

Prevalence of ocular pathology in adult captive cheetahs (*Acinonyx jubatus*)

by
Christie Boucher

Submitted in partial fulfilment of the requirements for the degree of

MMedVet(Ophthal)

Companion Animal Clinical Studies
Faculty of Veterinary Science
University of Pretoria

April 2017

Dissertation

Prevalence of ocular pathology in adult captive cheetahs (*Acinonyx jubatus*)

Christie Boucher

94288870

Supervisor: Dr Izak Venter

Department: Ophthalmic Clinic
Companion Animal Clinical Studies
Faculty of Veterinary Science

University: University of Pretoria

DEDICATIONS

I dedicate this thesis to my husband, my strong pillar, who understands me, who encouraged, supported and helped me to pursue my dreams.

To my kids, Charlie and Celeste who ensure that I keep my life balanced. Thank you for helping me to see the world through your eyes.

‘The eyes tell more than words could ever say’

ACKNOWLEDGMENTS

I would like to pay special gratitude, warmth and appreciation to the persons below who made my research successful and assisted me achieving my goal:

My supervisor, Dr Izak Venter, for his vital support, assistance and generous giving of his selfless time.

Dr Antony Goodhead, for his help, support and positive attitude throughout my post graduate studies.

Professor Peter Thompson for assisting with the statistical analyses.

Professor Kirberger for his expert opinion, constant motivation and support.

Mrs Zelda Coetzer for kindly editing the dissertation.

Axim for their technical support

The Department of Companion Animal Clinical Studies and Roy Johnston for their assistance in the funding of this project.

Peter Caldwell and the staff of Old Chapel Veterinary Clinic for always being willing to help with the data collection and cheetah examinations.

Ann van Dyk for encouraging the research to be performed on her cheetahs, to which she has dedicated her life.

AfriCat Foundation for all the help, support and dedication to this project.

My parents, parents in law and friends, for their moral and emotional support.

DECLARATION

I, Dr Christie Boucher, the author of the thesis title: “Prevalence of ocular pathology in captive adult cheetahs (*Acinonyx jubatus*)”, received ethics clearance for this project (V038-14) from the University of Pretoria Animal Ethics Committee on the 30th of June 2014 (Appendix 4).


I have upheld the ethical standards required in the University of Pretoria's *Code of ethics for researchers* and the *Policy guidelines for the responsible research*.

I hereby declare that the research presented in this dissertation was conceived and executed by myself, under the guidance of my supervisor, Dr I Venter.

Neither the substance, nor any part of the dissertation has been submitted in the past for a degree at the University of Pretoria or any other University.

This dissertation is presented as partial fulfilment of the requirements for the degree Master of Science in Veterinary Science.

The content of this thesis is original and has not been plagiarised.

Signature: _____  _____

Date: 2017-03-31



TABLE OF CONTENTS

DEDICATIONS	iii
ACKNOWLEDGMENTS	iv
DECLARATION.....	v
TABLE OF CONTENTS	vi
SUMMARY	viii
LIST OF FIGURES	ix
LIST OF TABLES.....	xi
LIST OF ABBREVIATIONS.....	xii
CHAPTER 1. INTRODUCTION	1
CHAPTER 2. LITERATURE REVIEW	3
2.1 Ophthalmic Examination	3
2.1.1 Schirmer Tear Test	3
2.1.2 Intraocular Pressure	5
2.1.3 Slit-lamp Biomicroscopy.....	11
2.1.4 Ophthalmoscopy	12
2.1.5 Fluorescein Dye Test	13
2.1.6 Ultrasonography.....	14
2.2 Ocular Infectious Diseases.....	17
2.2.1 Feline Coronavirus	17
2.2.2 Feline Herpesvirus 1	18
2.2.3 Feline Leukaemia Virus.....	19
2.2.4 Feline Immunodeficiency Virus	20
2.2.5 Feline Panleukopenia.....	20
2.2.6 Bartonellosis.....	22
2.2.7 Toxoplasmosis	23
2.2.8 Cryptococcosis.....	24



2.3 Cataracts.....	24
2.4 Retina	27
2.5 Miscellaneous	29
CHAPTER 3. OBJECTIVES, BENEFITS AND HYPOTHESIS	30
3.1 Objectives	30
3.2 Benefits.....	30
3.3 Hypothesis	30
CHAPTER 4. MATERIALS AND METHODS.....	31
4.1 Model System	31
4.2 Study Design.....	34
4.3 Patient Selection	34
4.4 Study Procedures.....	35
4.5 Data Analysis	44
4.6 Ethical Consideration	44
CHAPTER 5. RESULTS	45
CHAPTER 6. DISCUSSION.....	62
6.1 STT.....	62
6.2 Tonometry.....	63
6.3 Ultrasound.....	64
6.4 Cornea.....	65
6.5 Cataracts.....	65
6.6 Retina	66
6.7 Limitations.....	69
CHAPTER 7. CONCLUSIONS	70
REFERENCES	71
APPENDICES.....	92

SUMMARY

Objective: To determine the prevalence of ocular pathology in captive adult cheetahs.

Materials and Methods: An ophthalmic examination was performed on 73 cheetahs, between the ages of 1 to 14 years, while undergoing immobilisation for their routine health check. The population of adult cheetahs within the Ann van Dyk Cheetah Centre and the AfriCat Foundation was used for the research project.

Results: The most prevalent pathological lesions were cataracts (10%). Most of the cataracts were found bilaterally, at the posterior extremity of the lens, in young cheetahs (1 - 6 years), from the Ann van Dyk Cheetah Centre, while only one unilateral cataract was found at the AfriCat Foundation. Three siblings, from Ann van Dyk Cheetah Centre, were found to have the same type of cataracts and fundic lesions. These fundic lesions resembled retinal dysplasia. No fundic pathology was found in the cheetahs at the AfriCat Foundation. A unique retinal pigment was observed in 71.8% of the cheetahs. This was equally distributed throughout both centres.

Conclusions: These types of cataracts and fundic lesions could indicate hereditary, congenital or nutritional causes. This is a concern because of the future implications it could have on breeding programs and the cheetah species. Regular detailed ophthalmic examination in the cheetah can help with the early diagnosis and treatment of ocular lesions and may prove beneficial to the management of breeding programmes.

LIST OF FIGURES

Figure 1.	The Ann van Dyk Cheetah Centre.	33
Figure 2.	Cheetah at the Shingwedzi Centre.....	33
Figure 3.	The AfriCat Foundation’s logo.....	33
Figure 4.	Map indicating the location of the Okonjima Farm, home of the AfriCat Foundation in Namibia.	34
Figure 5.	The cheetah being carried on a stretcher from the vehicle.....	40
Figure 6.	Weighing the cheetah at the Shingwedzi Centre.....	40
Figure 7.	Blood being collected from the medial saphenous vein of the cheetah.	40
Figure 8.	Close up of blood being collected from the medial saphenous vein.	41
Figure 9.	The Schirmer tear test is being taken in both eyes of this cheetah.....	41
Figure 10.	Slit-lamp biomicroscopy of the cheetah eye.	41
Figure 11.	Indirect ophthalmoscopy examination of a cheetah.....	42
Figure 12.	Fundus imaging of a cheetah with a Volk Pictor Plus Ophthalmic camera.	42
Figure 13.	Ocular ultrasonography of the left eye of the cheetah.	42
Figure 14.	Biometry of an adult cheetah eye with B-mode ultrasonography. 1- Axial globe length. 2- axial lens thickness. 3- anterior chamber depth. 4- posterior segment depth.	43
Figure 15.	Cheetah recovering in a cheetah crate after immobilisation and examination. ..	43
Figure 16.	B-mode ultrasound of an adult cheetah eye.....	52
Figure 17.	An old laceration in the leading edge of the third eyelid membrane of the cheetah.....	56
Figure 18.	Symblepharon between the third eyelid, the palpebral conjunctiva and medial cornea of the cheetah.....	56
Figure 19.	An old lesion in the dorso-lateral cornea of the right eye of the cheetah. Note the corneal oedema, anterior synechia and the dyscoric pupil.....	56
Figure 20.	An immature posterior subcapsular cataract in the right eye of the cheetah.....	57
Figure 21.	Immature focal nuclear cataract in the left eye of the cheetah.....	57
Figure 22.	An immature, anterior subcapsular cataract in the right eye of the cheetah... ..	57

Figure 23. Normal fundus image of a cheetah.	58
Figure 24. Multiple retinal hyperpigmentation areas in the tapetum of the cheetah.	58
Figure 25. Multiple areas of hypo- and hyperreflectivity in the tapetum and on the border line of the tapetum and non-tapetal area are illustrated. An area of depigmentation with possible choroidal hypoplasia dorsolateral to the ONH is also visible. Note the small focal immature cataract which leads to the obscured visualisation of the fundus in the cheetah.	58
Figure26. Mild retinal pigmentation in the visual streak of the cheetah.....	59
Figure27. Marked increased retinal pigment in the medial and lateral area of the visual streak in the cheetah.....	59
Figure 28. Advanced increased retinal pigment in the medial and lateral area of the visual streak. Note the small focal immature cataract, which lead to obscured visualisation of the fundus of the cheetah.	59
Figure 29. An ultrasound image of a small immature posterior cortical cataract in the cheetah.....	60
Figure 30. An ultrasound image of a focal immature posterior cortical cataract in the cheetah.....	60
Figure 31. An ultrasound image of a small immature nuclear cataract in the cheetah...	61
Figure 32. Ultrasound image of an immature anterior and posterior subcapsular cataract in the cheetah.....	61

LIST OF TABLES

Table 1.	Group and gender distribution of cheetahs examined.	45
Table 2.	Group and age group distribution of cheetahs examined.	45
Table 3.	Gender and age group distribution of cheetahs examined.	45
Table 4.	Average measurements of the left and right eye of cheetahs examined.....	46
Table 5.	Average ocular measurements of total eyes of cheetahs examined.....	46
Table 6.	Ocular measurements between AvDCC and AfriCat cheetah groups.....	47
Table 7.	Ocular measurements between age groups of cheetahs examined.	47
Table 8.	Ocular measurements between genders of cheetahs examined.	48
Table 9.	Association of group, age and genders with STT values in cheetahs outcome of multiple linear regression analysis.	48
Table 10.	Association of group, age and genders with IOP values in cheetahs outcome of multiple linear regression analysis.	49
Table 11.	Association of group, age and genders on axial globe length values in cheetahs outcomes of multiple linear regression analysis.	49
Table 12.	Association of group, age and genders on axial lens length values in cheetahs outcomes of multiple linear regression analysis.	50
Table 13.	Association of group, age and genders on anterior chamber depth values in cheetahs outcome of multiple linear regression analysis.	50
Table 14.	Association of group, age and genders on posterior segment depth values in cheetahs outcome of multiple linear regression analysis.	51
Table 15.	Prevalence and confidence intervals for ocular lesions in the cheetahs examined.....	53
Table 16.	Number of lesions in different groups of cheetahs examined.	53
Table 17.	Number of lesions in different age groups of cheetahs examined.	53
Table 18.	Number of lesions in different genders of cheetahs examined.	54

LIST OF ABBREVIATIONS

AF	AfriCat Foundation
AvDCC	Ann van Dyk Cheetah Centre
ACD	Anterior chamber depth
AGL	Axial globe length
ALT	Axial lens thickness
CPV	Canine parvovirus
CNS	Central nervous system
CITES	Convention of International Trade in Endangered Species of Wild Fauna and Flora
D	Dioptre
DHA	Docosahexaenoic acid
EDTA	Ethylenediaminetetraacetic acid
ELISA	Enzyme-linked immunosorbent assay
ERG	Electroretinogram
FA	Fatty acid
FCRD	Feline central retinal degeneration
FCoV	Feline corona virus
FHV-1	Feline herpes virus 1
FIV	Feline immunodeficiency virus
FIP	Feline infectious peritonitis
FLV	Feline leukaemia virus
FPLV	Feline panleukopenia virus
Fig	Figure
g	Gram
IFA	Immunofluorescence antibody assay
IgG	Immunoglobulin G
IUCN	International Union for Conservation of Nature
IOL	Intraocular lens
IOP	Intraocular pressure
kg	Kilogram



km/h	Kilometre per hour
MHC	Major histocompatibility complex
MHz	Megahertz
ml	Millilitre
mm	Millimetre
mmHg	Millimetre mercury
mm/min	Millimetre per minute
MEV	Mink enteritis virus
nm	Nanometre
ng/ml	Nanogram per millilitre
NCCF-SA	National Cheetah Conservation Forum of South Africa
ONH	Optic nerve head
PHPV	Persistent hyperplastic primary vitreous
PHTVL	Persistent hyperplastic tunica vasculosa lentis
PPM	Persistent pupillary membranes
PCR	Polymerase chain reaction
PSD	Posterior segment depth
RPE	Retinal pigment epithelium
STT	Schirmer tear test
SD	Standard deviation
TBUT	Tear film break up time
yr	Year

CHAPTER 1. INTRODUCTION

In 1900 more than 100 000 cheetahs were estimated to be present in the world. Today, the known cheetah population is approximately 6 700 adult animals (Durant *et al.* 2015). The cheetah is currently classified as ‘vulnerable’ by the International Union for the Conservation of Nature (IUCN) and it is listed in Appendix 1 (Felidae) of the Convention of International Trade in Endangered Species of wild Fauna and Flora (CITES) (Durant *et al.* 2015). Cheetahs still occur widely, although sparsely throughout Africa and in a small pocketed area in Iran. Southern Africa has the highest number of cheetahs amounting to an estimated 4190 adults (Durant *et al.* 2015). The Red Data Book of Mammals of South Africa (Friedman & Daly 2004) classifies the cheetah as vulnerable, but the cheetah is close to being re-listed as endangered (Buk & Marnewick 2010). According to the National Cheetah Conservation Forum of South Africa (NCCF-SA), most of South Africa’s cheetahs are found outside conservation areas on privately owned land (Marnewick *et al.* 2007). The decline in cheetah numbers is due to habitat loss, illegal trade, non-regulated captive breeding as well as direct persecution of them and their prey (Buk & Marnewick 2010).

At the end of the last ice age, approximately 10 000 years ago, an extinction of large vertebrates occurred on several continents. This extreme climate change event also caused a reduction in the cheetah populations. This became known as ‘the bottleneck’ and resulted in inbreeding amongst close relatives which led to a reduction in overall genetic variability among the cheetah subspecies (Menotti-Raymond & O’Brien 1993). Krausman & Morales (2005), list five cheetah subspecies: 1) North Africa to central India (*Acinonyx jubatus venaticus*), 2) Northwest and Western Africa (*Acinonyx jubatus hecki*), 3) Eastern Africa (*Acinonyx jubatus fearsoni*), 4) Southern Africa (*Acinonyx jubatus jubatus*) and 5) Northeast Africa (*Acinonyx jubatus soemmeringii*). Cheetahs have a significantly reduced genomic variation compared to any other felid or mammal species (O’Brien *et al.* 1983). They are homogenic for the major histocompatibility complex (MHC) (Brower *et al.* 2013), which is the group of genes that is responsible for the immune response in vertebrates to adapt and respond to pathogens (Castro-Prieto, Wachter & Sommer 2011).

This loss of polymorphism could potentially cause congenital defects, infertility, susceptibility to disease and failure to adapt to environmental changes (Buk & Marnewick 2010).

Cheetahs mostly live a solitary lifestyle, avoiding contact with humans, other carnivores and unrelated cheetahs except during mating. Forced exposure in captivity could lead to chronic stress. The vulnerability to disease increases in captive situations due to closer contact of animals, restricted space, lack of exercise and chronic stress (Munson *et al.* 2005). The Ann van Dyk Cheetah Centre is one of the most successful cheetah breeding facilities in the world. They started breeding in 1971 and supply zoos, other breeding facilities and South African game reserves. An increase in the incidence of cataracts was noted in the cheetahs of the Ann van Dyk Cheetah Centre by their regular veterinarian. This is a concern because of the future implications that a genetic predisposition to cataracts could have on their breeding programme. This prompted the current investigation into the prevalence of cataracts as well as any other ocular pathology in captive bred cheetahs.

CHAPTER 2.LITERATURE REVIEW

The cheetah's speed and vision are very important for both hunting and survival. The cheetah, *Acinonyx jubatus*, is best known as the world's fastest land animal. They can increase their speed from 0–80 km/h in three seconds and can easily reach 103 km/h (Sharp 1997). They are diurnal hunters that normally hunt early in the morning or late afternoon when it is cooler, but there is still enough light (Schaller 1968). The large forward-facing, exposed eyes with binocular vision, allow a cheetah to accurately judge distance when stalking and chasing prey. This makes sight a very important sense for its survival. Their extraordinary eyesight helps to locate prey on open grasslands or plains. The cheetah's visual organisation is unique among felids and confirms the species specialisation as an open-terrain diurnal speed hunter. The cheetah's visual organisation has the highest cone number in the retinal visual streak compared to other felids (Ahnelt *et al.* 2005). Cones are very important for visual acuity and to distinguish colour. In the cheetah, the M-cone (medium wave length) density is 20 000/mm² along the visual streak and peaks in the temporal periphery at about 30000/mm². The domestic cat has about 26000/mm² M-cones in the area centralis (Linberg *et al.* 2001). The S-cone (short wave length) topography of the domestic cat increases from the superior hemisphere (10%) to the inferior hemisphere of the retina (18%) (Ahnelt *et al.* 2005). The cheetah's S-cone concentrations increase from the horizontal meridian (10%) towards both the inferior and superior periphery (25%) (Ahnelt *et al.* 2006). Its overall S-cone proportion is 14%. The domestic cat and African lion's (*Panthera leo*) S-cone proportion is 10% and 8% in tigers (*Panthera tigris*) (Ahnelt *et al.* 2005).

2.1 Ophthalmic Examination

A complete ocular examination is of great importance in accessing ocular pathology for early and correct diagnosis of ocular disorders.

