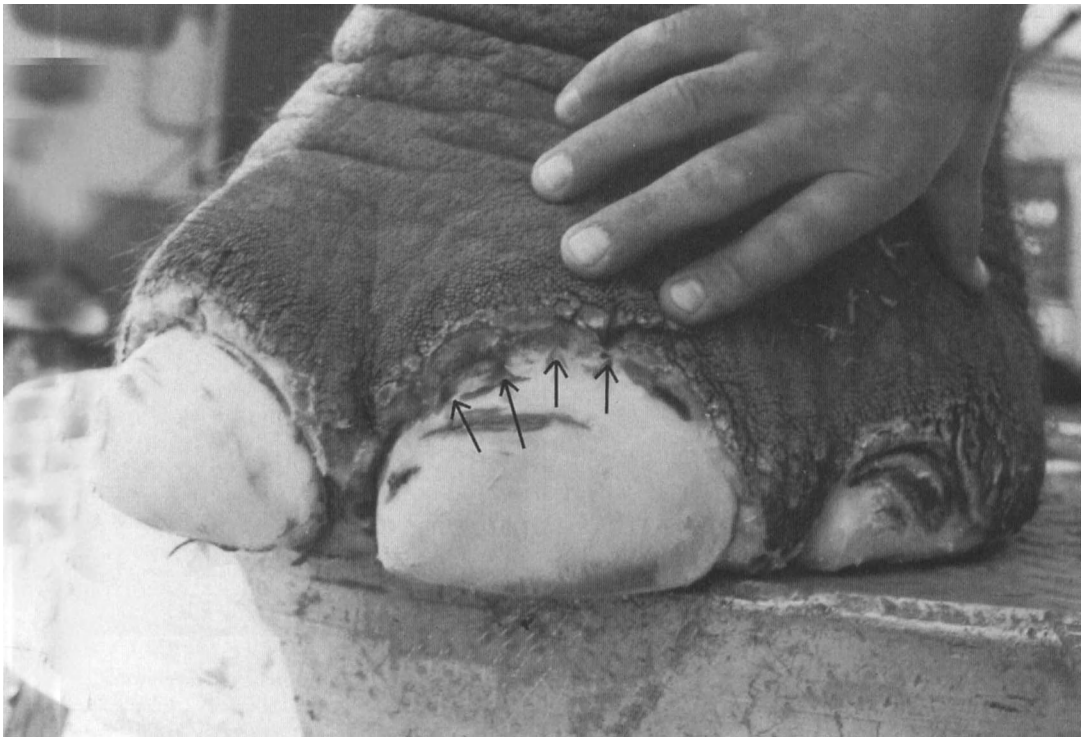

FIG. 5.28—Fluid pockets behind the thick cuticle growth.

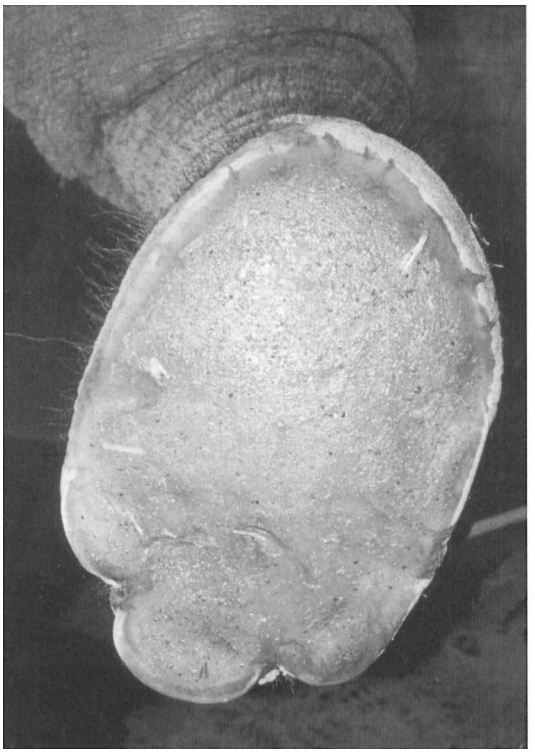

FIG. 5.29—Well-manicured pad.

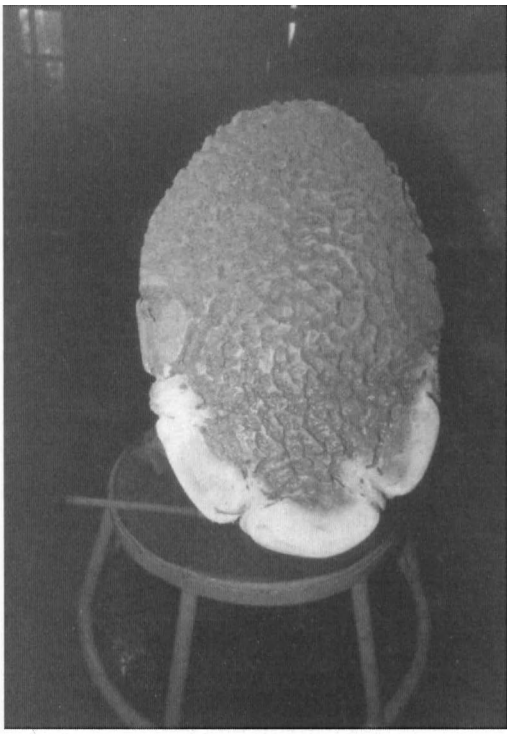

FIG. 5.30—The good pad of an employed elephant that has never been trimmed.

captive elephant lacks because of its sedentary lifestyle (Figures 5.29–5.32).

The wild elephant, unlike its captive counterpart, can walk away from its own feces and urine. In most management situations, the captive elephant is housed on a concrete or asphalt floor in an indoor facility for up to 60 percent of its time. Inevitably it must stand and walk in its own feces and urine, which collects in the cracks of the pads and between the nails. Urine is corrosive and feces contain numerous organisms that may cause infection if the feet are not washed daily.

Trimming the pad of an elephant foot too excessively is a common occurrence. The deeper the trim, the lighter in color the sole of the foot becomes. Sufficient pad needs to be left intact. The elephant should not become sore when walking and it should not be painful if they step on a rock. At no time is it appropriate to draw blood when trimming the pad (Figures 5.33–5.38).

Fissures and other irregularities on the pad can be trimmed and reduced over the course of several pedicures (Figure 5.39). It is also important to remember that once the pads are trimmed and the elephant is released, the unusual feeling of the trimmed pad will draw the elephant's attention. It is not uncommon for an elephant, out of curiosity, to continue to rub and wear the pad on a concrete floor or a structure in its environment. If the pad is trimmed too thin, the elephant could do substantial damage to itself.

COMMON PROBLEMS ASSOCIATED WITH ELEPHANT FEET

Abscesses Abscesses are commonly seen in many captive elephants, and their causes are usually not obvious. It is our opinion that they are rarely the result of a puncture or some other outside insult to the foot. Rather they are caused by internal blood supply disruption, which is a sign or symptom of the multitude of problems associated with keeping elephants in captivity. We feel that the elephant is not genetically programmed to withstand the constant gravitational pressure of living on hard surfaces and carrying the excessive weight typical of most captive elephants. Elephants certainly didn't evolve to stand motionless for long periods of time.

The inactive, overfed, overweight, out-of-shape, captive elephant, which may or may not have some abnormal behavioral activities, is predisposed to foot problems like abscesses and cracks. We feel that the lack of exercise decreases the overall vitality of the structure of the captive elephant's foot. This lack of vitality is further exacerbated by the added weight most

FIG. 5.31—Excessive pad growth.

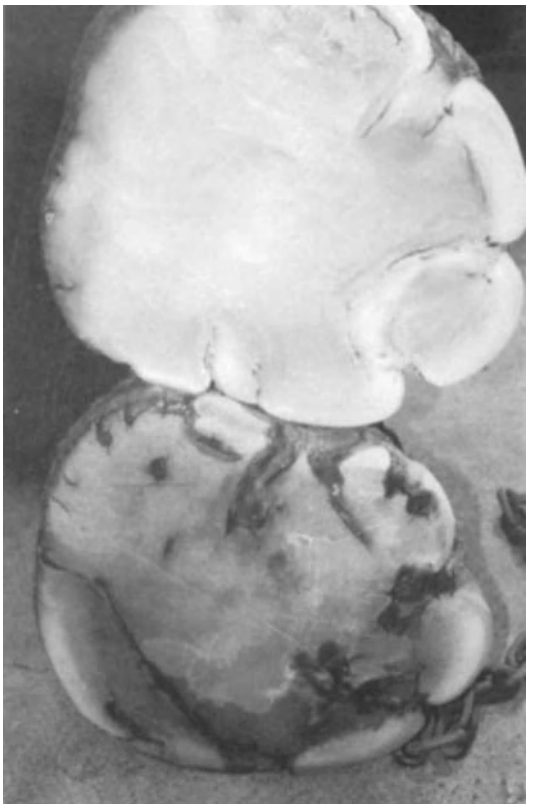

FIG. 5.32—Two different shades of pad tissue.

elephants carry and by the fact that the majority of their time is spent on hard, unyielding surfaces.

It is our opinion that when these factors are combined with abnormal behavioral movement, poor conformation, or previous injuries, the foot is destined to develop abscesses. Any abnormal pressure on the nails, as is seen on the lateral nails of the stereotypical "rocking" elephant, will result in a disruption of the blood supply to the sensitive tissue behind the nail. When this tissue is subject to constant or intermittent abnormal pressure, it will eventually become devitalized like a bad bruise and then form a sterile nail abscess. This abscess then follows the path of least resistance as the body tries to get rid of it. It usually ruptures toward the surface at the cuticle line or at the interface between the bottom of the nail and the pad. As soon as it ruptures it becomes an infected abscess.

Abscesses can also occur in the pad of the foot. These, unlike a nail abscess, may be caused by a puncture from a sharp object, but it is our opinion that this is still relatively rare. Rather, the pad can suffer the same tissue devitalization as is seen in the development of nail abscess. In the case of the pad, this can be caused by a single insult to the pad, such as a "stone

FIG. 5.33—Excessive pad growth.

FIG. 5.34—Rear pad before a trim.

FIG. 5.35—The pad in Figure 5.34, after a trim.

FIG. 5.36—Front pads before (bottom) and after (top) trimming.

bruise," or by improper trimming of the pad. Excessive walking on hard surfaces can also cause pad abscesses by wearing the pad too thin and causing devitalization of the underlying tissue. This results in a sterile abscess that will rupture at the surface, as is commonly seen in the heels of the rear feet of an elephant that walks too much on hard surfaces. In any case, early recognition of a developing abscess is important because it must be dealt with as soon as it ruptures, or if it becomes infected, it must be kept opened to minimize the spread of infection to surrounding tissue.

Abscesses that rupture at the cuticle first form a "hot spot" that swells, loses color, becomes devitalized and then ruptures and drains. Abscesses that migrate to the pad first form a small black spot between the bottom of the nail and the pad, which may go unnoticed until it ruptures (Figures 5.40–5.45). Regardless if an abscess is at the nail or pad, prompt, thorough treatment is important. The longer it is allowed to go untreated or undertreated, the worse it will become. As with any

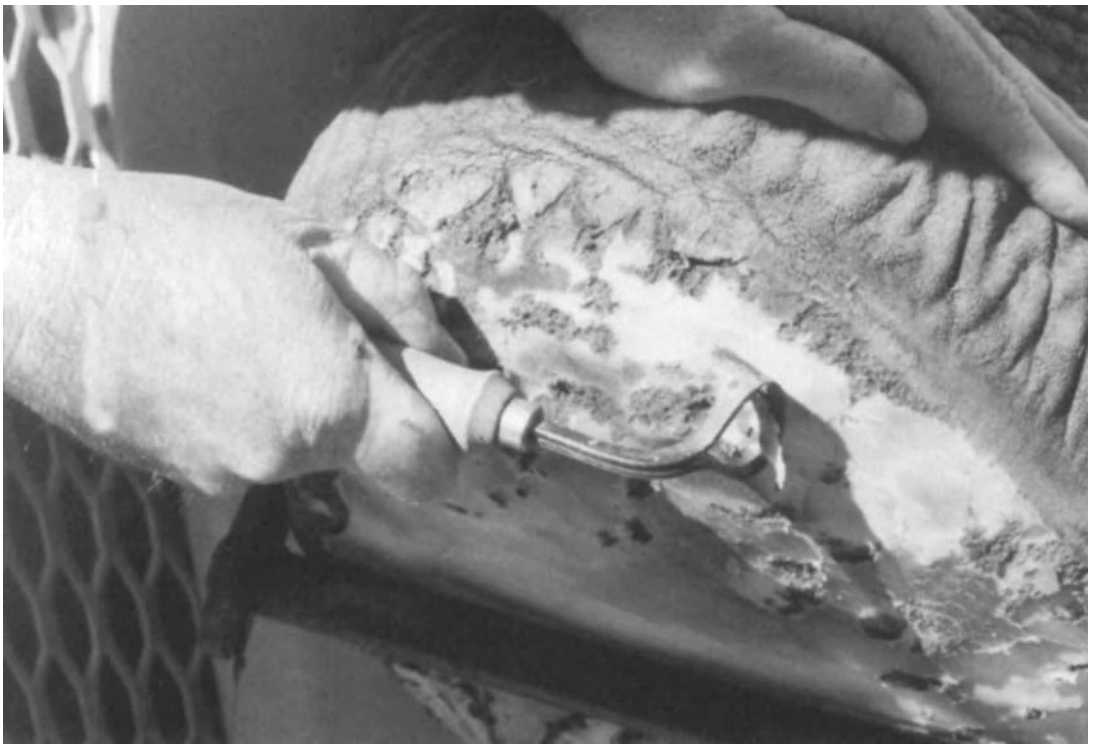

FIG. 5.37—Use of a Swiss hoof knife to trim a pad.

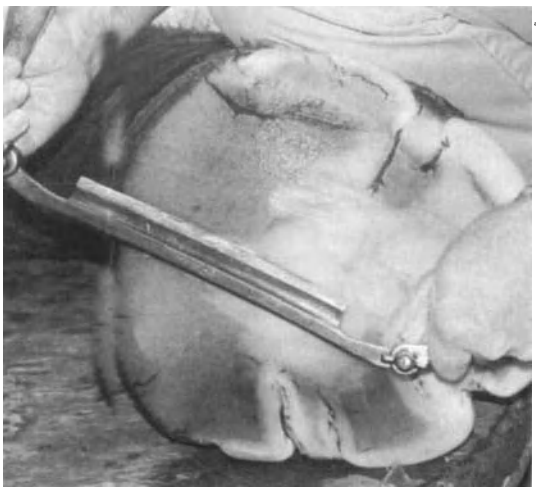

FIG. 5.38—Utilizing a draw knife to trim a pad.

abscess, constant removal of the necrotic material and keeping it open and drained are the most important activities to promote rapid healing.

If bacteria are allowed to colonize the abscess, they will invade the surrounding tissue and eventually cause tissue destruction that an elephant's immune system cannot fight. Unfortunately, many elephants have succumbed to a foot abscess that "got out of hand."

The second most important aspect of abscess treatment is to soak the foot in water as warm as the elephant can tolerate (Figure 5.46). Soaking should occur at least twice a day and especially each time after the abscess is "trimmed out." A disinfectant solution, such as chlorhexadine (Nolvasan) or tamed iodine (Betadine), should be added to the water. The foot should be soaked at least 30 minutes each time. An additional daily soaking with an Epsom salt solution can speed the "drawing out" of the abscess. This will help keep the abscess open so it heals from the inside out, which then gives the appearance that the abscess is "falling" or "dropping out."

Most abscesses can be successfully cured if they are treated as soon as they are detected and are constantly attended to by trimming of the dead tissue and daily soakings. Because of the localized nature of most foot abscesses, it is our opinion that the administration of

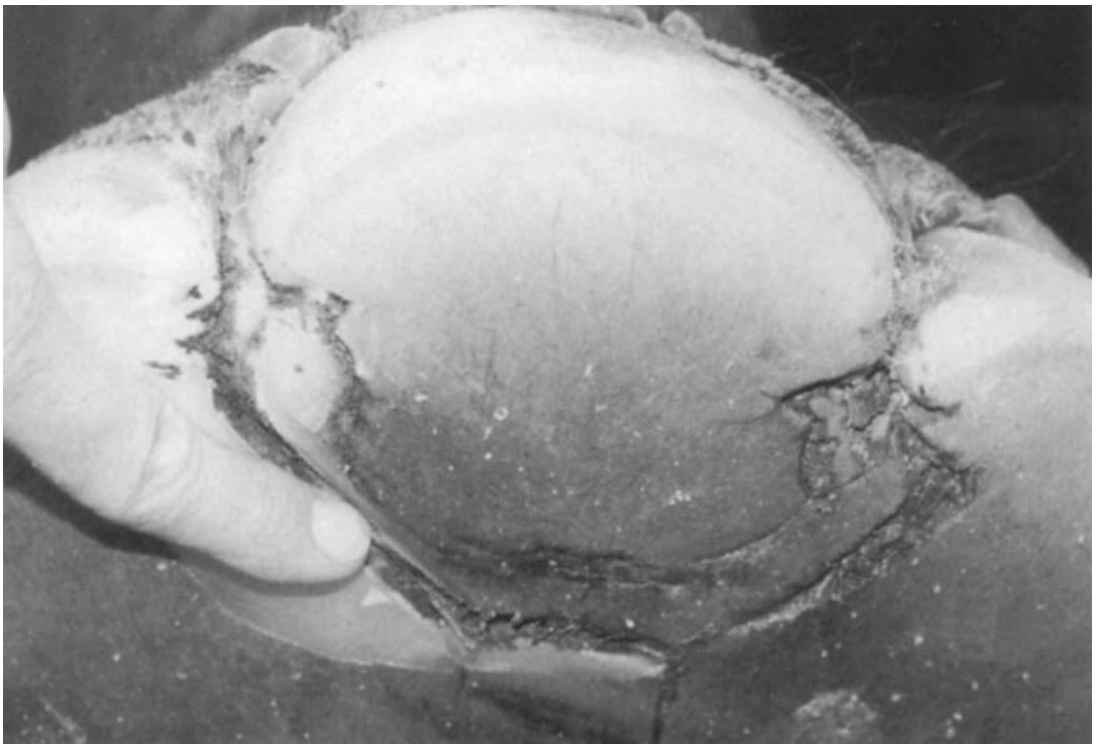

FIG. 5.39—Deep fissures in a pad.

FIG. 5.40—Slight swelling above nail

FIG. 5.41—Swelling above nail and black hole at base of nail before trimming.

FIG. 5.42—Black hole at base of nail after trimming.

FIG. 5.43—The nail in Figure 5.42, 17 days later, before trimming.

FIG. 5.44—The nail in Figure 5.43 after trimming.

FIG. 5.45—Healing abscess at 30 days.

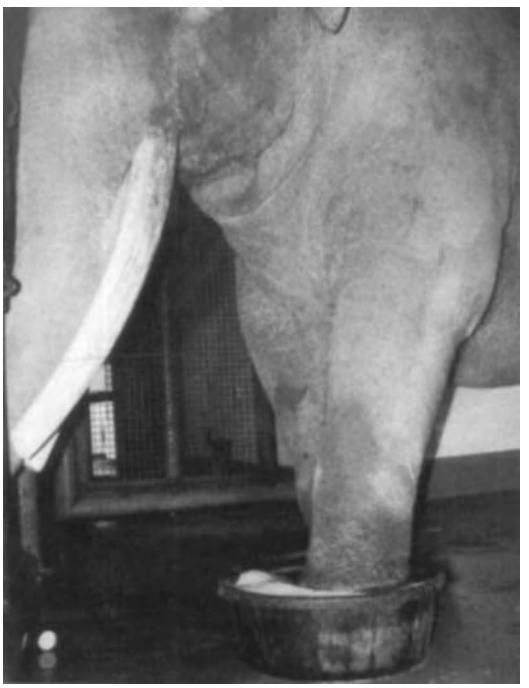

FIG. 5.46—An elephant soaking its foot.

parenteral antibiotics (oral or injectable) is not of much value. When an abscess gets out of hand, however, it can reach a point where the internal structures of the foot become involved and a persistent, rotten odor develops. When this happens, drastic salvage measures are usually undertaken, such as taking radiographs to evaluate the extent to which bones are involved, major surgical procedures under general anesthetic to remove necrotic tissue, and administration of systemic antibiotics. At this point, most people will fashion a boot to cover the foot to hold "packing" material in the abscess and to prevent further contamination of the wound. If a boot is used, it must be removed at least twice a day to allow for proper wound care (Figure 5.47).

It is our opinion that a boot should not be used except in worst cases. If an abscess is opened properly and cared for twice a day, a boot is not needed to keep the wound clean. In fact, it can inhibit the healing process by holding moisture in and inhibiting proper drainage of the abscess.

The bottom line is that abscess prevention is the best course of action. Prevention of abscesses requires: 1) exercise to strengthen foot structures and maintain good blood flow to the foot; 2) reduction in weight to reduce pressure on the foot; 3) allowing the elephant to live on soft, yielding surfaces; 4) elimination of behavioral motions that cause abnormal stress on the foot; 5) attention to good hygiene practices to minimize sur-

FIG. 5.47—Elephant boot used for treatment of abscess.

FIG. 5.48—A clean, well-maintained nail crack.

face contamination; and 6) regular, complete, and correct pedicures.

Cracks Cracks are normal in the pads of an elephant's foot but not in their nails. When cracks occur in the nails, they demand attention to prevent the development of serious problems. And even though cracks are normal in the pad, without proper care these too can lead to problems.

Nail cracks are usually the result of a repetitive movement that puts abnormal pressure on the nail. The environment of the elephant's enclosure can exacerbate this pressure. An example is the stereotypical "rocking" elephant, where an elephant stands in one place on a hard surface and rocks back and forth. This puts abnormal pressure on the lateral toes of the front feet, eventually leading to nail cracks. This problem will be compounded in an extremely arid climate, which will dry out the nails so they become hard and lose their flexibility.

A simple thing like sleeping can also lead to nail cracks. If an elephant sleeps on the same side each night on a hard surface, any slight movement can act to file down the surface of the lateral toenails. The nails may become so thin that they will easily crack when the elephant, especially if overweight, puts lateral pressure on them.

If an elephant gets up and down frequently on hard surfaces, the middle nail on the rear feet can also be predisposed to cracks, especially if the nails are allowed to grow too long.

Nail cracks can also result if an elephant has poor conformation. Any abnormality in an elephant's leg posture or gait can predispose them to problems. A pigeon-toed elephant will walk with excessive pressure on its lateral nails, which again can lead to nail cracks (Figures 5.48–5.49).

While nail cracks in older elephants can result from an accumulation of insults to the foot over many years, younger elephants can also develop nail cracks. Juvenile elephants seem to have little regard for their feet as they play and frolic around. In the process they will "trash" their feet to the point where they may experience nail cracks.

If a nail crack is not cared for properly, it can result in a chronic problem, especially if it extends upward to the cuticle and damages the nail's germinal tissue. Without treatment it can also lead to an abscess and more serious consequences (Figures 5.50–5.51). This is especially true for the overweight, inactive elephant, regardless of age.

Overall, most nail cracks are seen in older elephants and are the result of a combination of problems. If an elephant is evaluated carefully based on the contributing factors mentioned above, the nails that are likely to develop cracks can sometimes be predicted. Hopefully, eliminating one or more problems can prevent some cracks.

There are many opinions as to the best methods to use to care for a crack in the nail of an elephant's foot.

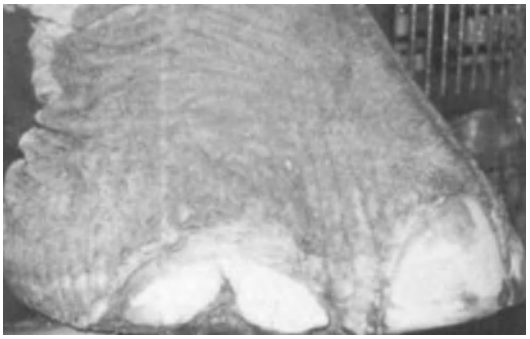

FIG. 5.49—A nail crack caused by contact with a concrete floor while the elephant was sleeping.

Some of these methods, such as cross notching and patching, are based on techniques that farriers use in horses. It is our opinion, however, that the differences in the dynamics of the elephant's toenails make these techniques of little practical value.

The goal in any treatment is to stop the advancement of the crack and to allow the nail to grow out until the crack is eliminated. We feel that cross notching weakens the nail and that patching usually comes loose, especially in nails with advanced deterioration (Figure 5.52). In many cases, patching hides the crack and prevents regular crack maintenance (Figure 5.53).

We feel that effective treatment of cracks involves using the edge of the rasp to open the crack at the bottom and up along its course. A small hoof knife is then used to remove debris from the crack down to healthy tissue. In this process, dark, foul-smelling nail tissue and any foreign material that may be in the crack is removed. Care must be taken not to cut into the sensitive tissue, if at all possible, as this will slow the healing process. The base of the nail is then rasped down as much as possible and rounded off, thus taking pressure off of the nail and crack when the elephant takes a step.

Crack maintenance is a continual and frequent process. It requires many conservative trims rather than infrequent aggressive trims until the nail grows out, which under most circumstances takes about six

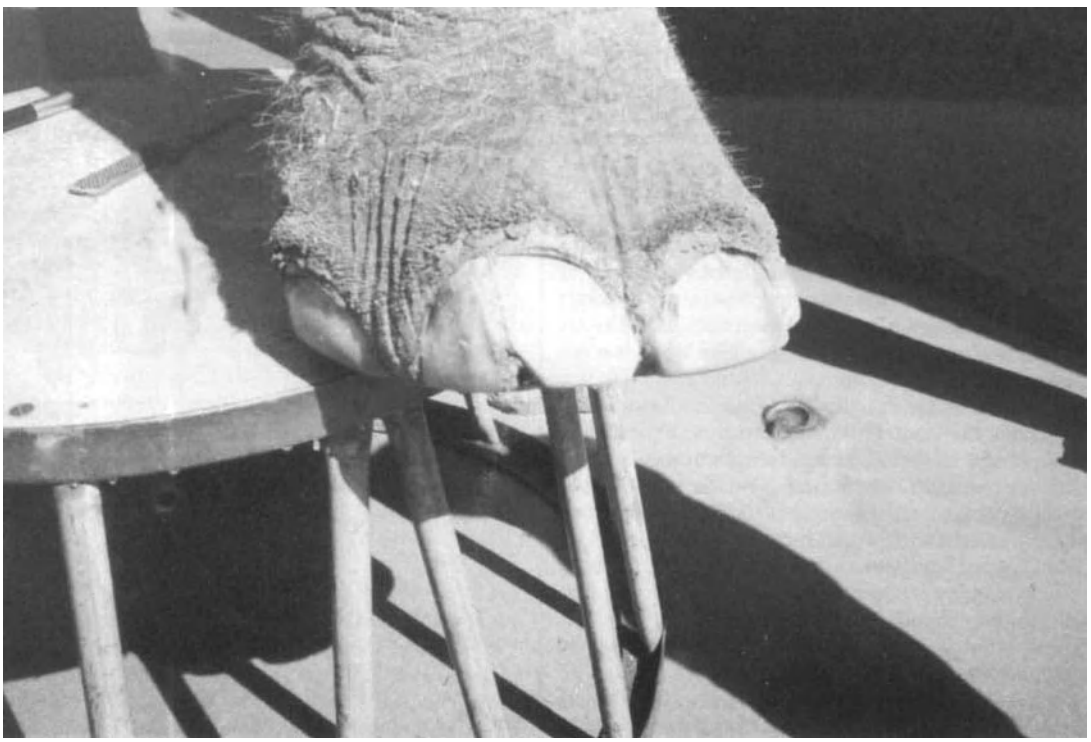

FIG. 5.50—A nail crack that developed into an abscess.

FIG. 5.51—The crack in Figure 5.50 after trimming.

FIG. 5.52—Cross notching a crack.

FIG. 5.53—An attempt at patching a crack.

months. The crack should be inspected daily and washed and scrubbed to remove any fecal contamination and to eliminate any dirt or sand that might slow the healing process. If the crack extends into the cuticle, the time for complete nail regrowth will be longer, since the germinal tissue at the cuticle must heal first. There has been a good deal of success when a crack is allowed to drift to one side of the nail, where it eventually grows out. We feel that this is successful because the center of elephants' nails appears to grow faster than the edges. In order to accomplish the drifting of the crack, a trimming schedule, where the smaller of the two nail sections is trimmed shorter than the other section, should be followed over a period of time. For nail cracks in young, rambunctious elephants, it may be easier to just maintain the crack for several years, then, when the elephant becomes more mature and conscientious of its feet, curative trimming can be initiated.

As was mentioned previously, cracks in the pad of the foot are normal, and they should not be eliminated during a pedicure. They are the elephant's fingerprints, with some elephants having numerous cracks while others have few cracks. A few elephants may not have any cracks in the pad. This condition must be carefully evaluated, since it may be an indication of excessive wear and critical thinning of the pad.

Cracks in the pad can become a problem if the pad is not cared for regularly. If the pad is allowed to overgrow, the cracks can become deep and angled, possibly trapping small stones, which are a source of bruises or punctures that can lead to an abscess. Likewise, if an attempt is made to trim out a pad crack completely, the sensitive tissue may be cut or the surface may be so thin that the pad is subject to bruising or easy penetration, which can also lead to an abscess.

In a comprehensive, elephant foot care program, each elephant should be evaluated for potential foot problems. Abscesses and cracks can be prevented by eliminating known causes and by performing regular pedicures.

CONDITIONS THAT CAN LEAD TO FOOT PROBLEMS

Conformation Elephants with poor leg conformation will walk with an abnormal gait. This will then lead to the foot touching the ground in an abnormal manner and will result in an excess of pressure being exerted on the toes. This excess pressure will result in increased wear and possible cracks and abscesses.

Abnormal Behaviors Repetitive or "stereotypical" behaviors can have the same effect as poor conformation on an elephant's feet.

Trauma When an elephant injures a leg, it will refuse to flex the joints and walk with a stiff leg. The end result in many cases is a permanently stiff leg, regardless of the original problem. When the elephant walks on this stiff leg, it will cause abnormal wear on the medial edge of the pad of that foot. Figures 5.54–5.59 illustrate the healing process of a pad abscess associated with a stiff leg.

Arthritis Another condition that can lead to foot problems is arthritis. The soreness in an elephant's joints will result in decreased joint flexibility. This will lead to an altering of the elephant's gait and, as mentioned before, abnormal pressure on the nails and pads (Figure 5.60).

Environment Environmental conditions are so important to the health of an elephant's feet that we are mentioning them again. When comparing the conditions of a captive elephant's environment to its counterpart in the wild, it is easy to see the multitude of insults we impose on their feet. Some conditions can cause problems rather quickly, like sharp metal objects that an elephant can accidentally hit with its feet. Others, including lack of movement, take years of accumulation to manifest into problems.

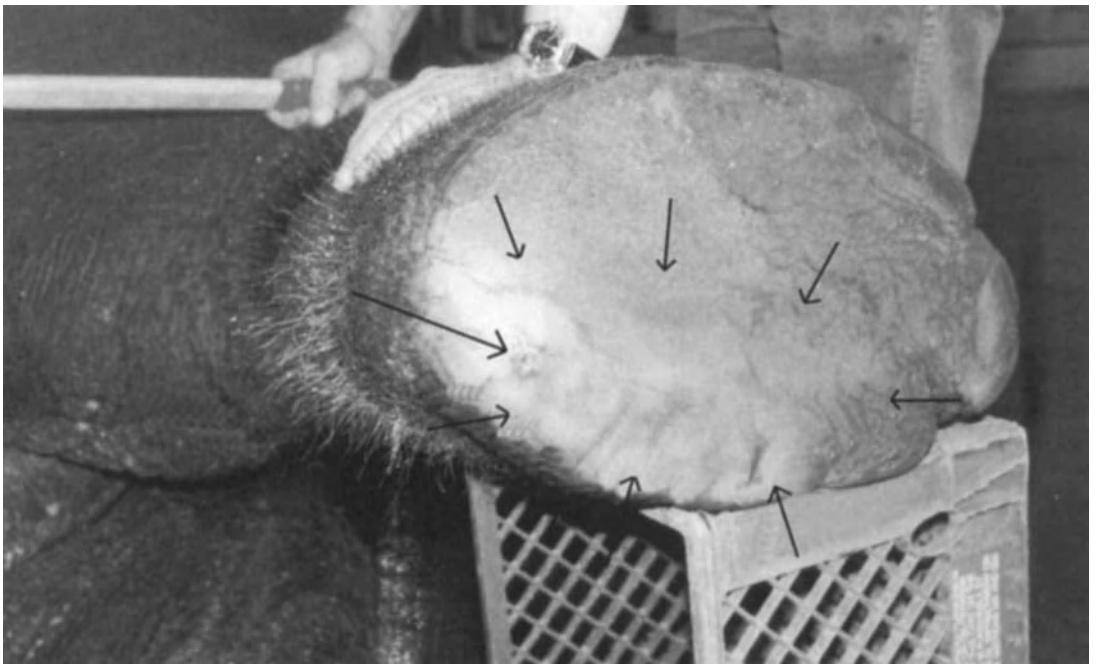

FIG. 5.54—Wear pattern, 13 June 1996.

FIG. 5.55—Developing abscess, 7 July 1996.

FIG. 5.56—The beginning of the healing process, 25 July 1996.

FIG. 5.57—Abscess migration, 8 August 1996.

PREVENTION OF FOOT PROBLEMS Every captive elephant program should undergo a thorough evaluation to assess the number and type of daily insults to which elephants' feet are subjected. Then both a short- and long-term program should be established to limit or change those conditions that can be controlled.

Simple things like overfeeding and lack of exercise can be corrected by establishing firm guidelines for food quantity and how elephants are fed. Making captive elephants work for their food by establishing several feeding stations and feeding at different times of the day are two ways to improve their health regimen.

Lack of exercise is probably the worst thing for a captive elephant's feet and probably the easiest thing to solve. Getting the elephant to move at least 1 to 2 hours each day not only will strengthen its feet, but will establish flexibility and good blood flow and will help with weight control.

Another relatively easy thing to implement is regular productive pedicures. Techniques for establishing access to feet in both free and protected-contact management situations are well known, and there are ways to learn proper foot care procedures.

FIG. 5.58—Condition after two months, 22 August 1996.

FIG. 5.59—After three months, the healing is nearly complete, 4 September 1996.

FIG. 5.60—An elephant with a stiff leg is still able to complete its behaviors.

FIG. 5.61—Elephant in a mud bath.

Correcting certain repetitive behaviors that lead to insults to the foot is probably harder to accomplish, but not impossible! Enriching the environment that elephants live in will stimulate their minds, provide recreation, encourage movement, and thus reduce detrimental repetitive behaviors, which are caused by boredom.

Relatively simple and inexpensive occupational improvements include providing a mud bath area or enticing the elephants to dig for buried browse branches or to move a tree stump (with roots attached) chained to the center of their exhibit (Figure 5.61).

Changing the location where elephants are housed is probably the hardest thing to accomplish. Available space and the enormous cost of constructing elephant containments limit most elephant exhibits and nighttime housing.

Concrete floors in night housing are nearly universal and there are few alternatives, but some changes can still be made, like providing rubber mats and limiting the amount of time elephants spend in the barn. As far as daytime areas go, if size can't be expanded, the substrate can be changed. Even dirt after a period of time becomes hard and unyielding. Periodically roto-tilling or adding different types of material, like sand, can soften the ground that elephants walk on.

Another difficult obstacle to overcome is the manpower issue. Caring for elephants takes time, dedication, and the knowledge necessary to do the right thing for the elephant.

6

CAPTIVE ELEPHANT FOOT CARE: NATURAL-HABITAT HUSBANDRY TECHNIQUES

CAROL BUCKLEY

Many factors, including environment, diet, and management, determine the psychological and physical health of captive elephants. When these factors are suboptimal, resulting in stress, the captive elephant's response will manifest in disorders of the mind and/or body. The link between these disorders and an unhealthy environment, inadequate diet, or inferior management techniques is not always obvious; but often it is painfully obvious.

For the purpose of this chapter, "natural habitat" is defined as a vast space of diverse terrain and natural substrate, complete with wetlands, seeded and volunteer pastures, wooded areas, natural year-round water sources (including spring-fed ponds, washes, streams, and dry creek beds), and a wide range of live vegetation suitable for the species being maintained.

ENVIRONMENT Much of my experience has been with captive elephants in zoo and circus environments. Because many of these elephants are restrained by chains for many hours and housed in relatively small concrete or dirt yards or in barns with concrete floors, they will require more foot care than elephants living in a natural-habitat environment.

Freedom Versus Confinement Freedom of movement and access to a variety of natural substrates and live vegetation is essential for maintaining good foot health as well as optimal mental and physical well-being. Because an elephant in a natural-habitat environment is not confined to areas contaminated with waste and spends its day walking, eating, dusting, grazing, foraging, digging, bathing, and napping in a vast area, its psychological and physical needs are satisfied. In a confined situation, solid waste can be removed but liquid waste contaminates outside yards. The contaminated soil deteriorates foot pads and nails and harbors bacteria that can cause foot infection, which necessitates trimming. Continual and frequent trimming can create a thin and/or smooth pad, providing little or no traction. As the pad becomes thinner, the chance of bruising and lameness increases. Foreign objects can easily penetrate a thin pad and become the site of bacterial infection.

Pastures and Natural Manicures In a natural-habitat environment, pastures can be a combination of both seeded and volunteer grasses. At The Elephant Sanctuary in Hohenwald, Tennessee, the pastures are comprised of fescue, Timothy hay, clover, sage, Japanese stilt, orchard grass, Johnson grass, *Sericea lespedeza,* winter wheat, and bamboo. When grazing, elephants use their feet, specifically their toes, to strike and sever the bamboo or coarse blades of grass. This continual striking across the abrasive grasses benefits the feet by wearing the area between the toes, where nails and cuticles can overgrow. Routine grazing aids foot health by naturally manicuring cuticles and nails.

Even a moderately active elephant in a natural-habitat environment requires little foot care (as little as one to two hours each year). In captivity, poor foot health usually implies neglect, but minimal foot care is a by-product and benefit of the natural-habitat environment. One way to evaluate if the environment is in balance with the elephants' needs is with an examination of the condition of their feet, while also determining the amount of foot care required and how quickly their feet return to health after treatment. The time that is required for an unhealthy foot to return to health in a natural-habitat environment is relatively short. Minor pad and nail overgrowth and cracks will be alleviated within weeks. With attention to stress reduction and a healthy diet, a severely infected and overgrown foot can be completely healed within a few months. Not only is recovery complete, but also there is no chronic reoccurrence of the foot problem. Although the time of recovery alone may not be impressive, recognizing that little time is required for trimming is noteworthy.

Forests of Benefits In the natural habitat, trees provide a valuable source of nutrients as well as an opportunity for foot conditioning. Leaves, young branches, bark, and roots are all eaten on a regular basis, which supplements the elephants' mineral and nutritional requirements. In temperate regions, most vegetation becomes dormant during the winter and elephants spend more time foraging. An elephant will use one foot to secure a fallen tree while using the other to step on, smash, and tear away at the tree bark and root system. Tops and bottoms of the toes are utilized to pry the bark and roots from the tree. Often the foot and toes are used in a repetitive dragging motion that eventually disintegrates an area of the tree and enables the elephant to peel the bark or pull loose the root with its trunk. Every part of the foot and nail are used in this

activity, which helps prevent nails and cuticles from becoming overgrown.

Working the Soil Soil rich in minerals is also consumed by elephants in a natural-habitat environment. They use their feet, specifically their toes, to tear away vegetation and uncover and loosen the soil. When a particularly rich deposit is found, the elephants will focus on mineral excavation. Using their foot like a shovel, the elephant can unearth a large area in only a few minutes. This digging activity stimulates blood flow, works the muscles, tendons, and joints of the foot, and wears the pads and nails.

