Novel treatment for chronic pododermatitis in an Indian elephant (Elephas maximus indicus) with Mohs’ paste

Nobuhide KIDO1*, Sohei TANAKA1, Tomoko OMIYA1, Yasuyuki SHOJI1, Masaru SENZAKI1, Sayuri HANZAWA1, Masato ANDO1, Tomohiro OSAKI2, Hitoshi HATA3, Noriaki MIYOSHI3, Tatsuro HIFUMI3, Naomi SUZUKI4 and Shigehisa KAWAKAMI5

1) Kanazawa Zoological Gardens, Yokohama Greenery Foundation, 5-15-1, Kamaraya higashi, Kanazawa-ku, Yokohama, Kanagawa 236-0014, Japan
2) Veterinary Surgery, Joint Department of Veterinary Medicine, Tottori University, 4-101, Koyama Minami, Tottori 680-8550, Japan
3) Department of Veterinary Histopathology, Joint Faculty of Veterinary Medicine, Kagoshima University, 1-21-24, Korimoto, Kagoshima 890-0065, Japan
4) Kono Seisakusho Co., Ltd., 2-11-10, Soya, Ichikawa, Chiba 272-0832, Japan
5) Gunma Safari Park, 1 Okamoto, Tomioka, Gunma 370-2321, Japan

ABSTRACT. Asian and African elephants are frequently afflicted by foot disorders that can be very challenging to manage even with aggressive therapy. Such conditions may have indirect life-threatening effects. Mohs’ paste (zinc chloride based escharotic agent) was used to treat a female Indian elephant (Elephas maximus indicus) aged 39 years with foot disorder at Kanazawa Zoological Gardens. Degenerated hyperplastic tissue was observed inside the hoofs of digits 2 and 5. Mohs’ paste was applied on the lesions, which coagulated the hyperplastic tissue and restrained its proliferation. Subsequently, the hyperplastic tissue could be trimmed with little pain, and the disorder became manageable. Mohs’ paste treatment was effective and is expected to be an alternative treatment for hoof disorder.

KEY WORDS: Elephas maximus indicus, haemostasis, hoof trimming, Mohs’ paste, tissue coagulation

A female Indian elephant (Elephas maximus indicus) (aged at 39 years in 2017; weighing 3,800 kg) housed at Kanazawa Zoological Gardens, and has been maintained since 1985. The elephant was born in wild and brought from Mumbai, India. The indoor and outdoor enclosures of the elephants are covered with concreted ground. The elephant is managed directly through contact and can be routinely treated. The elephant, at 31 years of age, had several cracks on her hoof sole, occasionally extended to the hoof wall, especially on digits 2 and 5 on the left forelimb. Copper naphthenate (concentration as Cu: 4.7–5.3%; Junsei Chemical Co., Ltd., Tokyo, Japan) was applied to the trimmed hoof. This treatment was repeated until the cracks were covered by the new hoof tissue.

When the elephant was 38 years old, a sole ulcer was found on digit 2 of the left forelimb. The elephant did not cooperate during treatment because of the pain. Although the lesion had been treated with five months of copper naphthenate application, the trimmed hoof had always remained haemorrhagic and the degenerated hoof tissue became hyperplastic (approximately 5.0 cm in diameter; Fig. 1a). Therefore, an alternative treatment was considered. Mohs’ paste that is a zinc chloride based escharotic agent was prepared from a mixture as Table 1. The modified Mohs’ paste for the elephant was prepared in the present study. Mohs’ paste was applied to the lesion in the sole ulcer (Fig. 1b), and a foot soak with liquid iodine was also initiated. The paste was initially applied on the lesion for only 10 min under the keeper’s observation during which the elephant was in the standing position. Next day, hyperplasia of degenerated hoof tissue was no longer observed, and the tissue surface became necrotic. This necrotic tissue was trimmed (about 2–5-mm thick) until the vascularizing tissue was exposed; afterward, the paste was applied to the lesion and haemostasis was observed because of the paste. The hoof was trimmed using different types of well-sharpened hoof knives and rasps, as was described in a previous study [2, 3, 19]. In addition, a rapid spray-type freezing mixture (EM freezer, Nisshin-em Co., Tokyo, Japan) was sprayed on the lesion and the lesion was frozen within a few second when the hyperplastic tissue was trimmed. An ultrasonic cutter (SUW-30CMH, SUZUKI Motor Co., Shizuoka, Japan) was used to trim the hard hoof and the...
hyperplastic tissue. The large black necrotic tissue remained prominent at the centre of the lesion. Therefore, paste application to the lesion was stopped on day 34. Afterward, the hyperplastic tissue vigorously proliferated from the peripheral lesion. On the 98th day, a fistula inside the hoof wall was detected from the hoof sole to the coronet by contrast radiography. Subsequently, the hoof wall was trimmed, and the degenerated hoof tissue was eventually detected inside the hoof wall. The application of the paste was resumed on day 137, and the wide area of the hoof wall was trimmed (Fig. 1c). The hyperplastic tissue was covered with scabs after applying the paste (Fig. 1d). On day 181, the centre of the lesion was covered with black necrotic tissue, and the