2.1.1 Schirmer Tear Test

The tear film plays an important role in the health of the conjunctiva and cornea as well as the maintenance of corneal clarity. Tears provide nutrients to the corneal surface and contain immunoglobulins, lysosomes and other important proteins to

help with the defences of the eye (Gum & Mackay 2013). Deficiency in the aqueous tear production is a frequent cause of corneal and conjunctival lesions in animals (Featherstone & Heinrich 2013). Standard values for the Schirmer tear test (STT) in domestic species are published and clinically useful for the evaluation and identification of quantitative tear film deficiencies. The STT measures the production of the aqueous component of the tear film. In this test, a standardised strip of Whatman no. 41 filter paper, with dimensions of 5 mm x 35 mm, is impregnated with blue dye and marked with 1 mm gradations. The strip is first bent at a notch 5 mm below the rounded tip. This step is done within the packaging to avoid contamination of the strip by oil from the examiner's hands. The strip's rounded tip is then placed in the lower conjunctival fornix of the eyelid and in contact with the cornea. The test strip is kept in the eye for one minute and tear production is seen as the dye migrates down the strip. This is recorded as mm wetting per minute. The test strips should be read immediately after removal from the eye, as fluid may continue to migrate over time and falsely elevate the measurements. Alternatively, strips can dry out after removal and lead to a false low production of tears. The STT can be performed concurrently or sequentially on each eye. Two STT readings have been described in the literature. The STT I measures reflex as well as basal tear secretion (Mould 2002). The mean value for the STT I in the domestic cat is 14.3 ± 4.7 mm/min (Cullen, Lim & Sykes 2005). The STT II measures only the basal tear production. This is the amount of tears that is usually produced to lubricate the corneal surface (Featherstone & Heinrich 2013). It is measured in the same way as the STT I with the difference that the test is performed after the instillation of topical anaesthetic. The STT II value in the normal cat is 13.2 ± 3.4 mm/min (McLaughlin *et al.* 1988). Waters (1994), found the inter-individual variation among cats to be very large with the STT II values differing by 1–3 mm/min when the left and right eyes were compared. STT values in the cat should therefore be interpreted very carefully and in combination with clinical signs. The STT II is not routinely used in animals in clinical settings, but is much more commonly used in humans where a low basal tear production might be masked by a high reflex tear production (Featherstone & Heinrich 2013). Although the STT has been reported to be inconsistent, it still remains the standard method to quantify aqueous tear production in veterinary ophthalmology (Hawkins & Murphy 1986).

A variety of species specific values for the STT have been published (Featherstone & Heinrich 2013), but to the author's knowledge, no current data on the normal STT values in cheetahs are available.

It is known that sedation and/or general anaesthesia cause a reduction in tear production. The following mechanisms of action have been suggested with the administration of these drugs: vasoconstriction of the vasculature or the tear gland itself, altered automatic regulation of tear production and an altered metabolism at the gland's cellular level (Dodam, Branson & Martin 1998). In a study from Arnett, Brightman & Musselman (1984), domestic cats that underwent anaesthesia with ketamine and acepromazine, showed a reduction in the tear production. Sanchez, Mellor & Mould (2006), described how the STT values in dogs fall below 15 mm/min after sedation with medetomidine, but return to normal levels once the medetomidine component of the sedation had been reversed. It has also been shown that general anaesthesia cause a significant decrease in tear production in dogs (Herring *et al.* 2000), horses (Brightman *et al.* 1983), and koalas (*Phascolarctus cineureus*) (Grundon *et al.* 2011). Tropicamide is a topical short-acting anticholinergic drug, used to facilitate visualisation during ophthalmic examination. It is a rapid-acting drug which causes mydriasis within 15 minutes after topical instillation in domestic cats and begins to decline within 4 hours (Herring 2013). Margadant *et al.* (2003) showed that tropicamide caused a significant reduction of the STT readings in cats, but not in dogs.

Featherstone & Heinrich (2013) reported that tear production is normally lower in younger animals. Similarly, it was found that in cats less than a year, the STT II values were significantly lower than cats older than one year (Waters 1994). Juvenile pigs (Trbolova & Ghaffari 2012) and juvenile dogs (Broadwater *et al.* 2010), showed an increase in STT values as the animals aged and gained body weight.

2.1.2 Intraocular Pressure

Tonometry is the measurement or estimation of intraocular pressure (IOP) in the eye. The assessment of IOP can assist in the diagnosis of ocular diseases like glaucoma and uveitis. Glaucoma is defined as an increase of intraocular pressure that results from inadequate drainage of aqueous humour. This is destructive to the health of the eye and may lead to loss of vision (Plummer, Regnier & Gelatt 2013).

Disrupted axoplasmic flow in the optic nerve head and death of retinal ganglion cells and their axons, inevitably lead to progressive loss of retinal sensitivity and function, reduction in the visual field and eventually blindness (Miller 2013).

Aetiologically, glaucoma can be classified as primary, secondary and congenital. Primary glaucomas have a breed predisposition and are believed to have a genetic basis (Miller 2013). These glaucomas are not associated with any ocular or systemic disorder. Primary glaucomas are divided into two forms: the open angle, in which the drainage angle appears gonioscopically normal, and the closed angle, where the drainage angle appears gonioscopically narrowed or closed. This is mostly caused by goniodysgenesis which is an abnormal development of the pectinate ligaments (Miller 2013). Secondary glaucomas are a much more common clinical finding when compared to primary glaucomas. These glaucomas are associated with other ocular or systemic disorders which disrupt the aqueous humour flow (Plummer *et al.* 2013). The most common causes for secondary glaucoma in cats are anterior uveitis with peripheral anterior synechia, or posterior synechia with pupillary obstruction, lens luxation due to trauma or cataracts, intumescent cataracts, phacolytic or phacoclastic uveitis, hyphema, intraocular neoplasia and malignant glaucoma as a result of aqueous misdirection (Stiles 2013). Congenital glaucomas are normally the result of extensive goniodysgenesis or trabecular maldevelopment and are diagnosed in the first few months of an animal's life (Plummer *et al.* 2013).

Uveitis can reduce the IOP. This inflammatory process leads to a reduction in the active secretion of aqueous humour because of the impinging on the active transport mechanisms. Prostaglandin release during inflammation increases aqueous humour outflow through the uveoscleral route and may contribute to the lower IOP. The IOP may vary depending on the severity and duration of the uveitis (Gabelt & Kaufman 2003) .

The most accurate method of assessing IOP is via direct tonometry with a manometer. This method is however invasive and impractical for clinical use. Indirect tonometry, the measurement of corneal tension, is a quick, non-invasive procedure and can be measured by four different methods: digital tonometry,

indentation tonometry, applanation tonometry and rebound tonometry (Featherstone & Heinrich 2013).

Digital tonometry is performed by placing the index or middle finger on the patient's closed upper eyelids and applying slight pressure to the eyeball. The difference between globes can give an indication of a 'soft' or 'hard' eye. This is a very subjective method of assessing IOP and varies considerably between clinicians and should only be used when no other method is possible (Featherstone & Heinrich 2013).

Indentation tonometry can be performed with a Schiøtz Tonometer. A specially designed scale with a specific weight and foot plate is placed on an anaesthetised cornea to measure corneal indentation produced by the given weight. The scale readings are converted to mmHg using the "1955 Friedenwald Nomogram" table. For accurate readings, the patient must be restrained with its head and eyes directed upwards. The footplate of the Schiøtz Tonometer was designed for human corneal curvature and therefore its accuracy may vary in veterinary patients. Eye, eyelid movement and protrusion of the third eyelid may affect the results. It is not recommended to use the Schiøtz Tonometer in diseased or weakened corneas because of inaccurate measurements and the chance of damaging the cornea further (Featherstone & Heinrich 2013). The average IOP reading of clinically normal domestic cats was greater than or equal to 30 mmHg when measured with a Schiøtz Tonometer (Miller & Pickett 1992).

Applanation tonometry estimates the intraocular pressure by measuring the force needed to flatten an area of the cornea. Different applanation tonometers are available, but the Tono-Pen is commonly used. Local anaesthesia is needed before the instrument can be used on the cornea. The Tono-Pen is held perpendicular to the cornea and the pen is used to let the probe tip make gentle contact with the central cornea without indenting it. The mean IOP is then displayed on the Tono-Pen (Featherstone & Heinrich 2013). Rusanen *et al.* (2010) showed the Tono-Pen compares well with direct manometry and an average of 18.4 mmHg was obtained in normal domestic cat eyes. Kroll, Miller & Rodan (2001), reported that the mean IOP measured with applanation tonometry in domestic cats older than 7 years, was 12.3 mmHg but can range from 3-31 mmHg in domestic cats with normal eyes.

Rebound tonometry is used by induction-impact tonometers. Studies have shown that its accuracy is comparable to that of direct manometry but that the IOP was 2–3 mmHg higher than measurements with the Tono-Pen (Rusanen *et al.* 2010). Rebound tonometry is performed without topical anaesthesia and is the most popular method of accessing IOP in the veterinary field because of ease of use and portability. It can also be used on any size eye. The rebound tonometer probe is electromagnetically activated to come into contact with the cornea and then rebounds from it. The characteristics of the rebound are used to estimate the intraocular pressure. This technique is affected by ocular surface tension and should be performed before application of any topical medications (Maggs 2013).

The TonoVet tonometer has been calibrated to measure IOP in cats and dogs (“d”) and horses (“h”) and has been used in other species (Rusanen *et al.* 2010). The TonoVet is firstly activated and then held horizontally at a range of about 4-8 mm from the axial cornea and at an angle of 90° to the cornea. Six consecutive readings must be taken from the centre of the cornea. After each successful reading is there a short beep. After six readings there is a longer beep and the average intra-ocular pressure is shown on the TonoVet and displayed in mmHg. The display also indicates the variance between readings. A blinking display with a line at the bottom means the variance is acceptable whereas a blinking display with a line at the top or in the middle means an unacceptable variance. The tonometer displays an error message if there is a problem with the probe motion, misalignment with the central portion of the cornea or excessive difference between measurements (Knollinger *et al.* 2005). Rusanen *et al.* (2010) showed an average IOP reading of 20.7 mmHg in clinically normal domestic cats with the rebound tonometer. The highest IOP has been documented in the rhinoceros (*Rhinocerotidae*) (32.1 ± 10.4 mmHg) (Ofri *et al.* 2002), and the lowest in the chinchilla (2.9 ± 1.8 mmHg) (Müller, Mauler & Eule 2010). Because of the large variation between species, it is important to establish a reference interval for IOP in each species. Anatomical and physiological differences of the corneas, the ciliary body and the drainage pathways of aqueous humour, are thought to be reasons for species differences in IOP readings (Ofri *et al.* 2002). To the author’s knowledge there is no current information available on normal IOP values for cheetahs.

A variety of factors can affect the IOP. Pressure by the fingers of the examiner on the globe or eyelids (Klein *et al.* 2011) or excessive restraint with pressure on the jugular (Klein *et al.* 2011, Pauli *et al.* 2006), can falsely elevate the IOP reading. Body position has been documented to cause a difference in IOP (Broadwater *et al.* 2008). It was reported that the mean IOP of horses increased significantly when the head was below the level of the heart compared to above the level of the heart (Komáromy *et al.* 2006). An increased IOP has also been described in mice in a head-down position (Aihara, Lindsey & Weinreb 2003). Human IOP also showed an increase in the supine position compared to the sitting or the standing position (Galín, McIvor & Magruder 1963). The suggested mechanisms that could contribute to such an increase in IOP are compressive forces on the globe by congested orbital contents, increases in episcleral venous pressure and when congestion of the uveal tract causes increases in the ocular blood volume (Weinreb, Cook & Friberg 1984).

Circadian rhythms have been documented to influence the IOP readings (Del Sole *et al.* 2007, Martin-Suarez *et al.* 2014). In nocturnal species such as cats and rabbits, IOP increases during the night (Del Sole *et al.* 2007, Rowland, Potter & Reiter 1981), whereas in diurnal species such as dogs, IOP peaks during the day (Giannetto, Piccione & Giudice 2009). It is hypothesized that the activity phase of each species, correlates with the higher values of IOP (Del Sole *et al.* 2007).

Age also affects the IOP. Kroll *et al.* (2001), showed a lower IOP reading in young kittens when compared to adolescent cats, a higher IOP reading in adolescent cats versus adult cats and a lower IOP reading in geriatric cats compared to cats. A lower IOP was reported in lions younger than 1 year of age (12.8 mmHg) compared to lions older than 1 year of age (23.9 mmHg) (Ofri *et al.* 2008). IOP reading in dromedary camels (*Camelus dromedarius*) proved the opposite, with the mean IOP for immature camels higher than that of mature camels (Marzok & El-khodery 2015). Ofri *et al.* (1998) also showed differences in IOP between genders of lions. A significantly higher IOP was reported in the male lion (24.9 mmHg) when compared to the female (20.9 mmHg). Ferrets (*Mustela putorius furo*) showed a similar pattern with a higher IOP in males (15 mmHg) compared to the females (13.4 mmHg) (Hernández-Guerra, Rodilla & López-Murcia 2007). In humans, females have been documented to have higher IOP levels than males (Wu *et al.* 2006).

The reproductive status in cats has been shown to cause a difference in IOP. The IOP for females in estrus and for those that were pregnant with a high progesterone concentration, was documented to be significantly higher than the females that were not in estrus or non-pregnant. No differences were found between male IOP and the female group that were not in estrus (Ofri *et al.* 2002). When comparing lionesses in different stages of their estrus cycle, it was shown that the IOP for lionesses in the luteal phase (progesterone concentration > 5 ng/ml) were significantly higher (27.1 mmHg) than females not in the luteal phase (progesterone concentration < 5 ng/ml) (21.0 mmHg) (Ofri *et al.* 1999).

Various medications, including anaesthetic premedication, induction, and maintenance drugs, can alter IOP by changing the rate of aqueous production or outflow, or by changing the extraocular muscle tone and relaxation of eyelid muscles (Cunningham & Barry 1986). All agents which are commonly used to induce general anaesthesia, lower the IOP (Murphy 1985). In contrast however, ketamine may increase extraocular muscle tone which can lead to an increase of IOP (Ofri *et al.* 1998). A significant increase was seen in the IOP of dogs (Hofmeister *et al.* 2006, Kovalcuka *et al.* 2013), and cats (Hahnenberger 1976), sedated with ketamine. Contradictory to these studies, no significant effect on IOP were seen where ketamine was combined with diazepam in lions (Ofri *et al.* 1998), or xylazine in cats (Ofri *et al.* 2002), and monkeys (Erickson-Lamy *et al.* 1984).

Topical administration of medetomidine caused a significant reduction in the IOP of rabbits and cats (Jinet *et al.* 1991), whereas sedation of dogs with intravenous medetomidine had no significant effect on the IOP (Verbruggen *et al.* 2000, Wallin-Håkanson & Wallin-Håkanson 2001). Dexmedetomidine however, showed a significant decrease of the IOP after 20 minutes (Artigas, Redondo & López-Murcia 2012). Tiletamine-zolazepam (Zoletil) showed no significant effect on the IOP of dogs (Jang *et al.* 2014), or cats (Hahnenberger 1976). Tiletamine alone caused no change in IOP although Zolazepam on its own resulted in a 10% reduction in the IOP (Hahnenberger 1976). Tiletamine is a dissociative agent and its pharmacodynamics is similar to those of ketamine. It is more potent and has longer duration of action (Jang *et al.* 2014), but unlike ketamine, has minimal effect on the contraction of the extraocular muscles (Hahnenberger 1976).

A possible explanation for this finding is that zolezapam reduce IOP slightly and may lessen the increase in IOP induced by tiletamine (Hahnenberger 1976).

Mydriatic agents like tropicamide, cause dilatation of the pupil and cause a rise in IOP of about 3 mmHg in domestic cats (Stadtbäumer, Köstlin & Zahn 2002).

Ocular pathology may influence the IOP reading and it is therefore advised that measurements should be taken from the most normal part of the cornea (Featherstone & Heinrich 2013). An increase of 100 μ m in corneal thickness can increase the IOP reading by 2 mmHg for the TonoVet (Park *et al.* 2011).

2.1.3 Slit-lamp Biomicroscopy

The slit-lamp biomicroscope is the instrument of choice for the examination of the ocular anterior segment. It improves visualisation of the eyelids, third eyelid, conjunctiva, sclera, cornea, anterior chamber, iris, lens and anterior vitreous. The slit-lamp biomicroscope combines magnification with bright focused light and provides a choice of full or slit beams. Full diffuse light is helpful with the examination of a large area of the eye. It gives the examiner an initial overview and is useful to assess gross pathology. The slit beams create an optical section of the tissues, by projecting a narrow, sharply focused light onto the eye. A slit beam provides information about the relationship of ocular tissues with each other as well as the topography of tissues examined. For example, the anterior lens capsule is visible as a convex bright line of illumination and the posterior lens capsule will be a concave, less bright line of illumination. Cataracts will be visible as bright opacities in the lens section and their position can be correctly identified and recorded (Featherstone & Heinrich 2013). The long slit beam can be reduced to a small pinpoint to allow visualisation of the Tyndall effect, as in the case of uveitis. The light beam is angled at 20 to 45 degrees from the axis of the microscope and the oculars are rested against the examiner's brow. When using the Keeler slit-lamp biomicroscope, the magnification can be adjusted between 10 and 16 times. The focal distance of the instrument is 7 to 10 cm. Fine focus can be achieved by moving either slightly closer or away from the eye. Both direct illumination and retro-illumination are used during ocular slit-lamp biomicroscopy.

During direct illumination, the structure to be examined is illuminated by the light source itself. When using retro-illumination, the structure of interest is illuminated by light reflected from neighbouring tissues (Featherstone & Heinrich 2013).

2.1.4 Ophthalmoscopy

Examination of the fundus is best performed on dilated pupils using direct or indirect ophthalmoscopy. Distant direct ophthalmoscopy gives a good and rapid assessment of the degree and distribution of an opacity in the visual axis. When an ophthalmoscope is set to '0' or zero, it is used with the light source directed at the patient's eye and the beam is parallel with the examiner's line of sight. The patient is viewed from an arm's length distance to observe the tapetal reflex. Any opacity in the path of the tapetal reflex will appear black. This evaluation also helps to distinguish nuclear sclerosis from cataracts. Nuclear sclerosis shows a refractive ring at the nuclear cortical interface, which is normally positioned just inside the pupillary margin. In cases of nuclear sclerosis, light is normally transmitted through the centre of the lens, whereas cataracts appear black and will block the tapetal reflex.