The Benefit of Creeks A creek bed is composed of many different sized rocks, from boulders to grains of sand. Some areas are dry, while others are spring-fed and flow year round. With this variation in substrate, the elephant's entire foot gets a good workout as the animal walks over and drags its feet through the rocks. In addition to walking through the creek bed, elephants spend a great deal of time digging. When they find a sand pit, they sink their feet in deep, twisting each foot back and forth. This movement is equivalent to the elephant wearing a sandpaper mitten on its foot and benefits the foot by removing debris from the nails and pad. When the elephant exits the creek bed, its feet become coated with mud, which conditions the elephant's foot and protects it from becoming dry and brittle.

Moisture Is Good In a natural-habit environment, an elephant's feet are seldom completely dry. The time that an elephant is in the barn should be the only time that their feet are not exposed to moisture. The idea that an elephant's feet must be kept dry in order to remain healthy is a misconception. Actually, noncontaminated moisture benefits their feet and helps to maintain a healthy pad. The moisture that the feet are exposed to during a day spent walking across pastures and through washes and streams is essential for optimum foot health. When an elephant's foot is depleted of moisture by unnatural surfaces, such as concrete, the pad becomes dry and brittle and problems can develop.

Most natural substrates contain moisture, and live vegetation retains moisture inside and out. Even on a hot summer day, moisture can be felt in the undergrowth of healthy pastures. In a natural-habitat environment, the majority of the elephant's waking hours is spent walking through moist areas. The moisture does not contribute to the decay of the foot pad but acts as a conditioner, softening dry areas and keeping the pad healthy. As the pad becomes more supple, foreign material will dislodge and overgrown areas will wear down. Any debris that has accumulated on the foot will be washed clean as the elephant moves through water. While in a pond or stream, moving the foot over and through natural substrates further aids in removal of embedded objects and debris.

DIET Poor diet and/or poor assimilation of nutrients is reflected in an elephant's foot condition. Slow growing nails and pads, nails prone to splits or cracks, excessively thin pads, and soft nails can all be the result of a poor diet or a diet that requires significant energy to digest.

In a specific case, an elephant, which had suffered low body weight for 10 years and was kept in a confined situation, did not have sufficient nail growth in 5 years to necessitate trimming because the nails and pads were not growing at a normal rate. Blood work supported the fact that this animal was not able to fully use her nutritional intake, which resulted in low body weight and overall poor body function and condition. When she was moved to a natural-habitat environment and her dietary deficiencies were addressed, she began to assimilate nutrients and the condition of her feet improved within weeks. Not only were normal nail and pad growth observed, but also nails and pads that previously had been soft and spongy became supple and healthy.

MANAGEMENT In a natural-habitat environment, the elephant is never chained. Free-choice access to the indoor facility enables the elephant to come and go at will. With free-choice access, elephants spend the majority of their time engaged in activities on natural substrate. With the absence of concrete, their nails and pads remain supple, not dry. Pads wear in an even fashion, leaving the necessary amount of texture to ensure traction for daily activity. Infected crevices and tracks do not develop. Legs and feet do not become fatigued nor do joints stiffen, as is observed in chained elephants that are forced to stand for long periods of time on concrete. Chaining has many negative effects on foot health. Not only are elephants forced to stand in their own excrement, but they also rock and sway unnaturally. This movement applies torque pressure on feet and nails, which can cause tissue damage as well as irregular wear and thin foot pads.

CASE HISTORY Jenny is a female Asian elephant born in 1970 in Southeast Asia. She was trained for the circus, where she performed for 26 years. Jenny arrived at The Elephant Sanctuary in Hohenwald, Tennessee, on 26 September 1996. The Elephant Sanctuary is the nation's first natural-habitat refuge for old or sick elephants retired from zoos and circuses. Jenny arrived in poor physical health but with a stable mental condition. Her captive life had been spent traveling and performing in circuses.

On arrival at the Sanctuary, Jenny's pads and nails were severely overgrown. Her pads were spongy and had numerous infected tracks, 1 inch wide and several inches deep (Figure 6.1). Her cuticles were 1 inch long, dry, and cracked. Several nails were 2 to 4 inches overgrown; five nails were severely infected and appeared

FIG. 6.1—Jenny's back right foot pad upon arrival, 26 September 1996.

FIG. 6.2—Jenny's back right foot pad two years later, 26 August 1998.

to be sloughing. The heels of her pads were dry and split with deep vertical cracks.

The deteriorated and infected condition of Jenny's feet appeared to be causing her extreme pain. Her behavior pattern after arrival was to lie down every 20 to 30 minutes to avoid the pain she experienced while standing. At every opportunity, Jenny would submerge in one of the ponds or the creek. The cool water appeared to help relieve her pain, and because she was buoyant, she was not putting weight on her feet. As days passed, Jenny showed marked improvement, indicated by less time spent reclining and the recovering condition of her pads and nails.

Jenny was conditioned to place her infected feet into tubs of lukewarm, diluted apple cider vinegar twice a day. Being a natural remedy, apple cider vinegar works exceptionally well in stopping infection as well as conditioning the flesh of the foot. After the initial soaking, necrotic tissue was trimmed to expose the infected areas. During a series of three trimmings over a 6-week period, more than 2 inches of foot pad was removed. Following the foot soaks and trimmings, Kopertox was applied generously. Immediately following treatments, Jenny was released into a 40-acre natural-habitat yard. Her daily activity included mud bath excavation, spring water swims, digging, dusting, napping, grazing, foraging, and tree felling. Over the course of each day, Jenny walked many miles, repeatedly submerged herself in fresh water, and moved several hundred pounds of earth and vegetation.

Pad trimming was discontinued after three sessions (6 weeks). Daily Kopertox application continued for 6 months, and apple cider vinegar soaks continued for 1 year. Jenny's pads have required no further trimming since her arrival 2 years ago. Her pads and nails remain at optimum length and condition and have shown no cracks, splits, overgrowth, or infections. Her pads and nails are supple and healthy (Figure 6.2).

ENVIRONMENT, DIET, AND MANAGEMENT

When a natural-habitat existence is not possible, every effort can be made to imitate the environment and diet of the wild. Natural substrates can be added. For indoor facilities, floors can be remodeled with a more suitable surface. Diets can be modified to include live vegetation and daily supplements of fresh-cut browse. With minimal effort, most facilities can be converted to a chain-free management system. Diminishing stress by attending to the natural and basic needs of the elephant will help to ensure healthy feet as well as overall mental and physical well-being.

7

FOOT CARE AT THE INDIANAPOLIS ZOO: A COMPREHENSIVE APPROACH

JILL SAMPSON

INTRODUCTION Maintaining healthy feet in captive elephants is one of the biggest challenges facing those who work with these large, complex mammals. Wild elephants walk great distances every day in search of food and water, while captive elephants occupy much smaller spaces and are provided with life's necessities. Lack of exercise and extended time spent on improper substrate can lead to overgrown pads and cracked nails, which in turn can result in infections. Foot care is an essential part of any captive elephant management program and depends on more than just careful trimming techniques. Healthy feet are the product of the entire husbandry program and the environment in which the elephants are kept.

The Indianapolis Zoo is home to five female African elephants managed in a free-contact system. None of the elephants have experienced any major foot problems. Our husbandry program emphasizes exercise and training, good nutrition, sanitary barn and yard conditions, cleanliness of the skin and feet, frequent inspections of the feet, and timely pad trimming and nail filing.

HOUSING AND DAILY MAINTENANCE The present elephant barn at the Indianapolis Zoo was built in 1988. The barn is 38 feet by 70 feet and consists of three stalls, which are separated from each other by vertical pipe barricades. At one end is a large stall that is used to house three elephants and measures 22 feet by 26 feet. The middle stall houses a single elephant and is 15 feet by 22 feet, and the third stall, also currently used to house one elephant, is 14 feet by 22 feet. The floors are poured cement and slope slightly toward the back where there is a shallow trough with drains. Underneath the cement is an electric heating cable, arranged into four body-sized pads, that keep the floor warm during cold weather. The heated floor not only improves the animals' comfort, it also helps keep the floor dry so the elephants are not standing on a cold, damp floor. The barn is kept warm during the colder seasons by forced air heat. For more information on the Indianapolis Zoo's large mammal facility, see Fields (1998).

The outdoor exhibit is approximately one-quarter acre with sand substrate over a clay and dirt foundation. Where clay alone would hold moisture at the surface, the sand allows water to seep through so the surface stays dry. Trees, protected by hot wire corrals, provide shade. The yard contains a 55,000 gallon pool, which is deep enough for an elephant to completely submerge and large enough that several elephants can swim at once. The elephants themselves create mud holes in the yard by digging. The holes fill with rainwater, which is then mixed by the elephants into the desired consistency of mud. Occasionally these mud holes become quite large. When the holes become too deep or threaten to damage underground irrigation, sand is brought in by a small front-end loader and the holes are filled in, thus giving the elephants a new project. Large sand piles are left for digging and dust bathing. In the summer, if the yard gets too dry, sprinklers can be attached to outlets in the center of the tree corrals and just outside the perimeter fence. The yard slopes downward and has good drainage. When they are in the outside exhibit, the elephants have a choice of dry or moist conditions for their skin and feet.

Since captive elephants are more likely to come in contact with their own feces and urine than their wild counterparts, cleanliness is important. When the elephants are outside, manure is picked up frequently throughout the day. Every day the yard is thoroughly raked to remove leftover hay. The pool is drained and refilled twice a week and thoroughly cleaned once a week. The barn is cleaned and hosed every day and disinfected once a week. During warmer months, the staff works in staggered shifts to extend time spent with the elephants. This increases activity time for the elephants, increases the variety of activities, and reduces time spent on the harder substrate of the barn, which has collected a night's worth of the elephants' deposits. During the winter months, due to colder temperatures and occasional inclement weather, the elephants spend more time indoors. When the elephants are inside, they are shifted back and forth when the stalls are cleaned in the morning. Excess water is pushed away with a squeegee. The heated floors dry quickly so the elephants do not spend long periods of time on wet floors. Feces are picked up and urine is pushed immediately into the drain to prevent these materials from collecting on the feet and nails. We encourage the elephants to back up and eliminate close to the drain trough, which helps keep the floors clean. Some of the elephants make more of an effort than others!

The elephants spend the night in the barn during all seasons. Two elephants are housed in individual stalls

and are not on chains. The other three elephants share a large stall and are restrained by chains for their safety. The chains are of proper length to enable them to turn on both sides and lie down comfortably. Pine shavings are placed underneath and behind the chained elephants to absorb urine. It is interesting to note that the elephants on chains have thicker, stronger pads with fewer divots, especially on the front feet. This is probably because they do not have as much contact with the feces and urine as the other two, who walk around during the night and collect material on their feet. Chaining is used as a security measure and not as a foot care management tool, but it is noteworthy that, in this particular situation, chaining appears to have a modest, positive effect on the feet.

Barn and yard cleanliness is important in preventing the buildup of bacteria, as is removing debris directly from the elephants' feet. Each morning, after the barn is cleaned, the elephants are lined up and given warm water from the hose. While they enjoy the drink, staff can also hose off debris and fecal matter that has collected overnight on the rims and nails of their feet. A more thorough cleaning is given during the daily bath, at which time the elephant is asked to lift each foot. The pads, rims, and nails of the feet are then scrubbed with livestock soap and rinsed. This removes debris from the feet, discourages the growth of bacteria, and allows keepers the opportunity for a close inspection of a dirt-free foot.

FIG. 7.1—Indianapolis Zoo elephants out for a walk.

FIG. 7.2—Five Indianapolis Zoo elephants out for a walk.

EXERCISE Exercise plays an important role in the health of captive elephants. Obviously, captive elephants cannot walk miles and miles over the savannah searching for food and water, but we can provide other forms of exercise that naturally wear down the foot pads and nails and increase circulation in the tissues of the feet. At the Indianapolis Zoo, we provide various opportunities for our elephants to exercise throughout the day.

At the elephant ride, zoo visitors get to experience a trip on the back of an elephant around a 220 foot sand path surrounded by grass and trees. The elephants take turns at the ride. To reach the ride area, we walk the elephant 675 feet on an asphalt road. Once there, the elephant spends approximately 3½ hours walking on the sand path. Each elephant works at the ride 2 to 4 days a week, but never on consecutive days. The ride is open late spring through early fall. During the summer, the ride is very busy and the elephants walk almost constantly throughout a shift. Fresh hay and water are always available to the elephants at the ride.

The elephants are also taken for walks on zoo grounds located behind the public areas (Figures 7.1–7.2). They are walked along an asphalt road to a large hilly area covered with grass and wildflowers where they can walk up and down the hill and graze. There is great excitement when they are taken for these walks, and their rumbling suggests psychological as well as physical benefits. Additionally, these walks help our horticulture department by providing an environmentally friendly mowing and fertilization service. For the elephants that tend to get more than their fair share of hay, brisk walks around the asphalt drive without grazing can also be used to help keep them in shape. The coarseness of the asphalt acts as a nail file and also helps wear down excess pad.

As part of our intensive training program, each elephant is taken out of the yard for a workout at least once a day in a separate 44 by 97 foot exercise yard, which has the same sand substrate as the exhibit yard. Sand provides an abrasive surface, which helps to wear down foot pads and toenails. During these training sessions, learned behaviors are practiced and new behaviors are taught. As *leading* is a very important behavior to maintain, each training session consists of leading the elephant around the yard, in both directions, in large and small circles. Other behaviors involve lifting the feet, pivoting in different directions, sidestepping, laying down, kneeling, and stretching. The elephants are sometimes worked in harness, pulling logs across the yard. They may also push and carry logs around the yard. A training session may include tub work, where

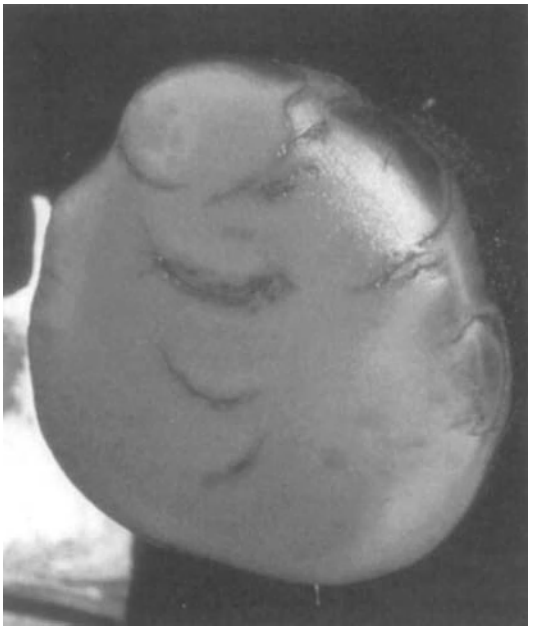

FIG. 7.3—Front foot pad of one of the African elephants at the Indianapolis Zoo.

the elephant steps onto a tub to perform certain behaviors. Not only do these exercise sessions benefit the elephants physically, but they also afford a close-up view of the feet (Figure 7.3). Stiff-bristle brushes are always nearby, so surface dirt can be quickly removed to allow closer inspection.

During the summer season, we present two daily demonstrations in our elephant encounters area. For these demonstrations, which are enormously popular with our visitors, one of the elephants is walked down an asphalt service drive and over a grass hill to the encounters area. One show is a bathing demonstration and the other is a natural history lesson in which the elephant performs basic behaviors. During these demonstrations, zoo visitors get the opportunity to see and learn about the elephant close-up and to touch the elephant. During our annual elephant awareness week, the elephants participate in different demonstrations every day, some of which involve walking to the zoo's large show arena to perform various behaviors. In the past, these performances have included pushing and carrying logs, walking on a balance beam, and turning on tubs. The shows include narration that helps educate the public about elephants. The shows entertain and educate our zoo visitors and provide exercise and enrichment for our elephants. The elephants participate in other zoo events throughout the busy season. For special events, we often walk one of the elephants across the zoo to the main entrance, where it greets arriving visitors. Our elephants also perform special demonstrations for members' nights or show up at the zoo's art fair to paint a picture. All of these events give us an opportunity to educate the public and involve getting the elephant out and walking.

After the busy routines of summer and early fall come to a close, life changes in the elephant barn. The ride is closed for the season and the daily demonstrations come to an end. The elephants are given access to the yard during the winter for at least part of every day, unless the weather conditions are too bitterly cold or otherwise inclement. When the weather prevents us from taking the elephants outside for exercise, we continue daily training sessions inside the barn. Although there is considerably less room, the elephants can still be walked around and led through various behaviors. Many of these behaviors involve pivoting and lifting the feet.

ROUTINE FOOT CARE Because we monitor the condition of the feet so closely, the elephants' feet are trimmed on an as-needed basis. We use several tools to work on our elephants' feet (Figure 7.4). Pads are trimmed with disposable X-acto blades attached to wood carving handles. Nails are hand-filed with a rasp or filed with a hand-held electric grinder fitted with a 4 inch, 24 grit sanding disc.

The elephants are trained to rest their feet on footstools. The foot that will be worked on is hosed and brushed to remove dirt. On average, the feet are trimmed and the nails are filed every 3 to 4 weeks. Summertime activities naturally wear down the elephants' feet so they require less trimming; decreased activity in the winter, of course, makes for more frequent trimming. In the winter, a fungal growth occasionally appears on the rims of some of the rear feet. This growth is trimmed away with an X-acto blade and disappears altogether with increased time spent outdoors. How much of the pad is trimmed depends on how thick it is. Usually the very top layer is removed and any cracks or divots are opened up and cleaned out (Figure 7.5). Large cracks and divots are worked on slowly, over as many sessions as is necessary, and are opened up a little at a time to allow new growth to take over. Cuticles are trimmed back around the nail, and where each side of the nail meets the foot, the nails are filed to allow air circulation.

As with every aspect of elephant care, each elephant has its own unique challenges. Three of the elephants have tough, thick pads. The areas that require the most attention on the feet of these elephants, especially on the rear feet, are located around the rims. Overgrowth of the pads may cause pockets, which can trap dirt and moisture. These can easily be kept in check by carefully monitoring the area of concern and trimming when necessary. The areas on the pad where the bottom of each side of the nail meets the pad also tend to develop canal-like indentations, which can spread and become deeper if not treated. Again, monitoring these areas and trimming small amounts as they develop keeps this from becoming a larger problem.

FIG. 7.4—Tools used in foot trimming. Clockwise from left to right: rasp, electric grinder with sanding disc, hoof pick and brush, carving handle with X-acto blade.

FIG. 7.5—Trimming the foot pad with the X-acto tool.

Two of the elephants have thinner, softer pads. This requires smaller amounts of the pad to be removed more frequently than is required for the other three elephants. The nails also require more frequent filing to keep them off the ground, probably because there is not as much pad to alleviate the pressure on the nails. The grinder is used primarily on the nails but can also be used on the pads (Figure 7.6). For elephants with thin pads, use of the grinder can be more precise than the X-acto blade because a very thin layer can be trimmed off the top of the pad. However, care should be taken to avoid overheating the pad—the sanding disc should not be held over any one area for too long. To test for excess heat, touch the area frequently using the fingertips. The grinder also helps create a smoother pad, while the X-acto tends to leave small ridges as rows of pad are removed. The grinder can be used to smooth any ridges that are left after the pad has been trimmed with the X-acto blade. The rasp can also be used on the pad for this purpose.

Toenails are filed so that the nails of a standing elephant are just off the ground and the weight of the elephant's foot falls on the center of the pad and spreads out (Figure 7.7). Toenails are filed at the bottom and

FIG. 7.6—Using the grinder on the foot pad.

FIG. 7.7—Using a rasp to file the toenails.

also over the entire surface to smooth out dents and scratches and prevent overgrowth. Following a trim, Betadine is sprayed on the pads and nails and worked in with a scrub brush. This helps reduce the risk of bacterial infections. (Note: be sure to check with a veterinarian before using any medication on a pregnant cow.)

Once a week, Hooflex is applied to the nails and cuticles to promote flexibility and strength. A&D ointment is also applied to the cuticles, as needed, to relieve dryness. At one time, chlorhexidine solution was used on the feet at bath time once a week. Although it seemed to help reduce the fungal growth encountered in the winter, it was thought to be too harsh and caused drying.

SPECIAL PROBLEMS Only one of our cows exhibits a recurring foot problem—chronic cracking of the middle nails on the rear feet. Poor conformation of the rear legs undoubtedly contributes to this problem. The rear ankles turn inward, causing uneven distribution of weight. Frequent filing of the nails helps, but inevitably the cracks return in a very short time, often extending all the way to the cuticle. A nail patch was applied following a description from the Detroit Zoo (Johnson and Nestale 1996). The acrylic patch was heated and then adhered with bonding cement to the clean, dry nail. The patch was successful in allowing the crack to grow completely out. After the patch was removed, however, the crack returned a short time later. This has been a life-long problem for this cow, and we will continue to search for ways to prevent the cracking. Fortunately, no infections have ever been associated with this condition.

NUTRITION The overall health of any animal depends on a nutritious diet. The elephants at the Indianapolis Zoo receive high-quality Timothy hay throughout the day and two measured servings of Mazuri elephant supplement twice a day. Salt and mineral blocks are given every week. To promote foot health, carefully measured doses of biotin are placed in a hollowed-out apple and given to each elephant twice a day with the grain feeding. The elephants receive five pounds of bran weekly and are also given fresh tree browse approximately every week.

CONCLUSION Foot care at the Indianapolis Zoo extends beyond just trimming. Two staff shifts, from mid-spring to late fall, extend the elephants' activity time and the time they spend off the harder substrate of the barn. For the time the elephants spend indoors, heated floors promote dryness and improve circulation in the tissues of the body, including the legs and feet. Frequent opportunities for close inspection of the feet allow keepers to detect small problems before they become larger ones. Exercise, which naturally wears down the foot pads, is available in the form of walks on zoo grounds, the elephant ride, demonstrations for the public, and exercise sessions in the yard or barn. Cleanliness of the barn and yard and careful trimming techniques aid in the prevention of problems. The zoo is currently planning modifications to our existing barn and yard, and a new barn may be constructed in the near future to accommodate the expansion of our breeding group of elephants. Changes to our current facility, as it may affect foot conditions, include increased space and the possible elimination of nightly chaining. However, the basic principles of our foot care program will remain the same with respect to facility maintenance. At the Indianapolis Zoo, the entire husbandry program, along with the environment in which the elephants are kept, contribute to the overall health and well-being of our elephants' feet.

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8

ELEPHANT FOOT CARE UNDER THE VOLUNTARY-CONTACT SYSTEM: PROBLEMS AND SOLUTIONS

PENNY KALK AND CHRIS WILGENKAMP

INTRODUCTION Dependable, consistent access to an elephant's nails and pads is a crucial aspect of keeping captive elephants healthy. This requires cooperation from the elephant, a facility design that allows safe access to the elephant, and flexible thinking from those who provide the care. This is true under any method of elephant management, but provides some new challenges with the relatively new, voluntary (or protected) contact style of elephant handling. We discuss in this chapter some simple elephant facility modifications and training strategies that have allowed us to provide sound foot care for elephants in a voluntary-contact facility.

Reliable foot care is critical to the health of captive elephants. There has been considerable concern about the restricted access to elephant feet, nails, and pads under a voluntary-contact system (Priest 1994). Voluntary contact (VC) is a more accurate and descriptive term than protected contact because it emphasizes the elephants' voluntary cooperation with its keeper (Doherty et al. 1996). VC has been the sole method of management for four of our Indian elephants (*Elephas maximus indicus*) since May 1995. We describe in this chapter our solutions to obstacles in VC elephant foot access, care, and treatment. Simple facility modification and systematic training, with thoughtful positioning of the elephant relative to the keeper, has allowed us to provide reliable, sound care for our elephants' feet.

FACILITY MODIFICATION Our elephant stall fronts are formed by vertical pipes 15 cm in diameter, placed 61 cm apart from the center. We modified these fronts for VC by placing four horizontal chains across three-quarters of the stall. The first chain is 51 cm from the floor and the remaining three chains are spaced 41 cm apart. The chains are attached to the vertical pipes by clevices so that larger temporary openings in the stall front can be easily made when needed.

FOOT WORK IN A VC SYSTEM Angles of the elephant's longitudinal body axis relative to the keeper and the stall front are the key to foot and pad work in the VC system. Targeting is used to teach the elephants to place and rest their feet on or through designated sections of the horizontal chains that cross the front of the stall.

The outside (lateral) and center nails on the front feet can be treated by positioning the elephant at 45 and 90 degree angles along the front of the "protected area."

Access to the inside (medial) nails and the pads on the front feet is achieved by training the elephant to present its foot *through* the opening, rather than placing and resting the foot *on* the chain. Outside and center nails on the back feet are accessed by positioning the elephant parallel to the stall front and targeting the back foot to the appropriate chain.

Inside nails and pads on the rear feet are accessed by training the elephant to position its head 180 degrees away from the keeper treating its nails. A second keeper feeds the elephant. The elephant then places its rear foot through the targeted opening in the protected area in the stall front. We always use a second keeper to assist the handler during foot work and blood work. The "feeder" keeper is responsible for watching the elephant and keeping it focused on him or her so that the handler trimming the feet can concentrate on the foot work.

Establishing a foot work routine began with training the elephants to present a foot to targeted areas, then having the elephant keep its foot there for greater and greater lengths of time. The elephants were then desensitized to a brush, file, and finally nippers. Sessions were initially kept short and then gradually expanded to 20 minutes. During prolonged foot care sessions, the elephants are given frequent 15 to 60 second breaks to keep the sessions positive and not overbearing.

TREATING A FOOT INFECTION IN A VC SYSTEM: A CASE STUDY On 16 September 1997, one of our Asian elephant cows, Happy (27 years old), was diagnosed with a stone bruise under the center nail on her right front foot. The area was very sore, and she was reluctant to hold position for inspection of the affected area. Our initial treatment consisted of washing the foot three times a day with Betadine and water, while carefully monitoring her for increased lameness or any change in the injured nail. Three days into treatment we saw the first sign of discharge between the nail and pad.

For the following 16 weeks, the injury was treated three to four times a day with Betadine and water scrubs and topped with tincture of iodine. As dead tissue formed it was trimmed away. On 19 January 1998, a new discharge was seen between the nail and pad. Her treatment was changed to soaking the foot in a tub of Nolvasan and water for 10 minutes, followed by infusion of Hetacin K ointment into the infected area twice a day. Happy readily accepted foot soaks and topical medications, but she initially was reluctant to stand for infusion of the medication into the tender cavity behind the nail.

Complete systematic desensitization to this treatment took 1 week. We conducted two treatment sets each day, gradually conditioning Happy to accept the somewhat painful treatment. At the end of each completed set, after holding for infusion of medications, she was given bonus rewards. The first few times we treated her she pulled her foot away, but the key was to keep the sets short and reinforced so that she came right back and reset her foot for another try. She has now reached a point in her training where she pulls the tub to her, places her foot in it, and positions it for application of the solution. She also places her foot in position for medicating and, once medicated, stands with her mouth open for a reward.

On 28 January 1998, the veterinary staff requested radiographs to see if the infection had affected any of the bones in her foot. Keepers built a radiograph platform 2 inches off the ground and worked with Happy for 2 days to practice positioning her foot for radiographs before the actual radiographs were taken. Radiographs were taken with no problem, and fortunately there was no bone involvement.

We have continued to treat the area with success in the VC system. Training, conditioning, and desensitization played a key role in treating Happy's foot.

ACKNOWLEDGMENTS Thanks to the Mammal Department Staff at the Wildlife Conservation Park for their guidance, ideas, and training efforts, especially James Doherty, Patrick Thomas, Mike Tiren, Joeseph Mahoney, Bryan Robidas, Jerry Stark, Kathy MacLaughlin, Lee Rosalinsky, and Gina Savastano. We also thank the WCP Health Center Staff for their full cooperation and support, especially Drs. Robert Cook, Paul Calle, and Bonnie Raphael.

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9

A HISTORY OF ELEPHANT FOOT CARE AT THE MILWAUKEE COUNTY ZOO

DAVID SORENSEN

INTRODUCTION The Milwaukee County Zoo's management of foot care for four female Asian and two female African elephants evolved over the last 20 years. During this time, we went from virtually no foot care, through a period of extensive foot care, and finally to the moderate amount of care we currently perform. Problems with overgrown nails and cuticles, minor to serious nail and pad necroses, and a recurring open tract in the foot of one of our elephants were treated in a variety of ways. Methods used included traditional trimming and soaking of feet, freezing of necrotic tissue, minor surgery, and the wearing of a protective boot. We are currently experimenting with a polymer-based floor covering.

This chapter presents a brief history of elephant foot problems seen at the Milwaukee County Zoo and the treatment of those problems. Examples are given from foot care for only three of our Asian elephants. While these elephants shared many of the foot problems described, each had her own type of problem that is best illustrated by her particular case. Information was collected principally from medical records and supplemented with information from keepers' daily report sheets and my memory of events.

CASE HISTORIES

Anne In November 1988, Anne's right front foot was observed to be swollen and tender. A possible infection in her left hip area caused the veterinarian to assume the swelling on her foot was related to her hip. Banamine (flunixin meglumine) and ampicillin trihydrate were given in the muscle of her left hip twice a day (b.i.d.) for 3 days. On 1 December, a hole, with some drainage, was noticed at the caudal aspect of the sole. This hole did not extend dorsally under the skin, as was suspected, but undermined almost the entire sole. On 2 December, treatment consisted of using a 1 inch diameter hole-saw to drill five openings through the separated sole, facilitating drainage and the flushing and hardening of the underlying sole. Banamine was given until 12 December when no signs of tenderness were observed. The animal tore off much of the separated sole flap on 13 December. From 14 December 1988 through 3 January 1989 additional undermined areas of the pad were trimmed away by the veterinarian and keepers. Kopertox was used as a drying agent for the newly exposed sole. By January 1989 healing was virtually complete. Today, this same problem would be treated by immediately trimming away the entire undermined pad from the point of the hole to healthy tissue.

The thinness of her front pads made trimming of cracks in the pads difficult. Her right front pad, in particular, was occasionally so thin that parts of it would appear pink in coloration and any more abrasion would have caused the pad to bleed. This was not caused by the keepers who worked on the pad but by the elephant herself. Although she was kept in the same environment with three other Asian elephants, they never developed this condition. While Anne was occasionally observed to engage in a bit of foot shuffling, it never seemed to last for more than several seconds at a time. Her pads never became a serious problem.

Lota Lota's records show that she suffered primarily from nail and cuticle cracks. Early records from 1964 through April 1974 mention "cracks in feet, a shoe boil on right foot, and lameness." The shoe boil was treated with a water-tincture of iodine solution and the lameness with cortisone injections. Beginning with our elephant program in 1981, this animal's records show a history of cracked, hard cuticles and nails. Between June 1981 and the end of November 1990, when Lota was sent to another institution, nine major nail cracks were noted in our veterinary records. Others undoubtedly occurred but were treated only by the keeper staff and not noted by the veterinarians.

For the first several years of the program, mineral oil was used to soften her cuticles. The cuticles were also cut back with a hoof knife and filed with rasps of various sizes. During this time period, nail cracks were treated with pine tar to aid in healing. Later, the use of pine tar was discontinued in favor of other treatments, and in recent years, Kopertox has been the only product used. The use of hoof knives was also discontinued in favor of using X-acto knives. By the late 1980s, her cuticles had improved to the point where only occasional filing was necessary. Her persistent vertical nail cracks were treated by cutting back and/or filing dead tissue from the cracks, usually in a V-shaped pattern from the center of the crack outward. Necrotic tissue was removed until only healthy tissue remained or until bleeding started. This process proceeded slowly over several sessions, sometimes over a week or more, until

all of the dead tissue was removed. Sometime in the mid- to late-1980s we began filing a horizontal line down into the nail at the top of the vertical crack. We found that it was important to file this line into the nail to a depth that nearly equaled the depth of the vertical crack at its dorsal point. While not always successful, this did seem to help keep the vertical crack from continuing to split up into the cuticle. In addition to abrading the bottom of the nail, we also abraded the surface of the nail on the side of the crack that had the smallest area. This seemed to encourage the crack to grow in that direction, as well as move downward and out of the nail. Additional treatment for nail cracks included the application of Kopertox to help dry and seal the nail.

Tamara Tamara's history is filled with foot problems. She had many of the problems the other elephants had, but others as well. As with Lota, Tamara had hard, cracked cuticles. These were treated using the same methods applied to Lota's cuticle condition, so that by the 1990s Tamara's cuticles needed only occasional maintenance with a rasp. Tamara's most interesting problems were with thin rear pads, which quickly developed necrotic areas, chronic pad/nail infections, a persistent crack in the pad of her left front foot, and a chronic fistula in her right front foot.

Tamara's rear pads were often soft and thin yet covered with numerous small and occasionally large cracks of various lengths and depths. Due to the thinness of these pads, it was difficult to regularly trim tissue from the entire pad. Soaking her feet in Nolvasan or Betadine solutions and painting the pads with formalin seemed to be of limited value. The cracks were treated by paring them out as best we could. In 1989 we replaced the asphalt floor in our Asian elephant stall with a new concrete floor. We believed that we would get better drainage after the installation of the new floor, and there did seem to be some corresponding improvement in the elephants' feet. In October 1990, a wooden pallet was installed for Tamara to stand on during the night. In my opinion, the pallet was of questionable value because the improvement in the condition of her feet seemed to be negligible.

Tamara had another interesting problem with her left front pad. She always had a large crease in this pad, which often developed into a deep crack. The crack angled cranially, producing a flap that trapped debris. Unlike most cracks that can be trimmed by creating a V- or U-shaped depression that debris cannot cling to easily, this crack was difficult to trim due to bleeding of the surrounding healthy tissue that created the flap. Any attempt to cut tissue away quickly resulted in considerable bleeding. It often took over a month to open this crack far enough to allow flushing with water or an antibacterial solution.

A chronic pad/nail infection, which was described as an abscess on her left rear foot next to the medial nail, began in June 1989. By July a fleshy protuberance adjacent to this nail had developed. Lidocaine was injected and a biopsy performed. The lesion was described as being firm, resilient, and vascular. Drainage from this site developed later in July, and by August granulation tissue was forming around a tract on the lateral aspect of nail three. Necrotic areas in both nail two and nail three were trimmed, and the foot was soaked in a Nolvasan solution. On 3 November, a consulting veterinarian froze the area of granulation tissue with liquid nitrogen. While it initially appeared that the results were good, by 4 December an abscess had developed behind the medial nail. A large area of necrotic tissue was removed, although the end of a tract going into the nail could not be found due to bleeding. Trimming the nail and soaking the foot were continued, and by January 1990 the area appeared to be healing.

On 24 February 1991, a growth of white fleshy, fatty tissue was protruding from a crack between nail one and nail two of this same foot. This tissue grew in size and bled easily. On 15 March 1991, cryosurgery was again performed on this fibrous lump. Treatment consisted of removing necrotic tissue from the pad and from nail one and Nolvasan foot soaks. This treatment seemed to heal the condition, as no further problems with this foot occurred until late October 1991, when another necrotic pocket developed behind nail one. Using the same methods of trimming and soaking the pad and nail, the foot again looked good by August 1992, although a series of infections in nail one and the pad just behind it did develop in the intervening time period.

Tamara also periodically developed a tract at the back of her third nail on her right rear foot. This extended upwards, occasionally leading out through a small hole at the top of the nail. Early treatment for this condition consisted of flushing out the tract with a Betadine-peroxide solution, applied using a syringe with a feeding needle tip. In later years, treatment consisted of following the tract upwards and removing the necrotic nail, starting at the bottom of the nail and proceeding as far up as could be done without causing the nail to bleed. A section of healthy nail in front of the tract was also removed. This would leave an odd looking nail, but it did seem to take care of the problem. Kopertox was then applied to the crack. It was not necessary to treat this condition by soaking the foot.

Tamara's most persistent and difficult problems were chronic tracts in her right front foot. The first record of a hole in Tamara's right front foot is from 6 January 1982. The record indicates an undermined sole with one hole. It was treated by applying Kopertox b.i.d. On 31 March 1986, the first mention of "a chronic draining tract" was recorded. It was located just caudal to the third nail on her right front foot. The record indicates that this reoccurred intermittently for 1½ years, although it is possible that this was the "hole" described on 6 January 1982. Radiographs taken in January 1986 showed that this tract led into the foot approaching P-3, with some osteomyelitis of P-3 and possible arthritis of the coffin joint. After injecting lidocaine into the pad, the tract was treated by trim-

ming the hyperplastic tissue. Soft tissue was cut away to create a 3 inch diameter depression in the pad and up into the nail. There was also a soft spot just above the cuticle on the third nail, which we believed would develop into a drain for this tract. Additional treatment involved soaking the swollen, warm foot in water prior to an Epsom salt-Betadine soak four times a day. Sulfamethoxazole trimethoprim tablets were also given. By 9 April 1986, the swelling receded. The soft area over the nail erupted on 15 April 1986. The tract led downwards to a plantar defect and was filled with thick pus. The track was flushed with Betadine solution. By 20 May 1986, the abscess was nearly healed, although the plantar defect was still present. On 3 June 1986 no evidence of the tract remained. The Epsom salt-Betadine foot soaks were reduced to twice a day, and the plantar defect was flushed b.i.d. with Betadine-peroxide. On 13 June, radiographs were again taken of the foot, showing lysis of P-2 and osteophyte formation on P-2 and P-3. Flushing with Betadine-peroxide and foot soaking continued.

By late October 1986, a fistula had developed on the caudal aspect of the same right front foot, and by 9 November another fistula had developed mid-sole. Considerable granulation tissue formed in and around these fistulas and occasionally "stringy tissue" was reported. Initially, this tissue was treated by flushing b.i.d. with Betadine-peroxide and soaking the foot in an Epsom salt bath. In December, chloramphenicol ointment was injected into the fistulas. By this time, there was considerable sloughing of the pad. Sometime around the beginning of May 1987 a formalin soak of the pad on her right front foot began, as the records indicate that this was reduced to twice a week on 5 May. Nolvasan foot soaks were also started on this date. By May, the tissue of the sole on the right front foot also began to harden, although there was now some drainage of pus from the back of the pad. In the middle of May, the formalin soaks were discontinued because the keepers felt that the formalin was irritating the skin along the bottom of her foot. At this time, a protective bag was placed over the foot when she was let into the outside yard. On 20 July 1987, the records indicate that for several weeks there was no evidence of pus from the mid-sole fistula. The pad had hardened except around the opening of the fistula. The foot was soaked in Novalsan and the pad was painted with formalin. By the middle of September, the tracts in her foot were overgrown by the sole. In November, a 6 inch section of the pad, caudal to the center fistula, was removed because it had been undermined. A Betadine flush of the tract once a week was initiated, and the formalin treatment was stopped. Sulfa-trimethoprim tablets were administered for 2 weeks. An abscess on the caudal aspect of the sole was noted at the beginning of January 1988. It was opened, and treatment by flushing with Betadine-peroxide began. Formalin was also applied to moist tissue under a central nail. On 2 September 1988, radiographs were again taken of the right front foot near a draining lesion by the third toe. There was no visible change since the last radiograph. A leather boot was made for Tamara, which she wore while inside. The daily log for 21 November mentions that white tissue was growing out of both fistulas in the bottom of the foot. A number of reports of pus between nails three and four were recorded between November 1988 and March 1989. It was not until May 1989 that the large defect behind the third nail began to heal. By the middle to the end of August, the foot was greatly improved. The fistulas were apparently gone, with only cracks in the pads remaining.

On 22 February 1990, an abscess, undermining nail two and the pad behind it, had developed. Caseous material was present under the nail, and it was treated by trimming back the dead nail and with Nolvasan soaks b.i.d. On 5 March 1990, it was recorded that Tamara had lost 1,700 pounds, down from her peak weight in March 1988. Even with continued trimming of the nail and pad, by the end of March a small tract had developed behind nail two. By April a plantar defect was developing. A 1 cm fistula recurred by the middle of July. The treatment of deliberately cutting into sensitive tissue around the fistula and soaking of the foot continued. Occasional abscesses developed, and the foot had still not healed when cryosurgery of the area around this fistula was performed on 15 March 1991. Continued debriding of the area around the fistula, trimming dead tissue, soaking the foot, and having Tamara wear a mailbag to keep the foot relatively clean were the treatments until April, when, due to anorexia, drug therapy began. Between 10 and 21 April, Banamine, ampicillin-sublactam, and gentamicin were all given intravenously. By the end of April, the ulcerated area was healing and she was let back outside. The ulcerated area continued to get smaller each month. By the end of November, it had closed, except for a small crack.