Fig. 1. Changes in digit 2 of the left forelimb in an Indian elephant (Elephas maximus indicus) affected by hoof disorder. (a) 1 month before the start of Mohs’ paste application. A large sole ulcer in the hoof sole that was bleeding and was painful for the elephant. (b) Day 3, when Mohs’ paste was applied on the hoof ulcer lesion. (c) Day 137, when the wide area inside the hoof wall was infiltrated by the hyperplastic tissue. (d) Day 145, when Mohs’ paste was applied on the hoof wall lesion. (e) Day 230, when Mohs’ paste was applied on the surface of the hyperplastic tissue and the surface was trimmed little by little. (f) Day 305, when the hyperplastic tissue was no longer observed and the hoof shape had almost recovered.
observation during the application of Mohs’ paste because the elephant could easily touch the paste using its trunk. Therefore, under controlled conditions during the application of Mohs’ paste. In the present study, the elephant had to be under the keeper’s veterinary medicine, there is the risk that the animals may accidentally ingest the paste. This, therefore, requires the animals to be of 1-mm-thick Mohs’ paste. In addition, the haemostatic effect was observed after 10 min of contact with Mohs’ paste [10]. In Shigeyama coagulated the hyperplastic tissue and allowed trimming without causing severe pain to the elephant.

haemorrhage was frequently observed on the trimmed lesion, the haemostatic effect of Mohs’ paste was present. Mohs’ paste is useful in preventing degenerated tissue proliferation. Haemostasis was also observed in the lesion after trimming. Various studies and the protein is coagulated by the astringent effect of ionised zinc [1, 15, 16, 21]. Therefore, this zinc fixation method might be proliferation of hyperplastic tissue. Mohs’ paste is known as zinc chloride fixative paste. Zinc is ionised by exudate from the lesion, the treatment of hyperplastic hoof disorders in elephants. Mohs’ paste could chemically coagulate the tissue and prevent the use of specialised instruments and experienced medical personnel. Our study revealed that Mohs’ paste was effective for without specialised instruments and experienced medical personnel. Further, specific instruments and well-trained and experienced personnel will be necessary [2, 9].

The degenerated hyperplastic tissue commonly observed in hoof disorder may prevent successful treatment, because the tissue is fragile, bleeds easily, and is very painful. Invasive surgery will occasionally be necessary under anesthesia along with long and intensive postoperative care. Further, specific instruments and well-trained and experienced personnel will be necessary [2, 9].

An alternative treatment that does not require anesthesia might be useful to treat captive elephants, particularly in settings without specialised instruments and experienced medical personnel. Our study revealed that Mohs’ paste was effective for the treatment of hyperplastic hoof disorders in elephants. Mohs’ paste could chemically coagulate the tissue and prevent the proliferation of hyperplastic tissue. Mohs’ paste is known as zinc chloride fixative paste. Zinc is ionised by exudate from the lesion, and the protein is coagulated by the astringent effect of ionised zinc [1, 15, 16, 21]. Therefore, this zinc fixation method might be useful in preventing degenerated tissue proliferation. Haemostasis was also observed in the lesion after trimming. Various studies have reported that Mohs’ paste has haemostatic effects on malignant wounds [4, 10, 12]. Although in the present study severe haemorrhage was frequently observed on the trimmed lesion, the haemostatic effect of Mohs’ paste was present. Mohs’ paste coagulated the hyperplastic tissue and allowed trimming without causing severe pain to the elephant.