When using direct ophthalmoscopy, the examiner's eye should be 2-3 cm from the patient's cornea. The image of the fundus is upright and highly magnified, but the field of view is very narrow. The magnification depends on the species being evaluated (Featherstone & Heinrich 2013).

Indirect ophthalmoscopy is performed with a light source and a biconvex lens. A 20 dioptre (D) lens or a 2.2 panretinal lens is normally used for domestic animals and gives a 4 x magnification in dogs and 5 x magnification in cats. A binocular ophthalmoscope on the head of the examiner allows stereoscopic vision and an intensified image. The examiner's head must be 0.50–0.75 m or an arm's length from the animal's eye, in the same axis as the lens. The lens is positioned between the index finger and the thumb, while the other fingers rest on the frontal sinus area of the dog's head for stability. The axis of the lens must lie in the same axis as the pupil and parallel to the iris. This gives the examiner a larger view, but inverted image of the fundus (Mould 2002).

2.1.5 Fluorescein Dye Test

The fluorescein dye test can be used to diagnose corneal and conjunctival defects, aqueous humour leakage, nasolacrimal duct patency and qualitative tear film abnormalities with the tear film break up time (TBUT) (Mould 2002). Fluorescein is a water soluble weak acid. Its absorption peaks at 490 nm and then converts the absorbed light to a peak wave length of 520 nm, which shows as fluorescent light. Fluorescein is an orange dye that changes to green in alkaline conditions. It is highly lipophobic and hydrophilic. Fluorescein is available as an impregnated paper strip or as a 2% alkaline solution. One drop of fluorescein solution is applied to each eye, or the strip can be moistened and the dorsal bulbar conjunctiva must be touched gently. When it is applied to the eye, it does not adhere to the lipid-containing cell membranes of the epithelium, but gets absorbed by any exposed corneal stroma. The stained area should be examined in a dark environment with magnification and a blue light source from a cobalt filter. Defects will appear as bright green areas. Fluorescein is very accurate in detecting corneal ulcers where the epithelium is absent and stroma is exposed. Fluorescein also stains inter-cellular spaces and can assist in detecting corneal abrasions. While it stains conjunctival ulcers and abrasions, the Descemet's membrane will not stain. The Seidel test assesses the leakage of aqueous humour through deep corneal ulcers, lacerations, puncture wounds and suture sites. Aqueous humour can be seen as a bright green colour when it is runs through and dilutes the fluorescein on the cornea (Mould 2002).

The fluorescein drainage test, which assesses tear drainage, is called the Jones test. Fluorescein is applied to the eye and the time taken for the fluorescein to pass through the nasolacrimal system to the ipsilateral nares is recorded (Jones 1961). The time required for the fluorescein to appear at the nostril is highly variable and depends on the species, snout length, skull formation and the way in which the test is performed (Maggs 2013). A time interval of 15 seconds to 1 minute has been reported in cats (Martin 2005).

The stability of the tear film can be evaluated by measuring the TBUT. It indirectly evaluates the lipid and/or mucin layers of the tear film. Fluorescein is applied to the eye, the animal is allowed to blink, and then the eyelids are manually held open until the tear film 'breaks up' as dark spots start appearing on the cornea.

The mean value for the TBUT in the juvenile cat is 16.7 seconds and 21 seconds in the adult cat (Cullen *et al.* 2005). TBUT is reduced in cats with conjunctivitis, ulcerative keratitis and FHV-1 (Cullen *et al.* 2005).

2.1.6 Ultrasonography

Ultrasound has become an important diagnostic tool in ophthalmic examinations to evaluate the soft tissues of the eye and orbit (Kassab 2012). Ultrasonography is a non-invasive imaging technique which is safe and rapid to use. It is used for the qualitative and quantitative evaluation of orbital and intraocular structures. Ultrasonography is indicated in suspected orbital diseases, ocular trauma, intraocular haemorrhage, intraocular or orbital foreign bodies or masses, lens luxations, retinal detachment and in cases when an ophthalmic examination cannot be performed in opaque eyes (Rubin & Koch 1968, Williams & Wilkie 1996). It is also helpful to determine any variation in size, form, or position of the eye (Toni *et al.* 2010). A thorough knowledge of the normal appearance, dimensions and anatomy is important in the assessment of ocular pathological changes. To date and to the author's knowledge, there are no reference ranges currently available for the cheetah species. Biometrics are used to determine changes in the ocular dimensions during diseases, such as buphthalmic globes in glaucoma, microphthalmos or phthisis bulbi (Hernández-Guerra, Rodilla & López-Murcia 2007). Biometry can also be used to calculate the intraocular lens (IOL) power, to determine artificial IOL implant size, and to estimate prosthetic globe size after an enucleation (Gonzalez, Rodriguez & Garcia 2001). Values for normal eyes have been established in many animals such as dogs (Cottrill, Banks & Pechman 1989, Ekestén & Torrang 1995, Schiffer *et al.* 1982), cats (Gilger, Davidson & Howard 1998), rabbits (Toni *et al.* 2010), horses (Rogers *et al.* 1986), bovine (Potter, Hallowell & Bowen 2008), Saanen goats (*Capra aegagrus hircus*) (Ribeiro *et al.* 2009), camels (Kassab 2012, Hamidzada & Osuobeni 1999), Asian elephants (*Elephas maximus*) (Bapodra *et al.* 2010), and ferrets (Hernández-Guerra, Rodilla & López-Murcia 2007).

Animals are examined following the application of topical anaesthetic. The probe is placed directly on the cornea or sclera while the eyelids are held open manually.

Scanning through closed eyelids is also possible, but the eyelids reduce the sound waves and quality of the image which generally makes this method less desirable. However, in cases of corneal injury, ocular trauma or after intraocular surgery, this is the recommended examination technique to avoid further damage to the cornea. Large amounts of coupling gel are used on the cornea to decrease near-field reverberation artifacts. A transverse and sagittal plane in the axial direction, are normally used to evaluate the eye during ultrasound examination (Dietrich 2013).

Ultrasound works on the basis of the reflection of sound waves from the border between two tissues of different acoustic impedance. The boundaries that reflect sound in the eye are the anterior and posterior corneal surfaces, the anterior and posterior lens surfaces and the retina. These echoes, from the reflections, are used in different ultrasound techniques such as A (amplitude) -mode, B (brightness) -mode, M (motion) -mode and Doppler scanning (Osuobeni & Hamidzada 1999).

B-mode ultrasonography is most commonly used in veterinary ophthalmology with a standard 10-14 MHz transducer and a focal range of 3-4 cm. This allows visualisation of anterior and posterior segment abnormalities as well as orbital lesions (Dietrich 2013).

A low frequency 7.5 MHz ultrasound transducer gives poor near-field visualisation but better tissue penetration for deeper structures like the retrobulbar area. High frequency ultrasound waves (20-50 MHz) and ultrasound biomicroscopy (50-100 MHz), penetrate only a few millimetres into tissue and are ideal for imaging structures such as the cornea, sclera, anterior chamber, iris, iridocorneal angle, ciliary body and anterior lens capsule (Pavlin & Foster 1995, Ye *et al.* 1995). A-mode ultrasonography is when a fixed, single beam of ultrasound is projected through the eye. The returning echoes are seen as vertical spikes on a horizontal line. The height of the spike reflects the intensity of the echo. The distance between the spikes is the time required for the ultrasound waves to reach a certain acoustic interface and to return to the transducer. The distance between the spikes indicates the measurements of the various intraocular distances. Biometric A-scan is commonly used for axial eye length measurements in both veterinary and human ophthalmology and requires a special biometric A-mode transducer.

B-mode is when multiple sound beams are projected through the eye and the returning echoes are seen as reflective lines or dots (Dietrich 2013).

Although A-mode ultrasound has been considered to be the most accurate and preferred modality to measure structures in the eye, B-mode ultrasound is an accessible and practical method, allowing the simultaneous evaluation of intraocular anatomy and measurement of intraocular distance (Ruiz *et al.* 2015). Although some studies have shown differences in ocular measurements between A-mode and B-mode ultrasound (Hamidzada & Osuobeni 1999), others have proved that there are no significant differences in the ocular measurements of veterinary patients when these modalities are compared (Boroffka *et al.* 2006, Cottrill *et al.* 1989, Grinninger, Skalicky & Nell 2010). According to Hamidzada & Osuobeni (1999), the B-mode measurements are significantly smaller in axial globe length, lens thickness and vitreous chamber depth than the A-mode technique, but overestimate the corneal thickness and anterior chamber.

Gender differences were observed in the axial globe length of dromedary camels, where the female globe was shown to be larger than the male globe (Yadegari *et al.* 2013). In dogs, the globe length was documented to be larger in males than females (Schiffer *et al.* 1982). In contrast, no significant gender differences were found in dogs (Cottrill *et al.* 1989), goats (Ribeiro *et al.* 2009), and ferrets (Hernández-Guerra *et al.* 2007).

The lens thickness was also shown to be affected by gender in dromedary camels (Yadegari *et al.* 2013), and in ferrets (Hernández-Guerra *et al.* 2007). The lens thickness of males appeared larger than the females in both species.

It has also been documented that ocular dimensions increase with age in miniature horses (Plummer, Ramsey & Hauptman 2003), Saanen goats (Ribeiro *et al.* 2009), Asian elephants (Bapodra *et al.* 2010), buffalo (*Bos bubalis*) (Kassab 2012), lions (Ofri *et al.* 2008), and one-humped camel (Kassab 2012). In dogs the axial globe length increases until 52 weeks of age (Tuntivanich *et al.* 2007).

In humans, the eye continues to develop, with an increase in ocular dimension until approximately 13 years of age (Larsen 1971, Tuntivanich *et al.* 2007).

2.2 Ocular Infectious Diseases

Severe inflammatory reactions to common infectious agents have been reported in captive cheetahs throughout the world (Munson *et al.* 2005). Several domestic cat viruses are known to infect non-domestic felids and could potentially affect their eyesight (Evermann *et al.* 1993). The cheetah's genetic uniformity and the chronic stress of a captive environment, could potentially increase disease development by changing normal physiological homeostasis and immunity (Munson *et al.* 2005).

The following diseases not only cause ocular problems, but can also have devastating consequences in the conservation of cheetahs.

2.2.1 Feline Coronavirus

Feline coronavirus (FCoV) is a contagious and serious pathogen of domestic and non-domestic felids. The FCoV in domestic cats may lead to be asymptomatic, or an enteric disease or Feline infectious peritonitis (FIP). Feline infectious peritonitis is a fatal arthrus-type immune reaction of cats to the viral infection (Foley *et al.* 1998). Large multicat, indoor environments are known to be predisposed to FCoV infection and FIP (Pedersen 2009). Sexually intact and purebred cats are more likely to develop FIP (Pesteanu-Somogyi, Radzai & Pressler 2006). Feline infectious peritonitis occurs most commonly in young cats and it may present as a dry, non-effusive form or a wet, effusive form of the disease. Neural and ocular lesions are more likely to be seen with the non-effusive form (Andrew 2000). Bilateral granulomatous anterior uveitis with fibrinous exudate in the anterior chamber and keratitic precipitates, are the most common ocular lesions in domestic cats. Chorioretinitis with pyogranulomatous exudate around the retinal vessels may be present. Retinal haemorrhages, detachments and optic neuritis can be additional findings (Campbell & Reed 1975).

Feline infectious peritonitis has also been reported in wild felids kept in zoos, namely lion, leopard (*Panthera pardus*), black leopard (*Panthera pardus*), jaguar (*Panthera onca*), caracal (*Caracal caracal*), lynx (*Lynx lynx*), serval (*Leptailurus serval*), puma (*Puma concolor*), tiger and cheetah (Van Rensburg & Silkstone 1984). Feline infectious peritonitis' morbidity and mortality were devastating in cheetah populations during 1982 – 1983 (Evermann, Roelke & Briggs 1986). Evermann *et al.* (1986)

noted that captive cheetahs are highly vulnerable to infection and disease from FCoV. Outbreaks in captive cheetahs have been documented by Brown *et al.* (1993), Heeney *et al.* (1990) and Peiffer & Gelatt (1975). Post mortem findings confirmed the diagnosis, however, no specific ocular lesions were recorded. Serology and examination of faecal contents can help to identify the majority of infected and carrier cheetahs who are shedding the virus. The inconsistent correlation between seropositive and faecal viral shedding make the diagnostic testing very challenging, unreliable and difficult to interpret (Gaffney *et al.* 2012, Kennedy *et al.* 2002).

2.2.2 Feline Herpesvirus1

Feline herpesvirus1 (FHV-1) is common and widespread among domestic cat populations. It is estimated that over 90% of domestic cats world-wide are seropositive to this virus (Maggs, Lappin & Nasisse 1999). Of these infected cats 80% remain latently infected and of these 45% will have spontaneous viral reactivations. This will manifest either as asymptomatic virus shedding or as clinical disease (Townsend *et al.* 2004). The virus is spread from cat to cat by aerosol transmission, fomites or by direct contact. The FHV-1 infects the epithelial surfaces of the corneal epithelium, conjunctiva and respiratory tract. When the virus replicates and invades nearby cells, it causes necrosis of these tissues (Hoover & Griesemer 1971). The virus travels via the neuronal axons to the trigeminal ganglion where it becomes latent (Maggs *et al.* 1999). FHV-1 is associated with the following lesions in domestic cats: serous to mucopurulent ocular and nasal discharge, conjunctivitis, ulcerative keratitis and non-ulcerative stromal keratitis, keratoconjunctivitis sicca, ophthalmia neonatorum, symblepharon, corneal sequestrum, eosinophilic keratitis and anterior uveitis (Cullen & Webb 2013). The identification of FHV-positive carrier animals is difficult because of the nonspecific clinical signs and the limitations of diagnostic tests. Many of the diagnostic tests, including Polymerase chain reaction (PCR) assay, Immunofluorescence antibody assay (IFA) techniques, viral isolation and histopathology, have false negative results. This is likely because these tests are dependent on the stage of infection, amount of viral shedding, sampling techniques and sample handling (Witte *et al.* 2013). Swabs from the conjunctiva, cornea or oropharynx are used for virus isolation and can help in the diagnosis and identification of carrier animals.

These areas should be swabbed aggressively to obtain cells because the FHV-1 is an intracellular organism. Vaccination does not protect against FHV-1 infection, however, it reduces the severity of clinical signs, reduces the active viral shedding and potentially prevents its reactivation later in life (Maggs 2005).

FHV-1 has been described in leopards, cheetahs, jaguars and lions (Junge *et al.* 1991). FHV-1 is an endemic and benign disease in free-ranging felids (Van Vuuren, Goosen & Rogers 1999). In captive situations some cheetahs acquire a self-limiting rhinitis and chronic epiphora, while others appear to be especially vulnerable to severe disease and can experience persistent or recurrent clinical signs or conditions. This might include keratitis, corneal ulcers, conjunctivitis, uveitis and even blindness (Munson *et al.* 2004, Witte *et al.* 2013). Persistent cutaneous ulcers, as a result of FHV, are unique to the cheetah and very rarely occur in FHV-1 infected domestic cats or other exotic species (Junge *et al.* 1991). Ulceration, crusting, purulent discharge and necrosis with eosinophilic inflammation are seen in lesions affecting the periocular, perinasal and periorbital regions (Flacke, Schmidt-Küntzel & Marker 2015, Hargis & Ginn 1999). Lesions occasionally also occur on the extremities (Flacke *et al.* 2015, Munson *et al.* 2004). Ulcerative herpes dermatitis is mostly diagnosed in young animals, but has been reported in a cheetah of nine years of age (Flacke *et al.* 2015). Recognising the clinical signs and syndromes of FHV could lead to earlier diagnosis and treatment of this condition (Witte *et al.* 2013).

2.2.3 Feline Leukaemia Virus

Feline leukaemia virus (FeLV) causes severe illness and death in domestic cats. It has, however, rarely been reported in non-domestic felids (Briggs & Ott 1986). The FeLV is a retrovirus that replicates in epithelial tissues and results in malignant transformation of specific lymphocytic/haematopoietic cells.

Transmission of FeLV is via saliva and blood while grooming or fighting. The FeLV infections cause few ocular problems in domestic cats, except for FeLV-associated ocular lymphosarcoma (Townsend 2008). Intrauterine or early neonatal infection cases can cause retinal dysplasia (Glaze 2005). The uveal tract is a common site for hematogenous metastasis of neoplastic lymphocytes. Ocular lymphosarcoma may initially present as uveitis.

The iris gradually becomes more involved and distorted and may lead to glaucoma. Marker *et al.* (2003), reported on a wild born-captive cheetah which died of multicentric T-cell lymphoma associated with FeLV, but no ocular lesions were noted. This cheetah was in a cage next to a FeLV infected cheetah which was in contact with domestic cats. The affected cheetah, which was previously FeLV negative, tested positive when diseased. Marker *et al.* (2003), tested captive cheetahs in Namibia and found FeLV not to be endemic to cheetahs. They are however very susceptible to FeLV. It is therefore advisable to be cautious about contact with FeLV positive domestic or wild felids. The enzyme-linked immunosorbant assay (ELISA) test can be used on serum samples to detect the FeLV antigen (Townsend 2008).

2.2.4 Feline Immunodeficiency Virus

Feline immunodeficiency virus (FIV) is a lentivirus which is most likely transmitted between animals via saliva and bite wounds (Pedersen *et al.* 1989). The FIV causes T-cell lymphocyte depletion and thereby compromises the animal's immune system. These animals are therefore susceptible to diseases like toxoplasmosis (Brown *et al.* 1993). Anterior uveitis is the most frequent ocular disease in domestic cats with FIV (English *et al.* 1990). Infection with FIV has been demonstrated serologically in several species of non-domestic felids, in captive and free-ranging populations including lions, pumas (*Puma concolor*), bobcats (*Lynx rufus*), snow leopards (*Panthera uncia*) and cheetahs (Barr *et al.* 1989). There is, however, little evidence of FIV pathology in wild felids (Brown *et al.* 1993). The ELISA test is specific in detecting FIV antibodies and can be done on serum samples (Pedersen *et al.* 1989).