On 23 January 1992, an ulcer again formed behind the third nail. The nail and pad behind it were again infected, and treatment included the removal of necrotic tissue down to where healthy tissue would bleed. By August it was healing. The application of Kopertox was added to the pared area, and in October, the foot soaks were changed from Nolvasan to Betadine. Radiographs in December showed that the bones of the foot were healing, with the previous osteolytic lesion of P-3 of the fourth digit completely healed. There was no evidence of osteomyelitis.

Babe and Lucy Our African elephants, Babe and Lucy, came to the zoo in 1962, at an age estimated between 4 and 5 years. They were housed under virtually identical conditions as our Asian elephants. They have had comparatively few problems with their feet. While occasionally minor nail cracks and rotten areas in the nails and pads occur, these problems were always taken care of by the keepers and have never required veterinary care. Recently, because we have been more heavily involved in other aspects of our protected-contact program, their feet have received less care. Deterioration in the condition of their feet resulted,

which demonstrates that there is always a potential for foot problems to occur. When we began regular maintenance again, their feet began returning to their former condition.

Last year we installed a high-density polymer floor in our new African elephant stall. The floor was poured and ready for use in a little over two weeks. This was done to help cushion the impact of the underlying concrete floor on the elephants' joints.

CONCLUSIONS Thin pads, coupled with conditions that lead to foot rot, create trimming headaches. Every attempt to dry out and eliminate dirty floors should be made. With some animals, it may not be possible to achieve this goal to the degree necessary to eliminate the problem, and close monitoring of the feet along with continuous trimming of the pad may be the only answer. Thin pads alone did not seem to be much of a problem in the one animal that experienced this condition. We did encounter occasional signs of bruising, but these were almost eliminated when we were able to replace our rock filled yard substrate with a sand-clay mix.

Healthy cuticles can be kept in good shape by occasional trimming or filing. Softening them is probably a good idea, but may not be necessary. Nails need to be kept trimmed to keep pressure off of them. The hard surfaces and moisture elephants are exposed to in most zoo situations may cause at least some animals to have occasional necrotic areas or cracks. When these occur, they should be treated aggressively, paring out necrotic tissue, and trimming the nail bottom. Interestingly, over the years of our elephant program, there was some debate over whether nail and cuticle cracks should be treated aggressively or whether they should be treated at all. We tried each method and concluded that leaving them alone is not a good idea.

Infected tracts leading into the foot are a serious problem. If no foreign object needs to be removed, then healing the wound from the inside out as quickly as possible is the objective. Continuous, aggressive trimming of the area, combined with foot soaks and the application of Kopertox to the area, seemed to work best for us. Additional treatment by brushing formalin on areas of soft pad may prove useful as well. Treatment with antibiotics may be necessary. In the experience of our program, it can easily take over a year to heal these infections.

There appeared to be a difference in the condition of the feet between our African and Asian elephants. Our African elephants did not show the magnitude of foot problems our Asian elephants did, either in the number of problems or in degree of severity. Whether this is species specific or due to their individual nature is not clear.

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10

ELEPHANT HUSBANDRY AND FOOT CARE AT THE SCHÖNBRUNNER TIERGARTEN, VIENNA

HARALD M. SCHWAMMER

INTRODUCTION Zoo visitors consistently rank elephants as number one on their list of the most fascinating animals. In the wild, the Asian elephant is nearing extinction and the African elephant is endangered. In captivity, the breeding results are still far from sufficient to maintain the zoo population. The cause is a lack of elephant facilities able to house bulls. In addition, many elephant keepers and handlers have insufficient training and knowledge of these species.

There is considerable discussion about the merits of two handling methods: protected contact (hands off) or free contact (hands on) (Doherty et al. 1996, Priest 1994). In 1996 the Schönbrunner Tiergarten, Vienna, erected a new facility for African elephants (Pechlaner et al. 1997). The facility provides for protected-contact or hands-off management for a 7-year-old bull and a free-contact system for the cows. The latter approach simply represents the most promising method for managing cows when well-trained animal keepers are available.

PROGRESSIVE BREEDING MANAGEMENT OF THE SCHÖNBRUNNER TIERGARTEN After several research projects, the first artificial insemination project on elephants in Europe was started in 1999 in Vienna (Schwammer 1999a). Vienna's population of African elephants consists of one male and five females. The bull is 7 years old and the females are aged 13, 13, 24, 39, and 40 years. The aim of the project is to introduce new genetic diversity into the population by using an outside bull (from the Colchester Zoo, Great Britain) and then to proceed with natural breeding when the Vienna bull is mature.

All procedures were done in free contact, without any sedation. Every training step for the necessary daily rectal ultrasonic examination and for the artificial insemination was videotaped to document the successful use of modern, humane training methods. The high level of professionalism by our elephant keepers resulted in well-trained elephants and made the procedures described above possible.

1999 European Workshop on Health Care for Elephants In cooperation with other specialists, the Schönbrunner Tiergarten began offering a series of training courses, starting in March 1999. Nineteen people participated in the 1st European Workshop on Training Elephants for Medical Care, Treatment and Research. Attendees included keepers, curators and veterinarians from Great Britain, Germany, Sweden, Indonesia, and Austria (Schwammer and Riddle 1999, Schwammer 1999b). The topics included: foot care, skin care, mouth examination, body measurements, blood samples, X-rays, ultrasound procedures, and preparation methods for artificial insemination.

Foot Care Foot problems occur in the wild and in captivity and seem to have multiple causes (Fowler 1998). The types of problems seen in domestic and nondomestic ungulates can also be seen in elephants. These include penetrating injuries, sole cracks, nail cracks, overgrowth, and infections. Wet conditions and inadequate exercise are predisposing factors to the development of these conditions (Mikota et al. 1994).

Differences in foot health management between African and Asian elephants must be considered. African elephants seem to have fewer foot problems than Asian elephants, but the reasons are unknown (Sorensen 1998). This has led to different philosophies about using floor heating for the two species. Some zoos do not warm the floor for Asian elephants, because they are afraid of disturbing the sweat glands between the toes, which can cause foot problems. Others are afraid of having stalls with concrete floors. Use of these practices is a matter of personal opinion, since data have not been collected to verify these hypotheses.

Floor Quality The new elephant facility at the Schönbrunner Tiergarten has a variety of floor materials inside the barn and in the outdoor yard. The indoor enclosure consists of six pens, the bottoms of which are covered with asphalt, and an additional inside area of about 500 square meters that is covered with a special recycled rubber layer. The surface is sloped so liquids, such as water and urine, drain away quickly. The floor is heated and dries quickly. The elephants' time spent on wet floors is minimized. The females (without the bull) are housed together and are free to move about during the night. Temperature is maintained by floor and wall heating.

Most of the outdoor yard is covered with a thick sand layer. There is an area covered with plaster stones near the barn. The animals also have access to a gently sloped, concrete-covered moat leading to the visitor viewing area. A special mud bath and a large pool are also available in the yard for skin care, enrichment, and

foot health. The yard was designed to offer the animals a variety of substrates.

Foot Control and Care Consistent control of every individual is an important part of an elephant's daily routine. Foot conditions must be monitored daily to avoid the occurrence of problems and to provide treatment for existing problems. Daily training of the elephant is a critical element for foot care, because procedures that must be done regularly must be done easily. Although we only started our program a year and a half ago, the incidence of nail cracks has diminished, and this common condition is now resolved.

CASE HISTORIES

Foot Abscess in a 39-year-old Female African Elephant (Schönbrunner Tiergarten, Vienna, Austria) In addition to having arthritic problems, this individual showed the first signs of an abscess on the right foreleg in 1998. The abscess reached from the coronary border of the toenail to the sole. It opened spontaneously at the top of the toenail. An additional opening was cut at the sole. It was treated by daily flushing with Betadine solution for the first 2 months. This treatment of the tract showed some positive results. During the summer, we decided to allow the elephant to go outside and walk in the sun-heated, dry sand. This activity was beneficial, because the hot sand seemed to dry the abscess. The abscess healed completely within 6 months

At the Schönbrunner Tiergarten, we are working in free contact with the cows and protected contact with the bull. Foot health can be managed using both methods (Kalk et al. 1998, Kam 1998), although we are convinced that the goals are best accomplished with the free-contact management method. Nevertheless, the bull had small toe cracks, which were cut open and were growing down without infection after some weeks.

Nail Injury (Bojnice Zoological Garden, Slovakia) After playing with a tree by kicking it around, a third of the middle toenail on the left foreleg of the elephant split away. The nail was treated by trimming it straight and it healed after 2 months of rapid regrowth.

Overgrowth of Toenails in Assam, an Adult Bull (Kharkov Zoo, Ukraine) In early 1997, Oleg Grischenko, an elephant keeper at the Kharkov Zoo, requested assistance concerning a dramatic situation in the feet of a 45-year-old bull. The nail growth, especially in the front feet, reached 20 to 30 cm, and the overall condition of the feet called for emergency treatment. This bull's feet had not been treated for 7 years! From pictures they received from Kharkov, many specialists originally thought that this was a hopeless situation. For enormous elephants like Assam, the condition of their feet is extremely important for their survival; therefore, this was an urgent case.

Support from several companies, as well individual donations, contributed financially to this campaign. The five specialists who directly worked on this case in Kharkov offered their services for free.

The two veterinarians of the Erfurt Zoo, Dr. Angelika Hinke and Dr. Dietmar Kulka, together with two elephant keepers, Karl and Carsten Kock, and a technician, Hans-Peter Schmidt, flew to Kiev on 8 August 1997. The zoo veterinarian delivered a sedative to the bull using a blowgun. While the veterinarians were busy monitoring the bull during his sedation, the keepers worked on the nails. Special knives, saws, tongs, and other tools were used to return the toenails of this elephant to their natural condition. It was of interest that no blood capillaries were found in the overgrown nails. The bull was sedated for about 2 hours, which was enough time to complete the detailed work on the toenails and foot soles. Sedation was neutralized though an antidote and stimulation of blood circulation. Minutes after initiating the antidote, Assam started moving his ears and trunk, and as a sign of his awakening, he spontaneously excreted dung and urine. Half an hour later he got on his feet without difficulty and nibbled some food (Hinke 1998).

PREVENTION OF FOOT PROBLEMS IS BETTER THAN MEDICAL TREATMENT International exchange of experiences is very important. Practical courses are taught at Riddle's Elephant Sanctuary (Arkansas, United States). Special training courses and workshops (i.e., training elephants for medical care, treatment, and research) are regularly offered at the Schönbrunner Tiergarten. Free-contact management provides the best opportunity for necessary foot care. Protected contact is a second choice for administering proper foot care, but has been successful in some cases (Kalk and Wilgenkamp 1998, Kam 1998).

The following are some measures that can help prevent the occurrence of foot problems in captive elephants:

- Provide different floor substrates in indoor and outdoor enclosures. Sand is the best ground cover; however, it is necessary to use river-washed sand. Avoid sand that is made by breaking up stones (such as decomposed granite) because of the sharp edges. Offering areas covered with grass or harder materials gives the animals a substrate choice. A mud bath and a wading pool provide moisture and protection, which is necessary for healthy skin.
- Different feeding methods can be used to increase elephant activity. Food can be provided in different places and offered five to eight times a day to effectively increase activity.
- Daily training and working routines contribute to good body condition and weight maintenance.
- Daily washing routines (such as showering once or twice a day) contribute to skin and foot health by removing dirt and excrement.

- Floors of indoor enclosures should be heated to maintain temperature and to speed drying. If soft floor coverings, such as recycled rubber, are used, the floor must be sloped, so that liquids can drain away quickly.
- In regions with cold winters, elephants must be kept indoors for long periods. The animals should be able to move freely day and night. Every effort should be made to maintain clean, dry floors.
- The quality of food is relevant to foot health. As in domestic ungulates, high-energy food leads to overgrown hoofs and toenails. These conditions often result from a nutrition issue and not from the mechanical abrasion of nails resulting from walking on hard ground, as is often assumed.
- All equipment for foot care should be kept clean and in good condition, and should be sterilized between uses, which will help prevent additional, secondary infections.
- In the case of wounds and abscesses, it is more successful to keep the foot dry than to use shoes or sandals. After disinfection, the animals should be allowed to go outside, because warm sun and fresh air contribute to the healing process.

CONCLUSION In many zoos and facilities, prevention is not succeeding; therefore, active foot treatment remains part of the basic elephant husbandry program. When foot problems occur the entire program should be evaluated: nutrition, housing, behavioral activities, physical exercise, skill of elephant handlers, and the training-level of the elephants. The cooperation between elephant handlers, veterinarians, and curators is a basic requirement for the successful prevention of foot problems and the provision of necessary foot care and treatment. There is agreement that more research on the prevention and treatment of elephant foot conditions is needed.

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PREVENTIVE FOOT CARE FOR AN ASIAN ELEPHANT AT MESKER PARK ZOO AND BOTANIC GARDEN

JOAN ALBERS HUGHES AND MADELINE SOUTHARD

INTRODUCTION Mesker Park Zoo and Botanic Garden, Evansville, Indiana, has a 46-year-old female Asian elephant (*Elephas maximus*) who is left unchained in a stall with a concrete floor at night. She has daily access to a yard with a substrate of large rock (number 53 limestone) covered with crushed limestone (number 10 with fines) and an area of sand. We have an aggressive, free-contact regimen to prevent serious foot problems. The preventive regimen includes interior exhibit and yard maintenance, general husbandry, daily hands-on inspections, twice a day foot scrubs, and weekly pedicures for all four feet. To make more efficient use of time, pedicures are done with power tools (planer, sander) in addition to the usual hand tools. If an incipient problem is detected, treatment is aggressive. Treatment usually consists of medical soaks, topical antimicrobials, and removal of all necrotic tissue. In this manner we have been able to contain relatively minor problems and prevent major problems from developing.

Therefore, Mesker Park Zoo and Botanic Garden has instituted a free-contact, preventive foot care program for our Asian elephant. Incorporated into this program are general husbandry practices, inside and outside exhibit maintenance, daily foot inspections, weekly pedicures, and two-way communication between keepers and veterinary staff. The program is updated as new problems arise and as old treatments cease to work. This preventive program allows minor problems to be identified and treated early, thus avoiding any major future problems.

GENERAL BACKGROUND INFORMATION Bunny, our female Asian elephant, was wild born in 1952 and came to Mesker Park Zoo and Botanic Garden in 1954. She has been housed alone, except for a short time in the early 1950s and approximately 5 years in the 1980s when she was housed with younger African elephants (*Loxodonta africana*). She has always been handled with a free-contact system, which is defined by Mikota et al. (1994) as "direct human handling of an elephant when the elephant and keeper share the same work space. The safety of the keeper is dependent upon the reliability and responsiveness of the elephant to all commands given."

Bunny's temperament is basically mild-mannered with intermittent fits of moodiness. She has had several different keepers over the years. She generally has a good relationship with her keepers, but like all elephants, she is easily spooked and does not react well to change of any kind. The present keeper has worked with her continuously for the last 12 years.

In the past, Bunny was chained nightly in the inside exhibit, but this was discontinued several years ago due to persistent problems on her rear feet caused by constant contact with urine and feces. Her daily diet consists of elephant chow (Mazuri, Purina Mills), three to four flakes (partial bales) of alfalfa, two to three bales of timothy hay, and various types of produce. She also receives supplemental vitamin E and rock salt. Bunny is weighed approximately every 6 months because her weight can have a major effect on the condition of her feet and nails. The more overweight she becomes the more the stones in the yard embed into her feet and the harder it is to keep pressure off any split nails.

ELEPHANT EXHIBIT AND YARD The condition of Bunny's yard is a major consideration when dealing with her foot problems. The size of the yard has been the same the entire time she has been at Mesker Park Zoo but has gone through many changes. It is a large circular yard with a deep pool at the bottom of a slight hill. The pool was formerly kept filled during warm weather, but this practice was stopped because her foot problems were exposed to the bacterial content of the pool, which promoted abscesses. Now the pool is usually filled only once a week. However, when the pool is not filled, a trickle of water is left running, so Bunny has constant access to water.

Two-thirds of the pool is encircled by railroad ties set on end, allowing for behavioral enrichment and rubbing of her feet and body. Years ago the substrate began as grass, then it was dirt and mud wallows. During this period, Bunny seemed to develop many more cuticle problems and foot abscesses. A rock substrate was added to cover the mud, which caused holes in the soles and nails of her feet. Now the yard has small, crushed limestone (number 10 with limestone fines) over 90 percent of the total area. Ten percent of the yard is a sand pit, where she spends the majority of her time while outside. There is a large tractor tire in the yard, against which she can rub herself, as well as logs and tires of varying sizes. A large ball is available for her use, and she takes it with her wherever she goes.

Minimal shade is available in the yard, so during the summer she is allowed access to her inside exhibit. Bunny stays inside a majority of the time during hot weather. This provides behavioral enrichment by allowing her to make the choice of where she wants to stay.

During cold weather she stays inside. Her inside exhibit consists of two stalls with concrete flooring. There are hanging tires for rubbing. Browse and/or logs with bark are provided, when available, so she can either eat or rub the bark off with her feet.

BUNNY'S FOOT CARE HISTORY Bunny has had a variety of foot problems over the years, caused by improper wear of the feet and nails, exhibit conditions, and lack of adequate exercise. As she ages, there have been more frequent foot problems, as well as general health problems. In the past 12 years, the condition of her feet and her foot care has changed in many ways.

In the Midwest, we have varying weather conditions that contribute to foot problems. Hot, humid weather during the summer can encourage the development of abscesses in the cuticles and nail splits. Moist conditions soften the nail, and inadequate wear or trimming can put unusual pressure on the softened nail, causing a split (Schmidt 1986). In the winter, a different set of problems arises. Since the elephant is kept inside most of the time, necrotic pododermatitis above the cuticles, commonly known and referred to here as foot rot, becomes more prevalent. This condition develops because she urinates on the insides of her rear legs and is unable to throw dirt to dry them. The urine keeps the area moist, which allows bacteria to colonize the skin, which can initiate the development of foot rot. Foot rot was more of a problem when she was chained at night. Leaving her unchained at night decreased the occurrence of this problem. Letting her move to a feces-free area also helped prevent abscesses. A small pool of water (not her drinking supply) can also become contaminated with fecal material, leading to abscesses in the cuticles above the nails. Major causes of abscesses and foot rot are chronically wet and dirty conditions and inadequate exercise (Schmidt 1986).

During warmer weather when she has access to the yard, the crushed limestone can contribute to foot problems. Stones can become lodged in the pads and nails of the feet, which, if not removed immediately, can cause the nail to rot or an abscess to form in the sole. Since lime acts as a drying agent, it can cause very small cracks in the nail. But, there are also a variety of items in the yard for her to rub on, helping to prevent cuticle overgrowth. Keeping her feet trimmed is also important since she is unable to walk as much as she would in the wild. This lack of exercise can cause overgrowth of the sole and nails, leading to major problems.

Bunny's foot problems did not become persistent until around 1980, when she was 28 years old. Before 1980 she had occasional and minor problems. When her feet were persistently cracking at the cuticles, a more regular foot care protocol was introduced. This protocol included use of povidone-iodine solution soaks followed by application of a 90 percent dimethyl sulfoxide (DMSO) and nitrofurazone solution. By mid-1981, the trimming of excess growth was added to the routine. The problem continued into late 1981. From 1982 to late 1985, the routine consisted of povidone-iodine solution soaks and scrubs and trimming of excess cuticle growth. In late 1985, her rear feet started cracking. Nitrofurazone applications were added to the routine. By early 1986, the cracks were still a problem. Povidone-iodine solution soaks were continued, but povidone-iodine solution was also now flushed into the foot cracks and Kopertox (Fort Dodge Animal Health, Fort Dodge, Iowa, United States) was applied. Throughout the remainder of 1986 the feet had no new problems.

In 1987, a hole developed in the right rear pad. This hole was approximately half an inch deep. Treatment consisted of a normal routine, plus flushing the hole with water and keeping it clean. During the next 5 months more holes appeared. Each new hole was pared out to improve drainage. At this time, more frequent foot trimming was instituted. By mid-1987, it was determined that the continual filling of the outside pool was contributing to Bunny's foot condition. The pool was drained until the holes and cuticles healed. A DMSO-nitrofurazone mixture was once again applied on the cuticles after scrubbing. A 3 percent hydrogen peroxide solution was used for flushing. The holes in the sole healed well, but the cuticles continued to be a problem through 1988 and 1989.

Early in 1990, there was a new problem—a deep nail crack in the lateral nail of the right front foot. This nail was previously treated for nail rot. In January 1990, surgical glue was used to try to prevent any further cracking. By February 1990, surgical glue was abandoned in favor of an acrylic patch. The patch filled in the entire crack. Regular foot trimming was continued, although more attention was given to any lameness or heat from the nail and/or cuticle, which is symptomatic of an infection. The patch fell out 2 months later and was reapplied. The cuticles were still a constant problem, and foot rot set in just above the cuticles of the rear feet. In July 1990, the acrylic patch was once again applied. We used a wire, woven through both sides of the crack in the nail, to help the material remain in the crack longer. This was the last application. When the patch came out, approximately 3 months later, the nail was sufficiently healed and did not require another application.

At various times during the summer of 1991, Bunny had an outbreak of abscesses on all four feet. We realized this was going to be a seasonal problem. The pool was once again drained and left empty to help keep Bunny's feet dry. Keeping Bunny's feet as dry as possible was the newest addition to the routine. By the end of 3 months and at the onset of autumn, her feet began improving.

In January 1992, we started using a power sander on her cuticles. This improved our ability to keep the cuticles from overgrowing and entrapping debris. Between this time and late 1994, abscesses were identified and dealt with early before they could undermine large areas.

In September of 1994, a fistulous tract of infection was discovered on the left front foot. It appeared to have originated on the sole and broke out a few inches proximal to the place of origin. This area was pared out for drainage and cleaning. Flushing was done three to four times daily with a 3 percent hydrogen peroxide solution and a solution consisting of one-third nitrofurazone, one-third chlorohexidine, and one-third 3 percent hydrogen peroxide. The abscess was then packed with a gauze sponge soaked in povidone-iodine solution. A bandage was used to hold the packing in place. The first bandage was a piece of disposable diaper covered with duct tape. Since the bandage was on the front foot and easily accessible, it was removed by the elephant within an hour. The final bandage design was a small waterproof pad that held the packing, which was then covered with duct tape and molded to cover only the nail area. This seemed to be acceptable to Bunny, and she left it alone. The key to the design seemed to be not allowing the duct tape on her cuticles. Using this treatment, the tract took only two months to heal.

In mid-1995, another fistulous tract was found on the sole. Treatment consisted of the normal cleaning routine and paring out the necrotic tissues until fresh blood was reached. The area was then flushed with a mixture of the aforementioned nitrofurazone-chlorohexidine-hydrogen peroxide solution. This procedure was done at least twice daily until it healed. The tract healed within 3 weeks. Since mid-1995, we have had no major foot or cuticle problems. Abscesses are opened immediately upon discovery and heal quickly.

In August 1998, a fairly large split appeared in the lateral nail of the left front foot. This was treated by paring out necrotic tissue, as necessary, to allow for drainage and keeping the nail clean and dry. Presently, the nail is starting to improve and heal.

With each additional incident, we have gathered more information to improve our preventive foot care program. Various aspects of Bunny's life have been looked into, including yard condition, condition of her feet, trimming protocol, general husbandry, and weather. Cultures taken during a couple of particularly persistent problems showed that enteric bacteria were the causative agents of the abscesses. This led to changes in the pool-filling schedule and exhibit management. For example, large fans have been placed outside the inside stalls to hasten the drying of the floors after cleaning.

EQUIPMENT FOR FOOT CARE There is a myriad of tools required in the care of an elephant's feet. For the Mesker Park Zoo, the ankus is the most important tool used to train and control our elephant. This tool is especially crucial when working on an elephant's feet in a free-contact system. Because we use the free-contact system, we require a minimum of two trained elephant keepers, each equipped with an ankus, to be present while working with the elephant. This requirement becomes even more imperative when a pedicure is given and power tools are used. One person controls and distracts the animal; the other works on the feet.

Elephant tubs are used to place the elephant's feet in an appropriate position for foot work. The tubs allow the feet to be placed in a position that improves visibility and prevents the keeper from having to stand on his or her head to see the condition of the sole.

A power sander with a flexible head adapter is used to shape nails and cuticles. This grooms any ragged and overgrown tissue, thus removing areas where debris and moisture become trapped and preventing the development of abscesses, which are associated with bacteria growing in the mixture of trapped debris and moisture.

A power planer is used to take very thin layers off the bottom of the soles and nails, allowing a better view of possible problem areas. It also prevents overgrown soles, which can allow an abscess to develop. Since abscesses can become very severe before being found, early detection is critical.

Power tools allow necessary work to be done more quickly than is possible with hand-held tools, which allows for scheduling more frequent foot care. The ability to give more time to foot care allows the feet to be maintained in a better condition and can help catch problems early. There are some drawbacks to the use of power tools. Cutting too much off the sole or nail with the planer can be a serious problem. This can lead to pain or inadvertent exposure of the circulatory system, which can result in contamination. Some problems associated with overplaning are folding of the sole and bruising of the tissue underlying the sole. Both of these can lead to serious abscesses and sloughing of the sole. To prevent removing too much, planing should always be done a little at a time. Usually, the planer is set on the lowest setting so only the thinnest amount of sole is cut. The rule of thumb when planing is to cut off only the smallest amount possible at one time. Misshaping the pad is another problem. The pads should be planed flat and should not follow the curve up to the back of the foot. If done improperly, the elephant's weight is shifted and other lameness conditions can occur.

Hand files of various sizes are used for smoothing out rough areas left by power tool trimming. This prevents debris, which can cause an abscess, from being trapped. Hand clippers, like those used to trim goats' feet, are used to trim excess growth around cuticles and to open up any abscesses in the cuticle. Hoof knives are used to pare open problem areas in the soles and nails. A hand-held scrub brush is used for daily scrubbing of the cuticles, nails, and soles, thus keeping feet as clean as possible. Cotton swabs come in handy for checking the depths of draining tracts and holes found in nails and cuticles. Only syringes (no needles) are used to

flush disinfectant and medications into the draining tracts associated with abscesses.

TRAINING BUNNY TO DEAL WITH THE POWER TOOLS Although Bunny was trained in the free-contact system, specific training was needed in order to do foot work, especially work done with power tools. The training process started by allowing the elephant to become accustomed to the sounds made by the power tools (i.e., the planer and sander), then allowing her to see them. Once this was accomplished she was trained to allow the power tools, which were not turned on, to be motioned over her feet. If she did not move while she allowed this to be done, she was given many treats. Next, the power tools were turned on and used on her feet. Treats were very important during this training, providing both positive reinforcement and distraction.

Even though Bunny has been trained to allow use of the power tools, caution must still be used at all times. The duration of foot work should last only as long as the elephant will tolerate it. Once the elephant's patience is spent, foot work should be suspended until the next day. This prevents the elephant from associating foot care with unpleasantness and fear.

GENERAL DAILY CARE Each morning all four feet are checked visually. This is accomplished by lifting and looking at each foot. Any debris is brushed off, and most importantly, any rocks embedded in the soles or nails are immediately removed. Embedded limestone, if not removed, invites nail rot and abscesses.

Twice weekly, each foot is put up on the tub and carefully inspected. This is when the foot can be seen the best and most of problems are found. A general foot treatment is performed, including cleaning of nails and cuticles, clipping excess flaps off the cuticles, and palpating around cuticles for abscesses. Early abscesses feel a bit more fluid and springy than the rest of the cuticle but "owing to the thickness and toughness of normal or overgrown sole, many abscesses of the foot are not readily observable externally as a fluctuant swelling" (Schmidt 1986). The pads are cleaned and the bottoms of the nails are checked for any problems, such as dark or soft spots.

At least once every 2 weeks the planer is used. The planer is set at the lowest setting and just the outer layer of the pad and nail is removed. This removes the darkened layer and allows any problems to be more visible. Any crushed limestone is cleaned out from under this top layer. Then the back of the foot is checked along the side of the pad. Any cracks in this area that appear moist or deep are widened along their sides, and the rough edges of the cut sides are filed smooth. After this, the cracks are filed following the contour of the foot from side-to-side, not from top-to-bottom. This leaves no areas that can entrap debris. If no problems are found, the elephant is then put on exhibit (outside in the summer, inside in the winter).

In the afternoon the elephant is bathed and the feet checked once more. Special attention is given to remove any new rocks. The feet are then scrubbed with a brush and a chlorohexidine scrub. Once the entire foot is clean and dry, a thin layer of Vaseline Antibacterial Intensive Care Cream is applied to the cuticle areas and to the medial side of the rear feet directly above the cuticles. This cream serves two purposes: 1) it softens the skin and allows the elephant to rub off excess growth; and 2) it gives some protection to these areas from the effects of urine and feces.

ADDITIONAL FOOT CARE TREATMENTS When a problem occurs, the general foot care routine is still done, but an additional treatment is done for the specific problem. The most commonly found problem is abscesses. It is best to find abscesses as early as possible. Since they are not generally visible until they are quite severe, palpating the cuticles is necessary. The cuticles around and between each nail are palpated. If a suspected abscess is found, then a small triangular clip is made over the area to verify that serous fluid or pus is underneath. The type of pus in the abscess depends on the bacteria involved. Many are filled with a serous fluid. If fluid or pus is found, a cotton swab is used to determine whether the direction the abscess is horizontal or vertical. If it is a horizontal abscess, then a small triangular hole is made at either end. If the abscess is vertical, a small triangular hole is made at the very bottom of the abscess. The skin on top of the abscess is left in place until the new growth underneath has caused the old skin to slough. This protects the new skin until it has sufficiently healed. The abscess is flushed twice daily with a 3 percent hydrogen peroxide solution or a mixture of one-half chlorohexidine and one-half 3 percent hydrogen peroxide solution. The area is observed daily and kept open until it is well on its way to healing (i.e., when no more fluid or pus forms under the skin).

Hairline fractures of the nail are a new and ongoing problem. Currently, any split is opened into an upside-down V and rounded at the top. The cut sides are filed down so there are no rough edges. The nails are trimmed along the bottom to make sure weight is not affecting the nail. The exhibit is kept as dry as possible to lessen the effects of moisture. We basically maintain the problem because we have not found that better preventive measures are necessary at this time.

Nail rot is caused mainly by rocks or crushed limestone becoming embedded in the nails. Treatment consists of finding the rocks and paring out the embedded area to a depth just a little deeper than the rock. If the area is blackened and appears rotten—it is nail rot. The area must then be cut back drastically and opened up to the front of the nail. An aggressive approach, involving removal of all necrotic tissue, is key to preventing the spread of nail rot. Sometimes it takes several attempts before all the necrotic tissue is finally eliminated. The nails must be trimmed short to keep any pressure off the

weakened nail, and all the edges of the nails are filed smooth. To verify this we have the elephant stand on the foot and make sure that nail does not touch the ground. A cotton swab is used to check depth. Draining tracts can be followed to reach the pulp of the nail, which causes bleeding when the rot is removed. Recurring necrotic tissue can be found for several days. The scraped areas are kept as clean and dry as possible. There is always a little ridge where the pulp and nail meet. This area needs to be carefully cleaned with a cotton swab. As the area is healing, some filing is needed to ensure it heals from the inside out. It must be kept opened at all times! Flushing is done several times a day. If the hole in the nail is very large, a gauze sponge soaked in povidone-iodine solution is wedged in place and left there until it falls out while the elephant is outside. Healing can take several weeks, or longer.

Keeping pads smooth using a planer helps prevent foot problems. Removing the darkened exterior layer makes problems below the surface visible. It also allows for early detection of abnormal conditions and prevention of more serious problems.

Foot rot on the medial side of rear feet, directly above the cuticles, is generally a seasonal problem, occurring most often during the winter months. When the elephant urinates, the urine runs down the inside of the rear legs. During summer, this is not a problem because the elephant throws dirt and sand to dry her legs. However, in winter, when she is inside most of the time, there is no dirt or sand to use and thus the damp urine remaining on her skin promotes the growth of bacteria associated with foot rot. Foot rot presents itself as a blackened area where the tissue has a very soft, rotten feeling and is easy to peel off. The first step in treatment is to remove any easily removable necrotic tissue, usually by filing. Filing also allows medications to reach healthy tissue. This is followed by soaking each foot for 3 or 4 minutes in a tub of povidone-iodine solution. The feet are scrubbed with a brush, rinsed, and dried completely. Then every other day, a thin layer of Vaseline Antibacterial Intensive Care Cream is applied to the affected area. On the opposite days, Kopertox is used instead of the cream. The Kopertox helps dry up the rot. Overall, the drier the exhibit, the better the condition of the elephant's feet.

CONCLUSION Consistency in the foot care routine is very important. At the Mesker Park Zoo, experienced keepers train new keepers in proper foot care procedures. Keeper vigilance is also very important to the success of this routine. This vigilance includes anticipating seasonal foot problems. When a problem is found, keepers must be aggressive in starting the proper treatment. Any break in this routine can have negative effects on the health of the feet.

Another very important part of proper foot care is open communication between elephant keepers and the veterinary staff. This includes a willingness to try new techniques and medications and discard ones that are nonproductive.

Other important factors not related to the actual care and treatment of the feet are the condition of the yard, the weather, and the general husbandry of the elephant. The substrate in the yard has a great impact on foot condition. If the yard is muddy and damp then abscesses can occur more frequently. Improper rock size can cause problems including nail rot, stone bruises, and sole abscesses. Standing water, like that found in a deep pool, can cause enteric bacteria associated with feces to contribute to the occurrence of abscesses in the cuticle area.

Bunny's feet have gone through many changes through the years, with problems increasing in frequency as she gets older. As the problems increased, the frequency of required preventive and general care to maintain healthy feet also increased. Preventive measures, such as correcting any conditions likely to cause foot problems, routine foot care, and immediate aggressive treatment when a foot problem occurs, are the most critical techniques required to maintain healthy elephant feet at Mesker Park Zoo and Botanic Garden.

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PART III

Common Elephant Foot Conditions and Their Treatment

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HISTORICAL LESSONS FOR THE TREATMENT OF FOOT DISEASES IN CAPTIVE ASIAN ELEPHANTS

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HISTORICAL BACKGROUND OF FOOT DISEASES This chapter is concerned with foot diseases in captive, working Asian elephants. Foot diseases in such Asian elephants are management problems that are induced by conditions of their captivity, particularly when picketed in fixed stalls. Foot diseases also occur in animals that are allowed to graze free at night but are hobbled to restrict the range of their movement. Under these conditions, elephants are perforce confined to a particular area close to the elephant camp and, therefore, are unable to choose their seasonal foraging ground. For example they cannot move to drier, higher ground in the monsoon season. Captured, wild elephants may have traumatic injuries, such as cracked nails or pierced soles, and although rare, some may have congenital deformities, which could hardly be termed "diseases." The earliest British author of a complete book on the Asian elephant is Emerson Tennent (1867). He described in detail, from personal observation, the capture of two small groups of wild elephants in Ceylon (now Sri Lanka) but does not mention such diseases in the animals. Sanderson (1878), who organized the capture of hundreds of elephants in south and northeast India and was in charge of the Kheddah department of the British government in India at Dhaka (the present capital of Bangladesh) and the princely State of Mysore (now Karnakata), does not mention foot diseases in newly captured animals as a serious problem. Although he frequently had more than 150 tame elephants under his charge, the ailment that most concerned Sanderson was saddle sores.

The occurrence of elephant foot diseases in British colonies, particularly *kari* and *sajan,* was recognized in the literature by Gilchrist as early as 1841. Here is a summary of Gilchrist as given by Wilberforce Clarke (1879):

> The parts inside and under the nails are liable to sores; and so tender does the foot become, that pressure of a finger on the spot will make the animal wince. This disease called 'kandi'[*kari*] will (if the sore gets no vent downwards) cause toe nail to fall off. It is a troublesome disease and takes months to cure.
>
> [Treatment:] In the case of sore toes or feet, clear the vicinity of sore; wash it well with a light solution of blue vitriol, forcibly squirted with syringe, till the offensive smell be overcome; then apply:
>
> chloride of lime—2 *chhataks* = 2 ounces
>
> common lime—4 *chhataks* = 4 ounces
>
> . . . mix both into a paste, and plaster the wound, which must be closed with cotton to prevent intrusion of dirt. The same may be applied to whitlows or *chajan* sores.

It is noteworthy that the identification of the adverse medical condition and even the quantity of the prescribed antidotes followed the treatment used by the locals of the region. The only addition is the cauterization using a light solution of blue vitriol. Exclude that step and the treatment is a straight English translation of the local, traditional wisdom, almost certainly acquired from the mahouts. This trend continues right through to the last days of the colonial rule and the dawn of freedom (Ferrier 1948).

The medicinal application of seeds, barks, leaves, and roots of plants and trees not only thrives in the oral tradition of mahouts but is still used today. It is also preserved in manuals that are printed in the vernacular languages of India and in manuscripts owned by old, elephant-owning families.

One manuscript, which deserves special mention, is the little-known, slim manual by J. H. Steel (1885). It is an especially fine summary of the local traditions for identifying elephant foot diseases. Steel identifies "thullee" as a form of *sajan,* that is, a fungal infection usually occurring round the rim of the back feet, at the edge of the hoof slipper. He rightly attributes this problem to "imperfect removal of urine and feces from the picketing ground" and recommends bathing the feet in a disinfectant alum water.

Steel identifies *kari/kandi* as a penetrating sore and notes that neglected *kari* (or *kandi* as he spells it) leads to a condition similar to what is called "quittor" in horses, or an escape of pus that takes place "either at the top of the nail or round the edge of the hoof slipper."

Steel identified other foot diseases, including:

- Sajan: Steel's observations on *sajan* are detailed, and he warns that if neglected, it may lead to the loss of the foot pad.
- Cracked heel: He mentioned cracked heels as a foot complication and recommended, apart from

administering the usual medication, tacking on a leather sole or putting a boot on the elephant.

- Cracked sole: He notes that surface chapping and cracking of the soles, in which ulcers form along the natural grooves, is a common complaint for elephants during hot, dry weather.
- Nail diseases: Steel also mentioned that horn tumor, which is an overgrowth with distortion of the toenails, requires surgical intervention.

Steel's final assertion regarding elephant foot care was: "Diseases of the feet of the elephant are numerous and severe, and such as liable to absolutely incapacitate him for service. **They are mostly due to want of care in his management and so are preventable**" (emphasis added).

LESSONS LEARNED: PRESENT-DAY ISSUES IN ELEPHANT FOOT CARE There are many papers on foot diseases in nineteenth century and present-day veterinary journals (e.g., *Veterinary Journal, Medical Examiner, Journal of Veterinary Science*) that draw on experience with working and captive elephants in Asia. Unfortunately, it seems they have been ignored by present-day veterinarians and managers in the West, determined as they are to reinvent the wheel.

Evans's (1910) magisterial work is still consulted by elephant veterinarians in India. Evans devotes a whole chapter to diseases of the feet and refers extensively to Steel. Identification of foot diseases, as in Steel, follows the indigenous tradition, and the prescribed treatments draw heavily on traditional lore. Of the 256 drugs listed by Evans for use in the treatment of elephants, 133 are leaves, bark, pith, and root (or the decoction) of local shrubs, plants, and trees. I take courage in both hands when I mention this because it may inspire some people to write patents for them. In India, we have just managed to save our *neem* tree from the iron clutches of Intellectual Property Right laws, and a battle is raging over *basmati* rice.