There are no existing rules regarding the contact time and frequency of use of Mohs’ paste in treating elephant hoof disorder. Shigeyama et al. [20] described that 5- and 10-mm-deep tumour tissues were fixed after 48 and 72 hr, respectively, after application of 1-mm-thick Mohs’ paste. In addition, the haemostatic effect was observed after 10 min of contact with Mohs’ paste [10]. In veterinary medicine, there is the risk that the animals may accidentally ingest the paste. This, therefore, requires the animals to be under controlled conditions during the application of Mohs’ paste. In the present study, the elephant had to be under the keeper’s observation during the application of Mohs’ paste because the elephant could easily touch the paste using its trunk. Therefore, initially, Mohs’ paste was only allowed to remain on the lesion for 10 min daily, and later increased to four hr daily after we

Table 1. Formulation of the modified Mohs’ paste in the present study

| Materials                        | Mohs (1941) [15] | Kakimoto et al. (2010) [10] | Fukuyama et al. (2016) [4] | Modified Mohs’ paste 1.25 timesa) |
|----------------------------------|-----------------|-----------------------------|---------------------------|-----------------------------------|
| Saturated zinc chloride (ml)     | 34.5            | 60                          | 5                         | 3.1                               |
| Zinc chloride (g)                |                 | 30                          | 2.5                       | 1.2                               |
| Purified water (ml)              |                 |                             |                           |                                   |
| Stibnite (g)                     | 40              |                             |                           |                                   |
| Powdered Sanguinaria canadensis (g) | 10          |                             |                           |                                   |
| Zinc oxide starch powder (g)     | 30              |                             | 2.5                       | 1.4                               |
| Glycerin (ml)                    | 15              |                             | 1                         |                                   |

a) The zinc content of the modified Mohs’ pastes was 1.25 times greater than the original Mohs’ paste.
recognised that the elephant did not touch the paste. Because Mohs’ paste had to affect the lesion during the limited application time, the zinc content of the modified Mohs’ pastes was 1.25 times greater than the original Mohs’ paste. Consequently, Mohs’ paste was contributed to gradually heal the wound.

Mohs’ paste also affects normal tissue [4]. Although the Mohs’ paste addressed the lesion, scorched necrotic tissue was observed at the centre of the lesion in the second digit, around day 180. At that time, there was a concern that the Mohs’ paste may affect the dermis. Therefore, much attention should be paid to the difference between the normal dermis and the hyperplastic tissue in the

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**Fig. 2.** Changes in digit 5 of the left forelimb in an Indian elephant (*Elephas maximus indicus*) with hoof disorder. (a) Day 16, when the hyperplastic tissue was observed inside of the hoof wall. (b) Day 47, when the hyperplastic tissue was almost completely trimmed and the conceivable dermis was identified just behind the trimmed tissue. (c) Day 128, when the center was occupied by the degenerated tissue. (d) Day 160, when the degenerated tissue in the center was gradually harden. (e) Day 225, when the normal hoof tissue was found after trimming. (f) Day 292, when the hoof shape had almost recovered.
hoof. One of the major differentiating factors is consistency. The hyperplastic tissue was very soft and fragile, whereas the normal dermis was tough and elastic.

The lesion on digit 5 could be trimmed rapidly than on digit 2. This difference may be caused of the following: the hoof wall and sole were widely opened on digit 5 at the first treatment stage and Mohs’ paste could be applied to the whole of the lesion. Therefore, the early trimming of the hoof wall and sole may be recommended.

Hoof infection has been observed to be common in captive and wild elephants [11, 13, 17]. Although a few reports have described the etiology of hoof infection, a previous study showed that abnormal pressure on the hoof might induce a bruise inside the hoof and cause sterile and abnormal tissue formation [19]. Subsequently, this tissue might spread inside the hoof and get infected via cracks in the hoof sole or ruptures in the cuticle. In our case, the hoof was infected, and histopathological examination of the hyperplastic tissue revealed supplicative dermatitis. Cracks had always been found in the hoof sole and the inside of the hoof wall. Although these cracks were trimmed and opened to prevent infection, one of the cracks might have been a route for bacterial infection in the hoof. Hoof disorders including laminitis and sole ulcers are also common in cattle and horses. The etiology and treatment of these diseases in cattle and horses are established, but those in the elephant should be further studied. The difference between these domestic animals and the elephant is the size of the lesion and the mode of treatment. Elephant cooperation for treatment is essential. Even if the elephant cooperates for treatment, the lesion cannot be normally covered with bandages or protected from dirt in the surrounding environment. Although hoof rubber shoes were recommended in previous studies [2], introducing such shoes might be difficult in most zoos. Therefore, specific treatment should be considered for elephant hoof disorder, and Mohs’ paste might be one of the effective solutions.

REFERENCES

1. Brooks, N. A. 2010. Chemosurgery for invasive melanoma. Dermatol. Surg. 36: 237–240. [Medline] [CrossRef]

2. Csaki, B., Sargent, E. L. and Bechert, U. S. 2001. The elephant’s foot. Iowa State University press, Iowa.

3. Fowler, M. E. 2006. Foot disorders. pp. 271–290. In: Biology, Medicine, and Surgery of Elephants. (Fowler, M. E. and Mikota, S. K. eds.), Blackwell Publishing, Ames.