2.2.5 Feline Panleukopenia

Feline panleukopenia virus (FPLV) is classified under the family Parvoviridae and related to Mink enteritis virus (MEV) and Canine parvovirus (CPV) (Nakamura *et al.* 2001, Truyen *et al.* 2009). It is highly contagious and is transmitted by direct and indirect contact with infected animals and their secretions, especially faeces. Fleas may also transmit the virus and/or the virus may spread by food bowls, bedding or cages (Cullen & Webb 2013). In utero transmission may also occur (Truyen *et al.* 2009).

Cats are easily exposed to the virus because it is extremely resistant and can survive for a long time in the environment (Nakamura *et al.* 2001). The FPLV infects rapidly dividing cells such as lymphoid tissue, bone marrow, and intestinal mucosal cells. It can cause a wide range of diseases and clinical signs including acute onset fever, depression, leukopenia, vomiting, haemorrhagic diarrhoea and secondary infections (Gould & Papasouliotis 2013). The severity of the infection may be influenced by the pathogenicity of secondary bacterial infections (Lane *et al.* 2016). Queens that are infected or vaccinated just before or during pregnancy, normally do not show clinical illness, but infertility or abortion are common signs. Central nervous system (CNS) involvement, cerebellar hypoplasia, ataxia, intention tremors and a hypermetric gait have been noticed in kittens with late fetal or early neonatal infection.

Retinal dysplasia is the main ocular manifestation of FPLV during in utero or postnatal infection. Retinal thinning, degeneration and optic nerve hypoplasia have also been described (Percy, Scott & Albert 1975). Retinal dysplasia is defined as the abnormal retinal development and is clinically suspected by visualising rosettes or folds in the retina. Rosettes are microscopic folds of the retina which look like circular lesions of foci (Stiles 2014). Retinal dysplasia can have different appearances on the fundus examination. Multiple gray foci can be located in the tapetum or non-tapetum. Affected areas can be visualised as hyperreflective or hyporefective lesions in the tapetum while lesions in the non-tapetal fundus will appear depigmented or pale (Stiles 2014). Lesions can be geographic or local (Stiles 2013). Less severe cases will show bilateral retinal folds and severe cases will also show areas of retinal degeneration and scarring (Narfstrom 1999). Diagnosis of FPLV can be confirmed by histological examination, electronmicroscopy and identification of the virus. Serological testing is of limited value (Gould & Papasouliotis 2013, Johnson 1964).

FPLV has been reported in many captive wild felids like leopards (Johnson 1964), lions (Chandran *et al.* 1993, Studdert, Kelly & Harrigan 1973), tigers (Povey&Davis 1977), cheetahs (Van Vuuren *et al.* 2000), European wild cat (*Felis sylvestris*) (Wasieri *et al.* 2009), African wild cat (*Felis lybica*), ocelot (*Leopardus pardalis*), puma, Siberian tiger (*Panthera tigris altaica*) and the spotted cat (*Prionailurus rubiginosus*). No ocular lesions were documented (Filoni *et al.* 2006).

Eighty four percent of the free ranging lions in the Kruger National Park (Spencer 1991) and 48% of the cheetahs in Namibia (Munson *et al.* 2004), also tested positive for FPLV antibodies. These animals were free of any clinical signs at the time of testing.

An outbreak of FPLV has been documented in young vaccinated cheetah cubs in 2012 at a breeding centre in South Africa. Eleven, 6-8 month old captive bred cheetah cubs were presented with lethargy, inappetence, vomiting and diarrhoea. Five of the cubs died, despite aggressive treatment. No ocular lesions were identified, clinically or on necropsy. Gross pathology, electron microscopy and PCR were used to diagnose FPLV (Lane *et al.* 2016). After this outbreak, 12 more cases of FPLV have been diagnosed in captive, unvaccinated African black-footed cats (*Felis nigripes*), caracal, cheetah, lion, ocelot and serval, throughout South Africa (Lane *et al.* 2016). Intensive farming conditions, a lack of vaccination, poor hygiene and the unsuccessful exclusion of domestic carnivores from enclosures have been suggested to cause the increasing incidence of FPLV in captive carnivores (Lane *et al.* 2016).

2.2.6 Bartonellosis

Bartonella is a vector-borne, gram negative bacterium that infects mammalian erythrocytes and endothelial cells. It causes long-lasting bacteraemia in its reservoir host (Cullen & Webb 2013). *Bartonella henselae* is common in domestic cats with 55-81% of cats being seropositive. Many infected cats, however, do not show any clinical signs (Lappin & Black 1999), and only 5-10% of infected patients have ocular signs (Cunningham Jr & Koehler 2000). Bartonellosis most commonly causes uveitis, but ocular pathology like blepharitis, conjunctivitis, keratitis and chorioretinitis has also been reported (Cullen & Webb 2013). Fleas, ticks and biting flies can carry the bacteria and act as vectors in the transmission of *Bartonella* from cat to cat. Chomel *et al.* (2006) isolated *B. henselae* in non-domestic felids from the *Panthera* genus (lions, tigers, leopards and jaguars), cheetahs and various small wild cats of the genus *Felis*, in zoological parks in California. He also diagnosed bartonellosis in captured lions and cheetahs in Africa between 1982 and 2002. No ocular lesions were noted.

Moila *et al.* (2016) isolated *B. Henselae* and *B. Koehlerae* in free-ranging lions from the Kruger National Park, a cheetah from Namibia and in semi-captive cheetahs from North America. PCR can be used on EDTA samples to detect *Bartonella* DNA. IFA can detect the presence of *Bartonella* antibodies in serum (Chomel *et al.* 2006).

2.2.7 Toxoplasmosis

Toxoplasma is an intracellular protozoal parasite with a worldwide distribution (Dubey *et al.* 2004). Cats are intermediate and definitive hosts of *Toxoplasma gondii* and are the only species that can shed oocysts which are infective to other species. Oocysts are resistant to environmental conditions and they may remain infectious for months to years (Dubey *et al.* 2004). Toxoplasmosis can cause multi-systemic disease. Ocular pathology typically is chorioretinitis with or without concurrent uveitis. Optic neuritis has also been reported in affected domestic cats (Davidson & English 1998). Associations have been made between toxoplasmosis and FIV. Positive serum antibody titres for toxoplasmosis have been found more often in FIV-positive domestic cats than in FIV-negative domestic cats (O'Neil *et al.* 1991). A number of reports identified *Toxoplasma gondii* exposure in cheetahs in zoological parks (Sedlák & Bártová 2006, Spencer, Higginbotham & Blagburn 2003) as well as in free-ranging populations (Cheadle, Spencer & Blagburn 1999). Although infection is prevalent in domestic and non-domestic felids, clinical disease is rare (Dubey *et al.* 2004) and no ocular lesions have been documented in clinically diseased captive cheetahs (Lloyd & Stidworthy 2007, Van Rensburg & Silkstone 1984). Cheadle *et al.* (1999) showed that captive and free-ranging non-domestic felids in Southern Africa have been exposed to, and are likely to be infected with *Toxoplasma gondii* and *Neospora caninum*. Serological tests are validated for use in domestic cats, but not in the cheetah (Lloyd & Stidworthy 2007). Although immunoglobulin G (IgG) titres are frequently raised in exposed non-domestic felids, single samples do not help in the diagnosis of active infection. This is because IgG levels may be elevated for months or years after exposure. Demonstration of a rising IgG titre over 2-3 weeks may indicate recent or active infection (Lappin & Powell 1991).

2.2.8 *Cryptococcosis*

Cryptococcus is an opportunistic, non-contagious organism and is the most prevalent systemic mycoses in mammals and humans (Cullen & Webb 2013). *Cryptococcus neoformans* is the most commonly reported feline mycotic infection. It is normally associated with high nitrogen-containing environments like soil enriched with avian faeces. Birds can therefore be vectors of *Cryptococcus* spp. (O'Brien *et al.* 2004). Inhalation of infective material is the most common route followed as it spreads systemically to sites like the nasal passages, skin and CNS. Ocular lesions such as chorioretinitis with granulomatous inflammation and retinal detachments, optic neuritis and anterior uveitis have been reported in domestic cats (Gerds-Grogan & Dayrell-Hart 1997). Millward & Williams (2005) reported a free-ranging cheetah with *Cryptococcus neoformans*, while all the previous reported cases have been in captive cheetahs (Bernstein 1979, Berry, Jardine & Espie 1997, Bolton *et al.* 1999). No ocular lesions were reported. Lateral flow antigen testing and CSF analysis can help in the diagnosis of cryptococcosis. Serological tests on serum for cryptococcal antibodies are also available (Berry *et al.* 1997).

2.3 Cataracts

A cataract is an opacity of the lens and/or its capsule. An important differential diagnosis is nuclear sclerosis. New lens cells are produced at the equator of the lens, throughout an animal's life. The new transformed lens fibres force the old lens fibres towards the centre called the lens nucleus. Nuclear sclerosis is the hardening of the nucleus of the lens due to compression of the central portion of the lens. Clinically it appears as an obvious but transparent sphere within the lens. Cataracts can be caused by several events and diseases such as embryological maldevelopment, heritability, diet, trauma, metabolic and infectious diseases.

The position of the cataract in the lens and the appearance of the opacity, can help to classify the cataract and determine a possible cause. The position of the opacity in the lens may be capsular, subcapsular, nuclear or cortical. It may lie at the anterior or posterior poles of the lens, or involve the equatorial region of the lens (Ofri 2013). Cataracts can also be classified by the stage of development. Incipient cataracts are very early lens changes and may involve just a few lens fibres.

Immature cataracts do not involve the entire lens and a fundic reflex can still be seen. Mature cataracts involve the entire lens and no tapetal reflex is visible. In advanced or hypermature cataracts, degradative enzymes from degenerative and ruptured lens fibres cause further proteolysis of areas in the lens. Lens proteins may liquefy and leak through the lens capsule and cause uveitis. Morgagnian cataracts have liquefied lens proteins and a dense nucleus which sinks ventrally in the lens capsular bag (Petersen-Jones 2002). Whether an animal is affected clinically by cataracts, depends on the lenticular opacifications. Minor changes may cause minimal to no visual problems while complete cataracts cause blindness in the affected eye (Narfstrom 1999).

Congenital cataracts are often associated with other ocular abnormalities such as microphthalmia, persistent pupillary membranes (PPM), persistent hyperplastic primary vitreous/persistent hyperplastic tunica vasculosa lentis (PHPV/PHTVL), and retinal dysplasia. Hereditary cataracts usually have characteristic anatomic localisation and appearance of the lens opacity in the initial stages. The age at the start, the progression, bilateral nature, and absence of other ocular disorders that might cause cataract formation, can indicate that these cataracts are likely to have a heritable basis (ACVO Genetics Committee, 2010). Hereditary cataracts most commonly involve the nucleus or the posterior cortex and progression is variable. Hereditary cataracts in domestic cats are rare (Williams & Heath 2006). Congenital cataracts have been described in Persian (Peiffer & Gelatt 1975), British shorthaired breeds (Irby 1983), Birman (Schwink 1986), Himalayan (Rubin 1986) and domestic short haired cats (Stiles 2013). Inherited cataracts have been shown to be caused by developmental disturbances during lenticular differentiation in the already-formed lens vesicle (Graw 1996). Williams and Heath (2006) reported that the prevalence of cataracts in the domestic cat population, increases with age and that by 17 years of age, all cats are affected to some extent by lens opacity.

Apart from the above mentioned congenital and hereditary types of cataracts, most feline cataracts are secondary to other ocular diseases such as uveitis, glaucoma, ocular neoplasia, nutrition or trauma (Narfstrom 1999).

Conditions such as anterior uveitis and glaucoma change the composition and characteristics of the aqueous humour. Aqueous humour is important for the nutrition and removal of waste products for the lens. Both of these disease processes can therefore induce cataract formation (Petersen-Jones 2002). Direct trauma to the lens or trauma-induced uveitis may result in cataract formation. These cataracts tend to be in the region of the incident, and are often associated with posterior synechia (Davidson & Nelms 2013).

Metabolic cataracts due to diabetes mellitus are very common in dogs and progress very quickly to mature cataracts. The increase of glucose in the blood levels leads to the increase of glucose in aqueous humour and in the lens. The normal hexokinase pathway for glucose in the lens becomes saturated. Glucose then enters the sorbitol pathway where aldose reductase converts glucose to sorbitol. Sorbitol is a larger molecule than glucose and cannot diffuse out of the lens fibres. This creates an osmotic gradient, which causes fluid uptake in the lens and leads to the disruption of the lens fibres, vacuolation and cataract formation (Petersen-Jones 2002). Diabetic cataracts are rare in felines because of the low activity of the aldose reductase in lenses of older cats compared to canines (Stiles 2013). Contrary to other findings, Williams and Heath (2006) found cataracts to be present in almost all of the diabetic domestic cats in their study. These feline cataracts were small linear opacities, posterior cortical opacities or posterior polar plaques.

Poor nutrition, like inappropriate milk substitute, can cause cataract formation. A study by Remillard *et al.* (1993) showed that milk replacements, with inadequate levels of arginine, can cause anterior and posterior lens opacification in kittens. Quam, Morris & Rogers (1987) also proved that histidine is an important requirement in kitten diets for normal lens fibre growth. The majority of the opacities faded to a perinuclear halo or incipient cortical opacities as the kittens matured and the milk replacement was substituted by a balanced growth diet (Remillard *et al.* 1993). The pathogenesis of these diet related opacities can be, according to Remillard *et al.* (1993), be more complex than just a single amino acid, protein or glucose deficiency or imbalance.

Electric shock, like biting through an electric cord (Brightman *et al.* 1984), electric fencing or a lightning strike can result in anterior subcapsular cataract formation (Davidson & Nelms 2013). Radiating energy, which is used for treatment of neoplasms of the head or nasal area, is reported to affect the newly formed lens fibres. This can result in equatorial and anterior and posterior subcapsular cataract changes (Roberts *et al.* 1987).

Cataracts in various stages of development were found in a group of closely related Angolan lions (*African leo bleyenberghi*) in two German zoos. Inherited and congenital cataracts were suspected in these cases (Steinmetz *et al.* 2006).

Unpublished reports from AfriCat in Namibia, showed that 75% of the cheetahs had ocular lesions and that the incidence of cataracts was 27.47%. A very high incidence of corneal lesions was also noted and both lesions were probably related to trauma from an overgrazed, bush encroached environment (Bauer n.d.).

2.4 Retina

Non-infectious ocular diseases, which have been documented in cheetahs, include feline central retinal degeneration (FCRD) associated with dietary taurine deficiency (Ofri *et al.* 1996). Taurine is an important amino acid in felines and is essential for vision, cardiac function, muscle function and proper function of the nervous, reproductive and immune system. Felines lack the enzyme cysteine sulfinic acid decarboxylase, which is needed to synthesize taurine (Lombardini 1991). Although dietary intake is the most important source of taurine in cats, their taurine homeostasis depends on many factors like endogenous synthesis, microbial degradation in the lower gut, turnover in the enterohepatic circulation and urinary and faecal losses (Morris, Rogers & Pacioretty 1990). Retinal changes can take several weeks to months to occur on a taurine deficient diet (Markwell & Earle 1995). Typical ocular lesions of taurine deficient retinopathy are the granular appearance of the tapetum which progresses to a hyperreflective horizontal streak in the region of the area centralis, dorsolateral to the optic disc (Cullen & Webb 2013). A second horizontal band of hyperreflectivity can appear on the medial side, which extends until the two sides coalesce superior to the optic disc.

Advanced cases can even show retinal degeneration with attenuation of retinal blood vessels and visual deficits. The degenerative process is more advanced in the outer retinal layers, where disorganisation and disorientation of the photoreceptors occur. Electroretinogram (ERG) abnormalities can be observed after several months (Barnett & Burger 1980). Partial vision loss might be reversible following taurine supplements, but the ophthalmic lesions are permanent (Berson *et al.* 1981).

Taurine levels can be measured by whole blood concentration or plasma levels to indicate insufficiency or to monitor supplementation. Whole blood concentration is a better indication (Hedberg, Dierenfeld & Rogers 2007), because plasma levels are influenced by dietary intake (Markwell & Earle 1995). Taurine blood levels of above 200 $\mu\text{mol/L}$ and plasma levels above 50 $\mu\text{mol/L}$, would indicate a satisfactory taurine status in the domestic cat (Morris *et al.* 1990). Dietary taurine levels of 1200 mg taurine/kg dry matter in dry extruded diets and 2500 mg taurine/kg dry matter in canned diets have been suggested to prevent retinal disease in felids (Earle & Smith 1991, Morris *et al.* 1990).

Taurine deficiency in captive leopard cats (*Felis bengalensis*) has also been described (Howard *et al.* 1987). Ophthalmic examination revealed bilateral mydriatic pupils with tapetal hyperreflectivity. Retinal blood vessels varied from being attenuated to complete avascularisation (Howard *et al.* 1987, Morris *et al.* 1990).

Docosahexaenoic acid (DHA) deficiency has been reported to cause decreases in ERG amplitudes and affects the phototransduction (Narfström & Peterson-Jones 2013). DHA is part of the omega-3 fatty acids and is concentrated in various cells of the retina and brain (Bazan 2006). The highest concentration of DHA is found in the outer segments of the photoreceptors. Retinal pigment epithelium (RPE) cells play an important role in the maintenance of the photoreceptors. During outer segment renewal, the RPE cells recycle DHA back to the inner segments of the photoreceptors (Bazan 2006). It has been reported that infant formulas supplemented with DHA, enhanced retinal function maturity, visual acuity and overall neurological performance in infants (Birch 1998, Uauy 1990). Essential fatty acid (FA) deficiencies have been suspected in captive cheetahs (Davidson, Cantrill & Varday 1986).

