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Case report

Corneal stromal abscess in a captive Asian elephant: diagnosis and treatment regimes

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Abstract

Ocular injuries are often observed in elephants, most due to accidents. Diagnostic and treatment are challenging, as the elephants usually keep their eyes closed during examinations. This article describes the diagnosis and treatment regime of a juvenile captive female Asian elephant (*Elephas maximus*; approximately four years old) that showed signs of severe epiphora, blepharospasm, and corneal opacity in her left eye. Ophthalmic examination using a slit lamp and ocular ultrasonography revealed a corneal stromal abscess. Intensive treatment was performed, including administering intravenous antibiotics and anti-inflammatory drugs and an hourly eye topical treatment. The treatment regime was adjusted from time to time following the clinical signs and diagnostic results. The abscess was invisible within approximately five weeks (day 37). The treatment was continued until day 74 and then ceased. The eye recovered entirely, and only a small scar remained at the center.

Keywords: : Corneal opacity, Elephant, Stromal abscess, Treatment

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INTRODUCTION

The eyes of elephants, in relation to their body size, are relatively small and located on the side of their head, providing a broad visual field of approximately 300 degrees (Suedmeyer, 2006). Despite their small size, the eyes of elephants are highly functional, allowing them to see both in color and low light condition with exceptional acuity. However, the full extent of their color vision remains underdetermined, as the specific cone cells responsible for color sensitivity in the elephant's retina have not yet to be identified (Murphy et al., 1992; Suedmeyer, 2006). The anatomy of an elephant's eye is similar to that of other mammals, except some unique features including the lack of a lacrimal apparatus, three layers of eyelid (superior palpebrae, inferior palpebrae, and nictitating membrane), and the muscled nictitating membrane (Suedmeyer, 2006). Therefore, diagnosing ophthalmological conditions in elephants can be challenging due to the presence of strong eyelid layers and the tear flow due to underdeveloped aqueous outflow system.

Similar to other animals, elephants can pose various eye abnormalities, which can affect their vision and overall health. Eye injuries, especially anterior ocular abnormality, are frequently observed in elephants, generally caused by traumatic injury or accident (Kraiwong et al., 2016; Suedmeyer, 2016). Approximately 25% of examined captive Asian elephants in Thailand (n = 1478) presented ocular abnormalities, including ocular discharge, corneal edema, conjunctivitis, uveitis, and lens abnormalities – indicating the urgent concern of ocular problems in Thai elephants (Kraiwong et al., 2016). Moreover, elephant behavior such as rubbing the eyes with the trunk or playing with dust can propagate the rapid progress of ocular lesions. Therefore, it is noted that proper veterinary care, including regular ocular examination and prompt treatment, is essential for preventing eye abnormalities in elephants.

Although, ocular abnormalities are common in elephants (Suedmeyer, 2016), documented case management are limited. Corneal stromal abscess is a type of ocular abnormality that has been reported in elephants, which requires either long-term medical treatment or surgery (Preena and Arevind, 2017; Paul et al., 2018). This condition is often associated with a bacterial or fungal infection resulting from a corneal injury. This infection leads to the formation of a pocket filled with pus within a middle layer of the cornea, known as the stroma. The resulting inflammation, pain, and potential vision loss can have a significantly impact on an elephant's health and wellbeing. This article describes the diagnosis and treatment protocols of a corneal stromal abscess in a juvenile captive Asian elephant (*Elephas maximus*) in Thailand. Disease progression and recovering are visualized and presented. Complications and recommendation are also discussed.

CASE DESCRIPTION

Case History

A 900 kg, 4-yr-old female captive Asian elephant showed signs of corneal opacity for five days and was referred to Kasetsart University Veterinary Teaching Hospital (KU-VTH) on December 14, 2021. This day will be referred to as day 1. History taken from the owner showed an unclear history of the cause of opacity. However, the rapid progression of the opacity, severe epiphora, blepharospasm, and slightly dullness was noted before referring.