The next big name in the subject of management and care of elephants is Milroy (1922). He distilled the diagnosis of various adverse medical conditions of elephants' feet into two basic categories: *kari* and *sajan*. The main difference between the two, as most of us understand it today, is that *kari* is a penetrating sore, whereas *sajan* is a fungal infection of the surface that, if neglected, may lead to *kari* and invite secondary infections.

Most veterinarians in India now treat *sajan* with topical antifungal drugs and external application of disinfectants, while insisting that the foot is kept dry. *Sajan* occurs mostly on the back feet, confirming the suspicion that it is caused by making the animal stand in an unclean stall, including its own excreta. *Kari* is still treated by scraping away the dead flesh and granulations, forcibly syringing the corroding wound with a mild solution of carbolic acid, and applying antibacterial ointments.

The traditional cauterizing agent for *sajan* was *hookah panee* (Steel 1885) or "hubble-bubble" water. (*Hookah:* "Oriental tobacco-pipe with long flexible or rigid tube, smoke being drawn through water in vase to which tube and bowl are attached;" *hubble-bubble:* "a rudimentary form of *hookah.*" [Steel 1885]. *Panee* is, of course, water.) This agent was nothing more exotic than a thin solution of nicotinic acid and water with perhaps a dash of tar and other such noxious matter that diffused into the water from the smoke. By the beginning of the nineteenth century, the fashion of *hookah* smoking among the expatriate British community in India almost died out. The British changed the cauterizing agent to nitric acid, and then to diluted carbolic acid, which is still the standard prescription. Perhaps the use of *hookah* water should be given another look. Diluted nicotinic acid could prove to be less damaging to healthy tissues than nitric or carbolic acid. Currently, powerful antibacterial and disinfecting drugs have been added to the veterinarian's arsenal; the spectacular and the expensive remain the surgeon's prerogative.

One of the latest Raj writings on the management of working elephants recognizes foot disease in elephants as a serious problem (Ferrier 1948). Ferrier's observations were based on traditional wisdom. *Kari* is not mentioned by name, perhaps because it is not a Burmese term, but corroding ulcers are described in detail.

Sanyal (1892) refers to the note by Wilberforce Clarke (1879) on diseases of elephants, but chooses to ignore foot diseases in elephants. Even Crandall (1964) shows little interest in the diseases of elephants. It remained for Schmidt (1986) to address the problem and point out that: "The feet of elephants, both in captivity [zoos] and in work camps, are probably the single greatest source of medical problems which confront veterinarians working with elephants." This is a fact that even the Western managers and veterinarians working with Asian elephants had realized more than 150 years ago. Schmidt (1986), describing abnormal medical conditions of the feet, does not really break new ground. A comparison between Steel, Evans, Milroy, and Schmidt would be instructive (Table 12.1).

Fowler (1993) questioned the concept of the disease laminitis on the ground that elephants' nails do not have laminae; thus, they could not develop laminitis. He has since revised his views (personal communication). Laminae of elephants' toenails are well described in Steel (1885): "The digits run obliquely downwards, the end bones each lying within one of the toe-nails . . . on the anterior surface of this small bone are attached the sensitive laminae which fit in between the horny laminae of the toe-nail; they much resemble those of the fingernail of man." The main lesson on laminitis is also ably summarized by Steel (1885): "It has been described as Laminitis from its resemblance to the disease of that name as affecting the horse—**but the main seat of inflammation is, here, the sensitive sole**" (emphasis added).

CONCLUDING THOUGHTS Mahouts, managers, and the veterinarians in charge of working elephants have always been acutely aware of the foot disease problems in elephants that can render an animal unfit

TABLE 12.1—Foot problems described in historical and current references.

Steel (1885)	Evans (1901)	Milroy (1922)	Schmidt (1986)
Foot Problems			
———	———	———	Overgrown sole [A zoo problem]
Thullee [form of *sajan*]	*Thullee*	———	Sore feet
Kandi/kari (penetrating abscess of feet and nails)	Laminitis	*Kari*	Abscessation
Cracked Heel (*Sajan*)	Cracked Heel (*Sajan*)	Cracked Heel (*Sajan*)	Cracked Heel
Cracked Sole(*Kari*)	Cracked Sole (*Kari*) (abscess of feet)	Cracked Sole (*Kari*)	———
Nail Problems			
Horn tumor and overgrowth with distortion of nails.	Warty growth around nails; ingrown and overgrown nails.	———	Split nails; Overgrown nails; ingrown nails.

for work, which is logical since fit working animals are their bread and butter. But zoo managers have been late to understand the problem. In fact, managers woke up to the problem only when importing wild-caught animals was banned under CITES (Convention on International Trade in Endangered Species) rules. Before this ban, it was much simpler and cheaper to buy one's requirement directly from the market.

However, the point is not that the awareness of foot problems in captive elephants among zoo managers has been late in coming, but that awareness has been growing, along with a keen desire to tackle the problem. Mikota et al. (1994) reported that medical problems of the feet were found in 50 percent of the 189 animals studied. They also pointed out that there had been no formal studies of the organisms encountered in elephant foot infections.

One purely technical point needs to be mentioned. The term "captive elephants" is usually equated with zoo animals. Saddle sores, a major problem with working elephants, are rarely mentioned in the literature published in North America. Although the term is used in the titles of many articles, it should be specified that zoo animals are being described.

For quite some time, research has been recognized as one of the main functions of zoos. Those of us from other regions of the world expect a lot of input from the high-tech zoos in North America toward the welfare and proper management of the species, both wild and captive. While it is understandable that the main concern of the managers in the West is for the animals in their charge, a more general approach and concern for the welfare of the species, I feel, would be in keeping with the spirit of the times.

Abnormal medical conditions of the feet continue to be determined clinically. Laboratory analyses and examinations to identify pathogens that cause foot conditions are still lacking. As Mikota et al. (1994) pointed out, there are no formal studies of organisms encountered in foot infections.

We in India can afford to wait for solutions, for unlike our western colleagues, we can still take the easy way out: restocking captive populations from the readily available pool of wild-caught stock. This easy alternative is no longer available to the countries without wild elephants; hence, the sudden sense of urgency. In the range countries this easy option is still available (although, I very much fear, not for long), and there is no sense of urgency yet. Human nature, let us face it, tends to be the same everywhere. Therefore, in the range countries, those who care are looking to well-equipped zoos to come up with solutions. This is as much for the benefit of the species as for the good of the people who have chosen elephants as their way of life. We can wait. After all we have been waiting for more than two and a half millennia. What are a few more years?

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13

SPLIT NAILS, ABSCESSES, AND CUTICULAR FLUID POCKETS

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During either long droughts or too much moisture, his feet become liable to sores that render him noneffective for months. Many attempts have been made to provide him with some protection for the sole of his foot but from his extreme weight and particular mode of planting the foot, they all have been unsuccessful. (Sir J. Emerson Tennent, 1861. *Sketches of the Natural History of Ceylon*)

INTRODUCTION As one peruses the historical and present-day literature on elephants, one constant that is found is foot problems. For relatively few types of foot problems, there are many types of treatments. We discuss two common problems: split nails and abscesses and similar lesions. We also discuss treatments for healing them. A third problem, fluid pockets at the cuticle, is somewhat unusual, and we present our description and treatment for this problem.

SPLIT NAILS A split nail is defined as a crack that runs roughly perpendicular from the bottom of the nail to the cuticle, exposing the quick. One theory for a cause of a nail split is that the nail was allowed to grow too long. Other contributing factors may include digging, kicking, or obesity. As a general guideline to determine proper nail length, the leading edge of the nail should not touch the ground when the animal is standing on a flat surface. The nails may be rounded on that edge to help properly distribute the pressure and avoid splitting.

Many treatments for split nails have been tried. The splits have been filled with various bonding materials in an attempt to bond the nail together and prevent further splitting. Acrylic patches (Johnson and Nestale 1996) and epoxy (Rakes 1996) have worked in managing split nails. Chemical agents have been used to prevent infection while the splits are healing and include: Kopertox, Metox, Supertox (Kopertox mixed with acetone), copper sulfate, zinc acetate liquid and gel, furacin ointment-DMSO, Nolvasan, and Wonder Dust, to name a few. Corrective trimming, similar to what was described by Blasko (1997), seems to have the most promise. Occasionally, the top edge of the split, towards the cuticle, can be notched to prevent further splitting, although our recent experience leads us to believe that this is not necessary. The split should be cut in a V-shape that extends down to the live tissue. A determination is first made as to which side of the nail the split should grow towards. Using a rasp, the length of that side is made shorter than the length of the other side. Secondary infection in the split is prevented by soaking the foot daily for 20 minutes in a weak Nolvasan solution (1 cup of stock Nolvasan solution to 4 gallons of hot, but tolerable water). If the split has advanced into bloody tissue, then the site is treated with Wonder Dust for 3 to 4 days to dry the wound. As the nail grows the split will actually migrate toward the shortened end until it is eliminated. This may take a year or more.

ABSCESSES AND SIMILAR LESIONS Although the technical definition of an abscess is a compartment of putrid exudate, we will group it here with other infected lesions of the nail or sole and refer to them collectively as abscesses. Infections of the nail can also mean a breakdown of the laminae. As with split nails, the treatments have been extremely varied. Along with trimming away any necrotic tissue, we have used numerous agents on the resulting lesion area. These have included: Kopertox, Metox, triple dye, turpentine-pine tar, zinc acetate, zinc sulfate, silvidene, silver nitrate to cauterize the area, xenodine-DMSO, Biozidal gel and powder, silicone, ether, ether-silver nitrate, Vaseline, Vaseline mixed with bismuth, phenol, sugar, Wonder Dust, and Bondo, to name a few. By the way, mixing red with blue Bondo results in a gray color that doesn't stand out.

Soaking the foot in a variety of agents has also been tried. These include Hexol, formaldehyde, Epsom salt, hydrogen peroxide, Poviderm solution, Xenodine-DMSO, and Nolvasan, each with various results.

Our current treatment is producing the most promising results. This treatment includes trimming away as much of the infected material as is possible without the use of anesthesia. This involves trimming down to live tissue and may result in some bleeding. The foot is soaked daily in a hot, but tolerable, diluted Nolvasan solution for at least 20 minutes. On subsequent trims (every 7 to 10 days) the area around the abscess is beveled back. Live tissue should be touching live tissue, and there should be no hard edges against soft, living tissue, especially if the abscess occurs in a nail.

Beveling back the area around the abscess allows the wound to drain, rather than trapping exudate that would force the abscess further up into the foot. The entire healing process may take up to a year or more.

FLUID POCKETS *Fluid pockets,* for lack of a better name, refer to pockets of fluid that generally develop in the cuticle areas and between nails. Treatment for fluid pockets has been wide and varied. Their cause is not known, and there is no treatment that can totally eliminate them.

When the pressure in the fluid pockets is sufficient to allow detection by feel or by sight, they are opened. Sometimes they will burst open. They are occasionally pus-filled, but most of the time they are filled with clear, sterile fluid with a chemical composition similar to sweat. There seems to be a reoccurring cycle every 8 to 12 days in the same area. If they are left unopened, they track into one massive pocket along the cuticle line. Some have postulated that these lesions are induced by allergic reactions. Contact with laundry soaps or copper- or iodine-containing substances was thought to be the culprit. We eliminated as many of these substances as we could, for example by changing to bleach instead of other disinfectants, using paper towels instead of laundered towels, and eliminating many of the topical agents we were using to treat the affected elephant. A topical steroid preparation (Halog) was also tried but we have not seen positive results. Infrared light therapy was tried on one of the affected cuticles. We used a regime of 30 minutes of equilight once a day for 60 days. At the end of the trial period, there was no noticeable improvement in the foot compared to a similarly affected foot.

When these pockets are opened, the pocket lining looks similar to a fungal plaque. For a while, treatment consisted of antifungal agents. Lotromin powder and creme, Myconizol, silvidene, Clortrimazol, Fungisen, and Monostat7 were used. Other treatments have included Kopertox, Metox, triple dye, thymol, ether, Biozidal powder and gel, Wonder Dust, Bondo, Bactoderm, copper sulfate gel, zinc acetate gel, and Melaleuca oil, to name a few.

Currently we think that the problem may be mechanical. These pockets may form due to unnatural pressures put on the nails. One affected elephant, "Pet," is pigeon-toed. The inward rotation of her front feet causes abnormal pressure on the outer nails. On the rear foot, where the pockets form, fluid pockets may result due to an excess buildup of sole on the inside of the foot.

Current corrective measures include opening the pockets, soaking the foot in Nolvasan solution, and corrective trimming. Care must be taken not to do a radical trim, because an abrupt change in the angle of the foot may cause as much of a problem for the joints as it does for the wear pattern change. As we cannot positively identify the cause of the pockets and have not found an effective treatment, we are open to any and all suggestions. Please feel free to contact the authors with any thoughts or suggestions.

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14

OUCH, DO THAT AGAIN! TREATMENT OF CHRONIC NAIL INFECTIONS IN AN ASIAN BULL ELEPHANT USING PROTECTED CONTACT

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INTRODUCTION The Houston Zoo currently manages one male and four female Asian elephants (*Elephas maximus*) in a protected-contact system. Target training is used, without hooks. Since a chute area is not used, the animal is asked to voluntarily participate in the training. Like most other institutions, we perform routine footwork and have, on occasion, dealt with minor foot problems. Our bull, however, has presented more of a foot-care problem.

CASE HISTORY Thailand, "Thai," is a 33-year-old bull that arrived at the Houston Zoo in 1980. He has had chronic problems in his front feet for over 10 years. These problems consist of an infection under the fourth nails of both front feet.

Many medicinal remedies have been tried in an attempt to cure the infections. Some ideas came from our veterinarians, while other suggestions have come from various institutions including circuses, private individuals, and other zoos. It seemed that almost anything that was suggested was tried, even if the treatment sounded a little strange. This not only included medical treatments but also changing the exhibit substrate and adding wood chips to the floor of Thai's barn to absorb excess material and help keep his feet dry. If only something could cure Thai's problem.

Prior to using protected-contact training at the zoo, Thai was maintained in a no-contact system. Up until 1992 his feet were treated through a large foot hole in the barn door. His nails were treated opportunistically because of short staffing conditions and a variety of other priorities. Actual foot trims were difficult and dangerous and depended on Thai's mood and behavior, as well as the skill and availability of the staff.

In the summer of 1992, a training wall was constructed. Thai was easily trained to present his feet through an opening in this wall. This made foot care safer, and therefore, trimming and medicating his infections could be more aggressive. Besides routine footwork, many different trimming techniques were tried to excise the infected tissue. At times, trimming was deep, causing Thai pain. Analgesics were sometimes used, but for the most part Thai was trimmed without sedatives or analgesics, depending on his cooperation. Thai was bridged and rewarded for tolerating the pain and, therefore, would come back for additional trimming even after he had pulled his foot away.

Trimming the area alone did not provide the desired results, so Thai was also trained to soak his feet. This behavior was started by having him put his foot through the foot hole into a black rubber tub that was placed on top of an elephant tub. The black tub was kept on the keeper side of the wall so he would not be tempted to use it for enrichment.

His feet were soaked one or two times daily for 10 minutes in either Epsom salt or Nolvasan and water. He seemed to enjoy these foot soaks and rarely, if at all, did he try to pull the equipment into the yard through the foot hole.

In 1996, the elephant exhibit was renovated and included the construction of training yards, which made foot soaks much easier. Now we were able to put the black tubs in one of the small yards with him. At this time, a water heater was installed to provide hot water for the foot soaks.

Since he was already familiar with the rubber tubs from the training at the old wall, it didn't take long before we had him putting both feet in the tubs. A routine was quickly developed. His feet were first rinsed at the foot hole. He was then leaned into a perpendicular wall and held by a trainer, while another keeper slid the first tub under the wall. Given the command "tub," he then backs up and puts his left foot into the tub. When the command "tub" is given a second time, he places his right foot in the second tub in almost the same way. After the soak, he was brought forward and turned around to allow us to retrieve both tubs. At first, we had a big problem when Thai seemed to enjoy this routine so much that he insisted on wearing the tubs for a while before giving them back.

To find out the extent of the infections and if the treatments were helping, it was also necessary that Thai be desensitized to having radiographs taken of his feet. This procedure was employed once at the first wall with a small machine and several times at the new training yard wall with a much larger machine.

For the first radiograph, radio-opaque dye was injected into the hole in Thai's foot so the tract could be identified. Radiographs were taken to determine the depth of the infected tissues and to specifically see if there was any bone involved.

Thai was trained for this procedure by first teaching him to extend his leg through the foot hole and to place his feet, one at a time, on a custom built footrest. The footrest was designed so that his foot could rest at an

angle comfortable for him, while allowing us all the necessary angles for diagnostic radiographs. Once he was comfortable with placing both feet flat on the footrest, an old radiograph cassette was used to train him to hold steady while the plate was positioned at various locations around his feet. The final step in the training was to move the machine into Thai's view while he placed and held his foot in the proper position. The machine was moved closer until it was in the position required for the procedure. Thai was accustomed to working with numerous people around him, but it was necessary to add desensitizing ("desens") training to nonfamiliar staff and to add unfamiliar situations to his routine. Through protected-contact training and desensitization to various medical procedures, such as trimmings, foot soaks, and radiographs, we have not been able to cure his nail infections, but we have been able to maintain some control over these problems. The cure of these infections is not limited by Thai's unwillingness to cooperate, but is hindered by not finding the right combination of husbandry and medical treatment.

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PROCEDURE FOR NAIL RECONSTRUCTION AND TREATMENT FOR AN ASIAN ELEPHANT (*ELEPHAS MAXIMUS*)

ALLAN SEIDON

INTRODUCTION One of the biggest challenges in modern elephant management is maintaining healthy elephant feet. The exact cause of cracked toenails is unclear but may include nutritional, genetic, environmental, and/or traumatic factors. What we currently know about the etiology of cracking toenails is insufficient for prevention. Exchanging information about both successful treatment procedures, as well as unsuccessful attempts, is essential to the health of the entire captive elephant population.

The following case study describes a series of procedures that were used in efforts to stabilize and repair a split toenail in one of the El Paso Zoo's female Asian elephants, Mona. Mona was born in the wild in approximately 1953. She has been continuously maintained at the same zoo for about 42 years. Between 1989 and 1996 her foot problems worsened; possibly this was age-related degeneration. Until approximately 1992, there was no set routine for normal foot care. The staff at that time had limited knowledge and experience in basic elephant husbandry. The limited foot work performed was more corrective than preventive. Even with the limited foot care, Mona had relatively few incidents of split nails until 1990. In 1992, the elephant staff implemented a regular schedule for elephant foot trimming. Each foot (both pad and nails) has since been trimmed on a rotating schedule, with one foot being trimmed each week. Each foot is inspected daily. When small problems are detected they are immediately corrected.

Even with a set maintenance schedule, Mona continued to have problematic, periodic nail cracks. The zoo's veterinary staff suggested that changing her diet might help correct her nail problems. Through Mona's formative, juvenile, and most of her adult years, her daily diet consisted of 16 percent protein "sweet feed" grain, alfalfa, a timothy grass/hay mixture, and at least 30 pounds of fruit and vegetables. In 1993 the diet was gradually changed from the sweet feed grain to Mazuri elephant supplements, and the general appearance of her grass/hay was subjectively improved. Alfalfa hay was completely removed from her diet, and she was fed only timothy or brome hays. The veterinarian added biotin (Mazuri number 9261 Biotin Supplement Tablet, Purina Mills, St Louis, Missouri, United States) in 1993, but as of 1994, there was no significant change in gross condition of her toenails. In 1994, vitamin E (Mazuri number 5M90 Elephant Supplement with vitamin E, Purina Mills) was also added to the diet in hopes that it would strengthen her nails. Since there were no serum vitamin E or biotin analyses performed, we are not able to evaluate blood levels of these compounds. However, the appearance of the animal's feet showed limited improvement. Bread and cracked corn were also added to her diet as enrichment treats in 1994. This gradual diet change and the routine foot work helped reduce cracking; however, it has not completely prevented reoccurrence.

CASE HISTORY In late 1993, Mona developed a severe crack at the distal edge on the left front, third digit nail. The staff was unable to stop the crack from continuing. Every time she put weight on the foot, the crack spread further, eventually penetrating the cuticle.

Understanding the progression of nail cracks requires a basic understanding of elephant locomotion. As weight is placed on each foot while walking, the sole of the foot expands, functioning as a shock absorber. The sole and digits spread as the weight is increased and elastically retract as the foot is lifted. This recurrent expansion and contraction, particularly on a packed surface or cement, widens an existing crack and extends it toward the cuticle. For an elephant of Mona's size, weighing approximately 9,000 pounds and having a sole diameter of 16 inches, the pressure, expressed as pounds per square inch (psi), can be approximately calculated. The area formula πr^2, where the radius (r) equals 8, gives $3.14 \times (8 \text{ in.})^2 = 201 \text{ in.}^2$, and one-half (at least) of the total weight over this area when stepping is $4{,}500 \text{ lbs.}/201 \text{ in.}^2 = 22.4$ psi. Even without the added force of locomotion, this pressure is absorbed or distributed by spreading the foot, and the crack is pulled apart with every step.

The elephant staff attempted to remedy the cracking problem by performing several foot-trimming techniques. The first method involved beveling the distal facial portion of the nail. Using a rasp, the bottom of the nail was beveled to a 20 to 30 degree angle. By effectively shortening the nail and allowing the bottom of the foot or pad to grow, the split nail did not bear any direct weight. This procedure did not prevent the crack from extending. The second method attempted was to completely remove the crack from the face of the nail using a standard hoof knife. However, upon further examination, this method was not feasible. The crack had already extended into the soft tissue and removing

it would cause too much damage to the underlying nail structure. Since the crack was too deep to completely remove, the third method was to groove the face of the nail perpendicular to the crack. Prior to the crack extending past the cuticle area, a rasp was used to cut a horizontal groove approximately 0.5 cm deep and 2 cm in length above the top of the split. However, the crack was already too critical for this technique to work. It could not compensate the expansive pressure of the elephant's weight. We were unable to stop the split from continuing into the cuticle.

By the time these different treatments were completed, the nail had continued to weaken and widen. There was a 1 cm diameter wide triangular fissure that started at the base of the nail and extended into the cuticle. No evidence of infection was present, although the veterinary and elephant staff became increasingly concerned with the potential for a deep infection. If the problem was not corrected immediately a more serious one could develop. Since previous corrective procedures had been unsuccessful, further research was done to find an effective method to arrest the progression of the splitting.

Placing a bonding material across the fissure was suggested. The ideal material would need to support the separated nail and prevent the animal's weight from expanding the fissure. Most of the products available are either potentially toxic to the animal and/or would irritate the soft tissue while drying. A quick-drying epoxy adhesive reinforced with fiberglass-woven (polyester) fiber matting was considered our best option. It is nontoxic once dry and initial bonding only required 5 minutes drying time and approximately 45 minutes for maximum strength. This epoxy creates an exothermic reaction, generating a small amount of heat during the curing process, but Mona did not demonstrate any aversion to the heat. The compound used was Poly Strate 5-Minute Epoxy (Devcon Corporation, Danvers, Massachusetts, United States), a rapid-curing, general-purpose adhesive/encapsulate. In minutes, it forms a transparent, rigid bond or coating. Fiberglass (polyester) matting or cloth can be incorporated with the epoxy to maximize tensile strength. The fiberglass also minimizes potential fracturing of the brittle resin, which can occur if the epoxy is used alone.

Materials The following equipment was needed to complete this process:

1. Dremel Moto-Tool (Racine, Wisconsin, United States; it can be purchased at most hobby stores) or other hand-held, variable speed drill.
2. Fiberglass-woven (polyester) cloth matting.
3. Dental drill bit (spherical, 2 mm or 0.2 cm diameter).
4. Wood rasp (of the type a farrier uses on horses).
5. Standard equine hoof knives.
6. Elephant foot stand.
7. 70 percent isopropyl alcohol (for cleaning the surface of the nail).
8. Poly Strate 5-Minute Epoxy.
9. Disposable mixing container (plastic cup or coffee can).
10. Spreading and application tool (e.g., wooden tongue depressor to mix and apply the epoxy on to the nail surface).

Application Procedure

1. Place the foot with cracked nail on the stand. This will allow easy access to the problem area and help keep the toenail area clean and away from debris. **Important:** the elephant must **not** bear any weight on the foot that is being repaired until the epoxy has completely dried (30 to 45 minutes).
2. Remove necrotic or damaged tissue from the nail and split area.
3. Wash the nail area thoroughly and remove all debris with a stiff bristle brush.
4. Bevel the lower facial portion of the nail so that the nail does not support any of the animal's weight.
5. Clean area with alcohol to remove any oils and allow it to dry completely.
6. To enhance epoxy adhesion, roughen the entire surface of the nail with a rasp.
7. Drill shallow grooves over the entire face of the nail, approximately 0.5 cm deep by 1 cm long, using the Dremel tool and a 0.2 cm diameter dental drill bit. By using this type of drill bit, small tunnels and grooves can be created on the surface of the nail to assist epoxy adhesion. The grooves should **not** extend deep enough to cause hemorrhaging. The epoxy may cause irritation, and excessive depth may also weaken the nail.
8. Cut the fiberglass (polyester) cloth matting into approximately 2 cm by 4 cm rectangles. Six to eight pieces are sufficient.
9. Mix the epoxy in the disposable container, following th. directions and using a 1:1 resin to catalyst ratio.
10. Apply a thin coat of the epoxy over the entire nail and split area. Layer the fiberglass (polyester) cloth or matting squares over the crack and nail. Once the first coat is complete, continue to alternate layers of epoxy and fiberglass (polyester) cloth until the entire crack and most of the nail is covered. The fiberglass must be overlapped for strength. After each layer of cloth or matting is applied, cover it with a sufficient amount of epoxy resin to saturate the fibers until they lose their white color and appear transparent. Only then should the next layer of fabric and resin be added. Repeat the process until the fissure is well bridged and the face of the nail is covered.
11. After the epoxy has hardened sufficiently to feel dry and cool (approximately 15 minutes), rasp or cut off the extra cloth or matting around the perimeter of the nail.
12. Functional cure temperature is approximately 75°F. During cooler weather, a hair dryer can be used to aid in the drying process.

This procedure was the most successful and cost effective. A 1 ounce container of Poly Strate 5-Minute

Epoxy cost approximately three to five dollars, and one container may be used for two applications. This depends on the severity of the toenail split and how far it has progressed.

Healing The healing process in this case was as follows. Within the first couple of months that the nail grew out, it did not continue to split. Complete resolution required several months. The patching procedure was repeated several times, as the nail grew and the patch loosened. As the nail grew downward, the epoxy patch moved with the nail. It was imperative that the distal facial portion of the nail be beveled continuously with a rasp. To minimize the force applied to the patch and to ensure that the nail did not bear any of the animal's weight, the nail was beveled away, and the distal portion of the epoxy patch that moved with the nail was removed. Sections of the patch can separate from the nail. These sections should be removed from the surface of the nail as they occur. If this is not done the elephants are more likely to remove the patch themselves, or it may be lost when the edge is caught on objects. We found it more effective to replace the entire patch than to remove small portions. To remove the patch, we simply rasped, ground, or cut the existing patch. To ensure maximum adhesion of the new patch, the application procedure was repeated. One patch can last a maximum of 3 weeks, unless the animal removes it. In the case of Mona's severe nail crack, the epoxy patching procedure kept the nail from separating and the crack grew out completely in 4 to 6 months.

CONCLUSION We particularly recommend this procedure for severe nail cracks. The epoxy product is inexpensive, and the application procedure is simple. It was very successful for this case.

PRODUCT INFORMATION

Features of Quick Drying Epoxy Resins

- 5-minute fixture time.
- 100 percent reactive, no solvents.
- Good dielectric strength.
- Good solvent resistance.
- Bonds metals, fabrics, ceramics, glass, wood, and concrete (in combination).
- Cures fast for quick metal-to-metal bonding and repairs.
- Pots and encapsulates electronic components and assemblies.
- Seals against dust, dirt, and contamination .
- Fast-curing, thin set, bonding above 40°F.

Product Data

- Physical properties (uncured).
- Color: Clear.
- Mix ratio by volume: 1:1.
- Mixed viscosity: 8,000 to 10,000 cps.
- Working time (28 g at 75°F): 4 minutes.
- Functional cure (at 75°F): 45 minutes.
- Coverage (based on 25 ml): 152 $in.^2$ at 0.10 inches thick.
- Specific volume: 23.7 $in.^3/lb$.
- Percent solids by volume: 100.

Performance Characteristics (cured for 7 days at 75°F)

- Adhesive tensile shear, ASTMD1002: 1,400 psi.
- Operating temperature, dry: -40°F to +200°F.
- Cured density ASTMD792: 1.10 gm/cm^3.
- Cured hardness, ASTMD2240: 85 D.
- Dielectric strength ASTMD149: 490 volts/mil.

Chemical Resistance (7 days room temperature cure, 30 days immersion at 75°F)

- Kerosene: Very good.
- Methanol: Unsatisfactory.
- 3 percent Hydrochloric Acid: Very good.
- Toluene: Very good.
- Chlorinated Solvent: Unsatisfactory.
- Ammonia: Very good.
- 10 percent Sulfuric Acid: Very good.
- 10 percent Sodium Hydroxide: Very good.

ACKNOWLEDGMENTS Special thanks to Mark Lloyd, D.V.M., for his help in this project.

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16

OCCURRENCE AND TREATMENT OF NAIL/FOOT ABSCESSES, NAIL CRACKS, AND SOLE ABSCESSES IN CAPTIVE ELEPHANTS

GARY WEST

INTRODUCTION More than 50 percent of captive elephants develop some sort of foot-related disease during their lifetime (Fowler 1998), and in one study, foot problems affected 50 percent of captive elephants (Mikota et al. 1994). Foot-related conditions and arthritis are the leading cause of euthanasia in captive elephants in the United States. In one survey, 3.7 percent of elephants had chronic foot infections, and seven were euthanized (Mikota et al. 1994).

The elephant toenail is a nonweight-bearing structure, and conditions such as abscessation and cracks are directly correlated to nail wear, inactivity, or the lack of adequate maintenance in captive situations. Traumas, such as a stone bruise or penetrating injury, may also cause cracks or abscesses. By far the most common place to see serious foot-related disease is the front feet. This is likely due to the increased weight load that is placed on these feet, amounting to approximately 60 percent of the elephant's weight.

Foot problems are also present in wild populations and occur in working, forest elephants in Asia. But forest elephants get adequate exercise, which helps maintain foot health by wearing down foot structures. Foot problems are often due to lack of adequate maintenance by mahouts (V. Krishnamurthy, personal communication).

Early diagnosis and treatment is critical in elephants with foot disease to prevent the spread and worsening of the condition. Treatment and husbandry changes are essential to halt the progression of foot diseases and, if done in a timely fashion, can reverse the disease process.

In this chapter, I was asked to compare the occurrence and treatment of foot problems in circus versus zoo elephants to determine if increased activity level decreases foot problems in captive elephants. Increased activity level is directly related to decreased foot and joint problems. I have dealt with both zoo and circus elephants, but it is difficult to see a significant difference in the occurrence of foot disease between groups. I have worked with a much larger number of circus elephants. Elephants in both zoo and circus situations have foot-related diseases, but in my experience, the incidence for both groups is lower than the 50 percent figure published for all captive elephants. Nail and foot abscesses are the most commonly occurring conditions. The incidence of foot abscesses, in my experience, seems to be similar in both groups. Both circus and zoo personnel that I have worked with have excellent maintenance programs that greatly reduce the incidence of foot problems. Good elephant managers are essential to the care of elephant feet in captivity. I have worked with free- and protected-contact systems, and both allow keepers to maintain the feet of their elephants.

Many factors and predisposing conditions are involved in the etiology of foot disease in elephants. I have listed them in order of importance, based on my experience.

THE ETIOLOGY OF ELEPHANT FOOT DISEASES

Activity Activity allows the elephant to wear down the structures of the feet normally. In the wild, elephants move or walk up to 18 hours daily in search of food and water. Although captive elephants may have large enclosures, they do not need to, and sometimes they cannot or often will not, move around. This contributes to the development of foot disease and arthritis. In most captive situations, elephants must be encouraged to exercise.

Maintenance Preventative trimming is used to detect any developing problems and to keep excessive growth to a minimum. This is needed less if the elephant is encouraged or forced to exercise, thus naturally wearing down the structures. Feet should be examined daily. Any excessive growth or necrotic tissue should be trimmed away.

Preexisting Disease or Other Conditions Arthritic elephants tend to develop foot conditions more commonly. This is due to uneven weight distribution and lack of mobility. Overweight elephants commonly develop foot problems. Conformational abnormalities also contribute to foot pathology (e.g., pigeon-toed).

Substrates Unyielding, hard surfaces, which are present in most elephant barns and yards, also contribute to foot diseases. This may be due to trauma to foot structures, development of arthritis, and lack of areas where the elephants can dig with their feet, which is a normal behavior of elephants in the wild. Also, chronically wet or dirty substrates can encourage proliferation of

pathogens that invade the feet of elephants, usually after some sort of trauma (e.g., stone bruises).

Age Older elephants frequently develop foot problems, likely due to diseases, such as arthritis, and to reduced activity levels.

Nutrition Lack of good nutrition is not a real problem in captive elephants in North America. However overfeeding and insufficient exercise has led to many overweight captive elephants. This causes abnormal stress on the joints and feet.

NAIL INFECTION/ABSCESS AND FOOT ABSCESSES In my experience nail infections are the most commonly occurring elephant foot condition. Nail infections, if not treated promptly, hold the greatest potential for subsequent serious sequelae, such as osteomyelits. Often nail infections are a symptom of a variety of problems related to the elephant's captive environment.

All of the above predisposing factors can contribute to the development of nail infection and abscessation of the elephant foot. The exact etiology of nail infections and abscesses is unknown. There is likely some sort of microtrauma to the nails that allows bacteria to invade and have a necrolytic effect on the nail tissues. Often a black tract is detected on the weight-bearing surface of the nail. The tract may spread to the cuticle, and exudate may be seen oozing from the nail-cuticular junction. If caught early, these tracts can be trimmed to reveal healthy tissue. In one treatment, vascular tissues are avoided, and the tract is exposed to air. Some bleeding with trimming is usually not a major problem. Often an astringent agent, such as gentian violet, brilliant green, or a proflavin combination, is applied, and the area heals quickly. Copper naphthenate (Kopertox, Fort Dodge Laboratories, Iowa, United States) has also been used with success on these lesions.

If not discovered and treated early, foot infections can become quite extensive and will have longer healing and treatment times. They may extend into the lamina and corium of the nail. If the infection is longstanding, some white, fleshy tissue usually appears in the infected area of the nail or foot.

Multiple abscesses can develop in the same foot and can involve several nails. These are challenging and take a long time to treat because tissue growth is slow and excessive trauma to vascularized tissues must be avoided. Corrective trimming sometimes takes months or years. Necrotic tissue debridement should be done in conjunction with exercise and soaking the foot in chlorhexidine diacetate (Nolvasan, Fort Dodge Laboratories) and hot water solutions. In other countries, sucrose is often applied to infected tissue in humans (M. E. Fowler, personal communication). This sugar appears to have an osmotic effect on the tissue, causing bacterial lysis and drawing moisture out of the lesion. I have personally used this treatment in combination with trimming, soaks, and exercise and have had good results.

With extensive swelling or cellulitis of associated foot structures, systemic antibiotics are sometimes used in combination with anti-inflammatory medications. These abscesses and infections must be treated aggressively, or extension into the lamina and then periosteum of the phalanges can occur. This will lead to osteomyelitis and may require surgery. All serious infections involving the foot should be radiographed, especially those involving the nails. The distal phalanx has a close association to the nail, and in most instances, osteomyelitis must be ruled out before treatment is begun.

Osteomyelitis is often treated with surgical intervention, but this may not always be necessary. Several factors should be considered before surgery is done. First, if the spread of infection can be halted with other treatment and management practices, surgery may not be needed immediately. Also, the animal's age, health, and tolerance for postoperative treatment need to be considered. An older elephant with advanced arthritis may have a difficult recovery. With progressive osteomyelitis, however, surgical treatment is necessary and has been successful (Gage 1998, Cooper et al. 1998). Occasionally the progression of bone lysis stops spontaneously, as evidenced by monitoring feet with radiography (Sorensen 1998). If only the third phalanx is involved, nonsurgical treatment can be tried and the foot monitored radiographically (Boardman et al. 1998).

Case Studies The following are cases of foot abscesses in elephants. Case one has infections primarily involving the nails of the front foot. This is the most common condition seen in captive elephants. Case two has abscess formation interdigitally and is managed differently.

CASE ONE This case involves a 40-year-old Asian elephant with multiple abscesses of the front foot and nails. There are several factors predisposing this elephant to foot disease, including: 1) arthritis in the contralateral forelimb causing increased weight bearing on this foot; 2) relative inactivity; and 3) housing on hard substrates.

Over a period of 2 years, trimming devitalized tissue and wound hygiene helped relieve the bacterial infection and allowed new tissue growth to replace devitalized and trimmed tissues. Trimming was used in combination with warm water and chlorhexidine diacetate soaks. Also, an exercise routine was implemented for this elephant. She was walked daily and the distance was gradually increased until the elephant was walking about 1 mile daily (A. Roocroft, personal communication). The increased exercise allowed the animal to increase mobility of her joints, increase muscle tone, and get in better physical condition. On lesions like these, trimming is done gradually and is accomplished

FIG. 16.1—Interdigital abscess.

FIG. 16.2—Close-up of interdigital abscess.

by slowly trimming and beveling necrotic tissue, allowing the abscess to be pushed out and heal from within. This case illustrates the most common foot disorder I have seen in captive elephants. If treated early, cases do not often become this severe.

CASE TWO This case involves a 33-year-old Asian female elephant with interdigital abscess formation. She is overweight and arthritic in both front limbs, and even though she has access to a large paddock, she does not move around much during the day. Lack of interdigital space between the nails also contributed to infection because the infected areas could not drain well. Large, fleshy, white growths often protruded interdigitally between toes two and three or three and four (Figures 16.1–16.2). These lesions seem to be exacerbated by wet conditions. To help identify the etiology of these tissues, they were biopsied.

The surrounding tissues were infused with 2 percent lidocaine. Then a section of this tissue was surgically resected. A part of the lesion was placed in formalin and another part in culture media for aerobic and anaerobic culture. Histopathological diagnosis indicated marked, focally extensive chronic suppurative eosinophilic panniculitis and dermatitis with fistulation. No neoplastic or infectious agents were present. The pathologist gave a good prognosis, and treatment included curettage and antibiotic therapy. Acid-fast and fungal stains did not reveal any pathogens; however, *Proteus mirabilis, Enterobacter* spp., *and Bacteroides* spp. were present. These organisms showed resistance to many antibiotics commonly used in elephants, including amoxicillin, ampicillin, cephalexin, neomycin, tetracycline, amikacin, and trimethoprim-sulfa.

Swelling and cellulitis of the distal limb associated with these foot lesions made systemic antibiotic therapy appropriate. First, ceftiofur was given parentally and metronidazole was given as a suppository (Gulland and Carwardine 1987). No improvement was seen, so florfenicol (Nuflor, Schering-Plough, New Jersey, United States) was given at a metabolically scaled dose, based on a labeled 20 mg/kg recommended dose for cattle. This seemed to help decrease the amount of swelling and the associated cellulitis.

Additional treatments for this condition included trimming to create space between adjacent toes. Trimming was also done ventrally to allow this abscess to grow out in this direction. Footbaths and soaks also helped resolve the infection and softened the tissue for trimming. To aid healing, exercise was added gradually. Currently, we are continuing the use of these various treatments and are considering cryosurgery, which has been used successfully in similar lesions (Sorensen 1998). We are also considering using carbon dioxide laser debridement of the interdigital lesions to increase the space and drainage between adjacent toes. In foot abscesses like this one, ultrasound could also be used to visualize the extent of the infectious process and to monitor healing (O'Sullivan and Junge 1998).