Tordiffe (2016) reported a marked difference in the serum FA profiles between captive and free-ranging cheetahs. These serum profiles indicated that free ranging cheetahs consumed significantly more saturated fat and less unsaturated fat when compared to captive cheetahs. It has been suggested that dietary FA composition can have a potential impact on the health of cheetahs in captivity.

2.5 Miscellaneous

Less common ocular pathology described in cheetahs are bilateral optic nerve hypoplasia or optic nerve atrophy (Walser-Reinhardt *et al.* 2010), and corneal squamous cell carcinoma (Caligiuri *et al.* 1988).

CHAPTER 3.OBJECTIVES, BENEFITS AND HYPOTHESIS

3.1 Objectives

The objective of this research programme is to describe the abnormalities and to provide an indication of the prevalence of the abnormalities that can be observed by routine ophthalmic examination of two populations of immobilised captive adult cheetahs.

3.2 Benefits

Knowledge about the prevalence of ocular diseases can help with the breeding selection, management and treatment of cheetahs in captivity.

To the author's knowledge, no data is currently available for the average STT, IOP and ocular ultrasonic appearance and biometry of the cheetah species. Reference values specifically for cheetahs can aid in the diagnosis and treatment of ocular disease in cheetahs.

3.3 Hypothesis

The prevalence of the ophthalmic observed abnormalities in immobilised captive adult cheetahs will be higher and of a different nature to that which is described for the domestic cat population.

CHAPTER 4. MATERIALS AND METHODS

4.1 Model System

The populations of adult cheetahs within the Ann van Dyk Cheetah Centre and AfriCat Foundation were used for this research project.

The Ann van Dyk Cheetah Centre is a breeding centre for cheetahs and other endangered animals. It was founded in 1971 by the conservationist Ann van Dyk. She has bred over 600 cheetahs since establishing the Centre (www.dewildt.co.za). Cheetahs owned by Ann van Dyk were examined during the period of June 2014 – June 2016. They were housed at the Ann van Dyk Cheetah Centre (Figure 1) and the Shingwedzi Centre (Figure 2) in camps with an average size of 1.5 hectares and 1-4 cheetahs per camp (Appendix no 1). The Ann van Dyk Cheetah Centre is situated in the foothills on the northern side of the Magaliesberg Mountain Range, to the northwest of Pretoria. GPS coordinates of the Centre are 25° 40' 25.1" S, 27° 55' 25.4" E. The farm is located in the savanna biodiversity region at 1118m above sea level. The average temperature is 23.4°C with January being the hottest month of the year with average temperatures of up to 30°C. June is normally the coldest month of the year when temperatures can fall to around 2°C. The annual rainfall is 620mm.

The Shingwedzi Centre is close to Bela-Bela in the Waterberg Mountains with coordinates of 24°40'12.4" S, 28° 02' 00.7" E. Shingwedzi is about 1151 m above sea level and is also located in the savannah biodiversity region. The average temperature is the same as at the Ann van Dyk Cheetah Centre and with an annual rainfall of 625mm.

Both of these two groups of cheetahs formed part of Ann van Dyk breeding programme. The management, diet, camp size and environment are similar. For the purposes of this study, these two groups will be treated as a single entity. The cheetah's diet consists of 1.2 kg mixed food once a day, six days a week. The mixed food consisted of 250 g Ultra Feline pellets (Scientific Veterinary Diets, South Africa), 600 g cooked chicken mince and 350 g horse mince. Once a week they received 1.5 kg bone, mixed with the meat.

Powdered supplements with calcium, multivitamins and minerals (Predator supplement; V-Tech, Centurion, South Africa) are given on alternative days.

The AfriCat Foundation (Figure 3) is situated on the Okonjima Farm, 50km southwest of Otjiwarango in central Namibia (Figure 4) (www.okonjima.com/www.africat.org). GPS coordinates are 20°49' 19.36''S, 16°38' 21.25''E. The Okonjima Farm is located at an average altitude of 1532 m and is surrounded by the Omboroko Mountains. The vegetation is described as savanna veld with woody trees and scrubs. The annual average temperature is 20.3°C, with December being the warmest month of the year (up to 30°C). June is the coldest month, with temperatures as low as 1°C. The annual rainfall at the AfriCat Foundation averages approximately 450 mm.

The AfriCat Foundation is a 22 000 hectare sanctuary dedicated to research and in particular in the rehabilitation of Namibia's carnivores, particularly cheetah and leopard as well as wild dogs and brown hyena. AfriCat rescues felids that are casualties of human and wildlife conflict on Namibia's farmlands and return more than 85% to the wild. All cheetahs are kept in captivity in large enclosures. The camp sizes vary from 3.5-25 hectare camps with 2-5 cheetahs per camp (Appendix no 2). All the females are treated yearly with contraceptive implants, as it is prohibited by law to breed with large carnivores in captivity in Namibia. Their diet consisted of 1.2–1.5 kg of donkey or horse meat and bones for 6 days of the week. The diet is supplemented with a powdered multivitamin and mineral supplement (Predator Powder®; Healthtech, South Africa).



Figure 1. The Ann van Dyk Cheetah Centre.



Figure 2. Cheetah at the Shingwedzi Centre.



Figure 3. The AfriCat Foundation's logo.

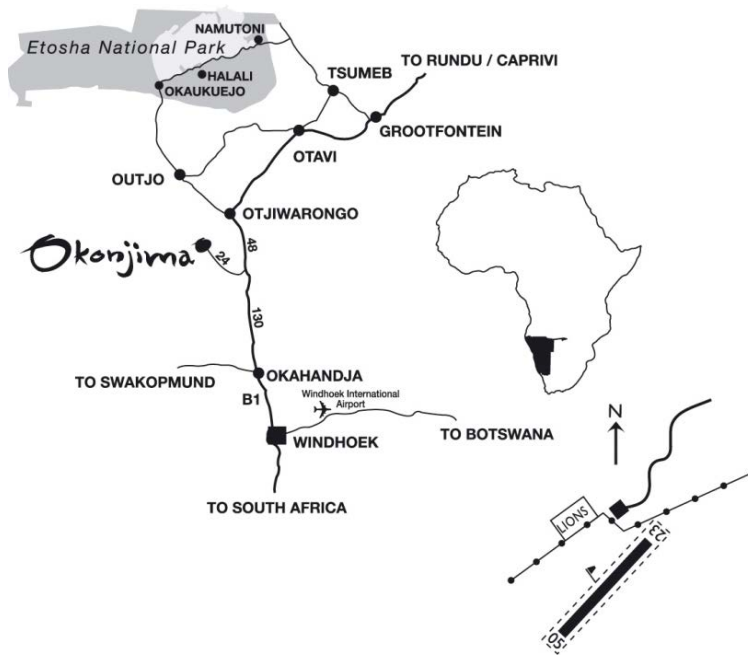


Figure 4. Map indicating the location of the Okonjima Farm, home of the AfriCat Foundation in Namibia.

4.2 Study Design

A prospective descriptive study design was used to determine the prevalence of ocular pathology in captive adult cheetahs.

4.3 Patient Selection

During the current study, a complete ocular examination was performed, during the period from June 2014 to July 2016, on immobilised adult cheetahs between 1 to 14 years old of age. These animals were undergoing routine health examinations which were performed as part of their health programme undertaken by the Ann van Dyk Cheetah Centre and the AfriCat Foundation.

The study design and cheetah immobilisation programme of the Ann van Dyk Cheetah Centre, was set up according to their breeding protocol, which did not allow for any study-specific immobilisation for research purposes. Twenty six females and 21 males were examined and formed part of Group 1.

In the case of the AfriCat Foundation cheetahs, eight females and 18 males were examined and formed part of Group 2.

4.4 Study Procedures

This study formed part of the cheetah's health examination while they were immobilised. The immobilisation was performed by wildlife veterinarians, experienced in cheetah anaesthesia. They immobilised and monitored the animals for the duration of the procedures. The health examination performed, included a combination of the following procedures: dental checks, abdominal ultrasound, gastric biopsies, blood collection, sperm collection and vaccinations. The concomitant ocular tests and examinations were solely performed by the author and included the following procedures: STT, IOP, slit-lamp biomicroscopy, indirect ophthalmoscopy, fluorescein testing and ocular ultrasound examination and measurements. The examination and measurements were taken between 08h00 and 16h00. The identification, microchip, sex, weight, ocular measurements and examination were recorded on an examination record sheet (Appendix no 3) for each cheetah.

Group 1:

- 1) The cheetahs were enticed with food to move into a small cage for immobilisation. The drug combination of 0.05-0.08 mg/kg medetomidine hydrochloride (Medetomidine 10mg/ml, Kyron Laboratories Pty Ltd, South Africa) and 3 mg/kg ketamine (Anaket V, Bayer (Pty) Ltd, Isando, 1601, South Africa) was used for immobilisation. This drug combination was administered intramuscular using a pole syringe. The dose was adapted to suit age, physical condition of the animal, excitement, stress and time of the day.
- 2) After immobilisation (7–15 minutes after administering of the injection), the cheetah was immediately removed from the cage onto a carry mat or stretcher (Figure 5). The cheetah was transported on the back of a vehicle to the hospital or examination area. It was weighed as soon as the cheetah was removed from the vehicle and before it was moved into the examination area (Figure 6).

- 3) The cheetah was placed on its left side. Blood samples were taken from the medial saphenous vein in labelled EDTA, serum (SST) and heparin vacuum containers (Figures 7 & 8). These blood samples were kept in a cooler bag with ice during examination. The blood in the serum container was centrifuged within six hours from collection and the serum was separated as soon as possible. The serum, EDTA and heparin were divided into aliquots of 1.2 ml, labelled and stored in the virology lab. Serum samples were stored at -20°C and the EDTA and heparin samples were stored at -80°C until needed for further testing. Potentially, this blood can be used for future DNA genetic testing, serum chemistry analyses, serology and virus isolation.
- 4) An intravenous catheter was placed in the saphenous vein and one litre Ringer's lactate drip was infused for the duration of the immobilisation.
- 5) The STT (Schirmer Tear Test, Merck Animal Health, 117 16th Road, Halfway House, Midrand, 1685, South Africa) (Figure 9) was measured and recorded on the data sheet.
- 6) Tonometry was done with the rebound TonoVet tonometer (Icare, Äyritie 22, FI-01510 Vantaa, Finland), using the 'd' setting. Care was taken to avoid excessive manipulation of the eyelids or pressure on the neck.
- 7) A conjunctival swab was taken for virus isolation. It was placed into transport medium, kept cold and stored at -80°C as soon as possible.
- 8) A drop of 1% Tropicamide (Mydracil, Alcon Laboratories (Pty) Ltd., 65 Peter Place, Bryanston Extension 13, South Africa) was applied to each eye to cause temporary mydriasis and assist in the evaluation of the lens and retina.
- 9) The examination area was darkened for the rest of the ocular examination.
- 10) Slit-lamp biomicroscopy (Keeler PSL Classic, Keeler Ltd, ClewerHill Road, Windsor, SL4 4AA, UK) was performed to assess the extraocular structures as well as the cornea, anterior chamber, iris, lens and anterior vitreous (Figure 10).
- 11) Other procedures including a health examination, dental examination, gastric biopsies and semen collection were also performed.
- 12) After these procedures the pupil was dilated sufficiently to perform the rest of the ocular examination. Another slit-lamp biomicroscopy examination was performed to evaluate the peripheral lens.

- 13) The fundus was examined with a binocular indirect ophthalmoscope (Neitz 10- α binocular indirect ophthalmoscope Neitz Co, Ltd, Tokyo, Japan) and a 20 dioptre biconvex lens (Heine Germany) (Figure 11).
- 14) Fundus images were taken (Volk PictorPlus Ophthalmic camera, Volk Optical, Inc. 7893 Enterprise Drive, Mentor, OH 44060) (Figure 12).
- 15) Fluorescein sodium 2% (Minis® Fluorescein Sodium 2% w/v, Bausch & Lomb, Chauvin Pharmaceuticals Ltd, UK) was applied and examined with a cobalt blue light.
- 16) A drop of Oxybuprocaine (Novesin Wander 0.4%, Novartis, Adcock Ingram Limited, Bryanston, 2021, South Africa) was installed in both eyes to provide local anaesthesia for the ocular ultrasound examination.
- 17) Ultrasonography was performed after application of acoustic ultrasonic coupling gel on the cornea (Figure 13). A portable ultrasound machine with B-mode transducer of 12 MHz and linear array probe was placed directly on the cornea (Sonoscape S2, SonoScape Medical Corporation from Axim, Midrand South Africa). Transverse and sagittal views were used to assess the globe. The following measurements: axial globe length (AGL), axial lens thickness (ALT), anterior chamber depth (ACD) and posterior segment depth (PSD) were taken in transverse view, using the electronic built-in calliper of the ultrasound unit (Figure 14).
- 18) Ultrasonic gel was removed by careful irrigation of the eyes with sterile eyewash after completion of the ultrasound examination.
- 19) Following full ophthalmological examination, the eyes were treated with an ocular lubricant containing sodium carboxymethyl cellulose (OptivePlus™, Allergan Pharmaceuticals (Pty) Ltd, 30 New Road, Randjiespark Ext 11, Midrand 1685, South Africa), to prevent desiccation of the cornea.
- 20) After examination, 0.03-0.06 mg/kg atipamazole (Antisedan, Pfizer Animal Health, Sandton, 2196, South Africa) was given intramuscularly to reverse the sedation.
- 21) The cheetah was placed into a cheetah crate, in a shady area for 30-60 minutes to ensure good recovery under supervision (Figure 15).
- 22) Once the wildlife veterinarian was satisfied with the cheetah's recovery, the cheetah was taken back to its normal enclosure.

Group 2.

- 1) To facilitate capture, the cheetahs were called from their large 'home' camps into adjacent smaller management camps prior to darting. Each cheetah was darted intramuscularly with a dart gun (Dartinject, Denmark) (2 ml air-pressured dart delivered by a carbon dioxide powered dart gun) with a combination of 0.94–1.4 mg/kg tiletamine/zolazepam (Zoletil®, Virbac, Halfway House, South Africa) and 0.033–0.045 mg/kg medetomidine hydrochloride (Medetomidine 10mg/ml, Kyron Laboratories Pty Ltd, South Africa). This was based on last known weight and visual assessment of each cheetah.
- 2) STT and IOP, in that order, were evaluated as soon as the animal could be safely approached, approximately 12-20 minutes after the animal had been darted. These measurements were taken as described in Group 1.
- 3) Topical Tropicamide (Mydriacil, Alcon Laboratories (Pty) Ltd., 65 Peter Place, Bryanston Extension 13, South Africa) was administered to each eye.
- 4) Once the wildlife veterinarian was satisfied that the cheetah was stable under immobilisation, the cheetah was carried on a stretcher to a vehicle and transported to the clinic (5–10 minutes drive).
- 5) The cheetah was weighed and placed in left lateral recumbency. Blood samples were taken for storage and an intravenous catheter was placed in the saphenous vein to infuse intravenous Ringer's lactate.
- 6) The cheetah was intubated with an endotracheal tube and general anaesthetic was maintained with either isoflurane in oxygen (Isofor, Safeline Pharmaceuticals, Johannesburg, South Africa) or a continuous rate infusion of intravenous propofol (Fresenius Propofol, Fresenius Kabi, Johannesburg, South Africa) with supplemental oxygen. The anaesthesia protocol was part of a research study and cheetahs were chosen randomly for isoflurane or propofol anaesthesia.
- 7) A number of other procedures were also performed on the immobilised cheetahs as part of concurrent studies, for example blood tests, gastric endoscopy with biopsies, dental assessment and treatment, sperm evaluation and abdominal ultrasonography.
- 8) The examination area was darkened to perform the ocular examinations.
- 9) Slit-lamp biomicroscopy was performed as described above for Group 1.

- 10) The fundic examination and photography were performed as previously described.
- 11) Fluorescein was applied topically as described above.
- 12) Ultrasound and biometry was performed after topical anaesthesia as described previously. A portable ultrasound machine was used with a 5-10 MHz linear array transducer set at 10 MHz (Mindray Model M7, Shenzhen Mindray Biomedical from Lomaen, Johannesburg, South Africa).
- 13) Ultrasonic gel was removed by careful irrigation of the eyes with sterile eyewash after completion of the ultrasound examination.
- 14) Following full ophthalmological examination, the eyes were being treated with an ocular lubricant containing sodium carboxymethyl cellulose (OptivePlusTM, Allergan Pharmaceuticals (Pty) Ltd, 30 New Road, Randjiespark Ext 11, Midrand 1685, South Africa), to prevent desiccation of the cornea.
- 15) After all the examinations were completed, the cheetahs were placed in a cheetah crate and given 0.08 – 0.12 mg/kg atipamazole (Antisedan, Pfizer Animal Health, Sandton, 2196, South Africa) intramuscularly, to antagonise the medetomidine.
- 16) The cheetahs were released once the wildlife veterinarian was satisfied with their recovery.



Figure 5. The cheetah being carried on a stretcher from the vehicle.



Figure 6. Weighing the cheetah at the Shingwedzi Centre.



Figure 7. Blood being collected from the medial saphenous vein of the cheetah.



Figure 8. Close up of blood being collected from the medial saphenous vein.

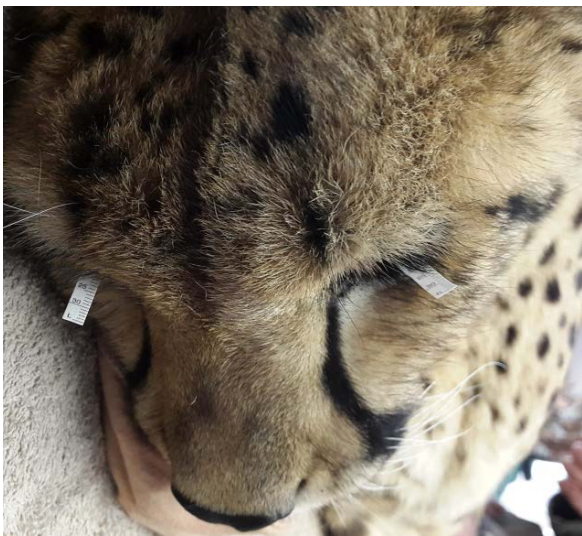


Figure 9. The Schirmer tear test is being taken in both eyes of this cheetah.