Present Illness and Clinical Examination

At the hospital (day 1), the elephant showed mild dullness and decreased appetite. Physical examination revealed a normal body temperature (98.4 °F; normal, 97°F – 99 °F) and respiratory rate (10 breaths/min; normal, 4 – 12 breaths/min). The left eye showed corneal edema and opacity with circular pus-like material at the center (Figure 1a), severe epiphora, blepharospasm, blepharitis, and third eyelid inflammation. However, the right eye was normal. A veterinary ophthalmologist performed an ophthalmological examination on the left eye, revealing positive menace and palpebral reflex. However, pupillary light response and dazzle reflex were underdetermined due to the opacity. Fluoresceine staining on the left eye was negative. Attempts to measure intra-ocular pressure failed due to the inability to open the eye for a certain time of the elephant. Slit-lamp bio-microscopy was used and revealed a corneal abscess. Hematological analysis showed leukocytosis (33,500 cells/µl; normal, 10,000-18,000 cells/µ, while other parameters were in normal ranges (Mikota, 2006). The differential count of white blood cells revealed the elevation of heterophil, lymphocyte and monocyte in relative percentage (heterophil 39%, normal 25-30%; lymphocyte 44%, normal 30-40%; monocyte 41%, normal 25-30%) (Mikota, 2006). The conjunctival and corneal swabs were collected and submitted for bacterial culture and drug sensitivity tests, which *Staphylococcus* sp. and *Acinetobacter* sp. were later identified.

Figure 1 The lesion on the left eye during the treatment period; a) corneal opacity with a circular abscess on day1, b) keratitis and vascularization on day 10, c) corneal melting on day 18, d) a white plaque covered cornea after corneal melting on day 18, e) and f) the reduction of abscess over times, g) abscess invisible on day 37, h) corneal opacity with a scar at the center on day 44, when corticosteroid eye drop was started, and I) clear cornea with a small scar at the center on day 74 when the elephant was discharged from the hospital.

Case Management

The initial treatment before drug sensitivity test's result included a broad-spectrum systemic antibiotic (Amoxycillin-clavulanic acid; 5 mg/kg IV SID), cimetidine (2 mg/kg IV SID) giving prior anti-inflammatory drug to prevent gastric ulcers, and non-steroidal anti-inflammatory drug (flunixin meglumine; 1 mg/kg, IV SID). Topical eye treatment included 0.5% moxifloxacin hydrochloride (Vigamox®, Alcon Laboratories Inc, Fort Worth, TX, USA; eye drop, q1hr), 1% atropine sulfate (Isopto®, Alcon Laboratories Inc, Fort Worth, TX, USA; eye drop BID), and 0.02% acetylcysteine (Acetin®, L.B.S. Laboratory Ltd, Bangkok, Thailand; eye drop BID), which served the purposes of bacterial infection prevention, pain reduction through pupil dilation, and corneal melting prevention, respectively. A 1-mL syringe containing approximately 0.5 mL of eye drop was used for drug application by gently placed inside the eye, either from the medial or lateral canthus. The topical eye treatment's hours were started from 8 am to 8 pm each day. The treatment was omitted during nighttime to let the elephant rest. Moreover, the elephant received 6000 mg of vitamin C per oral every day over the entire treatment period as an immune stimulator.

After the initial treatment, epiphora, third eyelid inflammation, and eyelid swelling were reduced, and the appetite regained to normal on day 3. However, the opacity remained. Therefore, the treatment was continued as planned for seven days. On day 8, the inflammation of the nictitating membrane, the swelling of the eyelid, and the blepharospasm were unnoticeable. Therefore, the anti-inflammatory drug and H2 blocker were changed to ibuprofen (600 mg/kg PO BID) and omeprazole (0.2 mg/kg PO BID), respectively and continued for additional seven days, then ceased as the absence of pain and inflammation signs and to prevent the potential adverse effects of the prolonged use of NSAIDs. The frequency of antibiotic eye drops was also changed from every hour to every two hours at this time. Later on day 10, keratitis and vascularization at the cornea were noted (Figure 1b). According to the drug sensitivity test, the antibiotic eye drop was changed to gentamycin (Genta-Oph®, Seng Thai Company Ltd, Bangkok, Thailand, eye drop, q2hr) on Day 14. In addition, corneal melting was observed on day 18 (Figure 1c). After corneal melting and dropping off, only a white opaque film covered the cornea's inner layer (Figure 1d). In addition, the systemic antibiotic was changed to Ciprofloxacin (2.5 mg/kg PO SID) on day 18, as the level of white blood cell count had nearly returned to normal (21,400 cells/µl; normal 10,000-18,000 cells/µl), in which only high level of lymphocyte count was observed (heterophil 30%, normal 25-30%; lymphocyte 48%, normal 30-40%; monocyte 21%, normal 25-30%) (Mikota, 2006). However, the other topical eye treatment was continued as planned.