NAIL CRACKS Nail cracks are likely due to overgrowth of the nail, trauma to the nail, or constant exposure to hard or wet substrates (Figure 16.3). Nail cracks are unstable, expand under the great weight of the elephant, are quite common in hind feet, and do not usually develop into serious problems. The key to treating nail cracks is trimming or rasping the nail so that the weight-bearing area is minimized immediately adjacent to the crack. The crack should be trimmed and explored to ensure there is no necrotic tissue, which could serve as a nidus for abscess formation. An effective technique is trimming the smaller side of the crack so that it does not bear weight (Blasko 1997). To decrease weight bearing, this side of the crack needs to be rasped and trimmed every 14 to 30 days with an equine hoof knife. The crack will grow out in that direction over a period of several months.

FIG. 16.3—Severe nail crack.

A horizontal notch in the nail above an incomplete crack does not seem effective in halting extension of nail cracks. Although I have not used acrylic and epoxy patches, they seem to be effective in treatment of extensive nail cracks (McConnell 1996, Rakes 1996). Before patches are applied, however, it is essential that the crack be cleaned of all necrotic tissue and other debris.

SOLE ABSCESS Abscessation and undermining of the sole and its separation from the dermal tissues is a difficult condition to treat. Fortunately it does not occur commonly. The etiology is usually based on a penetrating injury or trauma. Infectious processes may extend from the toes or other soft tissue structures. Treatment is a long and gradual process because healing of the sole slipper epithelium is slow (i.e., a year or longer). The undermined sole must be trimmed away gradually, and a boot or sandal may be helpful in protecting the tender tissues under the sole.

The foot must be kept clean and dry. Topical disinfectants can be applied, but topical agents must be used with caution because some may inhibit reepithelialization and delay the healing of the epidermis. Also, these medications may not adhere to the underlying dermis. Copper sulphate may help harden tissues (Schmidt 1986). Dilute footbaths are often used in conjunction with systemic antibiotics to prevent infection of the exposed dermis and corium. Footbaths may contain a variety of disinfectants, such as iodine-based solutions (Betadine, Purdue-Fredrick, Connecticut, United States) or chlorhexidine diacetate. Topical agents, such as trypsin-based enzyme spray (Trypzyme spray, Veterinary Products Laboratories, Arizona, United States), may also help debride necrotic tissues as the sole heals.

Chitosan has been used on a severe sole abscess in an African elephant in combination with a sandal as a protective cover (Houser et al. 1998). Trimming of necrotic tissue and systemic antibiotics were also used. The foot was cleaned daily with tap water and then rinsed with saline. The chitosan solution was then applied and the sandal attached to the foot. This may be a promising treatment for undermining sole abscesses by preventing bacterial infection and allowing epithelialization of the sole. In my experience, chitosan hastened healing in comparison to treating sloughed sole tissue with other medications. Keep in mind that healing of large areas of the sole's epithelium is slow and will require prolonged and intensive treatment.

SUMMARY There is rarely one cause of foot problems in captive elephants. Unless there is trauma or injury to the foot, diseases of elephants' feet have multiple etiologies. Increased activity and exercise is beneficial for all captive elephants; however, most animals have no motivation to exercise in their enclosures.

General guidelines for elephant foot care and maintenance include:

1. All four feet should be examined daily. Trim to remove any excess growth or necrotic tissue (usually with an equine hoof knife) and search the sole for stones or other foreign objects. Black tracts should be trimmed to healthy white tissue, avoiding vascular structures.

2. Observe elephants in movement to detect lameness, which could indicate the onset of degenerative joint disease, a foreign object in the foot, infection of deeper structures, or injury to the foot.

3. There are few published guidelines for use of anti-inflammatory or antibiotic agents in elephants. When appropriate, use empirically derived or metabolically scaled doses.

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17

SIRI'S DILEMMA: MANAGEMENT OF A CHRONIC FOOT PROBLEM

STEVE STAHL AND CHUCK DOYLE

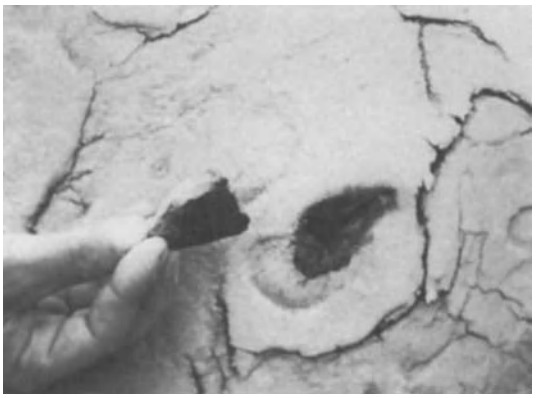


FIG. 17.1—2 September 1985. Siri, a female Asian elephant, stepped on a sharp stone that became embedded in her left front foot.

FIG. 17.2—2 September 1985. On the day of the injury, initial trimming was necessary to assess the extent of the damage.

FIG. 17.3—26 September 1985. In the weeks that followed, the condition of the foot declined. Surgery was performed to remove necrotic tissue and evaluate the degree of infection. The surgical area was 3 inches in diameter and 4 inches into the pad.

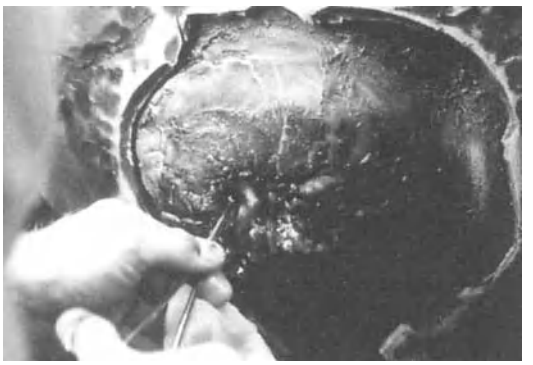


FIG. 17.4—2 October 1985. Following surgery, the wound was packed with gauze soaked in Betadine, DMSO, Furacin, and formaldehyde to stop foreign material from entering the wound and causing infection.

FIG. 17.5—20 October 1985. Despite additional efforts to prevent infection, such as hot Epsom soaks and penicillin injections, within a week the foot began to swell and abscesses broke out between the toes.

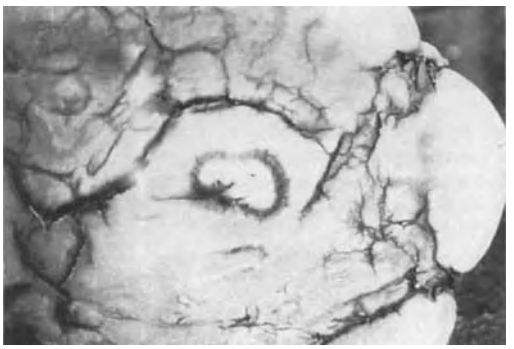


FIG. 17.6—15 November 1986. A year after the surgery, the pad appeared to be healing. There is still a ventral drainage hole present, but the abscess was still not draining well (see Figure 17.9).

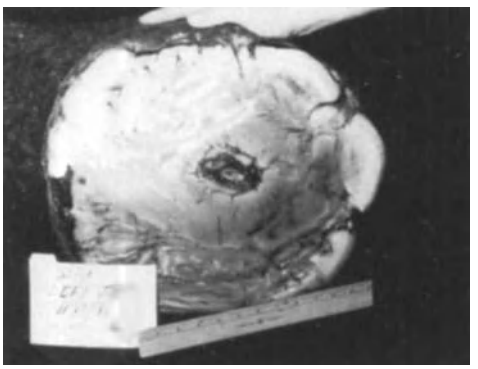


FIG. 17.7—17 November 1986. After pad trimming, it was found that the wound had only superficially healed.

FIG. 17.8—17 November 1986. Due to moisture, which was trapped inside the wound as it healed, the pad failed to properly attach to the connective tissue and sloughed off.

FIG. 17.9—15 May 1987. The pad was trimmed to form an inverted dish shape to allow proper ventral drainage. The area was then washed and treated with Kopertox four times a day.

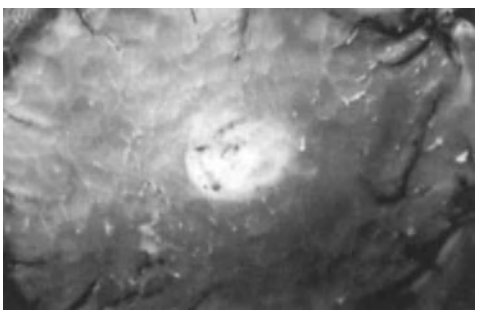


FIG. 17.10—7 March 1988. The old lesion area was still soft and tender. With proper trimming it was healing from the inside out.

FIG. 17.11—3 June 1989. A protective boot was designed to prevent moisture and foreign material from entering the wound. This boot allowed Siri to maintain her normal exercise routine while her foot was healing.

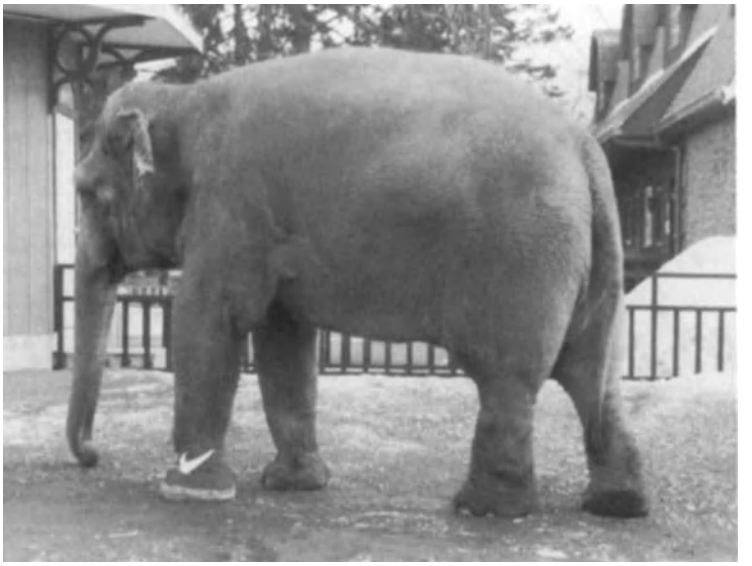


FIG. 17.12—Siri in her new boot.

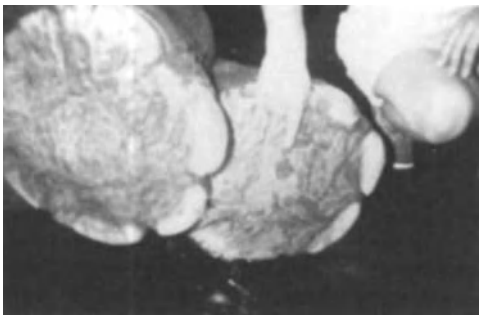
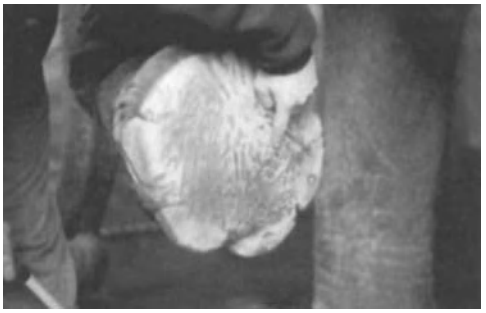


FIG. 17.13—17 July 1989. Finally, following continued Kopertox treatments, use of the boot, and maintaining an open ventral drainage tract, the foot healed properly.

a



b

FIG. 17.14a and b—18 December 1997. Twelve years after the initial injury we are still treating the area with Kopertox twice a day. Fortunately, for the past 9 years Siri has had no serious recurring foot problems.

18

MAKING A PROTECTIVE BOOT FOR AN ASIAN ELEPHANT

KATE WOODLE, TERRI KEPES, AND CHUCK DOYLE

INTRODUCTION In August of 1985, Siri, a female Asian elephant, stepped on a sharp stone that cut and embedded into her foot. The stone was removed immediately, but, in spite of treatments, an abscess developed. The abscess was treated over the next year. It healed leaving only a small crack. It was so small that it was hardly noticeable. However, when the wet slushy weather returned the next winter Siri started to have problems with the foot. Water and mud got into the crack, eventually causing the pad to separate from her foot. Koppertox was used to help dry out the foot, but it did not entirely eliminate the problem. It was felt that the only way to prevent this condition from getting worse was to keep the foot clean and dry. Since this was practically impossible in winter without keeping the elephant inside, we decided to try to make a boot to keep the foot dry.

MATERIALS

Latex
Cementex Latex Corporation
480 Canal Street, New York City, NY, U.S. 10012
Telephone: 212-226-5832

Plasticine or modeling clay,
found at most art supply stores.

PROCEDURE

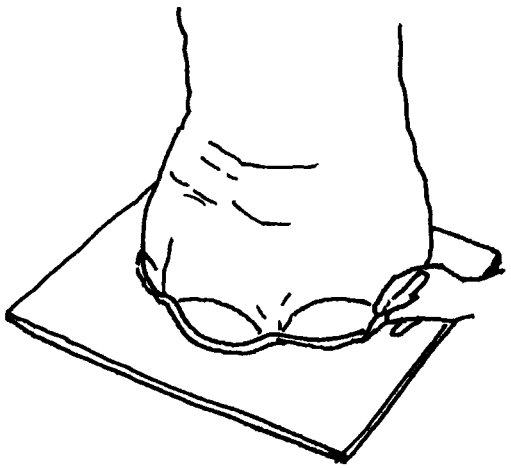


FIG. 18.1—Siri was asked to place her foot on a board. Chuck Doyle traced her foot and labeled the board. (Illustrations by K. Woodle)

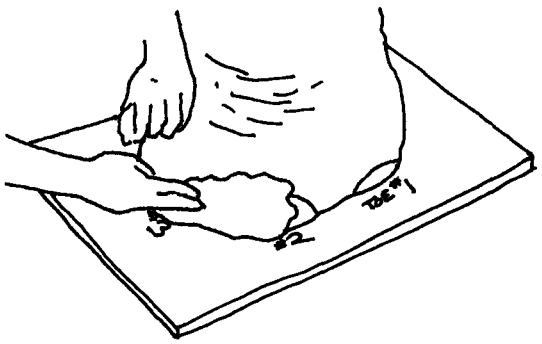


FIG. 18.2—Modeling clay was applied in sheets to form a mold of Siri's foot. Care was taken to make sure that the clay was attached to the board. A wall was built all the way around Siri's foot. Then the mold was carefully pulled from her foot.

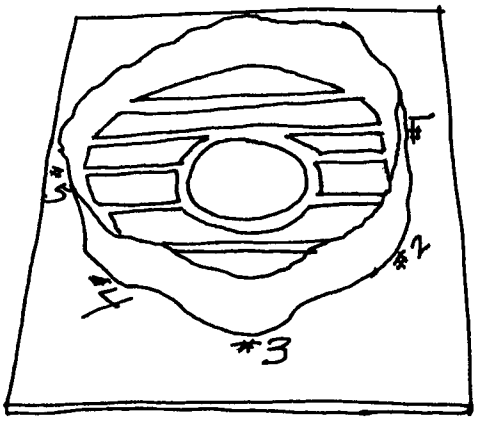


FIG. 18.3—Ridges were built out of clay. These became the treads of the boot. In order to put less pressure on the injured portion of Siri's foot, a circular depression was left in the center of the boot.

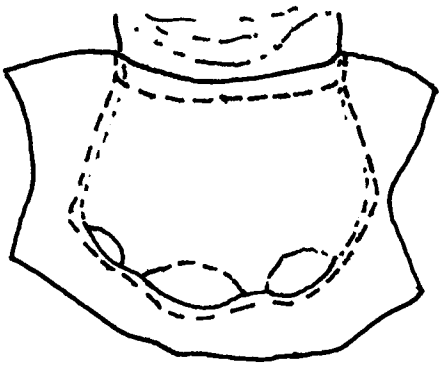


FIG. 18.5—To make the upper sections of the boot, canvas was placed against the front of Siri's foot. The foot was outlined with a marker at both the top and bottom and at about the midpoint on each side. This step was repeated for the back of her foot.

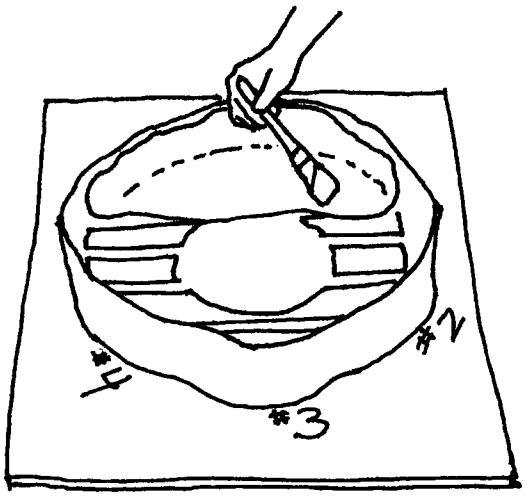


FIG. 18.4—First, the mold was coated with silicone spray, a mold-releasing agent. Next, liquid latex was painted into the mold. It took many layers of latex to buildup the desired thickness (⅜ inch). The circular area in the center of the boot was left thinner (¼ inch). When the last layer of latex was dry, the sole was peeled from the mold and trimmed around the top edge.

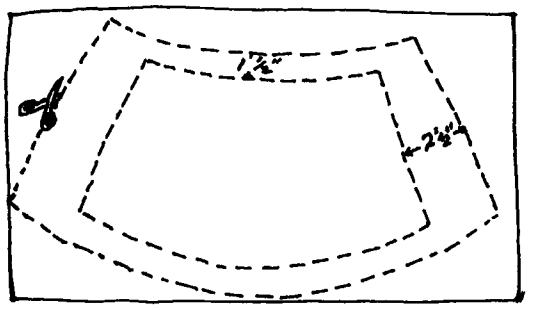


FIG. 18.6—To add material for the hems, 1½ inches were added to the top and bottom. Two and one-half inches were added to each side, which allowed the back to overlap the front and added material for the side hems.

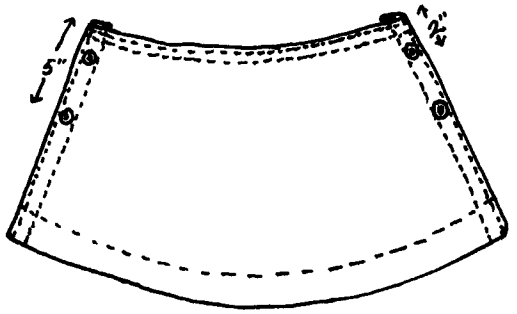


FIG. 18.7—The boot was hemmed on each end of both the front and the back, and grommets were added. The top was also hemmed. The hemming was done by a canvas company (Can Do Canvas), who volunteered their time. They also added the swoosh mark for decoration.

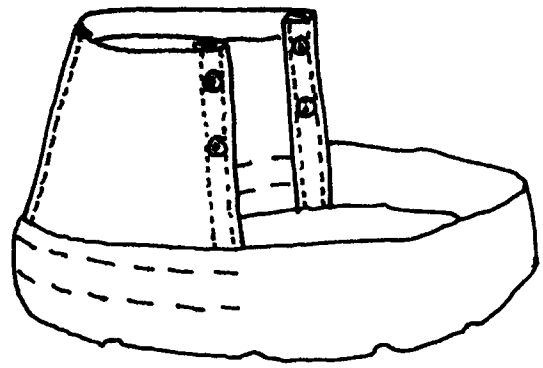


FIG. 18.9—The upper section of the boot was attached to the rubber sole by hand, using heavy waxed thread and a canvas-maker's awl. The back was stitched on first and then the front.

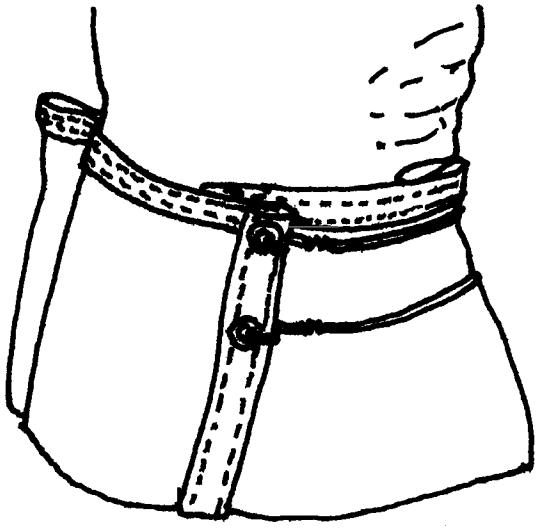


FIG. 18.8—The upper sections of the boot were refitted on Siri's foot inside out. This time they were fastened in place with small shock cords. Any necessary tucks that made the boot fit more snugly were pinned in place. The boot was returned to the canvas company, where the tucks were stitched and trimmed.

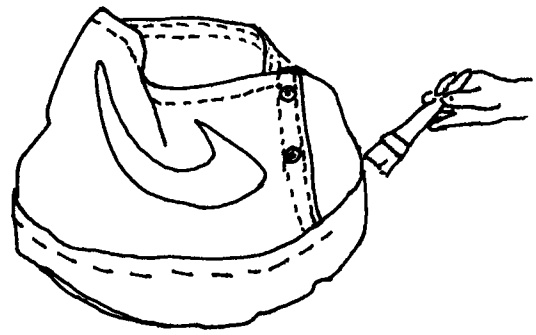


FIG. 18.10—Latex was brushed under the bottom edge of the canvas on the inside of the boot. This helped glue the loose edge to the sole. Next, latex was used to coat the canvas on the inside, up from the bottom and over the top row of stitches.

19

TREATMENT OF AN ABSCESSED FOOT PAD OF AN AFRICAN ELEPHANT (*LOXODONTA AFRICANA*) USING A SANDAL AND TOPICALLY APPLIED CHITOSAN

DANIEL HOUSER, LEE G. SIMMONS, AND DOUGLAS L. ARMSTRONG

INTRODUCTION An abscess formed beneath the pad of the left rear foot on a 43-year-old female African elephant, resulting in the sloughing of a nail and requiring the removal of approximately 25 percent of the sole to fully drain and expose the abscess. This resulted in a lesion approximately 8 cm in diameter and 1 cm deep, representing the full thickness of the foot pad epidermis. A sandal was constructed to protect the exposed soft tissue, maintain topical medications, ventilate the lesion, and deflect solid contaminants. The first 68 days of treatment involved various combinations of systemic antibiotics administered orally (sulfamethoxazole-trimethoprim, ampicillin trihydrate) and/or topical treatments (icthammol 2 percent ointment, Kopertox, Betadine, nitrofurazone 0.2 percent, saline). These treatments may have eliminated the bacterial cause of the abscess, but resulted in virtually no healing or development of new tissue. In general, the lesion site had developed into three visible areas: 1) the abscess' point of origin, which appeared as a deep pocket; 2) the path line the abscess traveled from the pocket to the sloughed nail; and 3) the convoluted tissue bordering each side of the path line. Eventually all treatments were discontinued with no apparent change in the lesion. On the 69th day that the lesion was present, a topical chitosan solution was introduced. The solution was prepared by dissolving chitosan flakes (Vanson Inc., Redmond, Washington, United States) in water to create a solution containing 1 percent chitosan, 1 percent glacial acetic acid, and 98 percent water. The daily treatment consisted of the following: 1) flushing the lesion with tap water; 2) flushing again with saline solution; 3) application of chitosan solution topically; and 4) securing the sandal to the foot. New tissue growth was recognized immediately after chitosan application was initiated. By the ninth day following the introduction of the chitosan, an estimated 65 percent of the lesion pocket had filled with new, normal tissue. One hundred sixty-five days after the chitosan treatment began, the lesion was determined to be fully healed and all treatments ceased.

Sole abscesses in elephants are difficult and often unrewarding cases to manage. Many of these cases remain unresolved for months or years and frequently conclude with extreme solutions including amputation and/or euthanasia. An abscess in the sole of a female elephant occurred at the Henry Doorly Zoo in 1997. The case was unresponsive to traditional medical treatments, but an innovative sandal constructed by the elephant keepers successfully protected the area from further damage. Zoo staff elected to apply an unusual medical treatment regimen, which had been successfully applied to a skin lesion in a male elephant at the zoo some years previously. A food supplement, chitosan, was mixed into solution and applied directly as a topical treatment to the lesion. Chitosan contact with the lesion was maintained via the sandal. The lesion showed rapid improvement with the application of chitosan and eventually healed completely.

CASE HISTORY On 13 April 1997, a 43-year-old, female African elephant sloughed the medial nail from her left rear leg. The area was cleaned and examined. No swelling or exudate was observed, and the animal did not exhibit lameness or pain on palpation. One week later, on 20 April 1997, a significant quantity of purulent discharge was observed at the ventral point where the nail had been lost. The area was cleaned, and a dark tract was found that appeared to extend into the epithelium of the sole. The tract opened at the outside margin of the sole of the foot and progressed toward the middle of the foot. The tract was aggressively debrided using normal hoof trimming tools and all discolored or abnormal tissue was removed. An abscess pocket, roughly 8 cm in diameter, was discovered in the approximate center of the foot. All areas of the pad that had been undermined were thoroughly trimmed out and no flaps of tissue were left. Approximately 25 percent of the sole had been excised to various depths. The abscess had penetrated into the dermis, and the spreading exudate had undermined deeply into the epidermis. Additionally, a narrow line of necrotic tissue was visible in the epidermis. This tract ran directly from the abscess to the point of rupture and ventral to the nail.

Treatment began on 14 April 1997 and ended 3 December 1997, spanning 233 days (33 weeks). Table 19.1 illustrates the sequence of systemic, oral and topical treatments utilized during treatment and recovery. Starting on 23 April, we used an inexpensive sandal to protect the foot. Initially, the twice-daily treatments involved cleansing the pad (flushing with tap water), trimming tissue to keep the abscess fully open, application of any topical medication, then attachment of the sandal. The sandal was worn 24 hours a day for the first 32 days. On 16 May 1997, the

TABLE 19.1—Sequence of oral antibiotics and topical treatments applied, beginning 14 April 1997 and ending 3 December 1997.

Treatment	Method	Date Started	Date Ended	Duration (Days)
Tribrissen	oral	14 April	3 May	18
Ampicillin	oral	3 May	18 June	45
Icthammol 2% ointment	topical	23 April	30 May	37
Kopertox	topical	23 April	30 May	37
Sandal	topical	23 April	3 December	232
Betadine	topical	15 May	30 May	15
Saline solution	topical	30 May	3 December	187
Nitrofurazone	topical	5 June	21 June	15
Chitosan solution	topical	21 June	3 December	165

decision was made to adjust the daily procedure and remove the sandal for approximately 6 hours a day. The intention was to provide abrasive wear and encourage separation of necrotic tissue.

Treatments administered during the first 68 days eliminated all signs of bacterial infection but insignificant development of new tissue. Following the introduction of chitosan as a topically applied medication, tissue developed rapidly. The twice-daily treatment involved cleansing with tap water, flushing with saline, and application of chitosan. Only the afternoon treatment included application of the sandal, which would be worn for approximately 18 hours. The abscess pocket was reduced by nearly two-thirds in 10 days. Full recovery was reached 155 days later and all treatment ceased, as tissue had filled in from the sides of the abscess, until closure was complete.

SANDAL

Purpose The sandal was developed to confront the conditions created by debridement of the abscess site. Debridement was accomplished by aggressively excising all of the sole tissue overlying the abscess pocket, as well as unhealthy tissue at the abscess site and affected nail. All sole tissue that was separated from underlying soft tissue was removed, as well as any sole tissue overlying darkened or discolored tissue, until the entire margin of the abscess pocket consisted of tissue that was firmly attached and normal and healthy in appearance. The area of overlying sole removed comprised approximately 25 percent of the pad surface. The tissue remaining in this area was highly vascular, soft tissue; it was very friable and susceptible to injury and potential infection. The sandal's design was intended to meet four objectives: 1) protect exposed dermal and soft epidermal tissue from additional injury; 2) maintain topically applied medications to attain the maximum contact time and effect; 3) provide ventilation to dry the site and to minimize the growth and invasion of anaerobic pathogens; and 4) deflect solid contaminants in an effort to keep the site reasonably clean.

Two layers of ¼-inch synthetic rubber provided protection. This material provided a barrier, which was impenetrable and very durable. The maintenance of topical medications, ventilation, and protection from solid contaminants were achieved with 1-inch thick, polyurethane foam. The foam, placed between the pad of the foot sole and the sole of the sandal, essentially served as a flexible cushion and bandage. The foam compressed under the animal's weight when standing then rebounded when weight was removed; thus, it conformed to the variable pressure against the sole of the sandal the entire time. It was the foam's ability to return to its original state after compression that provided the required benefits. As the animal took weight off the foot, the sandal would pull a short distance from the pad. This distance varied at different points of the pad, but no effort was made to quantify the distances. What was important was that the distance never exceeded the thickness of the foam, which remained in continual contact with the sole of the sandal and lesion site of the pad. The foam was an extremely effective barrier to solid contaminants and held medications in contact with the lesion. Additionally, the foam actively ventilated the pad because air was drawn into the cells of the polyurethane foam when it rebounded after compression.

Materials and Cost The cost for materials is illustrated in Table 19.2. The total calculated cost represents the highest possible monetary investment for materials. For example, the cost for a box of rivets was listed, yet less than a box was used during construction.

Assembly Sandal assembly was a nine-step process, consuming approximately 7 hours, disregarding the time invested for obtaining the construction materials. We had the advantage of working with a cooperative animal in a free-contact situation. Our access to the animal and ability to handle her allowed for expedient sandal construction (Figure 19.1).

STEP 1—MAKE SOLE PIECES The sole of the sandal consisted of two pieces of rubber conveyor-belt material riveted together. The top layer and the bottom layer of the sole were the same size, but each was modified slightly to serve different functions (see Steps 2 and 3 in the following). The elephant stood on the conveyer-belt material and the circumference of her pad was

TABLE 19.2—Materials and expenses.

Item (Description)	Per Unit Cost ($)	Cost ($)
Conveyer belt[a] (36 in. × 36 in.)	40.17	40.17
Solid woven-cotton belt[b] (20 ft.)	1.10/ft.	22.00
Rivets[c] (box of 100)	6.94/box	6.94
Washers (100 count)	0.02 each	2.00
Leather belts (3 with heavy duty buckles)	10.85 each	32.55
Kevlar thread	14.50/spool	14.50
Chain[d] (4 ft.)	2.15/ft.	8.60
Total		**126.76**

[a]Conveyer belt is a two-ply, 3/8 inch thick synthetic rubber
[b]2 inch wide, ⅛ inch thick
[c]3/16 inch by 1 inch
[d]3/8 inch welded steel

Elephant Sandal

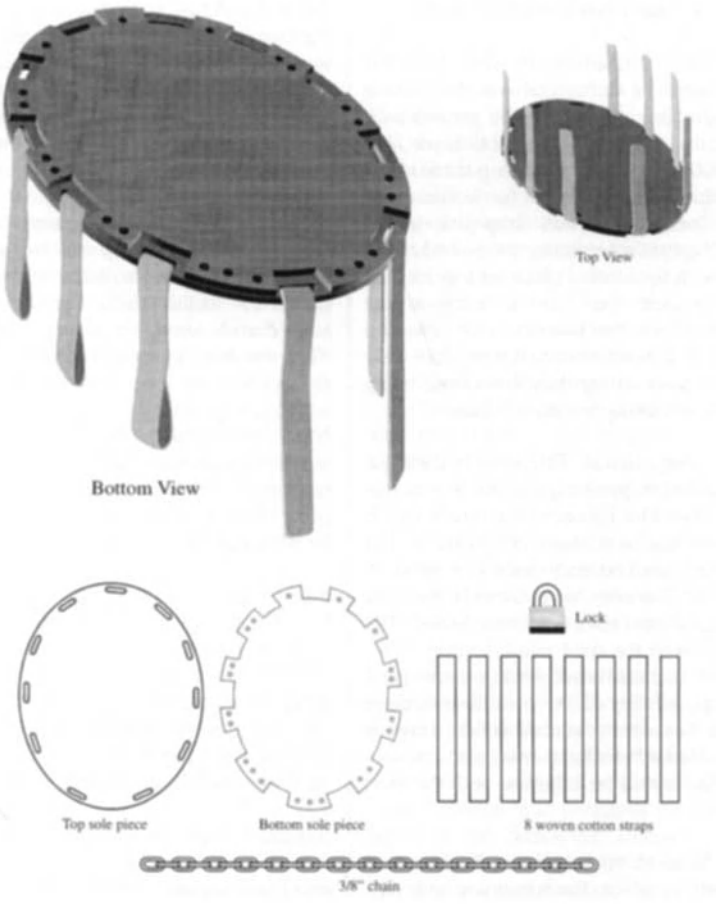


FIG. 19.1—Details of the elephant sandal constructed at Omaha Henry Doorly Zoo.

traced. Because the sole consisted of two pieces, the first tracing was made so that there was sufficient material remaining for the second piece. A jigsaw was used to cut the first sole piece along the traced line. We used the first sole piece as a template to trace the second, and then we traced and cut the second piece.

STEP 2—CUT SLOTS FOR SANDAL STRAPS Slots were cut in the top layer of the sandal sole to allow for the attachment of straps, which secured the sandal to the elephant's leg. The sandal we constructed had 11 straps, spaced somewhat evenly around the perimeter of the sole. The number of straps can be varied, based on the size of the sole piece and personal judgment as to the appropriate spacing. Each slot was roughly 1.5 inches in length, ran parallel to the edge of the sole piece, and was approximately 1.25 inches inward from the edge. To cut each slot, a line, 1.5 inches long, was drawn onto the sole piece, parallel to the margin. Two, 1/4-inch holes were drilled; one at each end of the 1.5-inch line. A jigsaw was used to cut each slot, using the 1/4-inch holes as entry points.

STEP 3—CUT STRAP NOTCHES IN THE SECOND SOLE The bottom layer of the sandal was the surface of the sandal that was in contact with the ground and, therefore, suffered the most wear. But this layer also protected the straps from wear by elevating them off of the floor surface. Notches were cut in the bottom sole piece at the same location as each strap slot on the upper sole piece. The two sole pieces were stacked on top of each other, with the slotted piece on top and the edges aligned. A marker was used to draw a line through the slots and onto the bottom piece. The top piece was removed, and then semicircular notches were cut from the bottom piece along the drawn lines using a jigsaw, effectively removing the drawn lines.

STEP 4—RIVET THE SOLE PIECES TOGETHER Rivets were set around the perimeter of the sole pieces to bond them together. The number of rivets between any two adjacent notches varied from one to three. The two sole pieces were stacked and exactly aligned. A rivet hole was drilled. The rivet was placed in the hole and finished before the next rivet hole was drilled. The size of the hole followed the rivet manufacturer's recommendations, and standard rivet-setting tools were used. To lessen the possibility of a rivet pulling through the sole material, a washer was placed on each end of the rivet. This provided a broader contact surface with the sole material than would be achieved with the rivet head alone.

STEP 5—ATTACH STRAPS TO THE SOLE Eight pieces of woven-cotton belt were cut. Each belt was approximately 30 inches in length. The sole pieces were stacked with the slotted piece on top. Each belt was inserted downward, through a slot, and the end pulled around the edge of the sandal and held against the belt above the slot. Duct tape was used to temporarily hold these adjoining areas of the belt, until they were sewn together with Kevlar thread. A belt was sewn at all but the three slots located at the back heel area. These three slots required adjustable belts, which were positioned at the final phase of construction.

STEP 6—MAKE THE SANDAL SUPPORT CHAIN A piece of 3/8-inch diameter chain was cut, fitted around the elephant's leg, and secured at the back of the leg with a padlock. The padlock had to hook through the end links of the chain, so we started with a 4-foot chain and progressively reduced its length until the proper length was determined. The chain had to support the sandal so it would not fit too loosely around the leg. We were also cautious to avoid restricting circulation to the foot with a chain that was too tight. In fact, we were initially too cautious and found the sandal was too loose. The chain turned and shifted its position easily. Removal of a single link made the chain adequately snug.

STEP 7—ATTACH STRAPS TO THE CHAIN After the leg chain was fitted around the leg and padlocked at the back, the elephant stood on the sole pieces, the slotted piece on top, so that the elephant's pad contacted the sole of the sandal. The loose end of each strap was pulled upward, between the chain and leg. The strap was pulled to remove slack, then folded over the chain and held against the rising strap, approximately 2 inches below the chain. A permanent marker was used to mark where the strap was folded and where one end of the strap aligned with the other. After this was completed for all the straps, the sandal was removed. The looped ends were then sewn at the ends of each strap. This was done by simply aligning the marks, temporarily securing the loop with duct tape, then sewing.

STEP 8—INSERT THE LEG CHAIN The chain was inserted progressively through each loop, starting and ending at the back of the sandal. The sandal chain was padlocked at the back of the leg, so the chain could not be removed from the sandal straps after assembly.

STEP 9—INSERT THE ADJUSTABLE STRAPS Initially, we used leather, buckle belts because of their availability, but ultimately we found that they were durable and, after using leather-punch pliers to make holes, they were easily adjustable. The belts were inserted upward, one through each slot, from the bottom of the sandal. These belts remained unbuckled until the sandal was secured to the animal's foot.

Sandal Usage Securing the sandal to the elephant's foot was most easily managed with two people; however, one person could complete the task in approximately 90 seconds. A piece of polyurethane foam was cut for placement between the elephant's abscessed pad and the top of the sandal sole. The piece of foam was usually cut larger than the sole of the sandal, then trimmed down to an acceptable size after placement on

the sandal. After completing the daily medical work associated with the abscessed pad, topical medication was applied to the polyurethane foam. The sandal was fitted onto the animal's foot by holding the padlock (linked through one end of the chain) in one hand and the other end of the chain in the other hand. The elephant held her foot off the ground while the sandal was slid on, starting at the front of the foot and moving toward the back. While the sandal was slipped into place, the chain was pulled around and padlocked at the back of the leg. The adjustable straps could be secured with the foot lifted above or set on the ground. The end of the belt was slipped upward, between the leg and chain, then pulled over the chain and buckled.

The sandal was removed by simply unlocking the padlock while the foot was lifted, then slipping the sandal down and forward and off the foot. The adjustable belts were unfastened at any time prior to reattaching the sandal.

Sandal Notes Initially, we weren't comfortable with the snug fit of the sandal's leg chain. An attempt was made to soften the chain-to-leg contact with a chain sleeve. We choose a synthetic rubber water hose to make the sleeve. This material was abandoned when we discovered that the snug fit and higher frictional coefficient of the sleeve material resulted in mild skin irritation. The sleeve pulled the epidermal surface, rather than sliding smoothly over it when slight changes in position were made.

Our original design did not include the three adjustable belts. Solid, woven-cotton belts were originally used at the back of the sandal. We discovered that the task of securing the sandal to the foot, while not impossible, was much more difficult with all the belts attached to the leg chain. There was only a little chain that we could hold, and the sandal allowed very little variance in positional alignment. At times, we simply could not secure the padlock. The conversion to three adjustable belts solved these problems and in no way compromised the sandal's performance.

Sewing the sandal straps required exerting a lot of force on the needle, so that some hand protection was required. Otherwise, the sewing process would have been difficult, painful, and prolonged.

CHITOSAN Chitosan is a polyhexosamine polymer, derived through the deacetylation of chitin, an abundant and naturally occurring polysaccharide. Chitin is commonly collected as a by-product during the commercial processing of crab, shrimp, shellfish, squid, fungi, krill, clams, and oysters.

Supportive Research We first became aware of chitosan in 1987, when a local hospital was investigating its effect on genitourinary wounds in dogs and recognized decreased fibrosis in all chitosan-treated tissues (Bartone et al. 1988). More recent research relates to chitosan's apparent enhancing effect on reepithelialization. In a study of open wound healing in dogs, chitosan-treated wounds "tended to be greater" in the development of new epithelium and showed fewer inflammatory cells than the control group (Okamoto et al. 1995a). In another study, N-carboxybutyl chitosan was prepared as a soft, freeze-dried pad and applied postsurgically to plastic surgery patients (Biagini et al. 1991). This study reported chitosan treated surgical sites, when "compared to control sites . . . [had] better histoarchitectural order, better vascularization and the absence of inflammatory cells . . . at the dermal level." An in vitro study of wounds in human skin compared tissues treated with heparin-chitosan, chitosan gel, heparin alone, and wounds incubated without treatment (Kratz et al. 1997). The heparin-chitosan group stimulated 90 percent of the wounds to reepithelialize, and the chitosan gel group was recorded at 30 percent. Untreated wounds and the heparin alone group demonstrated no recovery.