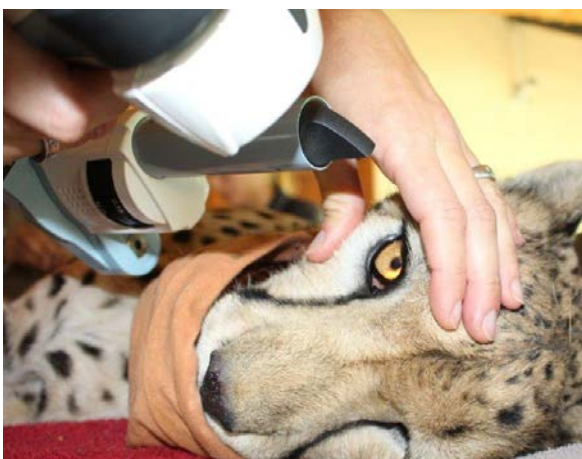


Figure 10. Slit-lamp biomicroscopy of the cheetah eye.



Figure 11. Indirect ophthalmoscopy examination of a cheetah.



Figure 12. Fundus imaging of a cheetah with a Volk PictorPlus Ophthalmic camera.



Figure 13. Ocular ultrasonography of the left eye of the cheetah.

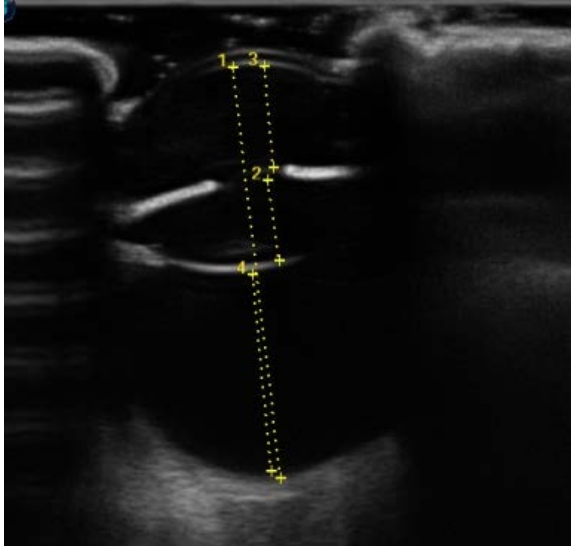


Figure 14. Biometry of an adult cheetah eye with B-mode ultrasonography. 1- Axial globe length. 2- axial lens thickness. 3- anterior chamber depth. 4- posterior segment depth.



Figure 15. Cheetah recovering in a cheetah crate after immobilisation and examination.

4.5 Data Analysis

Data from the examination sheets were entered into a spreadsheet (Microsoft Office Excel 2007). Age was categorised into three equal sized groups (1-4 yr / 5-6 yr/ ≥ 7 yr). Statistical significance was assessed at $P \leq 0.05$. Analyses were performed using Stata 14 (StataCorp, College Station, TX, U.S.A.).

For continuous outcome measurements (STT, IOP, AGL, ALT, ACD, PSD), the left and right eye were compared using paired *t*-tests. The values for left and right eyes of each animal were averaged and then considered as a single value for further analyses. The mean, standard deviation and range were calculated for each outcome. Means were compared between groups, age groups and genders using one-way ANOVA with Bonferroni adjustment. Multiple linear regression analyses were performed to investigate the simultaneous association of group, age group and gender with each of the continuous ocular variables and to adjust for potential confounding.

For binary outcome variables (presence of specific lesions), the prevalence of each lesion was calculated with a 95% confidence interval. These lesions were then compared between different groups, age groups and genders using cross tabulation and two-tailed Fisher's exact test. Multivariable analysis was not performed for the binary outcomes due to the very low numbers of positive outcomes for most lesions.

4.6 Ethical Consideration

This study was approved by the Animal Ethics Committee according to the South African National Standards (SANS 10386-2008). This project falls in the research category B where the procedures on the animals produced stress, but no pain was inflicted on any animal. No animal was specifically anaesthetised for the sole purpose of this study. The University of Pretoria Animal Ethics Committee authorised the Ann van Dyk Cheetah Centre project (Project no. V038-14). This research project also formed part of the African Foundation long-term health and immune-competence study of captive cheetahs and was approved by the University's Animal Use and Care Committee and Research Committee (Project no. V044-16).

CHAPTER 5. RESULTS

A total number of 73 cheetahs were examined. A summary of the total number of cheetahs examined, the different genders and the distribution of different age groups are reported in Tables 1, 2 & 3.

Table 1. Group and gender distribution of cheetahs examined.

Group	Female	Male	Total
AvDCC	26	21	47
AfriCat	8	18	26
Total	34	39	73

AvDCC = Ann van Dyk Cheetah Centre

Table 2. Group and age group distribution of cheetahs examined.

Group	1–4 yr	5–6 yr	≥7yr	Total
AvDCC	25	11	11	47
AfriCat	2	12	12	26
Total	27	23	23	73

AvDCC = Ann van Dyk Cheetah Centre

Table 3. Gender and age group distribution of cheetahs examined.

Group	1–4 yr	5–6 yr	≥7yr	Total
Females*	14	10	10	34
Males	13	13	13	39
Total	27	23	23	73

Measurements of the left and right eyes are reported in Table 4.

The STT measurements for the left and the right eye differed significantly ($P=0.03$).

The anterior chamber depth also showed a significant difference between the left and right eye ($P=0.04$), but the mean difference was only 0.25 mm. No other measurements showed a statistical difference between the left and right eyes.

Table 4. Average measurements of the left and right eye of cheetahs examined.

Variable	Right eye	Left eye	<i>P</i> - value
STT (mm/min)	11.79	13.61	0.03
IOP (mmHg)	30.69	30.21	0.40
AGL (mm)	32.55	32.53	0.94
ALT (mm)	6.85	6.83	0.89
ACD (mm)	8.66	8.91	0.04
PSD (mm)	16.25	16.03	0.31

STT = Schirmer tear test. IOP = Intraocular pressure AGL = anterior globe length. ALT = axial lens thickness, ACD = anterior chamber depth. PSD = posterior segment depth.

All the measurements between the eyes of each animal were averaged and each animal was considered as an individual for further calculations (Table 5).

Table 5. Average ocular measurements of total eyes of cheetahs examined.

Variable	Mean	SD	Range
STT (mm/min)	12.7	5.49	4 - 30
IOP (mmHg)	30.5	4.29	17 - 39.5
AGL (mm)	32.5	1.96	27.9 - 36.5
ALT (mm)	6.9	0.85	4.7 - 9.7
ACD (mm)	8.7	1.00	6.5 - 12
PSD (mm)	16.1	2.00	11.5 - 20.45

STT = Schirmer tear test. IOP = Intraocular pressure AGL = anterior globe length. ALT = axial lens thickness, ACD = anterior chamber depth. PSD = posterior segment depth. SD = standard deviation.

When ocular measurements were compared, no significant difference in STT values between the two groups of animals examined or between their genders were noted (Tables 6 & 8). The younger age group (1-4 yr) however, showed significantly lower STT readings when compared to the older cheetahs ($P=0.02$) (Table 7).

No significant difference in the IOP was found between the two groups, the age groups or genders (Tables 6, 7 & 8). There was however a tendency for higher IOP in the AvDCC group ($P=0.07$) (Table 6). Although not significant, the young cheetah group (1-4 yr) had higher IOP values and showed a tendency for these values to decrease with age (Table 7).

The axial globe length showed a significant difference between the two groups, the age groups and genders ($P<0.001$) (Tables 6, 7 & 8). A significant difference between groups and age groups were also reported in the posterior segment depth ($P<0.001$) (Tables 6 & 7).

Table 6. Ocular measurements between AvDCC and AfriCat cheetah groups.

Variable	AvDCC	AfriCat	P – value
STT (mm/min)	12.1	13.8	0.201
IOP (mmHg)	31.1	29.3	0.073
AGL (mm)	31.8	33.8	<0.001
ALT (mm)	7.0	6.7	0.099
ACD (mm)	8.5	9.2	0.003
PSD (mm)	15.2	17.8	<0.001

AvDCC = Ann van Dyk Cheetah Centre. STT = Schirmer tear test. IOP = Intraocular pressure. AGL = anterior globe length. ALT = axial lens thickness, ACD = anterior chamber depth. PSD = posterior segment depth.

Table 7. Ocular measurements between age groups of cheetahs examined.

Variable	1–4 yr	5–6 yr	≥7yr
STT mm/min	10.5 ^a	13.0 ^{ab}	14.8 ^b
IOP mmHg	31.2 ^a	29.6 ^a	30.4 ^a
AGL mm	30.8 ^a	33.5 ^b	33.2 ^b
ALT mm	6.9 ^a	6.9 ^a	6.7 ^a
ACD mm	8.4 ^a	9.0 ^a	8.8 ^a
PSD mm	14.4 ^a	17.1 ^b	16.9 ^b

Within rows, values with no superscript in common, differ significantly.

STT = Schirmer tear test. IOP = Intraocular pressure AGL = anterior globe length. ALT = axial lens thickness, ACD = anterior chamber depth. PSD = posterior segment depth.

Table 8. Ocular measurements between genders of cheetahs examined.

Variable	Female	Male	<i>P</i> - value
STT (mm/min)	12.6	12.8	0.843
IOP (mm/Hg)	30.2	30.6	0.661
AGL (mm)	31.9	32.9	0.030
ALT (mm)	6.9	6.9	0.874
ACD (mm)	8.6	8.9	0.236
PSD (mm)	15.7	16.4	0.140

STT = Schirmer tear test. *IOP* = Intraocular pressure *AGL* = anterior globe length. *ALT* = axial lens thickness, *ACD* = anterior chamber depth. *PSD* = posterior segment depth.

Multivariate analyses, where the association of group, age group and gender with ocular measurements, are reported in Tables 9–14. A significant difference ($P=0.02$) in the STT values was seen in older cheetahs (≥ 7 yr) compared to the young cheetah group (1-4 yr) (Table 9).

Table 9. Association of group, age and gender with STT values in cheetahs: outcome of multiple linear regression analysis.

Variable	<i>b</i>	95% Confidence interval	<i>P</i> - value
AfriCat vs AvDCC	0.281	-2.71, 3.28	0.852
Age: 1-4 yrs	0*	-	-
5-6 yrs	2.379	-0.94, 5.70	0.158
≥ 7 yrs	4.140	0.82, 7.46	0.015
Male vs Female	0.001	-2.59, 2.60	1.000

*reference level.

AvDCC = Ann van Dyk Cheetah Centre. *b* = regression coefficient.

No significant differences were reported when the IOP values were compared with the different groups, age and gender (Table 10).

Table 10. Association of group, age and gender with IOP values in cheetahs: outcome of multiple linear regression analysis.

Variable	<i>b</i>	95% Confidence interval	<i>P</i> - value
AfriCat vs AvDCC	-1.954	-4.35, 0.45	0.109
Age: 1-4 yrs	0*	-	-
5-6 yrs	-0.716	-3.36, 1.92	0.590
≥7yrs	0.066	-2.57, 2.71	0.960
Male vs female	0.914	-1.15, 2.98	0.380

*reference level

AvDCC = Ann van Dyk Cheetah Centre. *b* = regression coefficient.

Significant differences were detected when the axial globe length of the age groups ($P < 0.0001$) and genders ($P = 0.05$) were compared (Table 11). The young cheetahs and the females showed a smaller globe length compared to the older cheetahs and to the males (Table 11).

Table 11. Association of group, age and gender with axial globe length values in cheetahs: outcome of multiple linear regression analysis.

Variable	<i>b</i>	95% Confidence interval	<i>P</i> - value
AfriCat vs AvDCC	0.669	-0.23, 1.57	0.143
Age: 1-4 yrs	0*	-	-
5-6 yrs	2.302	1.32, 3.28	<0.001
≥7yrs	2.050	1.07, 3.03	<0.001
Male vs female	0.732	-0.001, 1.47	0.051

*reference value

AvDCC = Ann van Dyk Cheetah Centre. *b* = regression coefficient.

No statistically significant differences were reported on the axial lens length (Table 12).

Table 12. Association of group, age and gender with axial lens length values in cheetahs: outcome of multiple linear regression analysis.

Variable	<i>b</i>	95% Confidence interval	<i>P</i> - value
AfriCat vs AvDCC	-0.385	-0.90, 0.13	0.141
Age: 1-4 yrs	0*	-	-
5-6 yrs	0.138	-0.42, 0.70	0.624
≥7yrs	-0.061	-0.62, 0.50	0.827
Male vs female	0.053	-0.37, 0.47	0.801

*reference value

AvDCC = Ann van Dyk Cheetah Centre. *b* = regression coefficient.

The different cheetah groups showed a statistically significant difference of the anterior chamber depth ($P=0.05$) (Table 13). AvDCC showed a smaller ACD compared to AfriCat.

Table 13. Association of group, age and gender with anterior chamber depth values in cheetahs: outcome of multiple linear regression analysis.

Variable	<i>b</i>	95% Confidence interval	<i>P</i> -value
AfriCat vs AvDCC	0.576	-0.06, 1.16	0.052
Age: 1-4 yrs	0*	-	-
5-6 yrs	0.355	-0.28, 0.99	0.266
≥7yrs	0.094	-0.54, 0.73	0.767
Male vs female	0.142	-0.33, 0.62	0.553

*reference value

AvDCC = Ann van Dyk Cheetah Centre. *b* = regression coefficient.

The different cheetah groups and age groups, showed a significant difference in the posterior segment depth ($P < 0.0001$) (Table 14). The AfriCat and older cheetahs had a larger posterior segment.

Table 14. Association of group, age and gender with posterior depth values in cheetahs: outcome of multiple linear regression analysis.

Variable	<i>b</i>	95% Confidence interval	<i>P</i> - value
AfriCat vs AvDCC	1.61	0.75, 2.48	<0.0001
Age: 1-4 yrs	0*	-	-
5-6 yrs	1.84	0.91, 2.78	<0.0001
≥7yrs	1.77	0.83, 2.71	<0.0001
Male vs female	0.24	-0.47, 0.94	0.51

*reference value

AvDCC = Ann van Dyk Cheetah Centre. *b* = regression coefficient.

The eyes of all the animals appeared ultrasonographically similar. The cornea was seen as hyperechoic and slightly curvilinear. The anterior chamber, vitreous and lens were anechoic. The anterior and posterior lens capsules were observed as echogenic points, which gave the appearance of an ovoid lens. The entire surface was not visible in one scan plane. The iris and ciliary body appeared as echogenic structures. The iris was anterior to the anterior lens capsule, and the ciliary body was a thicker, more irregular structure peripheral to the lens. The posterior wall of the globes was seen as a concave echogenic line. The three layers, retina, choroid and sclera, could not be differentiated from each other ultrasonographically. The retrobulbar area appeared as a heterogenous echogenicity and the intra- and extraconal spaces could not be determined in the retrobulbar space (Figure 16).

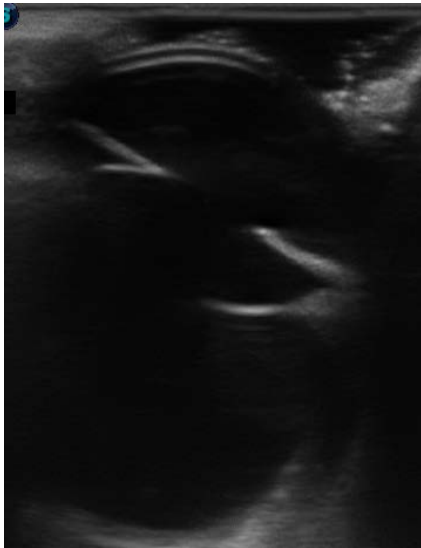


Figure 16. B-mode ultrasound of an adult cheetah eye.

Prevalence of ocular lesions and comparisons between different groups, age groups and genders are summarised in Tables 15-18.

Lens lesions were the most prevalent pathological finding in the cheetahs (Table 15) and revealed a significant difference between the age groups (Table 17). The young cheetah group (1-4 years) had the most lens lesions (Table 17). Other lesions were not statistically significant between the different groups, age groups or genders. Retinal pigment was highly prevalent (Table 15) in both of the cheetah groups, in all age groups and in all genders (Tables 16-18).

Table 15. Prevalence and confidence intervals for ocular lesions in the cheetahs examined.

Variable	N	Prevalence	95% Confidence interval
Extraocular	73	6.8%	2.3, 15.3
Cornea	73	5.4%	1.5 , 13.4
Anterior chamber	73	2.7%	3.3, 9.5
Lens	73	10.0%	4.9, 20.4
Vitreous	71	0.00	0.0, 4.9
Fundus	71	4.2%	8.8, 11.9
Retinal pigment	71	71.8%	59.9, 82.9

Table 16. Number of lesions in different groups of cheetahs examined.

Lesion	AvDCC	AfriCat	P - value
Extraocular	4 (5.5%)	1 (1.4%)	0.649
Cornea	2 (2.7%)	2 (2.7%)	0.613
Anteriorchamber	2 (2.7%)	0	0.535
Lens	7 (9.5%)	1 (1.4%)	0.245
Vitreous	0	0	-
Fundus	3 (4.1%)	0	0.294
Retinal pigment	34 (46.6%)	17 (23.3%)	0.417

AvDCC = Ann van Dyk Cheetah Centre

Table 17. Number of lesions in different age groups of cheetahs examined.

Lesion	1–4 yr	5–6 yr	≥7yr	P - value
Extraocular	2 (2.7%)	0	3 (4.1%)	0.265
Cornea	1 (1.4%)	1 (1.4%)	2 (2.7%)	0.829
Anterior chamber	2 (2.7%)	0	0	0.326
Lens	6 (8.2%)	2 (2.7%)	0	0.044
Vitreous	0	0	0	-
Fundus	3 (4.1%)	0	0	0.103
Retinal pigment	19 (26.0%)	18 (24.7%)	14 (19.2%)	0.308

Table 18. Number of lesions in different genders of cheetahs examined.