On day 24, the elephant was anesthetized using xylazine hydrochloride (0.04 mg/kg slow IV) to examine the eyes (Figure 2a). Ocular ultrasonography (Z5 Vet Mindray® Diagnostic Ultrasound system with Convex Probe Model 35C50EA; Sheinzhen Mindray Bio-Medical Eletronics Co. Ltd., Shenzhen, China) was performed and revealed normal globe and lens structure. Corneal thickening with hyperechoic resonance was noted, indicating a stromal abscess. In addition, narrowing of the anterior chamber was also noticed, which revealed the possibility of anterior synechiae (Figure 2b). Therefore, atropine eye drop was changed to three times per day for a week from this point in time. On the same day, a corneal swab sample was re-collected directly from the lesion for bacterial culture and drug sensitivity test, which later showed Pseudomonas aeruginosa as the main microorganism (Table 1). The vascularization continued to be observed to comprehend the healing process. The abscess gradually decreased in size, and the cornea opacity improved daily (Figure 1e and 1f). The abscess was eventually invisible on day 37 (Figure 1g), and the systemic antibiotic was then ceased. Only topical eye treatment was continued, including gentamycin (QID), 1% atropine (BID), and 0.02% acetylcysteine (BID). One week later (day 44), an ophthalmological examination revealed no abscess in the cornea. However, corneal opacity remained with a corneal scar at the center (Figure 1h). The fluorescein staining was also negative, indicating the absence of a corneal ulcer. Thus, the administration of acetylcysteine was discontinued as there was no evidence of corneal melting. Instead, 1% prednisolone acetate (Pred Forte®, Allergan Co Ltd, Bangkok, Thailand, eye drop TID) was added to facilitate the resolving of corneal scar. Antibiotic eye drops ceased on

day 60, while atropine and prednisolone acetate eye drops were continued administration twice a day for another two weeks. All treatment was ceased on day 74, in which the cornea was as clear as normal, and only a small scar remained at the center (Figure 1i). Summary of treatment protocols were listed in Table 2. The complications, including increasing in size of scar and opacity area, epiphora, conjunctivitis, and corneal ulcer, were followed for three months after the elephant was discharged; however, no recurrent abnormalities signs were observed.

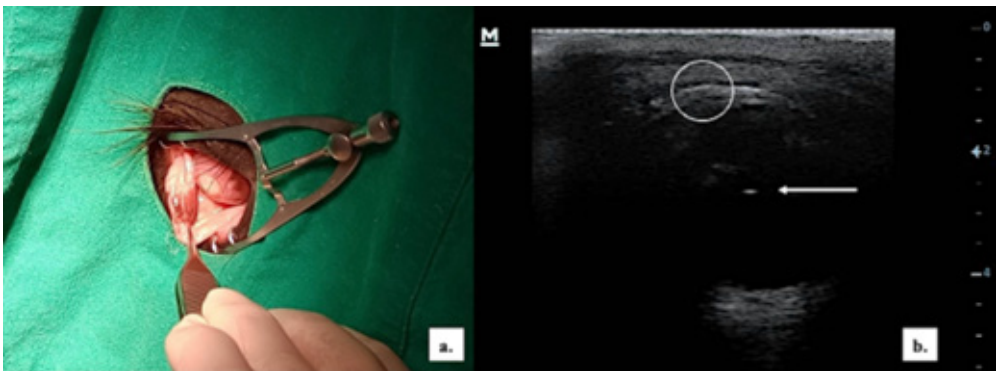

Figure 2 a) Elephant eye was examined under anesthesia using xylazine hydrochloride on Day 24, which revealed the thin layer of pus-covered the cornea area. Forceps were used to hold the nictitating membrane covering the globe. b) The transpalpebral ultrasonography examination of the left eye. The arrow indicates the posterior lens capsule, and the circle indicates the thickening of the corneal layer and the anterior chamber's narrowing.