Chitosan appears to have antimicrobial properties, evidenced by observations of various pathogens, in 298 cultures, that were exposed to N-carboxybutyl chitosan (Muzzarelli et al. 1990). Electron microscopic examinations showed "marked morphological alterations" of the exposed microbes and determined that N-carboxybutyl chitosan displayed "inhibitory, bactericidal, and candidacidal activities." One study, more closely resembling the abscess problem we managed, compared the effects of saline, ampicillin, and three chitosan treatments (0.01 mg, 0.1 mg, and 1.0 mg) for experimentally developed abscesses in dogs (Okamoto et al. 1995b). Abscesses cultivated with subcutaneous inoculations of *Staphylococcus aureus* T-6 were drained then treated. Chitosan was finely granulated and applied in suspension. Calculations were based on changes in the wound cavity diameter. The two higher concentrations of chitosan strongly outperformed the antibiotic agent (Table 19.3). In the 1.0 mg and 0.1 mg chitosan groups, 90 percent and 55 percent of the wounds healed in 8 days, respectively, versus 40 percent in the ampicillin group. No healing was seen in either the 0.01 mg chitosan group or the saline control group. The report also noted "abundant vascularization" in the granulation tissue.

Preparation and Treatment For our treatment purposes, a chitosan solution was prepared. Dry, finely ground chitosan was purchased from a distributor (Vanson Inc.) that markets chitosan as a dietary supplement for fish and not for biomedical purposes. The chitosan solution was prepared by mixing three components in the following amounts: 1.0 g of chitosan powder, 1.0 ml of 1 percent glacial acetic acid, and 98 ml of warm tap water. The mixture was a colorless, transparent, slightly viscous solution that behaved like a liquid during application, yet in large quantity, possessed the coherence of a conformable, near-liquid gel. The chitosan solution was applied to the lesion using a general purpose, 24-ounce spray bottle. The solution

TABLE 19.3—Percentage of experimental abscess cases healed in 8 days. Abscesses were drained and treated on day zero and day four.

Treatment	Percent Healed
1.0 mg Chitosan	90
0.1 mg Chitosan	55
0.01 mg Chitosan	No healing occurred
Ampicillin	40
Saline	No healing occurred

Adapted from Okamoto et al., 1995b.

was applied in a dispersion of fine particles until the lesion was superficially saturated.

Treatment Response Chitosan treatment began on 21 June 1997. At that time we had endeavored for 68 days to treat the problem, using twice-daily treatments of the previously described antibiotics and topically applied medications (see Table 19.1). The veterinary staff worked closely with the elephant handlers and allowed them to manage the daily treatments during the healing process. The elephant handlers kept a daily record to provide a history of medical treatments and to record any observed changes in tissue condition as the case progressed. During the first 68 days, the record is devoid of any notes regarding the development of new tissue. No noteworthy or observable tissue regeneration occurred. While no evidence of infection was present, the recovery process appeared static and unprogressive. The daily record details remarkable, visible changes in the abscess following the first day of the chitosan treatment and conveys the dramatic, visible changes witnessed.

> 22 June 97: Tissue is noticeably growing from the bottom of the deepest part of the lesion (to be referred to as the "hole") and has small, red dots.
>
> 23 June 97: Hole area is more shallow due to tissue growth from the bottom, especially on the outside edge.
>
> 24 June 97: The pad appears better than on the 21st. The deep part of the lesion appears to be less deep. The bottom of the hole is dull, white, with a trace of pink. The new tissue is slightly granular and firmer.
>
> 25 June 97: The deep part of the lesion can be touched without the elephant reacting. New tissue appears to develop in this area, with a concave shape. Prior to the chitosan, this area was flat. Three areas had visible blood drainage (very little blood which diluted quickly with surface moisture). This is new. No surface vascularity had been seen.
>
> 26 June 97: Still more growth of tissue at the bottom of the hole. A flap of tissue, from the bottom of the hole, is fusing to the new tissue. Looks like it has a blood supply.
>
> 27 June 97: In the past four days, the hole appears to have filled half of its void with new tissue. The tissue is pink and painfully sensitive to touch.
>
> 28 June 97: Some apparent fusion of tissue at the bottom of the lesion with the edges of the lesion. Appeared possible to see blood vessel lines in the bottom of the lesion.
>
> 30 June 97: No major changes; tissue continues to fill in the hole and attach to the sides.
>
> 1 July 97: New tissue appears to be developing on the inside wall of the hole. Estimate the depth of the hole has reduced 65 percent since the start of the chitosan.

The empirical evidence, though lacking quantitative data, illustrates the rapid improvement.

CONCLUSION Tissue development immediately following the use of chitosan in the daily procedure suggests it had an enhancing effect in cellular regeneration. The research literature provides concurring evidence but offers no explanation or theory as to the biological mechanism by which this is possible. In this case, successful recovery of the abscessed pad appears attributable to the following procedures:

1. Use of antibiotics to contend with the infectious agent.
2. Vigorous, daily attention to maintain an open abscess and trimming of any tissue that would enclose and incubate pathogens.
3. Use of the sandal (with the polyurethane foam) to protect the abscess from injury and contamination and to prolong chitosan contact.
4. Use of chitosan as a topical treatment for enhanced regeneration of epithelium.

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THE USE OF SONOGRAPHY IN THE FOLLOW-UP CARE OF A FOOT ABSCESS IN A FEMALE ASIAN ELEPHANT (*ELEPHAS MAXIMUS*)

TIMOTHY J. O'SULLIVAN AND RANDY E. JUNGE

INTRODUCTION This chapter covers the ongoing use of sonography to monitor the progress of an infected foot in one of the Asian elephants (*Elephas maximus*) at St. Louis Zoological Park. The elephant developed an abscess in her left rear foot that was initially treated with extensive foot trimming and daily foot soakings. We later used sonography to monitor the progress of the infection and to adjust our treatment accordingly. Sonography allowed us to determine the depth of the original abscessed areas and to visualize several new tracts of infection extending out from the original abscess. With continued sonography procedures, we were able to monitor the healing process of both the abscessed areas and the extending tracts. Through use of this information we were able to concentrate on the affected areas and avoid exploratory trimming of the pad. We found sonography a useful tool in visualizing the extent of the foot problem and monitoring the healing process.

CASE HISTORY On 5 August 1995, during a routine foot check, a large abscessed area was noticed in the pad of the left rear foot of our 41-year-old female Asian elephant, Clara. The area was located between the two outer toenails, approximately 7.5 cm from the outside of the foot and approximately 6 cm in diameter. During the next couple of days the macerated area was trimmed away, and it was concluded that more extensive treatment would be necessary. The treatment was attempted while the elephant was restrained in our elephant restraint device (ERD) and sedated with xylazine. Her foot was flushed and soaked in a betadine solution twice a day until a more extensive treatment could be scheduled.

On the morning of 15 August, Clara was shifted into our ERD and was sedated with an intramuscular (IM) injection of 300 mg of xylazine, using a hand syringe. After 20 minutes, Clara was sedate enough for us to secure her with leg and torso straps. Due to mechanical difficulties the ERD could not be successfully rotated. Clara was reversed with 150 mg IM of yohimbine and released into the building. The procedure was rescheduled for a later date.

On the morning of 17 August, an attempt to shift Clara back into the ERD was not successful, and the procedure was rescheduled for the following Monday, 21 August. It was decided, due the severity of the foot disease, that if she could not be restrained in the ERD at that time she would undergo general anesthesia. We then began a 10-day treatment with trimethoprim powder at a dosage of 187.5 g a day.

On 21 August, Clara readily entered the ERD and was injected IM with 350 mg of xylazine. After 40 minutes she was still not sedated enough to start the procedure and was supplemented with 150 mg IM of xylazine. After this injection Clara was sufficiently sedated for us to secure her with the leg and torso straps. The rotational function of the ERD worked well and allowed for complete and easy access to the foot. The infected area was trimmed as much as possible. While trimming the rest of the foot, another abscessed area, approximately 1 cm deep, was discovered towards the center of the foot. We also found a shallow, undermining heel abscess leading from this area. This abscessed area was trimmed to expose healthy pad. After the infected areas were cleaned, Clara was reversed with intravenous (IV) delivery of 150 mg yohimbine. She was then rotated upright and released into the stall.

The daily treatment that followed the procedure involved hosing the infected areas with warm water and flushing them with a diluted Nolvasan solution. The entire foot was soaked for 10 minutes in a Nolvasan solution and then sprayed with Kopertox. This was done two or three times a day. During this routine, the keepers noticed that there was drainage and tenderness in certain areas of the foot. Sonography was suggested as a way to visualize the abscessed areas under the pad and to determine the depth of the original abscessed area.

On 4 October, the veterinarians used a portable sonography machine (Aloka 500, Corometrics Medical Systems, Wallingford, Connecticut, United States) to examine the foot. We had the elephant position herself with her back towards us and her left rear foot presented through the bars and resting on a pipe. Using a 5.0 MHz linear transducer (Aloka 5.0 MHz linear array ultrasound transducer, Corometrics Medical Systems), we were able to visualize the original abscessed area. It appeared that the area was approximately 3 to 4 cm deep. A small 1 to 2 cm deep tract was visualized as extending laterally from the original lesion. In addition, several 1 cm deep tracts were present, which extended medially from the original abscess. These tracts were small and approximately 2 to 4 cm under the sole surface. After this examination, it was concluded that the

daily flushing and soaking would continue and the tracts seen on the ultrasound would be trimmed.

Six weeks later we reexamined the foot with sonography. The majority of the foot appeared healthy. The small 1 to 2 cm tracts were no longer present and no additional pockets or tracts could be identified. The original abscessed area was now approximately 2 cm deep. The previously visualized tract that ran laterally from the abscessed area did not appear to be tender or infected. It was determined that the daily foot care treatment was helping and should continue.

We repeated the examination 6 weeks later, and the entire sole appeared solid, with the exception of the original abscessed area and the laterally extending tract, which was now 1 cm deep. This tract appeared to be tissue-filled and not fluid-filled, as it was before. Because it was thought that the forced flushing was causing some of the tissue dissection, the keepers were instructed to discontinue this treatment. The daily Nolvasan soaks, however, were continued.

In the months that followed, the area of concern did not heal as well as we had hoped. The area remained soft and tender to the touch. The elephant would not let the keepers do major trimming of any part of the foot, especially around the macerated area. Rocks and other debris became wedged into the opening and were hosed out on a daily basis. The other parts of the foot deteriorated. The decision was made to sedate Clara in the ERD and secure her foot, allowing us to take a closer look at the area of concern and to trim the rest of the foot.

On 19 August 1997, she was secured in the ERD and given 500 mg IM of xylazine. Once sedated, her left rear foot was raised and secured to the bars. The entire pad surface was trimmed down to healthy tissue. The ultrasound results showed that there were no undermining tracts or pockets, with the exception of the chronic hole and tract. This area was pared down to healthy, bleeding tissue. There was very little necrotic debris present in this area.

To date, nearly 2½ years after the original eruption of the abscess, the elephant still has soft tissue exposed at this area. We clean the area daily with a hose and spray it with Kopertox. We periodically ultrasound the foot in order to monitor its progress and to determine if any other problems have arisen.

CONCLUSION The use of ultrasound has been extremely beneficial in detecting and monitoring any fluid-filled abscesses in this elephant's foot. Being a noninvasive, painless method of monitoring foot problems, sonography has allowed us to concentrate on specific areas of need and avoid exploratory and unnecessary trimming.

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TREATMENT OF OSTEOMYELITIS IN ELEPHANT FEET

LAURIE J. GAGE

INTRODUCTION Osteomyelitis of the digit of the elephant is a serious disorder and is often the result of untreated pododermatitis. Difficulty of treatment and the potential of the infection to rapidly ascend from the distal phalanges to the metacarpal bones make this problem potentially life threatening. Once the infection has reached the metacarpals, the integrity of the foot is in jeopardy, and the elephant may be in such discomfort that euthanasia may be the only humane choice left.

CAUSES OF OSTEOMYELITIS Infections in the pads and around the nails of elephant feet are common. Etiologies include foreign bodies embedded in the foot pad, inadequate foot care, trauma, poor nutrition, poor general health, moist or filthy substrates, and lack of exercise. Soft tissue infections of the foot, called pododermatitis, may progress to an osteomyelitis in one or more of the bones of the digits. Clinical signs of osteomyelitis include local swelling around the nail of the affected digit or of the entire foot, cellulitis, heat, and lameness. Radiographic studies of the digit will confirm the diagnosis of osteomyelitis and should be carried out frequently (at least weekly) to track the progression of the disease (Gage 1999).

Once the infection has entered the bone, causing an osteomyelitis in one of the phalanges, the entire digit is at risk. When an infection spreads to the distal phalanges, if left untreated, it usually ascends from one phalanx to the next. There has been one documented case where an infection in the distal phalanx, P-3, ascended and caused osteolysis of over half the middle phalanx, P-2, within a 10-day period. This occurred in spite of aggressive debridement of the infected tissue, using sterile Clowper's rongeurs, and three times daily aggressive irrigation with antiseptic solutions into the draining tract leading to the infected phalanx. The infection in this case was only controlled by surgically removing the infected tissue and bones and maintaining the elephant on systemic antibiotics.

PREVENTION OF OSTEOMYELITIS Due to the seriousness of the problem, aggressive preventive measures will certainly be worthwhile. The sole and nails of each foot should be examined frequently for damage or soft areas where a tract could be developing. Infections may begin as a swelling or a softness of the skin between or above the nails or on the sole. Fortunately, each phalanx is encased in a heavy, fibrous tissue that helps protect it from adjacent soft tissue infection. Therefore, these soft tissue infections, if treated promptly, often resolve without further complications.

Opening the lesion to allow drainage is of paramount importance. Soaking the foot in warm water and Epsom salts or povidone–iodine solution may help to draw out the infection; however, it may also cause the foot and sole to remain soft, thus creating more complications. Foot soaking in a variety of disinfectant solutions has yielded varying results. Deep-tissue cultures are important aids in identifying a causative organism and allow for an appropriate systemic antibiotic choice for the elephant. Locally injecting antibiotics into the infected tissues with a needle is not recommended, as the integrity of the fibrous sheath around each phalanx may be damaged and could increase the chance of the infection progressing to osteomyelitis.

There is mounting evidence that sedentary elephants have a greater tendency to develop foot problems. Elephants with poor limb conformation have a tendency to develop foot problems as they reach 30 to 40 years of age. This may be due to the fact that they are reluctant to walk as much as their normal counterparts, or it could be a result of unequal weight distribution to the individual limbs and feet. Measures taken to encourage elephants to exercise daily may help to prevent foot problems.

Substrates on which the elephants are housed may also be a factor in the health of elephant feet. Observations made over the past 20 years suggest that elephants housed on natural substrates have fewer foot and limb problems than elephants housed on asphalt or concrete.

TREATMENT Treating osteomyelitis in the elephant foot is a difficult challenge for the veterinarian. Aggressive antibiotic therapy is necessary and may be difficult to achieve. Large doses of often expensive drugs are generally indicated. Modes of treatment include oral, intramuscular, or rectal suppository dosing. Success rates may be improved if the elephant is well trained and allows these methods of medication or if it is housed in a facility with a good restraint system.

Daily irrigation of tracts leading to infected bones frequently yields poor results, and the infection usually progresses into the adjoining bone. Surgery has been the most effective way to stop the infection (Gage et al. 1997). While the decision to perform surgery is daunting, the difficulty of the procedure and the amount of aftercare are significantly reduced if the surgery is done while the infection is in the distal phalanx (P-3). Complications increase with the number of phalanges involved. Postsurgery therapy will be more effective if cultures for aerobic and anaerobic bacterial and fungal growth are collected every 2 to 3 days. Systemic antibiotic therapy may be adjusted accordingly.

Surgically removing any bone proximal to the middle phalanx, P-2, from one of the three central weight-bearing digits of a front limb will likely cause serious structural damage to the remaining digits and hence the entire foot, necessitating euthanasia. The medial and lateral digits may be removed in entirety with less risk.

Local digital perfusion with antibiotics has been tried and may be a viable alternative to surgery. This procedure requires the daily placement of a specialized tourniquet around the limb (above the carpus), perfusing locally with appropriate antibiotics, and leaving the tourniquet inflated for 20 minutes postperfusion. To date, this procedure slowed the progression of the osteomyelitis in the foot of one elephant but did not resolve the problem.

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PART IV

Surgical Intervention for Elephant Foot Disease

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THE MEDICAL AND SURGICAL MANAGEMENT OF FOOT ABSCESSES IN CAPTIVE ASIATIC ELEPHANTS: CASE STUDIES

WAYNE S. J. BOARDMAN, RICHARD JAKOB-HOFF, SHERRI HUNTRESS, MICHAEL LYNCH, ANDREA REISS, AND CREE MONAGHAN

INTRODUCTION Foot abscessation in captive Asiatic elephants (*Elephas maximus*) often results from poor foot care. The medical and surgical management of foot abscesses in three adult animals in three zoological parks is described in this chapter. Six separate abscesses were treated. The successful medical management of foot abscesses included curettage and debridement, footbathing and lavage, and use of antibiotic and antiseptic ointments. Two of these infections showed radiographic changes of the underlying third phalanx, which were consistent with osteomyelitis. Surgery was performed on two of the animals that had deep, chronic foot abscesses that were intractable to prolonged medical management. Radiographic changes associated with more extensive osteomyelitis affecting the underlying third phalanx (and in one case second and first phalanges) were noted. In each case, a wedge-shaped piece of nail incorporating the affected area was removed to access the underlying phalanges. The bones that showed a gross appearance of infection, lysis, and softening were removed or partially removed. Successfully managing the open surgical wound postoperatively was prolonged and intensive. Wound irrigation, regular wound dressing changes, analgesia, and parenteral and topical antibiotic therapies were used to promote healing by second intention. The radiographic appearance of marginal distal phalangeal osteomyelitis can be resolved with prolonged medical treatment. Extensive, chronic osteomyelitis of the distal phalanx and more proximal phalanges may require surgical intervention. Successfully treating minor foot infections requires gentle and thorough debridement, footbathing, and drying of the affected area with minimal recontamination. Good husbandry and preventative foot care practices are essential.

Infections in the feet of elephants may result from cracks in the nails, trauma, or foreign bodies embedded in the pad (Houck 1993). They usually respond well to soaking or irrigation of the lesion with disinfectant solutions (Mikota et al. 1994). In one survey, abscesses occurred in 127 events out of 68 animals (Mikota et al. 1994). Eighty-two abscesses resolved with one treatment, 30 events required more than one treatment (Mikota et al. 1994). In general, treatments were aggressive and typically included debridement and curettage, lavage, and the administration of topical and nonantibiotic preparations (Mikota et al. 1994). Occasionally these infections do not respond to local treatment and progress deeper into the tissues of the foot, causing an osteomyelitis when the infection reaches one of the distal phalanges (Gage et al. 1997). Foot abscesses that have led to osteomyelitis of the distal phalanx (P-3) can be treated conservatively. If, however, the osteomyelitis is rapidly progressing despite treatment or is found in proximal phalanges, surgical removal of the infection can be successful.

MEDICAL MANAGEMENT

Clinical Presentation

CASE ONE Three abscesses occurred in a 40-year-old, 3,500-kg female housed at Perth Zoological Gardens, South Perth, Western Australia, Australia. The foot care had been suboptimal for a period of nearly 12 months and an abscess was seen in the right foreleg in the nail of digit three (D-3). This deep abscess extended into the corium and the leading aspect of the distal phalanx (P-3). It had underrunning tracks of necrotic nail and a fetid smell. The external hole was much smaller than the inner cavity. Radiography revealed that 30 percent of the bone displayed signs of osteomyelitis. Low-grade lysis was seen with a roughened leading edge. A presumed sequestrum was seen in the middle of the phalanx. At the same time, an acute episode of a chronic abscess was seen in the left hind limb. Softening of the horn at the coronary band was seen in the nail of digit four (D-4) with inflammation of the adjacent epithelium. Radiographically, P-3 had fractured into two pieces. The underlying abscess burst through the nail at the coronary band producing a purulent fistula. The right hind limb had a purulent discharge from the medial aspect of the nail associated with digit one (D-1). No radiographic changes were noted in this foot.

CASE TWO The second case occurred in a 23-year-old, 3,600-kg female housed at the Auckland Zoological Park, Auckland, New Zealand. This animal had a 6-year history of a left forelimb abscess in the weight-bearing surface of the nail of D-4. Various treatments had been attempted with no noticeable long-term effect. The abscess was deep and extended into the corium and the leading aspect of P-3. Radiographically, there was low-grade lysis of 20 percent of the leading edge of P-3.

Treatment

CASE ONE Curettage and debridement of the left hind limb abscess was instituted to remove as much of the necrotic tissue as possible. Maintaining the integrity of the nail wall was thought to be important. The route of infection was through the weight bearing aspect of D-3. Necrotic, devitalized horn was removed from the distal fistula to encourage drainage. The initial treatment regime was footbathing in warm (40°C) salt water for 15 minutes twice a day (b.i.d) and then debridement and irrigation with copious quantities of dilute hydrogen peroxide and 1 percent povidine-iodine b.i.d. The abscess cavity was filled with silver sulphadiazine and chlorhexidine gluconate cream (Silvasine, Smith and Nephew Ltd., Auckland, New Zealand).

This regime seemed to have a limited effect. Further debridement was required, and pus was apparent each day. The regime was changed to hosing the cavity b.i.d. to remove most of the pus. The foot was then bathed in warm salt water as before, and the cavity was dried and sprayed with a trypsin-based enzyme spray (Debrisol, Ethical Agents, Ltd., Auckland, New Zealand) b.i.d. A 0.25 percent sodium hypochlorite solution was flushed into the cavity and then dried. A gauze swab soaked in a solution comprised of dimethyl-sulphoxide, trimethoprim-sulphadiazine, and metronidazole was inserted into the wound. The gauze swab was held in place with a cyanomethacrylate tissue adhesive. There were minor signs of improvement with this regime. The animal was on display during the day and sand often packed into the wound. The skin adjacent to the coronary band became soft due to the footbathing. When this occurred, treatment was stopped and a drying agent, "Colombo solution" (5 g of copper sulphate, 5 g of Calamine powder, 5 ml of concentrated formalin, and 20 ml of 10 percent povidone-iodine solution made up a 1 liter solution with water) was painted onto the horn b.i.d to harden the tissue. Several weeks later, when the animal was removed from display the abscess began to heal quickly. The wound was dried after each treatment with gauze swabs and cotton buds and left to dry completely. Standard scrubbing was suspended for 4 weeks. The wound was not contaminated with sand or feces. With this regime, the abscess healed rapidly as the deficit filled in with granulation tissue and then normal horn. After 10 weeks of treatment, the wound had healed and treatment ceased.

A very similar treatment regime was used for the other two abscesses. The latter regime having the most effect on the right rear abscess. Healing was markedly improved when the animal was kept off sand substrate and the wound was kept dry. Minor debridement was required for this foot. After 7 weeks of treatment, the wound had healed and treatment ceased.

At this time there had been no improvement in the abscess in the right forefoot. A very slight and intermittent lameness of this leg was occasionally noticed. The treatment of this lesion was reviewed and surgical removal or curettage of P-3 was proposed. Only minimal debridement was possible because of the localized pain. There were many underrunning tracts of necrotic horn. The foot was treated twice daily. First, it was soaked, as before, in warm salt water for 15 minutes, and then it was curetted with very small scissors and forceps. Debrisol was applied and the wound was then flushed with 10 percent povidone-iodine solution. "Kandy" cream (30 g of 2 percent miconazole cream, 20 g of 2 percent fusidic acid cream, and 20 g of 1 percent povidone-iodine ointment) was used in the wound. The cream was packed into the wound using a gauze swab that was held in place with a cyanometha-crylate tissue adhesive. Small pieces of very adhesive electrical tape held the gauze in place. A dose of 6.3 g of doxycycline monohydrate (Vibravet 100 mg, Pfizer Animal Health, Auckland, New Zealand) was given postoperatively (p.o.) as a parenteral antibiotic treatment. After 5 days of signs of mild diarrhea and partial anorexia, the treatment was discontinued. Six weeks later, the foot was again radiographed. There was marginal improvement in the osteomyelitis lesions. The central deficit had filled in a little and the edges were less rough, indicating a lessening of active bone infection.

Treatment continued, but the wound became contaminated with sand from the enclosure. At times debridement was not effective. A boot was designed to prevent contamination and stop the loss of the local treatment. Progress was slow. The wound occasionally discharged purulent material. However, despite the external appearance of a large necrotic abscess, radiography 5 months later revealed an increase in bone density in the lytic areas. Aggressive curettage was again undertaken to remove the necrotic tissue, and debris was removed daily. The area had become soft, so the saltwater footbaths were discontinued and Colombo solution was applied twice daily. The wound was dried with a hairdryer, and 1 percent povidone-iodine ointment was inserted into the wound cavity and held in place with gauze swab and adhesive tape. Contamination of the wound was prevented as much as possible and over the next 3 months the deficit filled in and healed. Subsequent radiography revealed a generalized increase in bone density in the previous bone lesions.

CASE TWO Over many years, the left forelimb abscess was treated with a variety of treatments including, poulticing, footbathing with 5 percent warm salt water and 2.5 percent formalin, or poulticing with 2.5 percent magnesium sulphate. Other local treatments consisted of astringents and antibiotic sprays. Periodically, the abscess would erupt at the coronary band, causing great pain. For 5 to 7 days, 5 g of phenylbutazone (Myoton Granules, Bayer NZ Ltd., Auckland, New Zealand), p.o. once a day (s.i.d.), was used periodically as an analgesic. Tylosin (Tylan injection, Bomac Labs Ltd., Manukau, New Zealand), 180 ml intramuscular (IM) s.i.d., was used for 10 days. Subsequent treatments included a 10-day course of penicillin and strepto-

mycin (Penstrep LA, Bomac Labs Ltd.), 150 ml IM s.i.d, followed by a 10-day course of doxycycline monohydrate (Vibravet 100 mg, Pfizer Animal Health), 7 g p.o s.i.d. The wound remained soft and wet, and despite the use of a boot, the foot became contaminated. Radiography revealed moderate lysis of P-3, which is consistent with chronic osteomyelitis.

Over the next 3 years, the abscess showed some improvement, but there were periods of minor purulent discharge. Various treatments were again used. Over the latter part of 1995, the wound was lavaged with warm salt water and 1 percent povidone-iodine solution b.i.d. A boot was used to keep the wound as clean as possible, and the animal was chained at night to reduce the possibility of contamination. Some nights the boot was left off to allow the abscess cavity to dry. Gradually the deficit filled in with healthy granulation tissue and horn covered the hole. Nearly 10 years after the abscess was first recorded in the clinical notes, the foot was healed. The lytic lesions were reduced and replaced by tissue of the same radio-density as adjacent healthy bone. The cavity continued to fill with healthy tissue. Occasionally, however, the cavity will reopen because of wet conditions. The wound heals with debridement and flushing with 1 percent povidone-iodine solution.

SURGICAL MANAGEMENT

Clinical Presentation

CASE ONE The first case that required surgical management occurred in the same animal (see "Case two" in the "Medical management" section above) that had been treated medically. The abscess occurred in the weight-bearing surface of the D-4 nail in the right forelimb. This abscess had been recorded for more than 8 years. The medical treatment regime had been the same as described above for Case two but eruption of the infection occurred more commonly at the coronary band. Initially, radiography revealed osteomyelitis lesions extending into P-3 and into P-2. Surgery was not considered. Despite ongoing treatment, radiographs 12 months later showed the lesion had extended into the medial aspect of P-1. Surgery was elected to prevent further progression of the infection into P-1.

CASE TWO The second case occurred in a 20-year-old, 5,300-kg male in a protected-contact situation at the Royal Melbourne Zoological Gardens, Melbourne, Victoria, Australia. He had a 2-year history of infection in the nail of D-4 in the right forelimb. The condition was intractable to aggressive wound therapy and parenteral antibiotics. Radiography showed lytic lesions of 30 percent of P-3, and subsequent radiographs, within 2 weeks of the first, showed the lysis to be rapidly extending through P-3, which appeared fractured in three roughly equal pieces. Surgery was elected because of the risk of the infection extending into P-2.

Surgical Procedure

CASE ONE AND TWO The surgical approach for both cases was very similar. The anaesthetized animal was laid in a left lateral position with the affected leg uppermost. The surgical site was prepared for surgery. An esmarchs bandage (a 2-cm-wide strip of tractor tire innertube) was used just above the carpus to reduce hemorrhage. An oscillating saw was used to remove a wedge-shaped piece of nail tissue from the affected nail. The cut extended about 2 cm from the coronary band and 4 cm caudal to the leading edge on the weight-bearing surface. In Case one, P-3 was removed and P-2 was dissected out. The medial aspect of P-1 was also removed. In Case two, the three pieces of P-3 were dissected out. Laparotomy sponges were used in Case one to reduce the bleeding, which was not excessive. The wound was packed with more sponges soaked in 1 percent povidone-iodine solution and wrapped first in a self-adherent bandage (Coban, 3M Medical-Surgical Division, St. Paul, Minnesota, United States) and second with adhesive tape (Elastoplast, Smith and Nephew, Auckland, New Zealand). A boot was placed over the dressing to reduce the possibility of contamination.

In Case two, antibiotic-impregnated, bone-cement beads were placed into the surgical site. But, these proved to be of minimal use and were very difficult to remove. Further sedation and anesthesia were required to remove them.

Postoperative Care

CASE ONE AND TWO In both Case one and Case two, postoperative care was similar, requiring intensive wound management to allow the surgical site to heal by second intention. In Case one, a prophylactic antibiotic, doxycycline monohydrate, 7 g p.o. (orally) s.i.d, was used for 3 weeks, and ibuprofen (Brufen, The Boot Company Pty. Ltd., North Rocks, New South Wales, Australia), 8 g p.o. b.i.d., was used for analgesia. When ibuprofen was increased to 8 g p.o. four times a day (q.i.d.), analgesia increased as shown by improved movement and less coronary band inflammation.

In Case one, a dark purple, very tenacious blood clot, which filled the wound site, appeared 24 hours postoperatively. Initially, the wound was flushed with normal saline. The wound site was then packed with laparotomy sponges soaked in 1 percent povidone-iodine solution and bandaged. The wound was dressed once daily for over 90 days.

The animal was kept indoors or only allowed into the training yard for the first 10 days. As the wound began to heal, organized granulation tissue appeared at about 7 days; a profuse white mucoid exudate also began to appear, which was thought to be normal. The wound was flushed with 1 percent povidone-iodine solution daily for 20 days. The povidone-iodine solution was then mixed 50:50 with a desloughing agent (Otoderm Multi cleanse Solution, Pfizer Animal Health). The

wound was regularly cultured for bacterial infection. Only contaminants were isolated. When *Pseudomonas aeruginosa* was isolated, the wound was flushed with vinegar to increase the local acidity. Subsequently, *P. aeruginosa* was not cultured.

The boot was useful at protecting the wound from contamination but made the vital tissues soft. At times, therefore, the boot was left off, for instance, when the staff was available to supervise the animal. During these times, the soft coronary band region was hardened using methylated spirits. The boot was kept on at night to avoid fecal contamination. During the ensuing months the wound healed, but occasional trimming was required to remove old necrotic horn. The white mucoid exudate was then replaced with healthy pink granulation tissue. As the horn grew down, the bed of granulation tissue shrank in size. At all times the foot was kept as clean as possible and the wound moist. A small pocket at the lateral aspect of the wound was formed by the growth of the granulation tissue. This required specific attention, which included application of a hydrogel (Intra Site Gel, Smith and Nephew). Following complete healing after 12 months, there were periodic, minor openings of the nail on the weight-bearing surface that occasionally required debridement.

The wound management procedure for Case two was similar. Initially, an alginate dressing was used to reduce hemorrhage. Later, Intra Site Gel was used to promote healing. The boot was used less frequently than in Case one to allow the wound to dry. Consequently, slightly more contamination of the wound occurred. But the contamination had very little effect on the healing of the wound because there was a good bed of granulation tissue. More debridement of the old, damaged nail was needed near the coronary band. Healing also took 12 months in this case, and periodic, minor openings also occurred on the weight-bearing surface.

DISCUSSION Cracks that develop in the toenail may result from nutritional, genetic, environmental, and/or traumatic causes, but the causes are usually unknown (Fowler 1993). In one survey seven animals (3.7 percent of those with foot problems) were euthanized as a result of chronic pododermatitis (Mikota et al. 1994). In these cases, factors which predispose the development of foot abscesses included fecal and urine contamination, poor night quarter drainage, inadequate and incorrect foot care, wet climate, wet and abrasive substrates, and stereotypic behavior.

Prolonged maceration of nail tissue may lead to fissures in the weight-bearing surface and the leading edge of the nail. As the nail becomes overgrown, fecal material may lodge in the cracks, which, in turn, exacerbates the maceration process and leads to devitalization of the softening nail. The foot has the ability to expand greatly when weight bearing and reduce in size when lifted. This anatomical feature could mean that feces and the associated bacteria might be sucked or forced into the fissures. In this way, the infection may occur in an antigravity fashion. Continued neglect or inappropriate care can lead to enlargement of the fissures, which can then develop into an underlying cellulitis.

Infection of the nail (onychitis) can progress into the laminae and corium associated with P-3. It is then only a very small distance for the infection to penetrate the periosteum and the bony matrix of P-3. Left unchecked the infection can cause lysis of the bone, and osteomyelitis, which can extend into the interphalangeal joint and progress proximally into P-2 and P-1. The infection can remain localized like this for many years, with an underlying, slowly progressing osteomyelitis. In some instances, the infection can also track proximally beneath the nail. Externally the nail can look healthy. The infection proceeds in an antigravity fashion, proximally to the coronary band. If there is no drainage, this area and the adjacent epithelium can become markedly inflamed and very painful to touch. Often the animal can be very lame. Within a few days, the developing abscess can erupt, which brings pain relief. These clinical signs represent an acute episode in an otherwise chronic condition.

A variety of aerobic and anaerobic bacteria and fungi have been isolated from the lesions of elephants' foot abscesses. The authors have isolated the following species of bacteria and fungi from the cases discussed above:

Streptococcus agalactiae
Staphylococcus aureus
Citrobacter freundii
Streptococcus spp.
Proteus mirabilis
Proteus morgani
Corynebacteria spp.
Bacteriodes melanogenicus
Pseudomonas aeruginosa
Gram-negative anaerobes
Candida albicans

Usually, there were several isolates from each culture. Commonly, gram-negative bacteria, which do not grow on culture media, were also seen. Most bacteria were contaminants, and some of them may have caused localized infections. These isolates appear to be ubiquitous.

Where there have been long-standing nail abscesses, it is important to radiograph the digits to evaluate the extent of the infection. Comparing radiographs of abscessed feet with radiographs of normal feet will help in diagnosis, and frequent radiographs of abscessed feet will allow the progress of the lesion to be followed. When radiographing elephants' feet, we noted that standardizing the angle of the X-ray beam produces consistent and reproducible results. We have found that angling the X-ray beam vertically at 30 degrees onto feet standing on the radiographic plate produced repeatable results.

Radiographic evidence of osteomyelitis can be treated conservatively or surgically. If radiographic lesions are slowly progressing and only affect the leading edge of P-3, the abscess may be treated conservatively. If however the radiographic lesions are

progressing more rapidly or there is evidence of osteomyelitis of P-2 and P-1, then surgery should be considered. The most extensive, chronic abscesses are seen in either D-3 or D-4 of the forelimbs. The reason for this higher frequency is not fully understood but may relate to weight distribution, the effects of stereotypic behavior, or poor forelimb conformation. The elephant housed at the Auckland Zoological Park had a slight inward rotation of the forelimbs, which may have contributed to the formation of foot lesions by placing more weight on the plantar surface of D-4.

Gentle and thorough debridement of the black necrotic tracts is very important when treating foot abscesses medically. Contact with vascular tissues should be avoided. The use of small scissors, forceps, and curettes aid this process. Debridement of the necrotic tract can be attempted every 4 to 7 days. Once drainage has been established, foot soaks, twice daily for 15 to 30 minutes in warm (45°C to 50°C) antiseptic solutions, are very effective. Solutions that can be used include 0.1 to 0.5 percent chlorhexidine, 1 percent povidone-iodine, or 4 percent salt. Alternatively, the wound can be lavaged with copious quantities of these same solutions twice a day. Before soaking or lavaging the foot, it is important to remove any material from the abscess, such as sand or fecal material. The area should then be dried with towels or hair dryers, and the foot should be kept dry.

Wet substrates prevent healing by causing maceration of the healing tissue. Contamination can be prevented by using boots for short periods or by using gauze swabs in the wound and covering with very adhesive tape. In addition, chaining the elephants during the night for short periods may help prevent excessive contamination. Povidone-iodine ointments can be used in the wound site. Parenteral antibiotics seemed to have minimal effect in these cases, but they were useful if signs of cellulitis or swelling of the soft tissues above the foot were apparent. Gentle, regular, hygienic wound management appears to be the most effective treatment.

The rationale for surgery for the cases described was the need to quickly remove the affected tissues and allow excellent drainage, so the wound would heal by second intention. Removing a wedge of nail using an oscillating saw was very quick and provided adequate access to the affected bones. P-3 was removed with the initial incision, and P-2 was dissected out. At the time of the surgery, it was important to remove all the excess necrotic horn tissue, which could have acted as a nidus of infection.

A specially designed boot afforded protection, prevented contamination, and allowed the bandages to remain on the foot. Initially there was seepage of blood into the wound site, which formed a very tenacious clot within 24 hours. As this clot became organized, granulation tissue appeared after 7 to 10 days and progressively filled the deficit, while the horn grew down from the coronary band region. Using a boot and bandages prevented contamination of the wound. After approximately 14 days, a thick, white mucoid exudate was seen on the bed of granulation tissue. It appeared normal and had no smell.

The use of new wound care products, like alginate dressings and hydrogels, and other mild wound desloughing agents, like normal saline, 1 percent povidone-iodine solution, and otoderm, was effective. Postoperative analgesia was very important to allow the elephant to move more freely. Using parenteral antibiotics appeared to have minimal effect on the course of the postoperative care. If cultures of a wound suggest pathogenic bacteria are present, then topical or parenteral antibiotics may be indicated. Treatment of abscesses in all cases is made easier if the elephant is in a free-contact situation. The use of antibiotic-impregnated, bone-cement beads should be avoided because of the difficulty in removing them later.

High-quality preventative foot care is essential for all elephants in captivity. The quality and type of substrate, wet climates, and allowing animals to stand in wet conditions for prolonged periods can often mean the horn tissues become very soft. All four feet should be examined on a daily basis. Any excessive growth of the weight-bearing surface of the solar pad or nail should be pared away. Any early stage superficial fissures should be chamfered to allow removal of any black, necrotic material, and allowing air to penetrate this anaerobic situation will greatly improve the situation. At the same time, it is important to allow this tissue to dry and slowly harden, perhaps with the use of a drying agent. Lavaging the foot with 0.1 percent to 0.5 percent chlorhexidine, 1 percent povidone-iodine solution, or weak mixtures of astringents (Copaderm, Bomac Labs Ltd.) or Colombo solution are helpful. These solutions effectively disinfect the sole and allow the horn tissue to withstand maceration from contamination from water, feces, and urine. Once treated, elephants should be allowed to stand on a dry surface, which will help the process of hardening of the horn. Finally, experienced elephant management personnel are critical to the success of preventative procedures and medical and surgical treatments.