4. Fukuyama, Y., Kawai, S., Tazuki, T., Katabata, A. and Maruo, T. 2016. The palliative efficacy of modified Mohs paste for controlling canine and feline malignant skin wounds. Vet. Q. 36: 176–182. [Medline] [CrossRef]

5. Gage, L. J., Fowler, M. E., Pascoe, J. R. and Blasko, D. 1997. Surgical removal of infected phalanges from an Asian elephant (Elephas maximus). J. Zoo Wildl. Med. 28: 208–211. [Medline]

6. Harris, M., Sherwin, C. and Harris, S. 2008. The welfare, housing and husbandry of elephants in U.K. zoos: Final report. University of Bristol, Bristol.

7. Hittmair, K. M. and Vielgrader, H. D. 2000. Radiographic diagnosis of lameness in African elephants (Loxodonta africana). Vet. Radiol. Ultrasound 41: 511–515. [Medline] [CrossRef]

8. Honeyman, V. L., Cooper, R. M. and Black, S. R. 1998. A protected contact approach to anesthesia and medical management of an Asian elephant (Elephas maximus). pp. 338–341. In: Proceedings of American Association of Zoo Veterinarians and American Association of Wildlife Veterinarians, Omaha.

9. Horne, W. A. and Loomis, M. R. 2007. Elephants and Hyrax. pp. 507–522. In: Zoo Animal And Wildlife Immobilization And Anesthesia. (West, G., Heard, D. and Caulkett, N. eds.), Blackwell Publishing, Ames.

10. Kakimoto, M., Tokita, H., Okamura, T. and Yoshino, K. 2010. A chemical hemostatic technique for bleeding from malignant wounds. J. Palliat. Med. 13: 11–13. [Medline] [CrossRef]

11. Keet, D. F., Gouws, J., Carstens, J. and Nesbit, J. W. 1997. Ulcerative pododermatitis in free-ranging African elephant (Loxodonta africana). Onderstepoort J. Vet. Res. 64: 25–32. [Medline] [CrossRef]

12. Harris, M., Sherwin, C. and Harris, S. 2008. The welfare, housing and husbandry of elephants in U.K. zoos: Final report. University of Bristol, Bristol.

13. Mikota, S. K., Sargent, E. L. and Ranglack, G. S. 1994. Medical management of the elephant. Indira, Michigan.

14. Miller, M. A., Hogan, J. N. and Meehan, C. L. 2016. Housing and demographic risk factors impacting foot and musculoskeletal health in African elephants (Loxodonta africana) and Asian elephants (Elephas maximus) in North American Zoos. PLoS One 11: e0155223. [Medline] [CrossRef]

15. Mohs, F. E., Sevringhaus, E. L. and Schmidt, E. R. 1997. Ulcerative pododermatitis in free-ranging African elephant (Loxodonta africana) in the Kruger National Park. Onderstepoort J. Vet. Res. 64: 25–32. [Medline]

16. Mohs, F. E. 1971. Chemosurgery for the microscopically controlled excision of skin cancer. J. Surg. Oncol. 3: 257–267. [Medline] [CrossRef]

17. Ollivet-Courtois, F., Lécu, A., Yates, R. A. and Spelman, L. H. 2003. Treatment of a sole abscess in an Asian elephant (Elephas maximus) using regional digital intravenous perfusion. J. Zoo Wildl. Med. 34: 292–295. [Medline] [CrossRef]

18. Panagiotopoulou, O., Patakis, T. C., Day, M., Hensman, M. C., Hensman, S., Hutchinson, J. R. and Clemente, C. J. 2016. Foot pressure distributions during walking in African elephants (Loxodonta africana). R. Soc. Open Sci. 3: 160203. [Medline] [CrossRef]

19. Roocroft, A. Abscesses in elephant’s feet. http://www.alanroocroft.com/articles-of-interest (accessed on 27 Dec 2017).

20. Shigeiayana, M., Ouguiya, T. and Okubo, T. 2005. Participation in chemosurgical treatment for patients with unrespectable cancer (in Japanese). Iyaku (Medicine and Drugs). Journal 41: 2289–2294.

21. Trost, L. B. and Bailin, P. L. 2011. History of Mohs surgery. Dermatol. Clin. 29: 135–139. vii. [Medline] [CrossRef]

22. Weissengruber, G. E., Egger, G. F., Hutchinson, J. R., Groenewald, H. B., Elsässer, L., Famin, D. and Forstenpointner, G. 2006. The structure of the cushions in the feet of African elephants (Loxodonta africana). J. Anat. 209: 781–792. [Medline] [CrossRef]