Lesion	Female	Male	<i>P</i> - value
Extraocular	4 (5.5%)	1 (1.4%)	0.177
Cornea	2 (2.7%)	2 (2.7%)	1.000
Anterior chamber	1 (1.14)	1 (1.4%)	1.000
Lens	3 (4.1%)	5 (6.8%)	0.716
Vitreous	0	0	-
Fundus	1 (1.4%)	2 (2.7%)	1.000
Retinal pigment	26 (35.6%)	25 (34.2%)	0.293

Extraocular lesions included an old lesion of a unilateral third eyelid laceration in an 11-year-old cheetah from the AfriCat group (Figure 18). Bilateral hyperaemic conjunctiva with and without a mucoid discharge, were noticed in 3 cheetahs from AvDCC. One of these had bilateral prolapsed third eyelids. A young one-year-old cheetah from AvDCC was noted to have unilateral symblepharon with mild clear ocular discharge. The third eyelid was prominent and adhered to the palpebral conjunctiva and medial cornea (Figure 19).

One 14-year-old cheetah from AvDCC had an active small superficial ulcer at the time of examination. The rest of the corneal lesions were corneal scars. The most extensive lesion was an old stable corneal lesion from a previous perforation in a four year old female from AvDCC. The dorsolateral cornea adjacent to the limbus had prominent oedema with anterior synechia from the iris towards the corneal lesion. The eye was stable, comfortable and without an aqueous flare at the time of examination (Figure 19).

Persistent pupillary membranes (PPM) were detected in two cheetahs from AvDCC. A four-year-old female cheetah showed bilateral multiple small iris-iris PPM's. Another four-year-old male also had a unilateral PPM. The PPM extended from the collarette region into the direction of the lens. It was not attached to the lens and no lesions were seen on the lens capsule.

Three litter mates from the young cheetah group (1-4 yr) of the AvDCC, had bilateral posterior cortical immature cataracts. These cataracts all had a similar appearance and were limited to the posterior extremity of the lens, while the remainder of the nucleus and lens cortex was found to be normal. The left and right lenses had similar lesions in each individual (Figures 20 & 29). Another young, two-year-old cheetah had similar bilateral posterior immature cataracts. The lens lesions were however more extensive (Figure 30).

Two, four-year-old cheetahs from AvDCC had each a unilateral posterior cortical immature cataract. An older, five-year-old cheetah had bilateral immature nuclear cataracts (Figures 21 & 31). Only one, five-year-old cheetah from AfriCat, had a unilateral immature anterior and posterior subcapsular cataract (Figures 22 & 32).

Retinal lesions were seen in three, four-year-old cheetahs from the AvDCC. Multiple 'streaks' and 'lines' of retinal hyperpigmentation were seen in the tapetal area. These lesions were dorsal to the optic nerve head (ONH) and on the border of the tapetum and non-tapetum (Figures 24 & 25). One of the males had obvious visual deficits and was observed to have mydriatic pupils. Apart from the areas of multiple retinal hyperpigmentation, a focal oval area of hypopigmentation was also visible dorsolateral to the ONH (Figure 25). These three cheetahs were the same three siblings which also had the bilateral posterior subcapsular immature cataracts as described above.

Retinal pigment was observed in 71% of the cheetahs. This pigment appeared as an increased density in the area centralis, dorsal to the ONH in a horizontal line. The pigment area did not appear to be raised or swollen. It varied from a small mild thin area or line of 'pigment' (Figure 26) to a thick discrete horizontal line from medial to lateral, in the visual streak (Figures 27 & 28).

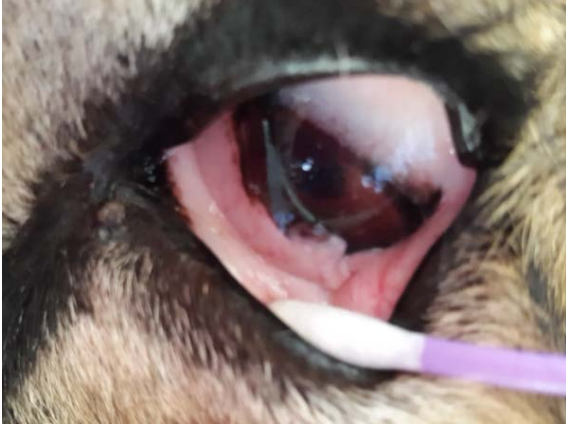


Figure 17. An old laceration in the leading edge of the third eyelid membrane of the cheetah.



Figure 18. Symblepharon between the third eyelid, the palpebral conjunctiva and medial cornea of the cheetah.

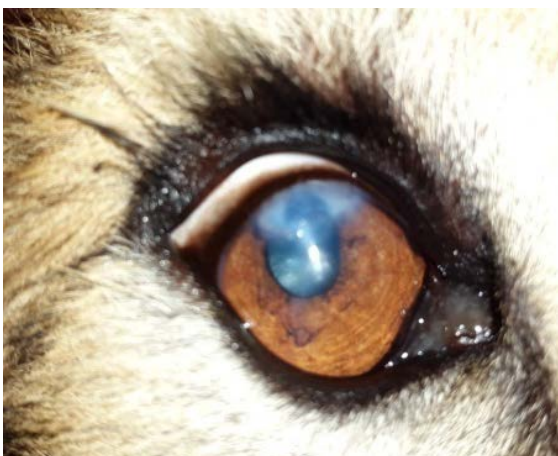


Figure 19. An old lesion in the dorso-lateral cornea of the right eye of the cheetah. Note the corneal oedema, anterior synechia and the dyscoric pupil.



Figure 20. An immature posterior subcapsular cataract in the right eye of the cheetah.



Figure 21. Immature focal nuclear cataract in the left eye of the cheetah.



Figure 22. An immature, anterior subcapsular cataract in the right eye of the cheetah.



Figure 23. Normal fundus image of a cheetah.

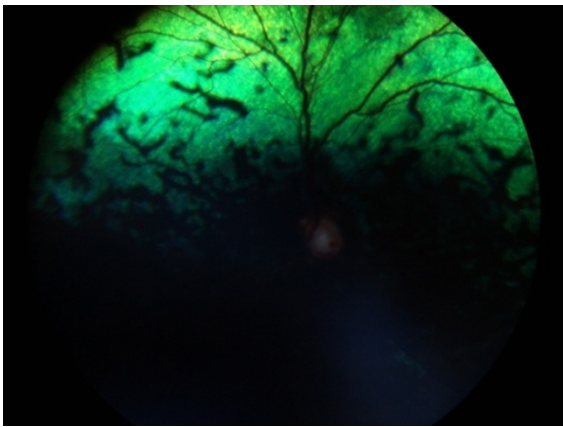


Figure 24. Multiple retinal hyperpigmentation areas in the tapetum of the cheetah.

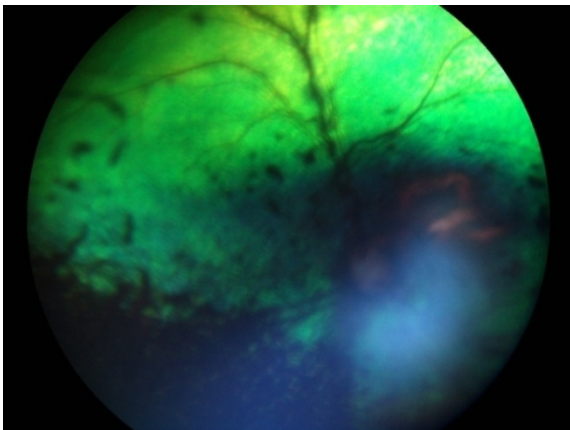


Figure 25. Multiple areas of hypo- and hyperreflectivity in the tapetum and on the border line of the tapetum and non-tapetal area are illustrated. An area of depigmentation with possible choroidal hypoplasia dorsolateral to the ONH is also visible. Note the small focal immature cataract which leads to the obscured visualisation of the fundus in the cheetah.

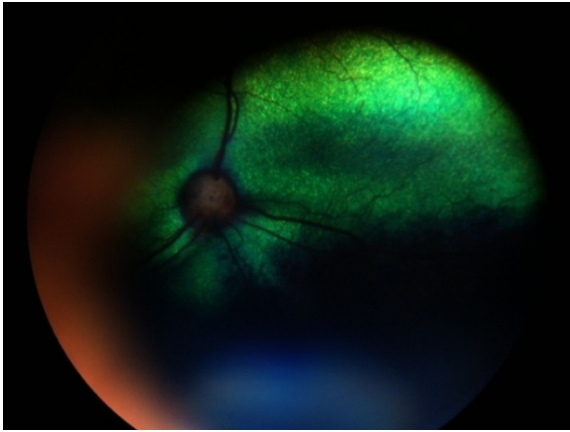


Figure26. Mild retinal pigmentation in the visual streak of the cheetah.

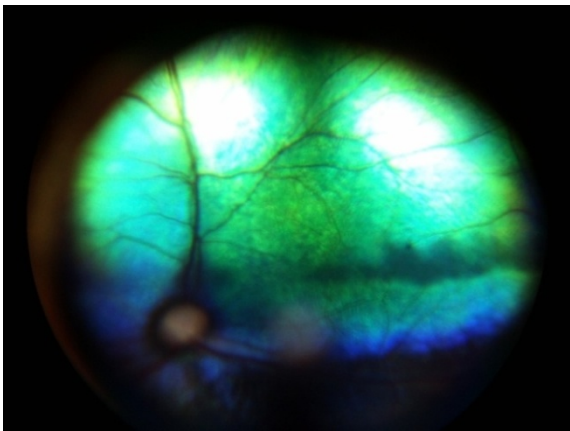


Figure27. Marked increased retinal pigment in the medial and lateral area of the visual streak in the cheetah.

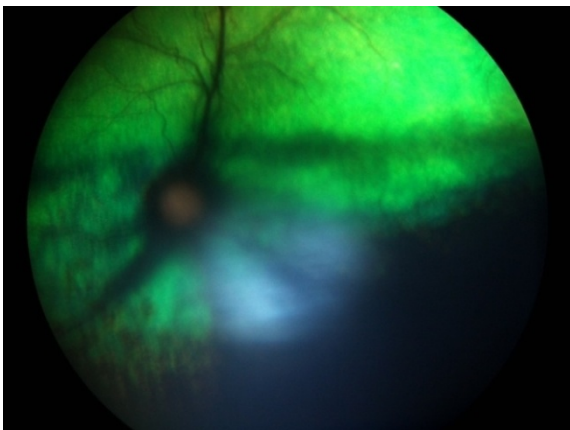


Figure 28. Advanced increased retinal pigment in the medial and lateral area of the visual streak. Note the small focal immature cataract, which lead to obscured visualisation of the fundus of the cheetah.

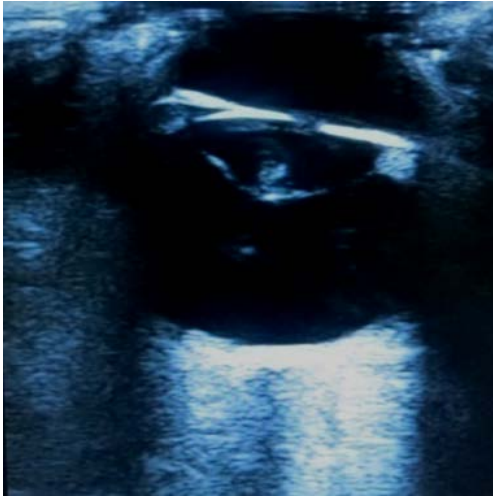


Figure 29. An ultrasound image of a small immature posterior cortical cataract in the cheetah.

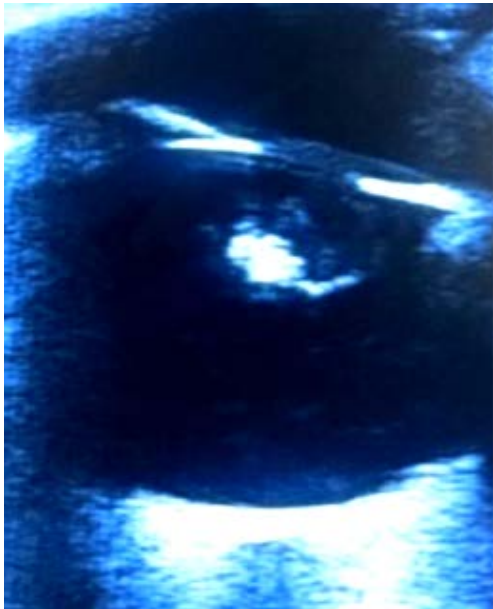


Figure 30. An ultrasound image of a focal immature posterior cortical cataract in the cheetah.

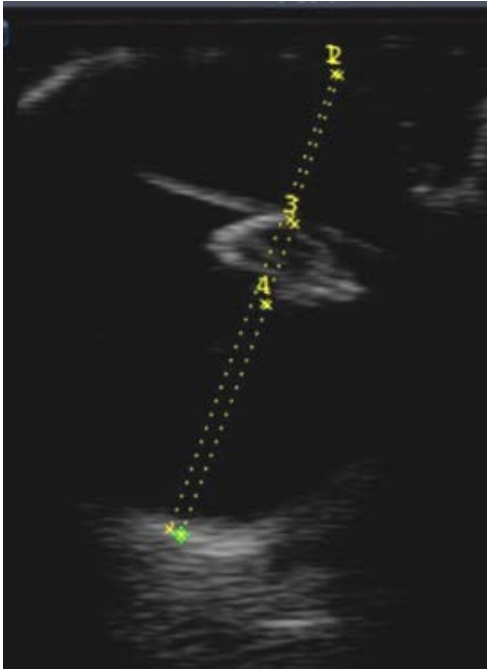


Figure 31. An ultrasound image of a small focal immature nuclear cataract in the cheetah.



Figure 32. Ultrasound image of an immature anterior and posterior subcapsular cataract in the cheetah.

CHAPTER 6. DISCUSSION

All the cheetahs examined were immobilised for their examination, and therefore the STT and IOP should be regarded as estimates, rather than true measurements of tear production and intraocular pressure. It is impractical and unsafe to perform these measurements in conscious cheetahs and wildlife practitioners are likely to perform these tests in immobilised animals under similar conditions, making the values highly applicable. The results of the STT, IOP and ocular measurements provide a reference of normal values to which individual animals can be compared.

6.1 STT

A significant difference was recorded between the STT reading of the left and right eye ($P=0.03$) (Table 3). The left eye recorded a higher STT reading of 13.61 mm/min compared to the right eye of 11.79 mm/min. A wide range of STT measurements was also found in the cheetahs examined (4-30 mm/min) (Table 4). As a result of the immobilisation, the STT could only be done 12-20 minutes after injecting or darting the animal, or only once the animal was brought to the clinic. During the interval the animal would be lying down in lateral recumbency as the immobilisation agents took effect. During the period the cheetahs had their eyes open. It can be presumed that wind, dust and humidity might play a role in the tear production measured. A limitation of the current study was that the side on which the cheetahs lay was not well recorded. It was therefore not possible to accurately determine whether lateral recumbency influenced the individual eye STT reading. The examiner measured the STT of the AvDCC cheetahs once they arrived from the camps and most of them were already lying on their left side. The cheetahs were transported from the camps to the examining area and placed in a left lateral recumbency which was ideal for the gastric scoping. The STT of cheetahs from the AF was measured as soon as it was safe to approach the animals, before they were transported to the examination area. These cheetahs were lying randomly on whatever side they went down following the immobilisation.

Most of the cheetahs examined were from the AvDCC and it is suspected that the positioning, together with the environmental factors might have an influence on the variability of the STT readings between the eyes. Therefore it is important to interpret STT measurements in immobilised cheetahs very carefully in conjunction with all other clinical findings.

The mean tear production was 12.7 ± 5.5 mm/min (Table 4). This was lower than that of the domestic cat (14.3 ± 4.7 - 16.92 ± 5.73 mm/min) (Arnett *et al.* 1984, Cullen *et al.* 2005, Margadant *et al.* 2003, McLaughlin *et al.* 1988, Veith, Cure & Gelatt 1970), the dog (21.0 mm/min) (Gelatt *et al.* 1975), and the African lion (24.4 mm/min) (Ofri *et al.* 1997). It is well documented that anaesthetic and pre-anaesthetic agents cause a reduction in tear production. The tear production measurement of the cheetahs in this research project, were taken under the influence of medetomidine and ketamine or medetomidine and Zoletil. As in the previously reported studies (Arnett *et al.* 1984, Dodam *et al.* 1998, Sanchez *et al.* 2006), it can therefore be assumed that the tear production in the conscious animal would most likely be higher than that of the anaesthetised immobilised animal.

A statistically significant difference was noted between the STT of the young cheetahs of 1-4 years (10.5 mm/min) compared to the older cheetahs (14.8 mm/min) (Table 6). This is in agreement with Featherstone (2013), that tear production is normally lower in younger animals.

6.2 Tonometry

IOP is a valuable tool in ophthalmology to diagnose ocular disease and its progression like glaucoma and uveitis. The mean IOP of 30.5 ± 4.3 mmHg in the cheetahs examined, is high compared to the domestic cat reading (Rusanen *et al.* 2010) and of an adult lion of 20.74 mmHg and 23.9 mmHg respectively (Ofri *et al.* 1998). All the measurements taken by the author, were taken while the cheetahs were lying in a lateral position. Body position has been documented to cause a difference in IOP (Aihara *et al.* 2003, Broadwater *et al.* 2008), and it is possible that the lateral recumbency of the cheetahs could have contributed to the high IOP measured.

The mean IOP readings of the cheetahs from the AvDCC were slightly higher than the IOP readings of the cheetahs from AfriCat. The only variance between the two groups was the immobilisation drugs that were used. Ketamine was used in the cheetahs of AvDCC compared to Zoletil used in the AfriCat group. Ketamine has been documented to increase IOP readings (Hahnenberger 1976, Hofmeister *et al.* 2006, Kovalcuka *et al.* 2013), and could explain the difference in IOP measurements.