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PREOPERATIVE CONDITIONING AND POSTOPERATIVE TREATMENTS OF A PROTECTED-CONTACT BULL ELEPHANT

ROBERT KAM

INTRODUCTION In September 1992, Ganesha ("Spike"), an Asian bull elephant, arrived in Calgary from the Metro Miami Zoo. At the time, he was 11 years old, 9 feet at the shoulders, and weighed about 9,000 pounds. Soon after this beautiful tusker became a Calgary Zoo resident, it was decided that he would be handled by means of the confined-contact and protected-contact systems rather than the free-contact system used with our female elephant. For the next year, all husbandry maintenance procedures were done in our elephant restraint chute ("hugger"). In January 1994, we began target training him to accomplish these same procedures outside the hugger. All his foot and skin care, blood collection, and bathing routines were now done by means of protected contact.

At the Calgary Zoo, we believe there is a need for all three methods of elephant handling and that the elephants themselves will decide which is best for them and their handlers. One question constantly on people's minds is: "Will one system offer better care and attention than another?" When Spike was diagnosed by our veterinary staff with a chronic foot problem, this question certainly came to our minds. It would be our responsibility to see that a dangerous, protected-contact animal like Spike would receive the same opportunity for health care that our free-contact cows receive. When the veterinarians decided that surgery was the only option for Spike, we did not realize it would begin a 2-year period of preoperative conditioning and postoperative treatment that would overwhelm us all. The knowledge and experience we all received, however, was invaluable to our professional development.

DEVELOPMENT OF THE PROBLEM The lesion was first noticed as a soft spot on the bottom of Spike's left front foot. Having seen what we thought were similar problems on the females, we felt that just a simple reaming would take care of the lesion. When this soft spot, approximately 1 inch in diameter, reoccurred, it did not harden but maintained a sponge-like consistency. As time passed, we began having problems with the cuticle on the nail directly above the soft area. The nail began splitting and sores developed on the tissue above the cuticle, which made it quite uncomfortable for Spike when we did foot cleaning or trimming procedures. At times, he would not offer us his foot because he knew there would be pain involved.

CONDITIONING FOR RADIOGRAPHS In April 1996, the veterinary staff decided it was time to take radiographs of his foot to determine the exact problem. Spike, at this time, was already conditioned to offer his foot for foot care through a door in the protective mesh wall, which is 15 inches wide and 36 inches high. We used this same doorway for radiographs. The first thing we did was design a larger and flatter foot stand, so his entire foot could rest flush with the surface area. Since radiograph plates are expensive pieces of equipment, we did not want to give Spike the opportunity to grab and crush one. It would be in his character to do just that. To prevent this, he was conditioned to bring his foot out and place it on a 3/4-inch thick piece of plywood, which was cut to the same size as the X-ray plates. Since the doorway was only large enough to have his foot protrude, he could not grab with his trunk unless he pulled his foot back first. This gave us lots of time to remove the fake plate if he attempted one of these moves. What he did enjoy doing was moving the piece of plywood to the edge of the stand and crushing it with his foot. When he did this, as with other conditioning procedures, we would end the session and walk away. Eventually, he learned that if he wanted our attention and his favorite treats, he would have to cooperate fully. Once he gained respect for this piece of wood and no longer tried to slide it about, we replaced it with the genuine radiograph plates. In April 1996, we were able to obtain our first radiograph of his infected toe. As we continued with regular sessions, it became routine and soon he accepted them quite readily. This seemed to be the secret with all conditioning procedures. The procedures that he did not like done to his foot, we would repeat many times, until he liked it. Unfortunately, each series of radiographs showed a continuously growing area of infection inside the foot.

The second toe from the left, on his left front foot, was the infected area. Also, his second phalange was being slowly eaten away. It was decided that surgery would have to take place in mid-September of 1996, after the summer programs were complete. We soon realized that the preoperative training and conditioning would go far beyond regular husbandry procedures. We also knew a successful surgery would mean nothing if we could not condition Spike to cooperate during all the painful postoperative treatments he would have to endure.

RUBBER FLOORING INSTALLATION Rubber flooring for the elephant enclosure had already been approved by February 1996. Now a rush was on to decide on a type and thickness. We felt it would be most useful as an insulating factor and a cushioning agent for Spike's sore foot after the surgery. Through different leads and contacts, we found a large petroleum company that was using vast amounts of rubber conveyor belt material in its northern Alberta tar sand operation. After explaining the "Spike story" to them, they offered to send 43,000 pounds of unused belt rubber at no charge to the Calgary Zoo. It arrived in huge rolls, 6 to 8 feet wide, and reinforced every 1/2-inch with wire cable. One piece of this material, 1 foot by 6 feet, weighed about 200 pounds and was 1.5 inches thick. We required bobcats and bulldozers to install it, but once in place it served our purpose well.

HUGGER CONDITIONING FOR ANTIBIOTIC SHOTS Regular constrictions in our elephant hugger had been fairly routine for Spike, but usually for positive procedures like scrubbing and bathing. Now conditioning was required for daily antibiotic shots in alternating hips. This was not nearly as much fun for Spike, because once we started on a series of shots, he would receive them at the same time every day with no allowance for refusal. Once we chose the most convenient scenario, we stuck with it: squeezing him, bridging, rewarding, and reopening the hugger. This routine was soon combined with a couple of swift punches in the rear hip area with our fists or jabs with the ankus. This was necessary to make him feel discomfort in the spots chosen for administering antibiotics. The final step was to actually stick him with needles while he was constricted. For this purpose a 1-inch, 16-gauge needle was chosen and used on a daily basis. It was a very sensitive procedure, so proper bridging and rewarding were critical. We also had to make sure he was not squeezed for too long. We opened the hugger immediately after the fake injection was completed. If we made these sessions as smooth as possible, which took practice on our part, he soon no longer realized that he was being jabbed. These practice sessions went on until 2 weeks prior to his surgery, when the actual antibiotic injections began.

CONDITIONING FOR TREATMENT All of Spike's treatments, radiographs, bandaging, and boot applications were performed through his foot care door. Foot care up to this point was quite undemanding on his part. It was more of an enjoyable, relaxing occasion or a quiet time spent with the keeper. That all changed. When we asked him to present his foot as we conditioned him for the treatment, we had to harass it to the extent that it would irritate and, at times, anger him. Once again bridging and rewarding with precise timing became very crucial. If he pulled his foot back, we gave him one chance to re-present it. If he did not, we ended the session and walked out of the room. Because he grew to enjoy these sessions with the keepers, this seemed to work best to maintain discipline and proper response. However, we realized this procedure would be impractical and intolerable when the actual postoperative treatments were performed. We had to instill in his mind that these painful procedures were going to be part of his life for many months to come. He soon realized that if he wanted the keepers to stay in the area and offer him his daily treats, he would have to withstand some major discomfort. We hoped that this would stay with him and hold through the critical times after the surgery. The treatments after the operation could last an hour or more, which is a longer time than was ever required for Spike's cooperation during preoperative conditioning. Because of this, we worked on stretching out his cooperation time span and created even more discomfort during these sessions. To aid in the desensitizing process, we scratched his foot with the ankus, pounded on it with our fists, and generally created annoyance in any way we could. Basically, we were conditioning him to withstand a great deal of pain in that foot.

BANDAGE CONDITIONING After surgery, Spike's foot would require a protective bandage over the incision area, and he would have to wear a protective boot to ensure that he would not tamper with the bandage. This bandage and boot would have to be worn 24 hours a day. Another conditioning process was in order. Wearing a bandage on his foot was not painful; it was just a nuisance in his mind and a new sensation that required some exploration. With this procedure, his favorite game was to pull his partially bandaged foot back, rip off the tape and gauze, and then proceed to eat them. Once again we had to go back to the basics. We started out with small pieces of duct tape and applied them to various parts of his foot and leg. If he pulled his foot back, ripped off the tape and ate it, once again we ended the session, removed his herbivore cubes, and walked away. Soon he learned that the duct tape never tasted nearly as good as his treats, and he allowed us to apply an entire bandage. Even though he allowed us the opportunity to apply this bandage, we did not expect that he would leave this bulky substance on his foot after he was released. The next step was to design a protective boot to ensure that the bandage would stay in place.

THE BOOT The boot had to be durable enough to withstand all the punishment a bull elephant could muster. There could be no chance of him removing it once it was in place. It had to fit snugly and be taken off and put on safely. One of our biggest challenges was locating a company that would devote the necessary time and commitment to such a project. Many were approached, and many thought it was a worthwhile venture but could not give us the dedication we needed.

Finally, we discovered a local tent and awning business that agreed to take on this responsibility.

We decided the boot would be open and bound in the back so it could be easily slid on and off, like a slipper. We chose seat belt buckles as a fastening device for ease of opening and closing. To prepare for a proper fit, his foot was mummified in duct tape from the bottom of his nails up to his knee. The tape was then slit open down the back with a knife, carefully removed, and presented to the manufacturer as a pattern for the first prototype. To achieve the exact dimensions of his foot pad, we had Spike step on a piece of cardboard and then traced around it. Then for inner and outer soles, we cut three pieces of 1/4-inch conveyor belt rubber per boot. We initially ordered three boots, at $900.00 per boot. It took several trips back and forth to the builders, many trial and error alterations, and much stitching and restitching before we finally constructed one boot that would withstand the punishment a bull elephant could administer.

BOOT CONDITIONING We were now at a stage where Spike had to be taught to accept his boot and wear it eagerly. Since the boots were expensive, we could not allow him to destroy even one. The conditioning process consisted of having Spike become accustomed to wearing a bulky, unnatural piece of footwear. The entire procedure created an atmosphere quite conducive to the type of games that Spike enjoyed playing. It was mainly one of grab what he could, then either eat it, tear it apart, or both.

Once again, it was a matter of introducing him to new sensations on his foot. First, we trained him with a chain anklet, maneuvering it up and down his leg but not attaching it. At this point, we also rubbed our hands behind his leg; thus, allowing him to adapt to our handling him where the buckles would actually be fastened on the boot. He had not had a chain on his foot for years, so basically it was like starting all over again with the anklet. If he pulled his foot back, it was crucial that we did not have our hands behind his leg because they could easily be trapped and squeezed against the frame of the doorway. Soon, we were able to snap the anklet off and on, and he wore it for short intervals. We found it was just as valuable to bridge and reward him for allowing us to take it off, as it was to put it on. We did not want him to think one procedure was more important than the other. Once he accepted this piece of chain routinely, we combined it with duct tape so he could begin to experience more than one unique sensation on his foot at a time. Some of what he would experience after surgery would be painful, while other experiences would just make him curious as to what we were doing. We had to condition him to everything he would experience after the surgery.

FOOTBAND WITH SEATBELT STRAPS Our next step was to condition him with a device that would more closely simulate the boot. To achieve this goal, we had a 12-inch-wide canvas belt constructed. We required two seat belt straps, complete with buckles, to fasten the belt in the back. It was made from the same material as the manufactured boots. Once the belt was attached to his leg, he would not be able to remove it. The problem was having enough time to slip the belt around his leg and fasten both buckles before he pulled his foot back. Even though his conditioning had come a long way, every time we introduced something slightly different he had the urge to pull back and check it out. If one of the seat belts were left hanging unfastened when he pulled back, he would surely rip it off with his trunk and destroy it. To prevent this from occurring, we attached an O-ring to the front of the belt during the conditioning process. We strung a rope from the ring, by means of a snap clip, to an anchor in the wall about 8 feet behind the foot access door in the keeper area. This rope was just long enough to reach the access door but not long enough to allow Spike to pull the belt inside. This provided us with the opportunity to manipulate the belt on his foot. We moved it around on his leg, clicked the buckles together, and basically desensitized his foot to this large cumbersome strap. We did everything except actually attach it and fasten the buckles, because if he pulled back, the rope, the O-ring, or the buckles would be torn off. This method gave us the freedom and ease to ensure that Spike was entirely accustomed to the belt being put on and off his leg, with no fear of losing a costly piece of equipment. If he decided to pull his foot inside his enclosure, the rope attachment made it very difficult for the belt to go along with it. As Spike withdrew his foot, he soon realized the belt would stay on our side, which made it less fun and exciting for him. There was no reward for him, no treats, and no belt to play with and tear apart. Once he lost interest in lunging for the strap and displayed no signs of claiming it for entertainment purposes, it was actually time to attach the strap and fasten the buckles. As soon as we did, Spike was rewarded generously. As he became more willing to allow us to remove and apply the belt, we began repeating the process several times during a session. He was also rewarded generously for allowing us to remove the belt.

By now Spike was conditioned to do everything we would want to do to his foot. The O-ring and anchor mechanism was quite valuable throughout a very similar boot fitting operation conducted later. Still, anytime he pulled his foot back into his enclosure without us telling him to, we gave him a time-out. This meant that we abruptly ended the session, pulled all hay and treats from his reach, ended verbal communication, turned out the lights, and walked out of the room and out of his view for about 15 minutes. We knew that this would not be possible during actual postoperative treatments, so we had to be as strict as necessary for preoperative conditioning. This psychology worked almost all the time, probably because he so enjoyed our presence and attention and seemed to look forward to the training sessions.

The fact that he looked forward to the time he spent with us was all that we could really depend on to make this entire process successful. We were careful not to turn him off of this program. In protected-contact training, there is no raising your voice, no yelling "No!," and no jumping into the enclosure and disciplining him because he just ate one of the expensive boots. There is only patience and encouragement. Positive methods are used to obtain cooperation and misbehavior is never made into a big deal. As difficult as it was sometimes, it was best to just ignore his antics and not play into them. He seemed to enjoy getting us upset, and if we displayed these feelings towards him, it got us nowhere. If we became angry, it was another good reason to end the session and continue later when we had cooled off.

FITTING THE BOOT When the first boot finally arrived, it was not just a matter of inserting his foot into it and releasing him. The straps and buckles had to be sized and fitted and other alterations made. For this reason, a process similar to that used for conditioning him with the foot strap was used to fit the boot. We once again made use of an installed O-ring on the front of the boot, which we could anchor to the wall behind us. The training process was identical to the conditioning for the strap. Patience was required: progress was made one step at a time. The bridge and reward system was applied until we could fasten all three buckles.

Once the boot was in place and fastened, we found that it never fitted perfectly or tight enough. This was possibly because as he had to lift and offer us his foot through the door, it had to be at an angle and with a bent knee. Also, since an elephant's front foot is almost round, we were faced with the problem of the boot spinning 180 degrees, which would expose the bandage and his infected toe. This made the design of the boot useless. To prevent this problem from occurring, we used large amounts of duct tape to attach the boot to his leg. The boot no longer spun, but eventually the tape over his skin created minor sores. It was, however, the lesser of two evils, since the major concern was to make sure no further infection would develop in the incision areas after his surgery.

COOPERATION AFFECTED BY MUSTH Since Spike is only 17 years old, he is only now beginning to come into a full musth. He does have what we call mini-musth, which seems to be sparked by one of our three females coming into estrous. It usually only lasts for a week or so but certainly had to be dealt with several times throughout preoperative and postoperative handling. His level of tolerance for the pain on his foot was much lower. Also, his desire to cooperate during bandage and boot application and removal was much less. There were often critical times when the sore was being treated, cleaned, and flushed that he would pull back while we were applying his bandage. If this happened, he would normally rip the bandage off and eat it. This always meant starting the cleansing process from the beginning. We discovered that using peppermints as treats rather than using his regular favorite herbivore pellets or pieces of fruit sometimes helped us keep his attention longer and got us through an entire treatment. During musth, Spike's appetite is always reduced, so it wasn't always important to him to be rewarded with his regular food items. The flavor of the mints seemed to work well during these times and encouraged better cooperation. In spite of these challenging episodes, there were only two or three times throughout the year that these treatments could not be completed.

SURGERY AND POSTSURGERY When the day of the surgery finally arrived, we felt we were only semi-prepared as far as the conditioning process was concerned. As someone put it: "Now the ball was in our court." What if we did not have him trained well enough to cooperate during all the upcoming painful treatments? What if he destroyed his boots? What if he would not even offer us his foot because the pain was too great? All these questions and more crossed our minds several times during the long tedious surgery. The fact was that once the operation was over, there would be no more time for conditioning, no more trial and error, and no more time-outs when he didn't cooperate. He had to respond positively and cooperate every time. We knew that if he did not, his incision would not get proper care, infection would undoubtedly set in, and he would probably die.

We became very excited and positive after the first couple of successful treatments and boot changes were performed. We realized that our efforts were not in vain. At times, Spike would offer us his foot and grimace because the pain was so great, yet he did not pull back his foot. Perhaps he knew we were trying to help.

In time, the boot change became a well-known ceremony for Calgarians and the media. We have always had an open door policy at the zoo, and people regularly came in to watch the treatment procedure and boot change. We felt that it was important that Spike become accustomed to responding positively when strangers were present. We also wanted the citizens of our city to feel what we felt for our bull elephant and to know the lengths we would go through to cure one of our elephants of a foot infection.

SECOND SURGERY Spike endured this major inconvenience for a full year, until it was determined that his problem was not yet on the mend and that a second surgery would be necessary. By this time, however, the treatment sessions were a routine part of his life. Basically, we had just spent a full year preparing him for the second surgery, whether we realized it or not. This time we were much more confident in our abilities, and the veterinary staff knew exactly what had

to be done in this second surgery to help Spike's healing process begin. From then on, it was just more of what Spike and we had been doing for over a year. As his healing progressed and sessions got shorter, Spike actually became angry because he wanted them to go on longer.

There is always a chance of a reoccurrence or the development of a new foot problem, so we are still taking regular radiographs to monitor the bone and healing progress. We are content and positive, however, about the progress made since his last surgery. For the first time in 17 months, the veterinary staff found it unnecessary to make daily visits for treatments, but they are allowing the keeper staff to perform the cleaning of the lesion every other day. Soon all will be back to normal in the Calgary Zoo Elephant Building.

CONCLUSION If a zoo is to contribute to the survival of this species, we must learn all that we can about what can and cannot be accomplished with different handling techniques. We feel that our training procedures were valuable and, to this point, successful. To have an 11,000-pound, potentially dangerous, bull elephant conditioned to respond to severely painful treatments and to have him do this willingly now amazes us. There is little doubt that our bull, in a protected-contact scenario, will receive the same care and attention toward health problems that our free-contact cows receive. We, as professional animal handlers, had the unique opportunity to better understand the mind of such a beautiful, majestic, and intelligent creature.

Spike still receives cards and letters from the general public expressing their interest and concern. Reporters from all media sources are still making inquiries and doing updates on his recovery and healing progress. Spike made many friends throughout these trying times, and the Calgary Zoo gained respect from people across the country because of our dedication and devotion to the well-being of this magnificent animal.

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SURGICAL MANAGEMENT OF A CHRONIC INFECTION INVOLVING THE PHALANGE OF AN ASIAN ELEPHANT (*ELEPHAS MAXIMUS*)

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INTRODUCTION Surgical treatment of a chronic infection of the left front foot of a 16-year-old male Indian elephant is described. Surgery was initially indicated when there was radiographic evidence of what appeared to be a progressive osteomyelitis involving the second phalanx of the second digit. Two surgeries were performed in an effort to deal with the infection. The first surgery involved a solar approach enabling debridement of the draining tract and exposure of phalanx two. Postsurgical infection inhibited total resolution of the infection. A second surgery was performed 14 months later to debride the lesion and remove a portion of the affected second phalanx. The second surgical approach was via an incision above the nail to facilitate approach to the phalanx and allow an enbloc resection of the distal third of the second phalanx. In addition, the solar tract was again debrided. Surgical approach, technique, and postoperative challenges are addressed. The surgeries themselves could be considered successful, but in both instances postoperative complications have delayed healing. At the time of writing, it appears that there has been resolution of the infection in the second phalanx.

CASE REPORT An infection involving the left front foot was first noted when the elephant was 7 years old. This occurrence and a number of subsequent other infections responded to a variety of topical therapies. When he was 14 years old a more chronic infection occurred, involving a solar defect with associated onchyitis and paronychitis. His condition was evaluated radiographically using a Mini X-ray 300 (MiniXray Inc., Evanston, Illinois, United States) and assisted by the use of a contrast agent (Omnipaque 300, Sanofi/Winthrop, Markham, Ontario, Canada). Sonography was unrewarding. Ongoing aggressive treatment, including irrigation and flushing that incorporated antibiotics based on cultures and sensitivities, was also unrewarding. Surgical intervention was indicated when there was radiographic indication of a progression of the osteolytic infection involving the second phalange.

While standing in the elephant restraint chute ("the hugger"), the elephant was induced with carfentanil (Wildnil, Wildlife Pharmaceuticals Canada, Inc., Callander, Canada) and xylazine (Rompun, Miles, Agriculture Division, Animal Health, Etobicoke, Ontario, Canada) given intramuscularly. He was positioned on his right side on a system of air cushions (Jumbo Lift International Air Cushion Systems) with the assistance of an overhead crane and hoists. Anesthesia was maintained using a combination of gaseous anesthesia (Isoflurane, Abbott Laboratories Limited, Saint-Laurent, Quebec, Canada) and supplemental Carfentanil.

After surgical preparation, a solar approach was used to explore the draining tract. The sole was pared away using a hoof knife, and then a 2 cm by 2 cm square block of necrotic tissue was removed surgically, allowing visualization of the tract. Further debridement using a combination of blunt and sharp dissection enabled visualization of the medial surface of phalange two. Roughened areas of phalange two were smoothed using a bone curette. Further exploration of the site did not reveal any tracts or necrotic tissue. Hemostasis was excellent and appeared to be achieved by having the leg elevated above the heart. The area was repeatedly flushed with sterile fluids and then packed with three antibiotic-impregnated polymethacrylate beads, approximately 1 cm in diameter (using 4 g of ceftiofur [Excenel, Upjohn company, Animal Health Division, Orangeville, Ontario, Canada] combined with 40 g of polymethacrylate as the base for bead composition). The area was bandaged and covered with a custom-made, protective boot. Reversal was achieved using naltrexone (Naltrexone HCL, Wildlife Pharmaceuticals Canada, Inc.). The elephant was also treated pre- and postoperatively with systemic antibiotics (Excenel) based on culture sensitivities.

Follow-up treatment revealed an increased amount of discharge, and when the beads were removed 10 days postoperatively, the discharge was cultured and revealed to be a pure growth of *Pseudomonas* sp. For the following 12 months, the lesion was treated by a variety of means including disinfectant and antibiotic flushes, poultices, focal debridement (including placement of a drain above the nail to facilitate flushing), and other topical therapies. Although there appeared to be slow but steady improvement, the lesion broke down again almost a year postoperatively, and radiographs showed further indications of bone deterioration.

A second surgery was scheduled to more aggressively explore the site. Induction and preoperative preparations were as described for the first surgery. The surgical approach involved making an approximately 15 cm incision using a number 60 blade midline above the affected nail. Again, there was minimal hemorrhage,

associated, as before, with elevation of the leg above the heart. Dissection using the blade was made down to phalange two at an approximate depth of 10 cm. Retraction of the tissues was achieved using custom-made "elephant skin retractors" that allowed adequate visualization of the site. A necrotic tract and pocket were identified overlying phalange two. This material was removed using blunt dissection including curettage. The distal one-third of the phalange was removed using a Maxidriver bone saw. The site was perfused with saline and excess fluid was removed by suction. The bone was split in three pieces to facilitate removal. The lateral aspect, which was the most markedly affected portion, was easier to remove than the essentially unaffected medial section. A bone osteotome and hammer were required to complete the enbloc resection of phalange two. The piece of bone was 8.5 cm long (with the lateral section believed to be the affected portion), 1 cm wide at the nonreactive end, 3.5 cm wide at the reactive end, 2 cm deep at the nonaffected end, and 4 cm deep at the affected end. Histological examination revealed no septic involvement, just homogeneous reactive bone, suggesting a response to surrounding soft tissue infection. The remaining synovial tissues between the remnant of phalange three and two were removed using scissors and a scalpel for curettage. A second distinct tract was followed up through the sole at the level of the coronary band. The tract was isolated and debrided using a combination of a hoof knife, curette, scalpel, and scissors in a fashion similar to a "street nail" type procedure used in equine surgery. Ceftiofur-soaked gauzes were used to facilitate debridement and to aid in closure of the tract. The sites were infused with ceftiofur under high pressure. The area was infused with 20 ml of lidocaine (Lidocaine Neat, Langford, Guelph, Ontario, Canada) most of which remained on the surface due to the density of the tissues. Ketoprofen (Anafen, Rhone Merieux Canada, Inc., Victoriaville, Quebec, Canada) was given for postoperative analgesia. The area was packed with five elongated ceftiofur-soaked gauzes and one through-and-through drain into the solar tract. These were overlain with gauzes and a diaper then bandaged routinely, including the custom-made, protective boot. Excenel was again used as the postoperative antibiotic based on current culture sensitivities. Postoperative treatment again experienced copious amounts of discharge, which inhibited healing. Culture results often revealed no organisms or a mixed array of flora. The lesion has been slowly resolving with no progression of bony involvement at this time.

CONCLUSION Surgical intervention of bone-related changes in foot problems in elephants should be considered as an option for treatment. A team-oriented approach to handle the logistics is essential. The surgery is facilitated by achieving adequate hemostasis, in this case by elevation of the leg above the level of the heart, and appropriate visualization of the surgical site, in this case facilitated by the use of custom retractors. The major challenge presented in the management of the case was postoperative complications and associated production of inflammatory tissue and discharge.

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SURGICAL MANAGEMENT OF PHALANGEAL OSTEOMYELITIS IN A FEMALE ASIAN ELEPHANT (*ELEPHAS MAXIMUS*)

MITCH FINNEGAN AND MARGOT MONTI

INTRODUCTION A 44-year-old, long-term captive female Asian elephant (*Elephas maximus*) was treated for phalangeal osteomyelitis that resulted from the extension of a chronic ulcerative lesion on the solar surface of the nail of the left front fourth digit. Over the course of the 16 months, the lesion was treated using corrective nail/sole trimmings; topical, oral, and parenteral medications; and two surgical debridements. The infection continued to progress despite treatment and ultimately led to tenosynovitis of the digital flexor tendons and fistulation of the digital cushion, which resulted in euthanasia. A previous injury, which resulted in ankylosis of the right elbow, was thought to have contributed to the development of the lesion and complicated the treatment. The medical and surgical management of the case and the use of the case as a tool to educate the public about the challenges of maintaining elephants in captivity are discussed in this chapter.

CASE HISTORY Belle was a 44-year-old female Asian elephant born in Thailand in 1952. She was imported to the United States as a calf and came to the Oregon Zoo in 1961. She delivered her first and only calf in April 1962 and soon became the matriarch of the Portland herd.

In April 1983, Belle suffered an undiagnosed injury to her right elbow during dominance aggression with two other elephants. Over the course of the next 7 years, despite treatment with orally administered and injected, nonsteroidal anti-inflammatory drugs, polysulfated glycosaminoglycans, narcotics, and topical DMSO, her lameness persisted and the range of motion of her right elbow steadily decreased. In May 1990, her right elbow appeared to have fully ankylosed. She ambulated by abducting and swinging the right front limb in a counterclockwise arc during the cranial phase of the stride. She was not observed to lie down after this time.

In March 1994, swollen and inflamed areas of the left front foot were first noted in the interdigital space between the nails of the first and second digits and between the fourth and fifth digits several weeks after the areas were debrided due to impingement of the adjacent nails on each other. Over the next year, the ulcerative lesion between the fourth and fifth digits extended distally and medially around the lateral edge of the fourth nail to the solar surface. During this time, the lesion was treated with corrective trimming and sequentially with a variety of topical medications including, copper naphthenate, zinc acetate, silver sulfadiazine, triple antibiotic ointment, copper sulfate, gentian violet, clotramizole, and silver nitrate.

An infected tract was dissected proximally along the nail laminae from the solar aspect of the lesion and erupted at the cuticle. When this occurred, most of the lateral half of the face of the nail was undermined and debrided. Radiographs taken in March 1994 showed no bone abnormalities. The animal was sedated with butorphanol and deeper debridement was attempted. Leather sandals were designed and worn on both of her front feet in an attempt to keep the wound as clean as possible. Treatment continued with topical povodine-iodine products and intermittent parenteral procaine and benzathine penicillin.

In April 1996, radiographs again showed no bone involvement. Treatment continued with topical medications and intermittent systemic antibiotics until November 1996, when radiographs showed lysis of the third phalanx (P-3) of the fourth digit. Foot soaks with chlorhexidine were instituted, and a variety of topical medications and systemic procaine and benzathine penicillin were administered. Bacterial cultures yielded nonhemolytic *Streptococcus* sp. and coagulase-negative *Staphylococcus* sp.

In December 1996, radiographs showed lysis of the distal aspect of the second phalanx (P-2) of the fourth digit. Debridements, under sedation, became more aggressive and a radio-scalpel was used to establish positive drainage. Repeated bacterial cultures now grew *Morganella* sp., *Pseudomonas* sp., *Klebsiella* sp., *Enterobacter* sp., and *Proteus* sp. To monitor limb swelling, a record of limb circumference at several places proximal to the foot was started.

At this point surgical alternatives were first considered, and the zoo's media liaison was notified of the seriousness of Belle's condition. The first news reports about Belle's condition were printed and broadcast with an emphasis on public education and condition updates. Zoo medicine and surgical specialists were brought as consultants to the zoo from the College of Veterinary Medicine, University of California, Davis. The consultants advised amputation of the digit at the level of the distal first phalanx.

Several significant obstacles and potential contraindications to surgery were identified during the

consultation process. Belle's ankylosed elbow prevented her from lying down on her own. A method to put her into lateral recumbancy for surgery was needed. The integrity of her right elbow was in question. It was felt that increased stress placed on this joint following surgery could lead to destabilization of the joint. Finally, due to rapid turnover of her molars in the past, Belle had her sixth set of teeth in wear.

A crane supply company donated and installed a hydraulically controlled heavy-duty, overhead winch, which was mounted on an overhead track in the elephant barn. A horse-sling manufacturer constructed and donated to the zoo a custom-designed sling. A waterbed manufacturer designed and donated a large, water-filled mattress to serve as a surgical bed.

The right elbow was radiographed to document that the joint was fully ankylosed and that a solid bone bridge spanned the joint. A local human hospital donated a blood gas analyzer to use during the surgery. News reports concerning Belle's condition and upcoming surgery were printed and broadcast regularly. Newspaper journalists published articles diagramming the plan to anesthetize Belle while she was in a sling, hoisting her off the ground and then rotating her into right lateral recumbency onto the waterbed.

On 19 March 1996, all the elements were brought together. Six veterinarians, one medical doctor, three animal health technicians, five keepers, and seven others convened to perform the surgery. Representatives from the crane supply company, waterbed company, and sling company were on-site to troubleshoot any problems with the equipment they contributed to the surgery. Belle had been conditioned to the sling and was anesthetized with etorphine while in the sling, which was connected to the overhead winch. Ropes were connected to all of her legs and were used to rotate her into right lateral recumbency as she was set down on the deflated waterbed. The bed was filled with warm water as she was entubated, started on isoflurane gas anesthesia, and connected to monitoring equipment (EKG, pulse oximetry, end tidal carbon dioxide).

With print and broadcast media in attendance, the surgeons successfully amputated the digit at distal P-1 through an inverted T-shaped incision over the dorsal aspect of the digit. Surgeons debrided deeper tissues to the best of their ability. Visibility was poor due to uncontrolled hemorrhage. Bone cement impregnated with antibiotics was placed in the wound. The wound was left unsutured to heal by secondary intention. A sterile bandage was placed over the entire foot. The animal was lifted off the waterbed and rotated to standing and supported by the sling and winch until recovery from the anesthesia was nearly complete.

In the days following the surgery, Belle's bandage was changed daily and she was kept in her sandals to help protect the bandages. She was maintained on injectable antibiotics.

Two weeks after the surgery, granulation was beginning but radiographs showed lysis of the distal aspect of P-1. Cultures revealed a pure culture of *Pseudomonas* sp. The antibiotic-impregnated bone cement was removed and the wound and distal P-1 were debrided under sedation and local anesthesia. Radiographs taken a week later showed a large bone sequestrum in distal P-1. Bacterial culture of the debrided sequestrum revealed a pure culture of *Pseudomonas* sp. Antibiotics were switched to intravenous (IV) ticarcillin and clavulinic acid. Over 1.5 liters of serosanguinous fluid was removed from the palmar aspect of the proximal metacarpal area. Belle's appetite was depressed. She had lost over 200 kg since the surgery.

On 22 April, Belle was anesthetized again. An amputation at the level of the distal fourth metacarpal was planned. The same anesthetic procedure was repeated, and the surgeons removed the remainder of P-1 and the distal fourth metacarpal and its associated sesamoids. Once these structures were removed, with the benefit of an improved tourniquet, infectious tracts were discovered in the digital cushion and superficial and deep flexor tendons. The tracts could be followed to the palmar aspect of the proximal metacarpus, where the serosanguinous fluid had been previously drained.

Because of the poor prognosis associated with infection of the flexor tendons and their associated sheaths and digital cushion, the decision was made to euthanize Belle while she was under anesthesia.

DISCUSSION Many of the traditions of captive elephant husbandry revolve around care of the feet. Infectious foot problems in captive elephants (*Elephas maximus* and *Loxodonta africana*) are relatively common and may be more prevalent and severe in captive Asian elephants than captive African elephants.

Infectious foot lesions in Asian elephants often appear to start as ulcerations on the solar aspect of the major weight bearing digits (three and four) of the front limbs. Infection often travels proximally along the laminae and exits at the coronary band (cuticle) at the proximal edge of the infected nail. The course of the disease is frequently prolonged and recurrence is common. Although relatively uncommon, involvement of adjacent deep, soft tissue structures and bone may occur.

Many factors may contribute to the development and tenacity of foot lesions in elephants including: obesity; concurrent orthopedic conditions; endocrine dysfunction; prolonged exposure to hard flooring and/or chronic wet conditions; nutritional deficiencies; unsanitary husbandry practices, resulting in high environmental bacterial populations; fungal infection; trauma; and poor blood circulation, resulting from prolonged inactivity.

Treatment of infected, fistulated nails varies from institution to institution but commonly involves corrective trimming/superficial debridement and the application of topical disinfectants or antibiotics. One of the goals of managing captive elephants should be the prevention of foot lesions. Among the management methods that should be explored to reduce foot disease in

elephants are: training keepers to perform regular, proper foot trims; developing elephant exercise programs to encourage activity and decrease the incidence of obesity; and instituting husbandry changes designed to limit the time animals spend standing on concrete.

Although the animal presented in this case did not survive her foot infection, the case illustrates several important points. The involvement of specialists brought expertise and experience to the management of this case and greatly improved the level of care we were able to provide. A proactive approach to information management, rather than a reactive approach, worked well for the zoo on several fronts. Community awareness of elephants was raised, and a great upwelling of public support and sympathy toward Belle rallied the public behind the zoo's efforts to save her. Donations of money and supplies to help in the zoo's efforts came in from across the United States. An increased awareness of the importance of elephant foot care and reforms in the zoo's foot care procedures were forthcoming. Our goal is to never have another case like Belle's again.

PART V

Antibiotic and Anti-inflammatory Dosages for Elephants

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DETERMINING DOSAGES FOR ANTIBIOTIC AND ANTI-INFLAMMATORY AGENTS

JACK MORTENSON

INTRODUCTION Foot problems in captive elephants are considered a significant health issue in North American zoos, but no documentation of their prevalence exists. The various pathological conditions seen in feet have multiple etiologies that are generally accepted as contributory factors. They include type of substrate, moisture level, degree of preventative foot care, level of activity, and exposure to urine and feces. When foot care concerns arise, veterinarians and elephant care staff often use antibiotics and anti-inflammatory agents in conjunction with corrective trimming, foot soaks, surgical excision, and modification of the above husbandry factors.

Choosing an appropriate drug and dosage for use in elephants is difficult for veterinarians due to a lack of research in related pharmacology. Clinical application of drug use in elephants for safe, reliable, and effective results necessitates the establishment of a treatment response curve or blood concentration profile for each individual drug and potentially each species (*Loxodonta africana* versus *Elephas maximus*). There are few published reports of pharmacokinetic studies, and results are usually based on small numbers of elephants. There is some evidence of a possible species difference (African versus Asian), but this is not well documented (Page et al. 1991). Because of the difficulty in obtaining accurate pharmacokinetic information, it is common for zoo veterinarians to select a drug dosage and frequency interval based on what has been effective for cattle and horses. By using livestock dosages, the potential for dosage and treatment errors increases as the weight difference between the animals treated increases (Sedgwick 1993). Knowledge of the dosages and treatment intervals needed to provide appropriate therapy for elephants without toxicity is lacking.

This chapter summarizes the antibiotics and anti-inflammatory agents currently used by zoo veterinarians for Asian and African elephants in North America, discusses metabolic scaling attempts, and reviews pharmacokinetic studies previously conducted with elephants.

CURRENT ZOO DOSAGES An informal survey was sent to forty zoos in the United States that hold two or more elephants to determine how zoo veterinarians currently use antibiotics and anti-inflammatory agents in both African and Asian elephants. From the 27 zoos that responded, the median dosages and treatment intervals were determined for the most commonly used drugs (Table 26.1). Of the respondents, 14 held African elephants and 13 held Asian elephants. Although patient age was not requested in the survey, it is assumed that the reported dosages mainly reflect usage on adult elephants. Dosages for gentamicin, enrofloxacin, isoniazid, sulfadimethoxine (Albon, Roche, New Jersey, United States), polysulfated glycosaminoglycans (Adequan, Luitpold Pharmaceuticals, Inc., New York, United States), glycosaminoglycan enhancers (Cosequin, Nutramax Laboratories, Inc., Maryland, United States), acetaminophen, aspirin, butorphanol, and ketofen were also reported in the survey but only by one respondent for each drug. These were not included in the comparisons.

METABOLIC SCALING Although treatment monitoring by determining serum concentrations of a drug is difficult, extrapolation of treatment regimens between species of extraordinarily different sizes may be done by metabolic or allometric scaling. The principle of metabolic scaling of pharmacokinetic parameters is based on the well-established scaling of physiological processes across animals of various sizes. There is a direct relationship between metabolic rate and size within five major animal taxa including placenta mammals, marsupial mammals, passerine birds, nonpasserine birds, and reptiles.

Many biological parameters have been measured and demonstrate a logarithmic, linear relationship with body weight. Some examples include cardiac output, capillary density, kidney filtration rate, and oxygen consumption (Schmidt-Nielsen 1984). Metabolic scaling for drugs is based on body weight that is converted to metabolic size. The uptake, distribution, and elimination of a drug depend on physiological processes, which scale allometrically (Calder 1984, Schmidt-Nielsen 1984, Peters 1987). This concept has been commonly used for more than 30 years in human medicine and more recently in veterinary nutrition and for the administration of anti-neoplastic drugs. Other authors describe metabolic-scaling calculation worksheets, and I refer the reader to Sedgwick (1993) and Sedgwick and Borkowski (1996). With these formulas, I calculated specific minimum energy cost (SMEC)

TABLE 26.1—Comparison of dosage determination of antibiotics. (Drug dosage in mg/kg unless otherwise noted).

Drug	Zoo Veterinarian Dosing Regimen (mg/kg)	Equine Formulary[a]	Metabolic Scaling[b]	Pharmacokinetics
Amikacin	3-5 q[c] 12-24 hr	6.6 q 8 hr	2.7 q 40 hr	6-8 q 24 hr
Amoxicillin	8-10 q 12-24 hr	20-30 q 12 hr	15 q 20 hr	11 q 24 hr
Ceftiofur	0.5 q 24 hr	0.5 q 24 hr	0.3 q 40 hr	None
Procaine G Pen (IU/kg)	22,000 q 24 hr	20,000 q 24 hr	12,000 q 40 hr	2,500-4,500 q 24-96 hr
Trimeth-sulfa	30 q 12-24 hr	24 q 24 hr	15 q 40 hr	22 q 12 hr
Oxytetracycline	5 q 48 hr	20 q 48-72 hr[d]	12 q 78-117 hr	20 q 48-72 hr

[a]Plumb (1995)
[b]Metabolic-scaling dosages based on a 3,200 kg elephant
[c]q = every
[d]Cattle dosage

doses and treatment intervals for a 3,200-kg elephant, using the horse as a model species and referenced equine and cattle dosages. Because there is no established intramuscular (IM) dosage for oxytetracycline for horses, cattle were used as the model species and as a point of comparison for dosages and treatment intervals (Table 26.1).