Table 1 Result of bacterial culture and drug sensitivity test from corneal swab on Day 1 (without sedation) and Day 24 (under sedation)

Antibiotic / Bacteria	Day 1			Day 24
	Staphylococcus sciuri	***Staphylococcus arlettae***	***Actinobacterium* spp.**	***Pseudomonas aeruginosa***
Amikacin			susceptible	susceptible
Ampicillin			susceptible	
Cefotaxime			intermediate	
Ceftriaxone			intermediate	
Ceftazidime			susceptible	susceptible
Ciprofloxacin	intermediate	susceptible	resistance	susceptible
Clindamycin	resistance	susceptible		
Gentamicin	susceptible	susceptible	susceptible	susceptible
Levofloxacin				intermediate
Oxacillin	susceptible	susceptible		
Penicillin	susceptible	susceptible		
Tetracycline	susceptible	susceptible		
Sulfa trimethoprim	susceptible	susceptible	resistance	

Table 2 Summary of the treatment protocols, including systemic and topical treatment, for corneal stromal abscess in this case. Day 1 refers to admitted day to the hospital, Day 24 refers to anesthetized and ultrasonography performance day, Day 37 refers to abscess invisible's day, and Day 74 refers to a discharge day from the hospital (S = SID, B = BID, T = TID, Q = QID, 1h = q1hr, 2h = q2hr)

Medication	Day of Treatment
	1 → 8 → 15 → 18 → 24 → 30 → 37 44 → 60 → 74
Systematic Treatment	
Amoxy-clav, IV	S S S S S S — *17 days*
Ciprofloxacin, PO	S S S S S S — *19 days*
Cimetidine, IV	S S — *7 days*
Flunixin, IV	S S — *7 days*
Ibuprofen, PO	B B B B — *10 days*
Omeprazole, PO	B B B B — *10 days*
Topical Treatment	
Moxifloxacin	1h 1h 2h 2h — *14 days*
Gentamycin	2h 2h 2h 2h 2h 2h 2h 2h Q Q Q Q Q — *45 days*
Atropine	B B B B B B B B T T B B B B B B B B B — *74 days*
Acetylcysteine	B B B B B B B B B B B B B B — *44 days*
Prednisolone	T T B B B — *30 days*

DISCUSSION

Applying topical eye treatment to an elephant is challenging, as the elephant usually keeps their eyes completely closed during treatment. Also, the nictitating membrane always covers the elephant's eye. Therefore, for drug administration of this presented case, the blunt tip of a 1-mL syringe containing approximately 0.5 mL of eye drop was gently placed inside the eye, either from the medial or lateral canthus. The eyes should be held closed for a few seconds to allow drug absorption. Managing ocular abnormalities in elephants presents a challenge due to their natural behavior, such as dust playing and eye rubbing, which can exacerbate the condition (Schulte, 2006; Suedmeyer, 2006). To mitigate these issues, the elephant was provided access to a ground field to reduce stress from confinement but required constant supervision by the mahout to prevent unwanted behavior. During nighttime, the elephant rested on a concrete floor without ground access until the corneal ulcer had healed.

A complete ophthalmological examination is essential for diagnosis and monitoring disease progression. Unfortunately, slit-lamp microscopy may not provide sufficient information in the case of opacity, as the light cannot pass through the cloudiness. Thus, transpalpebral ultrasonography is suggested

in every eye injury case. It is a non-invasive technique that can reveal the intraocular structure without chemical restraint or topical anesthesia (Bapoda et al., 2010). Nonetheless, in cases where the elephants are not well-trained, sedation may be required, as demonstrated in this case report. Therefore, it may be beneficial to train elephants to become familiar to medical interventions from an early stage of life, as this could enhance the standard of veterinary practice and improve their quality of life. In the present case, fluorescein staining yielded negative results on both occasions despite the suspicion of positivity in cases of corneal ulcer. The negative outcome on the first attempt can be attributed to the difficulty in administering fluorescein stain to an untrained or non-sedated elephant, resulting in inadequate amount of fluorescein towards the lesion (Suedmeyer, 2006). Furthermore, the second attempt was performed under anesthesia (day 24), yet the negative outcome persisted, which possibly due to the presence of a pus layer on the cornea, which hindered the penetration of fluorescein into the stromal layer. Hence, it is imperative to interpret the results of fluorescein staining with caution, considering the potential influence of other factors that may interface with the staining outcome.