PHARMACOKINETIC STUDIES Eight published reports on antibiotic use in a total of thirty-eight elephants are available, along with thorough reviews by Page (1994) and Olsen (1999). No published research has been done in elephants on the use of anti-inflammatory agents, and currently used dosages are empirically derived (Table 26.2).

Based on measurements of serum levels in a 2,300-kg Asian elephant over a 7-hour period, Devine et al. (1983) suggest a dosage of 5 mg/kg for oral isoniazid once daily. This dosage was compatible to that used in human medicine for prophylactic, anti-tuberculosis therapy.

One 7-year-old Asian elephant was treated with metronidazole for an infected tusk (Gulland and Carwardine 1987). The metronidazole dose was 15 mg/kg given once every 24 hours for 10 days as a rectal suppository, and a good clinical response was seen in 7 days. Plasma concentrations achieved with the above dosage were comparable to levels required in human medicine.

Schmidt (1978) studied two antibiotic drugs in five adult Asian elephants. He recommended a dosage for penicillin G of 2,273 to 4,545 IU/kg given IM every 24 to 96 hours, depending on susceptibility of the organisms involved. Amoxicillin was recommended at 11 mg/kg given IM every 24 hours; however, serum concentrations were only measured up to 12 hours postadministration. It was assumed that serum concentrations would remain high enough to require drug administration on a 24 hour basis, and it was suggested the amoxicillin dosage for bacteria other than *Salmonella* and *E. coli* was potentially much lower than 11 mg/kg.

Absorption and elimination rates for trimethoprim-sulfamethoxoazole (TMP-SMZ), given both orally and intravenously (IV) in one adult Asian elephant and three African (two juvenile and one adult) elephants, were comparable to rates in horses (Page et al. 1991). Based on these findings, the authors speculated that a metabolic scaling dose for elephants would have produced serum concentrations of TMP-SMZ below minimum inhibitory levels for bacterial isolates of equine origin. Pharmacokinetic values differed between Asian and African elephants and were considered to be due to interspecies or individual variation. An average combined dose of 22 mg/kg TMP-SMZ given twice daily was recommended.

Limpoka et al. (1987), using six Asian elephants, determined that oxytetracycline administered IM in a long-acting form maintains therapeutic serum concentrations for 72 hours, postinjection. A dosage for long-acting oxytetracycline, given IM or IV (based on length plus girth), was determined by Bush et al. (1996) in thirteen African elephants (Table 26.1). A dosage of 60 to 80 mg/cm resulted in appropriate serum concentrations for at least 48 hours.

Three Asian elephants were used to determine a suggested ampicillin oral dosage of 8 mg/kg two or three times a day (Rosin et al. 1993). The authors suggest replacing ampicillin with amoxicillin to decrease variability in drug absorption, but they note that no studies to confirm serum levels have been done with ampicillin administered orally.

Amikacin pharmacokinetics was studied by Lodwick et al. (1994) in five African elephants. Based on IM and IV administration, recommended dosage of 6 to

TABLE 26.2—Comparison of dosage determination of anti-inflammatory drugs.

Drug	Zoo Veterinarian Dosing Regimen (mg/kg)	Equine Formulary[a]	Metabolic Scaling[b]	Pharmaco-kinetics
Flunixin	1.0 q[c] 24 hr	1.1 q 12-24 hr	0.7 q 40 hr	None
Ibuprofen	0.5-4 q 24 hr	None	None	None
Phenylbutazone	1-2 q 24 hr	4 q 12 hr	2.5 q 40 hr	None

[a]Plumb (1995)
[b]Metabolic-scaling dosages based on a 3,200 kg elephant
[c]q = every

8 mg/kg given IM every 24 hours was suggested. A metabolic scaled dosage, based on minimum inhibitory concentrations, resulted in serum concentration levels below a recommended threshold.

DISCUSSION When using antibiotics in elephants, zoo veterinarians generally use either an equine dosage or a dosage based on pharmacokinetic research. It appears that both amikacin and amoxicillin are being used on a twice-daily basis, even though research has demonstrated adequate minimum inhibitory concentrations (MIC) on a once daily treatment schedule. Although amikacin is the least nephrotoxic of the aminoglycosides (Plumb 1995), it does have the ability to damage kidney function. Based on postinjection blood levels, procaine penicillin G is generally given in a dosage several times higher and more frequently than is required. This is important because proper administration would decrease the volume and frequency of IM injections, which might keep elephants more cooperative and receptive to treatments. Long-acting oxytetracyclines given IM have been used by few zoo veterinary survey respondents but at relatively low doses compared to the dosage recommended by Limpoka et al. (1987). This is likely due to the side effects, which include muscle necrosis, inflammation, and pain at the injection site. For these reasons Bush et al. (1996) recommend IV administration of oxytetracyclines via an indwelling catheter.

Trimethoprim-sulfamethoxazole is currently being administered orally once or twice daily. Pharmacokinetic research demonstrates the need for dosing on a 12-hour interval. It is possible that only once a day dosing is used due to the poor palatability of the drug.

Metabolic scaling dosages did not correlate well with recommended dosages based on pharmacokinetic research. Amoxicillin was an exception when an adult elephant (3,200 kg) dosage was calculated. The scaled dosage for this drug would be significantly larger for an infant or subadult elephant.

With the exception of ibuprofen, dosages for anti-inflammatory agents used for elephants by zoo veterinarians were close to those reported for the equine. No metabolic scaling was done for ibuprofen because there is no established equine dosage. There are no reported pharmacokinetic studies for anti-inflammatory drugs in elephants. Research in this area is required to allow clinicians to more appropriately utilize this class of drugs. Phenylbutazone use has the most potential for adverse side effects of the three anti-inflammatory drugs compared (Kadir et al. 1997). Currently, zoo veterinarians are using phenylbutazone at a treatment interval much shorter than is predicted by metabolic scaling and could be a health risk if used on a chronic basis.

Based on results from pharmacokinetic studies conducted with small sample sizes, it appears that metabolic-scaling dosage calculations are often too low and treatment intervals are excessively long. Reasons for this difference are likely related to the following biological functions: biotransformation of the drug, cardiac output, tissue receptor sites, plasma protein binding, enzyme systems, hepatic and renal clearance, and drug distribution. Drugs that are minimally biotransformed most likely will be therapeutically effective at metabolically scaled dosages. Using equine dosages can lead to excessively high drug dosages and frequent treatment intervals. At this time, zoo veterinarians are not routinely using metabolic scaling formulas to calculate elephant drug dosages, and many of the dosages utilized are less than the direct equine dosages. Zoo veterinarians apparently understand that dosages need to be reduced, but they do not know by what amount. There is a reported difference in trimethoprim-sulfamethoxazole dosage between African and Asian elephants (Page et al. 1991). In the survey, one zoo veterinarian reported using a lower dose of flunixin meglumine in Asian as compared to African elephants. Research is required to determine if there is a true species difference in pharmacokinetic parameters.

Both antibiotic and anti-inflammatory drugs are used in the treatment of foot pathology. Due to difficulties associated with oral or intramuscular administration of medications, their use in elephant care is often limited. Antibiotics should be administered when there is a potential for cellulitis or septic osteomyelitis. Anti-inflammatory drugs are useful for reducing soft tissue

swelling and providing analgesia. These clinical signs are assumed to be present in a wide array of foot disorders but are difficult to assess clinically in a large, relatively inactive animal.

Based on pharmacokinetic research, it appears that several drugs are being dosed too frequently (e.g., amikacin and amoxicillin) or not frequently enough (e.g., trimethoprim-sulfmethoxazole). Metabolic-scaling dosages and treatment intervals do not correlate well with antibiotic pharmacokinetic research recommendations for both African and Asian elephants. Collaborative pharmacokinetic projects among zoos holding multiple elephants should be conducted.

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PART VI

Conclusions and Recommendations

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27

ELEPHANT FOOT CARE: CONCLUDING REMARKS

MURRAY E. FOWLER

INTRODUCTION Participants in this landmark conference shared their frustrations and successes in dealing with foot disorders in elephants. A variety of foot conditions were described, some of which can be easily corrected by simple trimming. Other conditions progressed to osteomyelitis and/or suppurative arthritis of one or more digits. Vigorous discussion of various topics ensued, and general agreement was reached on a few. For example, it was agreed that African elephants generally have fewer foot problems than Asian elephants and that more exercise would be beneficial for the well-being of all captive elephants.

At the beginning of the discussions, the topic of protected-contact versus free-contact elephant management and its influence on predisposition to foot problems was highly controversial, which was expected. At the conclusion of the conference, a consensus was reached, indicating that appropriate foot care may be provided under both systems. Both systems require dedicated, skilled elephant handlers and adequate training of the elephants. Protected-contact management requires specialized facilities and more time to carry out many of the procedures.

The theme that arose as the conference progressed was that time spent on preventive measures yielded great rewards (Table 27.1). The value of early recognition that allows prevention of more serious problems was stressed. Preventive medicine involves all aspects of an elephant's life that will have a bearing on the well-being of the elephant, including nutrition, housing, behavioral activities, social structure, physical exercise, and genetics, as well as vaccinations and parasite control.

Small group discussions synthesized the feelings of the attendees. The final hour of the conference was devoted to selecting recommendations for preventive measures for elephant foot care. The items represent the collective wisdom of the assembled elephant managers, curators, keepers, veterinarians, and elephant enthusiasts. General agreement was reached concerning the following:

1. Keeping elephants is a costly responsibility. Adequate resources (e.g., staff, money, time, and space) must be made available at each institution that maintains elephants.

2. A written exercise program should be designed for each elephant according to its individual needs. The protocol should be developed in consultation with the elephant manager, keepers, and the veterinarian(s).

3. Radiography is important in elephant foot care. Baseline foot radiographs of all adult elephants should be taken and kept on file. In some facilities, it may be appropriate to annually monitor selected elephants.

4. Each elephant facility should have a written protocol for routine foot care. This protocol must include daily cleaning and inspection of each elephant's feet.

5. Each elephant facility should minimize the amount of time elephants spend on hard, unyielding surfaces.

6. Each elephant should be given a thorough physical examination annually. At least twice a year, keepers, trainers, and curators should review written protocols, practices, and the condition of elephants in their care.

The foregoing items were accepted by consensus of the conference attendees. These recommendations were forwarded to the Elephant Species Survival Plan, Elephant Managers Association, Elephant Specialist Group of The World Conservation Union (IUCN), and the American Association of Zoo Veterinarians. Other items were discussed, but insufficient information is currently available to allow conclusions to be reached. The conference attendees went on record as requesting that the following research projects be conducted. These recommendations have been forwarded to the Zoo Research Committee of the American Zoo and Aquarium Association (AZA) and institutions that may be interested in conducting studies through graduate student projects.

1. Studies of the general anatomy of the soft tissue structures of the foot, including vascular supply, nerves, ligaments, and tendons.

2. Histologic studies, particularly of the sole (slipper, pad), nail, and bones of phalanges two and three.

3. Studies to determine the minimum amount of exercise necessary to promote foot health.

4. Delineating the differences between Asian and African elephant feet that have a bearing on foot care.

5. Pharmacokinetic studies on medications utilized in foot disorder management. Such studies must be in compliance with institution policies.

6. The correlation between conformation, skeletal diseases, and foot disorders.

7. Establishing the median or mean weight to size ratios for both captive and free-ranging wild elephants. Some of this information may be gleaned from the literature. Other aspects may require field studies (captive and free-ranging).

TABLE 27.1—Comparison of the time devoted to elephant foot preventive care to the time devoted to treatment of a serious problem.

	Routine Preventive Care			Treatment—Serious Problem	
	Pedicure (Hours)	Exercise (Hours)	Total Work Days	Infected Foot (Hours/Day)	Total Work Days
Per month	2 (2 people)	30	4	Vet. = 1 Keeper = 2	11.25
Total				90 hours	
Per 4 months	8 (2 people)	120	16	360 hours	45

TABLE 27.2—Tools used for elephant foot care.

Tool
Hoof knife
Hoof rasp
Hoof groover
Drawing knife (spoke shaver)
Equine hoof nipper
Electric sander
Swiss Cutting knife
X-acto knife (X-router blade, No. X161)
Currette
Wire brush
Rat-tailed file
Sharpening stone

8. Studies to elucidate the etiology and epidemiology of foot disorders.

The tools used for performing routine pedicure vary with the experience of the elephant care team and availability of equipment (Table 27.2). The important factor is the training of personnel in the appropriate use of the tools, including sharpening.

TOPICAL ANTIMICROBIALS Topical medications and solutions used for foot disorders vary widely. Some are derived from folklore medicine or herbal medicine. Such products may well have antiseptic, disinfectant, or healing activity but most have not been subjected to scientific pharmacologic testing. A few of the products available through pharmaceutical distributors include the following:

- *Ciderm liquid and gel* (chlorine-dioxideoxychlor complex).
  Action: a powerful oxidizing agent. Also an excellent antimicrobial and deodorant.
  Source: ARCO Research Inc., SUNY Farmingdale, Conklin Hall, Farmingdale, New York 11735, U.S.; Telephone (516) 777-1420; FAX (516) 777-1422.
- *Copper sulfate* ($CuSO_4$, bluestone, blue vitrol).
  Description: A blue granular powder.
  Action: Antiseptic and astringent in dilute solution, caustic in concentrated solution. As an astringent, a 1 percent solution (10 g/l of water or 2 teaspoons per quart of water) is recommended.
  Source: A garden store or a pharmaceutical company.
- *Dilute acetic acid* (vinegar, 4 to 7 percent acetic acid).
  Action: Used as an antimicrobial and cleansing solution.
  Glacial acetic acid is 36 to 37 percent acetic acid and is caustic.
- *Dimethylsulfoxide* (DMSO).
  Action: Used as a solvent to facilitate movement of other medications into the tissue. Causes a disagreeable odor in the breath of the animal.
- *Formalin*, 10 percent.
  Action: Powerful disinfectant, but also quite caustic.
- *Hydrated lime powder* ($Ca(OH)_2$).
  Description: A mixture of CaO and water.
  Action: Used as a mild disinfectant and astringent powder. Do not confuse with lime (Ca0, quicklime, burntlime), which is caustic.
- *Hydrogen peroxide* (H_2O_2) 20 percent.
  Description: Solution is a colorless, odorless liquid.
  Action: Powerful antiseptic when in contact with tissue fluids, causing foaming and cleansing. Do not inject into puncture wounds or closed cavities.
  Source: Any drugstore or pharmacy.
- *Ichthamol* (bitumen sulfonatum, ammonium ichthyolsulfonate).
  Description: A mixture of a product of the distillation of bitumen with lanolin and petrolatum. Contains 10 percent sulfur.
  Action: Slightly irritant. It draws abscesses to a head, reduces swelling, and is somewhat antiseptic.
- *Kopertox* (37.5 percent copper naphthenate).
  Application: Apply daily, following the cleansing of the wound. Not to be used on animals intended for food. Can be removed from hands and clothing with lighter fluid.
  Source: Aveco or Fort Dodge Laboratories, 800 5th Street, NW (P.O. Box 717), Fort Dodge, Iowa 50501, U.S.; FAX (515) 955-3730
- *Nitrofurazone* (furazone).
  Description: Usually in a 0.2 percent solution or aerosol.
- *Zinc oxide* (ZnO).

Description: A white to yellowish-white powder.
Action: May be made into a 20 percent ointment.

SOLUTIONS FOR SOAKING THE FOOT OR IRRIGATING FOOT LESIONS

- *Magnesium sulfate* ($MgSO_4$, Epsom salt).
  Action: A saturated solution of Epsom salts is hypertonic and draws fluid from tissue. Used for local inflammation, cellulitis, arthritis, and contusions. Dissolve Epsom salts in a small amount of boiling water, and then add hot water to the quantity desired. One formula is 280 ml (10 fluid ounces) glycerin and 1134 g (40 ounces) of Epsom salts and water to make 1182 ml (40 fluid ounces). More likely for an elephant foot, 225 g (0.5 pounds) of Epsom salts in 2 liters (2 quarts) hot water. Allow water to cool.
  Source: Any drugstore or pharmacy.
- *Nolvasan solution* (Chlorhexidine diacetate).
  Action: Dilution for use as a disinfectant solution is 84 ml (3 ounces) of the 2 percent stock solution to 3.7 liters (1 gallon) of clean water. It is not effective against *Pseudomonas* spp.
  Source: Aveco or Fort Dodge Laboratories, 800 5th Street, NW (P.O. Box 717), Fort Dodge, Iowa 50501, U.S.; FAX (515) 955-3730
- *Povidone-Iodine solution* (Betadine) 5 percent stock solution. Action: Dilution is one part povidone-iodine to four parts water. It should not be used on food-producing animals.
  Source: Purdue Frederick Co., 100 Connecticut Ave., Norwalk, Connecticut, U.S. 06850-3590; Telephone (203) 853-0123; FAX (203) 838-1576.
- *Sodium hypochlorite* (NaOCl; common household bleach, 5.25 percent).
  Action: As a general disinfectant, dilute 200 ml (7 fluid ounces) of bleach to 3.7 liters (1 gallon) water. Deactivated rapidly in presence of organic material
  Source: Any grocery store.

SUMMARY BENEFITS Table 27.3 is a general summary of many of the conditions affecting elephant feet, along with predisposing factors and prevention and management recommendations.

TABLE 27.3—Elephant foot conditions, predisposing factors, and prevention and management recommendations.

Condition	Predisposing Factors	Prevention and Management
Abrasion, sole	Stereotypic movements	Behavioral enrichment, avoid harsh enclosure surfaces
Abscess, subsolar	Foreign body penetration, gravel, pits	C,I,P*
Abscess, toenail	Gravel, Failure to clean routinely	C,I,P
Abscess, interdigital	Pododermatitis, interdigital hyperkeratosis	Avoid wet, muddy surfaces
Arthritis	Numerous, lack of exercise	Monitor feet radiographically, medication
Bulla	Infection	Avoid insanitary conditions
Contusion, sole	Stone bruise	Provide proper enclosure surface
Canker	Chronic infection	C,I,P
Crack, heel	Pododermatitis	C,I,P
Crack, toenail	Toenail overgrown	C,I,P
Crack, sole	Sole overgrown	C,I,P
Cuticle overgrown	Lack of proper maintenance	C,I,P
Fissure	Sole overgrown	C,I,P
Fracture	Blow to the foot, struggling in chains	Standard fracture management
Gravel	Failure of proper cleaning of foot	C,I,P
Groove, sole	Sole overgrown	C,I,P
Hangnail	Lack of proper maintenance	C,I,P
Hematoma	Contusion to sole or skin	Protect sole with bot until hematoma is absorbed
Ingrown toenail	Lack of proper trimming	C,I,P
Laceration	Exposure to sharp objects	Avoid exposure to sharp objects
Maceration. sole	Constant standing in filth and moisture	Proper enclosure cleaning, provide drainage
Maceration. skin	Constant standing in filth and moisture	Proper enclosure cleaning, provide drainage
Onychia	Malnourishment to toenail	Rasp bottom of nail to relieve pressure on the nail
Osteomyelitis	Progression of cellulitis or abscesses	Surgical amputation of phalange(s)
Paroncychia	Pododermatitis	C,I,P
Pitting	Sole overgrown	Proper pedicure
Pockets	Sole overgrown	Proper pedicure
Pododermatitis	Continual standing in filth and moisture	Proper enclosure cleaning, provide drainage
Puncture wound	Access to sharp objects	Tetanus toxoid vaccination. Avoid sharp objects
Pustule	Cracks in skin	C,I,P, antibiotics
Ridge, sole	Normal, or sole overgrown	Proper enclosure cleaning, C,I,P
Ulcers	Failure to clean out pockets	C,I,P
Vesicle	Friction or infection	May be viral or bacterial, antibiotics

*C,I,P = Routine foot cleaning, inspection, and pedicures

APPENDIX I

ELEPHANT MANAGEMENT GUIDELINES (MARCH 1997)

AMERICAN ZOO AND AQUARIUM ASSOCIATION[1]

PREAMBLE Regardless of the elephant management method used, any human/elephant contact is inherently dangerous. All available precautions suitable for the institution should be evaluated and utilized whenever possible. Staff should be properly trained and experienced in the professionally recognized forms of elephant management and should be constantly aware of the risk of human injury and death.

RECOMMENDATIONS

1. As bull elephants begin to mature, they should be critically evaluated. As early as 5 years of age, they may show behavioral changes that can put handlers in danger. When these changes become evident or suspected, the animal should be removed from free-contact management. If the bull is to remain in the herd structure, reproduction must be managed.

2. It is strongly recommended that all facilities that maintain elephants have an elephant restraining chute (ERC).

3. Both genera of elephants are highly social animals during all or significant portions of their lives. Females and immature males should not be kept alone on a long-term basis.

4. A minimum of two qualified elephant keepers should be present during any contact with elephants. A qualified elephant keeper is a person the institution acknowledges as a trained, responsible individual capable of and experienced in the maintenance of elephants. Until qualifying regimens are designed and implemented, the qualifications of the elephant keepers must be left up to the judgment of the institution and its staff.

5. Each institution must have a written protocol, approved by the Director/CEO, that specifically addresses elephant management policies and protocols. This must be a living document that is reviewed semiannually and is always subject to upgrading and improving.

6. Each institution should have a dedicated staff position that is responsible for the direct management of the elephant program. This person's skills in the area of personnel management, elephant management, and personnel safety are crucial to the success of the program.

7. Nomenclature of current elephant management systems:

- Free contact: Direct handling of an elephant when the keeper and the elephant share the same unrestricted space. Neither the use of chains nor the posture or position of the elephant alters this definition.
- Protected contact: Handling of an elephant when the keeper and the elephant do not share the same unrestricted space. Typically in this system, the keeper has contact with the elephant through a protective barrier of some type, while the elephant is *not* spatially confined and may leave the work area at will.
- Confined contact: Handling of an elephant through the protective barrier where the elephant is spatially confined as in an ERC.
- No contact: Handling an elephant with no contact made unless the elephant is chemically sedated. This is not recommended as the primary form of management.

8. All institutions must undertake at least semiannual elephant facility and program safety assessment to identify safety needs and, if required, fully implement corrective measures. Furthermore, institutions must recognize that elephant facilities and programs will require modification over time, as management practices are changed and refined. To accomplish this, each facility should establish a safety assessment team. The team may include, but not be limited to, elephant staff, management staff, animal health care staff, and experts in the area of risk management and safety. Each facility should establish the makeup of the team based on its own needs and resources. A written record should be kept for each inspection and the record must be reviewed and its recommendations acted upon.

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APPENDIX

II

RESULTS OF A SURVEY OF ELEPHANT FOOT CONDITION AND CARE IN NORTH AMERICA

NORIE DIMEO-EDIGER

INTRODUCTION There is a wealth of information that is shared informally among elephant managers about the state of foot health in captive elephants and preferred forms of treatment. However, in an attempt to quantify and compile what is known about the institutional status of elephant foot health, staff from the Oregon Zoo and the San Francisco Zoo developed the Survey on Elephant Foot Husbandry and Veterinary Care. The survey was mailed in October 1997 to the institutional representative at each of the 84 institutions that participate in the Elephant Species Survival Plan (SSP). With few exceptions, all of the participants are American Zoo and Aquarium Association (AZA) accredited facilities. The few that are not AZA-accredited facilities went through the Wildlife Conservation Management Committee (WCMC) non-AZA member application process. There are 31 institutions that only house Asian elephants, 36 that only house African elephants, and 17 institutions that house both Asian and African elephants. Fifty-four surveys were returned by the December 1997 deadline and are included in this report. The survey included questions about the physical environment of the elephant facility, the incidence of foot problems, and the types of treatment that elephant managers use with most success.

SURVEY RESULTS Concrete was the substrate in 91 percent of the indoor elephant enclosures. Ninety-three percent of the facilities have sloped floors, while only 18.5 percent of the floors have grooves for drainage. While conventional wisdom might indicate a relationship between type of substrate and foot disease, only half (52 percent) of respondents saw a relationship between concrete flooring and foot disease. In the majority of institutions (67 percent), it was a low priority to change the indoor flooring.

Sixty-three percent of respondents thought that a relationship existed between inactivity and foot disease, and for 80 percent it is a priority to give their elephants more exercise. At present, 32 percent of elephants are getting more than 30 minutes of exercise each day.

The survey divided foot problem treatments into five main categories: trimming, soaking, topical medications, bandaging and booting, and systemic agents. Trimming was the most popular treatment and was also used with the most success. The majority of institutions use nail trimming with good success, but surprisingly, about one-quarter of the institutions do not trim nails. Nearly equal numbers of institutions use soaking (both in warm water, Epsom salt, and antiseptic solutions) as those that don't soak. The majority of those that use soaking find it to be successful. Overall, topical medications are not used by the majority of institutions. Of the topical medications that are used, antiseptic solutions are used with the most success. Very few institutions use bandaging or boots/sandals. However, those that do find them to be a very successful treatment. This was also true of systemic agents. The majority of the institutions do not use them, but those that do use them reported a high degree of success.

In an attempt to look for regional patterns in elephant foot disease, surveys were arranged into four geographical groups: northwest, northeast, southwest, and southeast. Soft nails (perionchia with softening of nail) are the most frequent form of foot disease found in elephants in facilities in the northwest and the northeast. In the southwest, erosions on the sole of the foot with penetration to vital tissue are seen more than any other problem. In institutions in the southeast, lesions between the nails (perionychia) are the most frequent form of foot disease.

This survey was extensive, and we want to thank all of those institutions that participated. Although some questions were not easily scored, they did offer an opportunity to determine which aspects of elephant foot care should be a focus of further studies.

GLOSSARY

MURRAY E. FOWLER

Abrasion, sole—See **Sole, abrasion.**

Abscess—A localized collection of pus buried in tissues, organs, or confined spaces.

Abscess, subsolar—An abscess located beneath the sole (i.e., slipper, pad).

Amble—See **Gait, amble.**

Ankus—A metal prod and hook attached to a handle. The points on the prod and hook should be dull to prevent accidental tearing of the skin. Also known as bull hook; elephant hook; goad; hook.

Ankylosis—The fusion of a joint due to disease, injury, or surgery. May be partial, associated with pain, or complete, often without pain, but may cause a mechanical lameness. (plural, ankyloses)

Apitong—An imported hardwood lumber that is often used for the decking of trucks and trailers. It is derived from a tree of the same name from the Philippines. It is also used to surface elephant night enclosures. Moveable panels of the lumber are usually constructed to allow for cleaning. Planks come in a width of 8 inches with a half-inch lap joint. The thickness is 1.25 inches. The retail price is $2.50 per linear foot. A closely related wood is keruing from Malaysia, which is an alternative to apitong.

Arthritis—Inflammation of a joint and surrounding structures.

Arthritis, rheumatoid—A chronic disease, primarily of the joints and usually involving multiple joints, marked by inflammatory changes in the synovial membrane and articular structures.

Arthritis, suppurative (exudative)—Arthritis with an exudate within or surrounding a joint.

Asphalt—A mixture of tars and small gravel that is used for surfacing roads, enclosures, feeding areas, and stalls. Also known as bitumen; blacktop; macadam; paving.

b.i.d.—Application of a veterinary treatment or medicine twice a day.

Bitumen—See **Asphalt.**

Black tracts—Holes in the sole, or at the junction of the nail and the sole, that are filled with a blackish exudate, which should be cleaned to reveal healthy tissue when trimming a foot.

Blacktop— See **Asphalt.**

Blister—A small accumulation of clear fluid between the layers of the skin, generally caused by friction or by some viral disease process. In elephants the term is applied to seropurulent, fluid-filled pockets in the area of the cuticle. Also known as vesicle. See also bulla.

Blood blister—See **Hematoma.**

Bulla—A large blister, more than 5 mm in circumference, containing serous or seropurulent fluid. Also called a bleb or a vesicle. (plural, bullae)

Bruise—See **Contusion.**

Callus, interdigital (callosity)—A localized proliferation of the horny layer of the skin between toenails. May be caused by pressure, friction, or infection.

Carpus—The knee of a horse or wrist of a human. In the elephant, the carpus is part of the foot of the forelimb.

Cellulitis—An acute, diffuse, edematous, suppurative inflammation of the deep subcutaneous tissue, often surrounding an abscess. See also phlegmon.

Contusion—An injury to the skin or the sole caused by a blow but without a break in the skin or sole. Also known as bruise.

Corium—The highly vascularized fibrous tissue that nourishes the skin, toenail, and sole. The corium also provides the fibrous connection between the nail and the distal phalanx.

Coronary groove—The base of the hoof containing the germinal epithelium from which the hoof wall grows downward. May be used to describe the top of the nail in an elephant. Also known as coronary band.

Crack, heel—Cracks in the skin near the rear of the foot.

Crack, sole—Cracks in the keratinized layer of the sole (i.e., slipper, pad) of an elephant foot.

Crack, toenail, deep—A crack penetrating the full thickness of the nail, into the quick. Also known as split toenail.

Crack, toenail, superficial—A crack that only penetrates the outer layers of the nail, not into the quick.

Crack, toenail, transverse—A defect in a toenail characterized by a crack across the long axis of the nail. May be initiated by an infection of the nail bed. Also known as horizontal toenail crack.

Crack, toenail, vertical—Either a superficial or deep crack that parallels the vertical axis of the nail. Such a crack may originate at the bottom or the top of the nail.

Cushion, digital—A mass of fatty-fibroelastic tissue occupying the space below the digits of the elephant foot.

Cuticle—The narrow band of epidermis that extends from the base of the nail wall onto the surface of the nail. Also known as eponychium.

Cuticle, overgrown—Excessive growth of the epithelium at the top of the nail. See also hang nail.

Decomposed granite (DG)—A type of coarse soil derived from granite rock that can be compacted into a firm surface.

Digit—A finger or a toe.

Digital cushion—See **Cushion, digital.**

Digitigrade—Having feet shaped so that the toes, but not the heels, are on the ground (dogs, cats). Elephants are semidigitigrade in the forefeet and semiplantigrade in the hind feet.

Discharge, purulent—A discharge composed of pus.

Dove-tailing—Beveling the edges of a crack or groove to prevent impacting dirt or feces in the crack. Also known as feathering.

Eponychium—See **Cuticle.**

Exudate—A protein-rich fluid composed of serum, blood cells (primarily leukocytes), tissue cells, and/or cellular debris escaping from a wound or from the surface of a diseased tissue.

Exudation—The flow of an exudate from a wound.

Feathering—See **Dove-tailing.**

Fissure—Any cleft or groove (normal or abnormal) on the surface of an organ, such as the skin or sole of an elephant foot.

Fistula—Any abnormal, tube-like passage within body tissue.

Fistulous—Pertaining to or of the nature of a fistula.

Foot, forefoot—The distal segment of the forelimb including the carpus, metacarpals, digits, tendons, ligaments, nerves, blood vessels, joints, skin, and nails. Also known as manus.

Foot, hind foot (pes)—The distal segment of the hind limb including the tarsus, metatarsals, tendons, ligaments, nerves, blood vessels, joints, skin and nails.

Foot rot—A general term used to describe various types of infection of the foot.

Gait, amble (modified pace, single-foot)—A four beat gait in which the limbs on the same side of the body move forward at the same time, but the hind foot hits the ground slightly before the forefoot. The amble is the medium to rapid gait of the elephant.

Gait, walk—A four beat gait, in which there are always three feet on the ground at any one time. This is the slow gait of an elephant.

Germinal epithelium—The layer of cells at the base of the epidermis of the skin, sole, and toenail that continues the growth of these structures.

Goad—See **Ankus.**

Granulation tissue—The newly formed vascular tissue, normally produced in the healing of wounds of soft tissue.

Gravel—An equine term, describing an infection that usually begins at the white line (junction of the hoof and sole), progresses dorsally deep into the hoof wall, and then usually breaks out (heads out) above the coronary band. As applied to an elephant foot, it describes an infection that invades the tissue just deep to the nail at the bottom of the foot, and then migrates dorsally to the top of the nail bed. It was once thought that the infection was caused by the migration of a piece of gravel. In the horse, a piece of gravel may be present at the bottom of the tract, but it is now thought that this is coincidental to the infection.

Hang nail—A small piece of skin hanging by one end at the side or base of a nail. This can be a significant problem of elephant feet that are not properly cared for.

Heel cracks—See **Crack, heel.**

Hematoma—An accumulation of blood in a confined space, in a tissue, such as the sensitive fibrous tissue beneath the sole. Caused by rupture of a capillary or other vessel. Also known as blood blister.

Hoof—The hard, horny covering of the feet of horses, cattle, sheep, swine, and wild ruminants. The elephant nail is sometimes referred to as a hoof, and this may be appropriate in view of the laminae that connect P-3 to the nail.

Hyperkeratosis—Excessive production of keratin or horny tissue.

IM—Intramuscular.

Infection—Invasion of a tissue or organ by bacteria, fungi, or viruses.

Ingrown toenail—See **Toenail, ingrown.**

Interdigital callus—See **Callus, interdigital.**

IV—Intravenously.

Keratinization—The normal process of production of horny tissue on the surface of the sole or production of the outer cells of the skin.

Laceration—A wound caused by a sharp object (e.g., glass, metal, teeth, jagged edge of wood). Also known as cut; wound.

Laminitis—An inflammation of the lamina (the attachment between the hoof and P-3). Elephants have simple laminae that may be contused, producing a laminitis. Elephants are not susceptible to the type of laminitis found in the horse. Also known as founder.

Macadam— See **Asphalt.**

Maceration—The softening and degeneration of the sole or skin of the foot caused by prolonged exposure to moisture and feces.
Manus—See **Foot, forefoot.**
Metacarpal bones—The cannon bone of a horse. In elephants, the bones between the carpus and the digits of the fore limb.
Metatarsal (MT) bones—The hind cannon bone of a horse. In elephants, the bones between the tarsus (hock) and the digits.

Nail, overgrown—Elongation of the nail caused by failure of the nail to wear properly. The toenail may grow as much as 6.4 mm (1/4-inch) per month.
Nailbed—The tissue upon which the nail is situated.
Nailing—Penetration of the sole (i.e., slipper, pad) by a sharp object (e.g., nail, screw, bolt, piece of glass, sliver). The penetration may be only within the keratinized tissue, or into the corium or digital cushion.
Necrotic pododermatitis—Inflammation of the skin of the foot, leading to cell damage caused by enzymatic degradation.

Onychia also **Onychitis**—Inflammation of the matrix of the nail, resulting in the loss of the nail.
Osteoarthrosis—An arthritic condition characterized by degeneration of the articular cartilage, hypertrophy of bone at the margins, and changes in the synovial membrane. Classified as a degenerative joint disease (DJD).
Osteomyelitis—An inflammation of bone caused by pyogenic bacteria.
Overgrown, cuticle—See **Cuticle, overgrown.**
Overgrown, nail—See **Nail, overgrown.**
Overgrown, sole—See **Sole, overgrown.**

Pad—See **Sole.**
Paving—See **Asphalt.**
Paronychia also **Perionychia**—Inflammation involving the folds of the skin and tissue surrounding the nail.
Pedestal—See **Tub.**
Pedicure—Professional care and treatment of the feet.
Periople—The layer of soft, light-colored horn (keratinized) covering the outer aspect of the hoof or nail of ungulates. One of the functions of the periople is to protect the hoof or nail from moisture penetration.
Phalanx—The individual bones of the digits. P-1 = proximal phalanx, P-2 = middle phalanx, P-3 = distal phalanx. Not all digits in the elephant have three phalanges. (plural, phalanges)
Phalanx three (P-3) fracture—Characterized by multiple segments of P-3, as seen on a radiograph. May be the result of trauma, osteomyelitis, decalcification, or general degeneration.
Phlegmon—A spreading, diffuse inflammatory reaction to infection with small pockets of pus. The infection may be just beneath the skin, or extend into muscles and other vital tissues. See also cellulitis.
Pit—A hole or cavity in the sole (i.e., slipper, pad). The pit may be superficial or extend into the quick, which is sensitive tissue. A pit may be hidden by an overgrowth of keratinized tissue.
Plantigrade—Foot structure that allows the animals to walk with the toes in a horizontal position (e.g., bears, humans). The hind feet of elephants are semiplantigrade.
p.o.—Given orally.
Pocket—A hollow space or an enclosed space.
Pododermatitis—Inflammation of the skin, nail, and associated structures of the foot.
Puncture wound—A penetration of the skin or sole (i.e., slipper, pad) by a sharp object (e.g., nail, screw, bolt, piece of glass, sliver).
Pus—A protein-rich fluid composed of blood cells (primarily leukocytes), tissue cells, and/or cellular debris and bacteria escaping from a wound or from the surface of a diseased tissue.
Pustule—A visible collection of pus within or beneath the epidermis, often in a hair follicle or sweat pore.

q.i.d.—Application of a veterinary treatment or medicine four times a day.
Quick—The sensitive tissue (supplied with nerves and blood vessels) deep to the sole or nail.

Ridge—A long, narrow proliferation of keratin in the sole of the foot. The pattern of the ridges and grooves may produce a unique footprint of each elephant.

Seedy toe—A horse disease characterized by horny, honeycombed fungal growth between the hoof wall and P-3. May be present in elephants.
Sesamoid bone—A small bone embedded in a tendon or joint capsule at points of heavy pressure or acting like a pulley where a tendon changes direction. Elephants have a pair of sesamoid bones, which may be fused at the distal end of the metacarpal and metatarsal bones.
s.i.d—Application of a veterinary treatment or medicine once a day.
Slipper—See **Sole.**
Sole—The bottom of the elephant foot, characterized by a flexible, keratinized layer overlying a germinal epithelium and corium (fibrous tissue). Also known as slipper; pad.
Sole, abrasion—Excessive wear of a segment of the sole. Usually caused by stereotypic behavior, such as turning continually in one direction or pawing with a foot.
Sole, bruised (or contused)—Inflammation of the sensitive tissue beneath the sole. Evidence of a bruise may be localized over the area. Later, the spot may show reddening of the keratinized tissue caused from a deep hemorrhage.

Sole, overgrown—Excessive keratin on the sole caused by failure of the foot to wear properly.
Split toenail—See **Crack, toenail, deep.**
Subsolar abscess—See **Abscess, subsolar.**
Substrate—By definition, this is a layer of soil beneath the surface layer. In practical usage, it is the composition of the surface upon which an elephant walks. Types employed in elephant enclosures include decomposed granite, dirt, sand, gravel, asphalt (black top), and concrete (rough or smooth).
Synovitis—Inflammation of the tendon sheaths that surround tendons in the feet. Also known as tendosynovitis.

Tarsus—The hock of a horse or the heel and ankle of a human. In the elephant, the tarsus is part of the foot of the hind limb.
Thrush—An equine term, used to describe a fetid, gray to black discharge alongside the frog. Usually associated with degeneration of keratinized tissue. In elephants, it may describe the foul smelling, accumulated debris in cracks, crevices, or pockets in the sole.
t.i.d. —Application of a veterinary treatment or medicine three times a day.
Toenail—The cornified (keratinized) structure at the extremity of a digit.
Toenail, ingrown—Abnormal growth of a nail into adjacent soft tissue of the nailbed.
Tract, black—Holes in the sole that are filled with a blackish exudate. They should be explored and feathered to healthy tissue when trimming a foot.
Tub—A reinforced stand or platform upon which an elephant is trained to place a foot for trimming. Also known as pedestal.

Ulcer—A local defect or excavation of the surface of the skin or sole, which is produced by the sloughing of inflammatory necrotic tissue.
Ungulate—The usual meaning is hoofed mammal, but animals such as tapirs, rhinos, and elephants, which have more of a nail than a hoof, are often included in the ungulate category.

Vesicle—See **Blister.**

Waist—The narrowed circumference of the foot just above the nails.
Wound, penetrating (puncture)—A wound caused by a foreign body (e.g., nail, screw, bolt, piece of glass, sliver) that penetrates the skin or the sole of the foot.
Wrist—The carpus.

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