Corneal stromal abscess can be treated by either medical or surgical management, which have their own advantages and disadvantages. The medical management does not require sedation or the skills of a specialized veterinarian, but typically involves a longer treatment period. While the surgical management may result in a faster recovery period, but post-operative management can be challenging – particularly for untrained elephants, who have a tendency to rub their eyes and potentially worsen the surgical wound. The medical treatment of corneal stromal abscess was previously reported in a 47-yr-old Asian elephant, which resolved within seven weeks by applying an antibiotic, antifungal, and atropine eye drop (Wiedner et al., 2006). Here, corticosteroid eye drops were used, which rapidly improved the corneal opacity and reduced scar's size within approximately four weeks. However, the topical corticosteroid should be used with caution in case of corneal perforation and fungal keratitis (Srinivasan, 2012).

Minor eye surgery such as keratotomy, subconjunctival administration of human placenta extraction, or corticosteroid injection was previously performed on elephants with corneal opacity (Wolfer and Rich, 1992; Cheeran and Chandrasekharan, 2006; Ramani et al., 2016; Preena and Arevind, 2017; Paul et al., 2018). However, although all the mentioned procedures showed good improvement, sedation, a well-trained elephant, and a skilled veterinarian were usually required, which is not applicable for untrained elephants like the juveniles. Therefore, training the elephant to receive medical care is needed and recommended for captive population management (Angkawanish et al., 2009).

Staphylococcus spp., Corynebacterium spp., and Acinetobacter lowoffii were the main bacteria identified from the conjunctiva swab of healthy elephants (Tuntivanich et al., 2002). A previous study described that corneal culture might not be helpful for treatment decisions in elephant, as it generally represented a normal flora (Wiedner et al., 2006). Staphylococcus sp. and Acinetobacter sp. were also identified in the first attempt of corneal culture. Similar to the previous study that showed 39% of bacterial cultures from a corneal ulcer were Staphylococcus spp (Kodikaran et al., 1999). However, samples were re-collected directly from the cornea under anesthesia, which

showed Pseudomonas aeruginosa as the main microorganism. The bacterial culture results changed the treatment regime according to the drug sensitivity test, which showed rapid improvement. Therefore, sedation or anesthesia may require for proper sample collection. While it is ideal to select antibiotics based on bacterial culture and drug sensitivity tests, this process may delay the treatment process. Therefore, we are recommended to use broad-spectrum antibiotics, such as quinolones (e.g., moxifloxacin, ciprofloxacin), penicillin (e.g., amoxicillin/clavulanic acid), or aminoglycosides (e.g., gentamicin) for initial treatment.

The treatment of ocular disease does not always require the administration of systemic and topic medications in combination. However, systemic antibiotic is recommended for certain types of ocular abnormalities, particularly the endogenous endophthalmitis (Grzybowski et al., 2020). In the presented case, systemic antibiotic and anti-inflammatory drugs were employed due to the presence of severe periocular soft tissue inflammation, the possibility of orbital infection spreading to the anterior chamber, and an elevated of total white blood cell. The use of systemic antibiotic should be approached with caution due to the potential of drug distribution to other organs (Rodriguez-Una et al., 2017). In this case, only topical medication was maintained until the completion of treatment.

CONCLUSIONS

Diagnosis and treatment of ocular abnormalities in elephants require urgent consideration due to their rapid progression, unique ocular anatomy, and elephant's behavior. Ocular ultrasonography is a valuable tool for assessing the severity of internal ocular structure in case of corneal opacity. Bacterial and fungal culture from lesions is helpful for drug selection, however sedation may require obtaining a good quality sample and avoid contamination. In case of corneal stromal abscess, either medical or surgical interventions can be applied, however both have their advantages and disadvantages. This case report demonstrated a successful medical intervention for treating a corneal stromal abscess in a juvenile elephant, with the abscess invisible within five weeks and the scar resolving within nine to ten weeks. Overall, understanding the challenges and potential solutions for diagnosing and treating ocular abnormalities in elephants is crucial for ensuring their health and well-being under the human care which need urgent concern from either elephant owner, mahout, or veterinarian.

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AUTHOR CONTRIBUTIONS

Conducting veterinary daily care and planning the treatment protocols (SP, SS), helping veterinary daily care and case discussion (PD, PM, RS, NT), performing ocular examination and planning treatment protocols (NP, MK, KP), summarizing and writing manuscript (SP, SS).

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Angkawanish, T., Boonprasert, K., Homkong, P., Sombutputorn, P., Mahasawangkul, S., Jansitiwate, S., Keratimanochaya, S., Clausen, B., 2009. Elephant health status in Thailand: the role of mobile clinic and elephant hospital. Gajah. 31, 15-20.

Bapodra, P., Bouts, T., Mahoney, P., Turner, S., Silva-Fletcher, A., Waters, M., 2010. Ultrasonographic anatomy of the Asian elephant (Elephas maximus) eye. J. Zoo Wildl. Med. 41, 409-417.

Cheeran, J.V., Chandrasekharan, K., 2006. Veterinary problems of geographical concern: Section II-India. In: Fowler M.E., Mikota S.K. (Eds.), Biology, medicine, and surgery of elephants. Blackwell Publishing, Oxford, pp. 439-474.

Grzybowski, A., Turczynowska, M., Schwartz, S.G., Relhan, N., Flynn, H.W., 2020. The role of systemic antimicrobials in the treatment of endophthalmitis: a review and an international perspective. Ophthalmol. Ther. 9(3), 485-498.

Kodikaran, D.S., Silva, N., Makuloluwa, C.A.B., Silva, N., Gunatilake, M., 1999. Bacterial and fungal pathogens isolated from corneal ulcerations in domesticated elephant (Elephas maximus maximus) in Sri Lanka. Vet. Ophthalomol. 2, 191-192.

Kraiwong, N., Sanyathitiseree, P., Boonprasert, K., Diskul, P., Chaoenpan, P., Pintawong, W., Thayananuphat, A., 2016. Anterior ocular abnormality of captive Asian elephants (Elephas maximus indicus) in Thailand. Vet. Ophthalmol. 19, 269-274.

Mikota, S.K., 2006. Hemolymphatic system. In: Fowler M.E., Mikota S.K. (Eds.), Biology, medicine, and surgery of elephants. Blackwell Publishing, Oxford, pp. 325-346

Murphy, C.J., Kern T.J., Howland, H.C., 1992. Refractive state, corneal curvature, accommodative rage and ocular anatomy of the Asian elephant (Elephas maximus). Vis. Res. 32(11), 2013-2021.

Paul, P., Hasan, T., Rahman, M.M., 2018. Medical management of bilateral corneal opacity in an Asian elephant (Elephas maximus): a case report. J. Adv. Vet. Anima. Res. 5, 98-100.

Preena, P., Arevind, B., 2017. Case report on the medical management of corneal opacity in a captive elephant tusker. Adv. Anim. Vet. Sci. 5, 342-345.

Ramani, C., Thilagar, S., Babu, S., 2016. A report of bilateral hypopyon and uveitis in an Asian elephant. Intas. Polivet. 17, 378-379.

Rodriguez-Una, I., Baneros-Rojas, P., Jimenez, C., Diaz-Valle, D., Gegundez-Fernandez, J.A., Benitez-del-Castillo, J., 2017. Systemic antibiotics with ophthalmic clinical usefulness. Available online: https://www.jaypeedigital.com/book/9789351524991/chapter/ch7.

Suedmeyer, W.K., 2006. Special senses. In: Fowler M.E., Mikota S.K. (Eds.), Biology, medicine, and surgery of elephants. Blackwell Publishing, Oxford, pp. 399-407.

Tuntivanich, P., Soontornvipart, K., Tuntivanich, N., Won-gaumnuaykul, S., Briksawan, P., 2002. Conjunctival microflora in clinically normal Asian elephants in Thailand. Vet. Res. Commun. 26, 251–254.

Wiedner, E.B., Isaza, R., Galle, L.E., Barrie, K., Lindsay, W., 2006. Medical management of corneal stromal abscess in a female Asian elephant (Elephas maximus). J. Zoo. Wildl. Med. 37, 397-400.

Srinivasan, M., 2012. Corticosteroids: a possible treatment for corneal ulcers?. Expert Rev. Ophthalmol. 7, 1-3.
Wolfer, J., Rich, P., 1992. Persistent corneal erosion in an Asian elephant. Can. Vet. J. 33, 337–339.

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