Circadian rhythms have been shown to influence the IOP readings (Bertolucci *et al.* 2009, Del Sole *et al.* 2007, Giannetto *et al.* 2009, Martin-Suarez *et al.* 2014, Rowland *et al.* 1981). A limitation of this study was that the IOP readings were measured during different times of the year, and different times of the day (8h00 to 16h00).

6.3 Ultrasound

Ultrasonographically, the cheetah eye and its structures are very similar in appearance to those in cats (Gilger *et al.* 1998, Mirshahi, Shafigh & Azizzadeh 2014), and dogs (Cottrill *et al.* 1989). Weak echoes of the anterior and posterior lens capsule were identified. This is possibly due to the refraction of the sound beams from the convex lens capsule, which makes the peripheral echoes very difficult to identify. Reverberation artifacts or the result of poor alignment of the axial axis in the lateral recumbency, could also have played a role. Ocular measurements (Tables 11 & 14) showed a significant difference between the axial globe length and posterior segment depth of young cheetahs compared to older cheetahs. Similar, age-related ocular dimension increases have been reported in goats (Ribeiro *et al.* 2009), elephants (Bapodra *et al.* 2010), buffalo and one-humped camels (Kassab 2012). The globe length in this study was also found to be larger in males compared to females (Table 11). Similar findings were reported by Schiffer *et al.* (1982) in dogs.

6.4 Cornea

Corneal lesions were observed equally in both groups of captive cheetahs in our study. Old scar lesions were mostly noted, but the incidence was much lower (5.4%) compared to the corneal lesions previously observed at AfriCat Foundation (47.2%) (Bauer n.d.). This higher incidence of corneal lesions was most likely due to poor environmental management at that time, which led to large areas of overgrazed, bush-encroached vegetation. This in turn led to an increased risk of corneal injuries for the cheetahs that were confined to these areas. This issue was subsequently addressed by rehabilitation of the veld and clearing of the bush encroached areas. This may explain the lower incidence of corneal lesions observed in our study.

Only one potential FHV - 1 infection has been recorded in a one-year-old cheetah from AvDCC. At the time of examination, symblepharon was observed between the third eyelid, the palpebral conjunctiva and medial cornea. This cheetah was part of a litter which was relocated at five weeks of age. The entire litter had clinical signs of conjunctivitis and sneezing after the relocation. Because of the limitations of the diagnostic tests and carrier stage of the virus (Witte *et al.* 2013), no diagnostic tests have been done and a diagnosis was made based on the history and clinical signs. Symblepharon is a common sequel of FHV – 1. It is a cytopathic virus causing lysis of tissues and large ulcerated areas will form. These ulcerated areas can form adhesions to one another. Symblepharon is a permanent adhesion between tissues like the conjunctiva, third eyelid and cornea. This can distort the eyelid opening and tear film distribution and/or drainage, which is the case in this particular cheetah. Surgery can correct the deformity, but the prognosis is guarded and recurrence is likely (Stiles 2013).

6.5 Cataracts

The age and anatomical distribution of cataracts in the AvDCC cheetah group were suggestive of a hereditary or congenital aetiology. In contrast, the unilateral cataract seen in an AF cheetah is most likely due to previous inflammation or trauma. No breeding is permitted at AF while AvDCC is a breeding facility. These findings could indicate a new problem arising within the genetics and breeding management of the cheetahs. Nutritional cataracts can't be excluded because remnants of nutritional cataracts could look like incipient cortical opacities.

No cataracts were seen in cheetahs older than seven years, during the research project. It may be possible that very old cheetahs with cataracts, had died and were not available for examination at the time. Cheetahs less than one year of age were also not examined during the research project. Further investigation to confirm a genetic, hereditary or nutritional origin would appear necessary in this cheetah population.

Only one unilateral cataract was recorded at the AfriCat Foundation. This prevalence is much lower than the lesions previously described by Bauer (n.d.) (27.47%). As previously discussed under corneal lesions, this may be due to better environmental management, resulting in less trauma associated ocular pathology

6.6 Retina

The fundic examination of three cheetah siblings, revealed similar retinal lesions associated with multiple hyperpigmented lines and 'folds'. These lesions resemble retinal dysplasia. A congenital defect due to abnormal development of the retinal is most likely. An intra-uterine infection or post-natal infections like FPLV (Glaze 2005, Percy *et al.* 1975), or FeLV (Albert *et al.* 1977, Glaze 2005) can cause retinal dysplasia. A suspected hereditary multifocal dysplasia has been documented in Somali cats (Narfstrom 1999), and therefore, a hereditary cause cannot be excluded in these cheetahs.

Although FPLV infection was not definitely diagnosed in this population, an outbreak of FPLV, where five cheetah cubs died, was described and confirmed by Lane *et al.* (2016), in a breeding institution in South Africa. It is possible that the affected cheetah siblings survived the viral infection, but were affected at the stage of retinal development, which caused retinal dysplasia. The source of the initial outbreak in the cheetahs remains uncertain. Lane *et al.* (2016) proposed the loss of cold chain management during a 2012 transport strike may have led to vaccination failure. Maternal immunity lasts between 2-4.5 months and domestic cats are therefore usually affected at 3-5 months of age. The vaccination of domestic cats prevents disease caused by FPLV (Chalmers *et al.* 1999). Inactivated (killed) vaccines can be used in kittens younger than four weeks of age, pregnant queens, debilitated and old cats (Parrish 1995).

It has been proven in cheetahs that inactivated vaccines are safe to use and induce persistently high levels of serum antibodies to FPLV (Wack *et al.* 1993). Modified live FPLV vaccinations in adult domestic cats give lifelong immunity, but the vaccines are not registered for use in other felids. Its efficacy against different variants in non-domestic felids, is not well documented (Risi *et al.* 2012). According to Munson *et al.* (2005), a vaccination regime, using a combination of inactive (dams in late pregnancy and cubs at eight and 12 weeks of age) and live vaccines (cubs at 16 weeks of age), has been proven to be safe, effective and reduce cub mortality in captive cheetah populations. Stress, inadequate vaccination and vaccine failure are predisposing factors in the susceptibility to the disease (Lane *et al.* 2016). Although cataractous lesions were also detected in the same three siblings, cataracts are not commonly associated with FPLV and are more likely to have a hereditary, congenital or nutritional origin.

Retinal pigment was observed in 70% of the cheetahs. This finding has not been described before in any of the literature and is unique to our study. Feline central retinal degeneration (FCRD) is the most obvious differential diagnosis. This nutritional deficiency of taurine, presents in exactly the same anatomical location within the area centralis of the retina. The fundic lesion of FCRD is described as an oval area of tapetal hyperreflectivity which becomes progressively ellipsoid and extends in a band from the temporal fundus across the top of the optic disc to the nasal fundus. At later stages severely affected animals show retinal blood vessel attenuation, retinal degeneration and irreversible blindness. The affected cheetahs in this research study presented with hyperpigmentation and not hyperreflectivity. Although it is very difficult to evaluate vision in animals and even more of a challenge in wild animals, no obvious visual deficits were noted or reported in any of the hyperpigmented cheetahs. There was no history, clinical or ophthalmic evidence of taurine deficiency in this population and hence serum taurine determinations were not considered in their annual health examination.

Another possible nutritional cause that could explain the retinal pigmentation is DHA deficiency. Tordiffe (2016) reported a marked difference in the serum levels of FA between captive and free-ranging cheetahs. It is possible that these nutritional differences may have an impact on the health of captive cheetahs. Further research is indicated to compare the fundic findings and ERG values of free-ranging cheetahs to that of captive cheetahs.

Other differentials for retinal lesions are infectious disease like FIP, FCoV, FELV, FIV or fungal agents (Ofri *et al.* 1996). Typically, retinal lesions induced by these infectious diseases are characterised by chorioretinitis, which differs significantly from the retinal lesions noted in these two cheetah populations. There was also no evidence of concurrent anterior disease such as uveitis, which is frequently present in these infections.

Because retinal pigmentation was observed in so many cheetahs without any evidence of retinal degeneration, it is possible it could be a normal variant. These hyperpigmentation areas could be a normal variant of a high concentration of RPE cells, or any cell type in a specific sub retinal or retinal layer. Histopathology and electronmicroscopy are the ideal ways to evaluate this pigment. Optical coherence tomography (OCT) is a modern modality which is regularly used in human ophthalmic conditions like macular diseases, glaucoma and optic neuropathies. It compares favourably to histopathology *in vivo* and would be the ideal next step to evaluate the fundus and in particular the hyperpigmented area centralis of the cheetah species. OCT uses the reflectivity of light waves to produce detailed cross-sectional images of ocular tissues. Light from a source is directed onto a partially reflecting mirror and is split into a reference and a sample beam. The sample beam reflects light from the specimen and consists of multiple echoes. The light from the reference beam reflects from a mirror of known optical distance from the light source. When these two beams combine, an interference pattern occurs and only the non-scattered light is detected. High resolution pictures of the retinal layers parallel at differing depths are achieved (Donaldson & Hartley 2013). It would have been ideal to evaluate the fundus and in particular the pigmented area centralis in the cheetah, but unfortunately a portable OCT device was not available for use during this particular project. This aspect should receive further attentions as it could provide answers as to the role of the hyperpigmented area centralis in the cheetah.

6.7 Limitations

Young cheetahs of less than a year old were not examined in our study. This age group of cheetahs may potentially have more ocular problems, like cataracts and infectious diseases, which could influence the incidence of ocular pathology in captive cheetahs.

Diagnostic studies like serology, virology or further blood analysis were not performed on the cheetah groups. The definitive cause of the lesions recorded in our study was therefore not always determined.

The IOP values were measured during different times of the day and year. The circadian rhythms of the cheetahs may have influenced the readings as described before.

Accuracy and precision of reference values could be improved by having a larger sample size of cheetahs. This would reduce the standard error of the mean, ensuring the mean is a closer estimate of the true population mean.

•

CHAPTER 7. CONCLUSIONS

Establishing STT, IOP and biometric reference values are important for evaluating the ocular health status of the species. These reference values will assist veterinarians working with the cheetah species to perform a full and informed ophthalmic examination.

The prevalence of ocular pathology in captive adult cheetahs in these two populations is of different nature to those documented in domestic cat populations. Although herpesvirus is widespread among domestic cats, a very low percentage of clinical signs, potentially associated with this virus, were observed in these cheetah populations. A higher incidence of cataracts was recorded in young cheetahs, compared to domestic cats. Fundic lesions were relative rare and compare well with domestic cats. The types of cataracts and fundic lesions found in these cheetahs, could indicate hereditary, congenital or nutritional causes. This is a concern because of the future implications it could have on breeding programmes of captive cheetahs. Regular detailed ophthalmic examination in the cheetah can help with the early diagnosis, management and treatment of ocular lesions.

A unique retinal pigment was observed and further investigation is needed to clarify this lesion. Ongoing research, monitoring and investigation of the eye of the cheetah species can greatly benefit the survival of this special and endangered species.

REFERENCES

- Ahnelt, P., Schubert, C., Kübber-Heiss, A. & Anger, E., 2005, 'Adaptive design in retinal cone topographies of the Cheetah and other Felids', *Investigative Ophthalmology & Visual Science* 46(13), 4540.
- Ahnelt, P.K., Schubert, C., Kuebber-Heiss, A., Schiviz, A. & Anger, E., 2006, 'Independent variation of retinal S and M cone photoreceptor topographies: A survey of four families of mammals', *Visual Neuroscience* 23(3-4), 429-435.
- Aihara, M., Lindsey, J.D. & Weinreb, R.N., 2003, 'Twenty-four-hour pattern of mouse intraocular pressure', *Experimental Eye Research* 77(6), 681-686.
- Albert, D., Lahav, M., Colby, E., Shaddock, J. & Sang, D., 1977, 'Retinal neoplasia and dysplasia. I. Induction by feline leukemia virus.', *Investigative Ophthalmology & Visual Science* 16(4), 325-337.
- Anderson, G.J., William, E.C. & Corliss, J.D., 1990, 'Docosahexaenoic acid is the preferred dietary n-3 fatty acid for the development of the brain and retina', *Pediatric Research* 27(1), 89-95.
- American College of Veterinary Ophthalmologists Genetic Committee, 2010. Ocular disorders presumed to be inherited in pure-bred dogs, Purdue University.
- Andrew, S.E., 2000, 'Feline infectious peritonitis.', *The Veterinary Clinics of North America: Small Animal Practice* 30(5), 987-1000.
- Arnett, B.D., Brightman 2nd, A.H. & Musselman, E.E., 1984, 'Effect of atropine sulfate on tear production in the cat when used with ketamine hydrochloride and acetylpromazine maleate', *Journal of the American Veterinary Medical Association* 185(2), 214-215.
- Artigas, C., Redondo, J.I. & López-Murcia, M.M., 2012, 'Effects of intravenous administration of dexmedetomidine on intraocular pressure and pupil size in clinically normal dogs', *Veterinary Ophthalmology* 15(s1), 79-82.
- Bapodra, P., Bouts, T., Mahoney, P., Turner, S., Silva-Fletcher, A. & Waters, M., 2010, 'Ultrasonographic anatomy of the Asian Elephant (*Elephas maximus*) eye', *Journal of Zoo and Wildlife Medicine* 41(3), 409-417.

- Barnett, K. & Burger, I., 1980, 'Taurine deficiency retinopathy in the cat', *Journal of Small Animal Practice* 21(10), 521-534.
- Bauer, G.A., n.d., *Ocular abnormalities of cheetah examined at AfriCat*, viewed 22 November 2013, from www.africat.org.programmeresearch.html
- Barr, M.C., Calle, P.P., Roelke, M.R. & Scott, F.W., 1989, 'Feline immunodeficiency virus infection in nondomestic felids', *Journal of Zoo and Wildlife Medicine* 20(3), 265-272.
- Bazan, N.G., 2006, 'Cell survival matters: docosahexaenoic acid signaling, neuroprotection and photoreceptors', *Trends in Neuroscience* 29(5), 263 - 271.
- Bernstein, J., 1979, 'Cryptococcus osteomyelitis in a cheetah', *Feline Practice* 9(5), 23-25.
- Berry, W.L., Jardine, J.E. & Espie, I.W., 1997, 'Pulmonary cryptococcoma and cryptococcal meningoencephalomyelitis in a king cheetah (*Acinonyx jubatus*)', *Journal of Zoo and Wildlife Medicine* 28(4), 485-490.
- Berson, E.L., Watson, G., Grasse, K.L. & Szamier, R.B., 1981, 'Retinal degeneration in cats fed casein. IV. The early receptor potential', *Investigative Ophthalmology & Visual Science* 21(2), 345-350.
- Bertolucci, C., Giudice, E., Fazio, F. & Piccione, G., 2009, 'Circadian intraocular pressure rhythms in athletic horses under different lighting regime', *Chronobiology international* 26(2), 348-358.
- Birch, E.E., Hoffman, D.R., Uauy, R. & Birch, D.G., 1998, 'Visual acuity and the essentiality of docosahexaenoic acid and arachidonic acid in the diet of term infants', *Pediatric Research* 44, 201-209.
- Bolton, L.A., Lobetti, R.G., Evezard, D.N., Picard, J.A., Nesbit, J.W., Heerden, J.v. & Burroughs, R.E.J., 1999, 'Cryptococcosis in captive cheetah (*Acinonyx jubatus*): two cases', *Journal of the South African Veterinary Association* 70(1), 35-39.
- Boroffka, S.A., Voorhout, G., Verbruggen, A. & Teske, E., 2006, 'Intraobserver and interobserver repeatability of ocular biometric measurements obtained by means of B-mode ultrasonography in dogs', *American Journal of Veterinary Research* 67(10), 1743-1749.

- Briggs, M. & Ott, R., 1986, 'Possible feline leukemia virus infection in a captive cheetah (*Acinonyx jubatus*) and the response of captive cheetahs to feline leukemia vaccination', *Proceedings of the Annual Meeting, American Association of Zoo Veterinarians, Chicago, Illinois, November 2-6, 1986*, pp.137-139.
- Brightman, A., Brogdon, J., Helper, L. & Everds, N., 1984, 'Electric cataracts in the canine: a case report', *The Journal of the American Animal Hospital Association* 20(6), 895-898.
- Brightman 2nd, A.H., Manning, J.P., Benson, G.J. & Musselman, E.E., 1983, 'Decreased tear production associated with general anesthesia in the horse', *Journal of the American Veterinary Medical Association* 182(3), 243-244.
- Broadwater, J.J., Colitz, C., Carastro, S. & Saville, W., 2010, 'Tear production in normal juvenile dogs', *Veterinary Ophthalmology* 13(5), 321-325.
- Broadwater, J.J., Schorling, J.J., Herring, I.P. & Elvinger, F., 2008, 'Effect of body position on intraocular pressure in dogs without glaucoma', *American Journal of Veterinary Research* 69(4), 527-530.
- Brower, A.I., Munson, L., Radcliffe, R.W., Citino, S.B., Lackey, L.B., Van Winkle, T.J., Stalis, I., Terio, K.A., Summers, B.A. & De Lahunta, A., 2014, 'Leukoencephalomyelopathy of Mature Captive Cheetahs and Other Large Felids: A Novel Neurodegenerative Disease That Came and Went?', *Veterinary Pathology* 51(5), 1013-1021.
- Brown, E.W., Olmsted, R.A., Martenson, J.S. & O'Brien, S.J., 1993, 'Exposure to FIV and FIPV in wild and captive cheetahs', *Zoo Biology* 12(1), 135-142.
- Buk, K. & Marnewick, K., 2010, 'Cheetah conservation in South Africa', *Africa Insight* 39(4), 212-224 .
- Caligiuri, R., Carrier, M., Jacobson, E.R. & Buergelt, C.D., 1988, 'Corneal squamous cell carcinoma in a cheetah (*Acinonyx jubatus*)', *Journal of Zoo Animal Medicine* 19(4), 219-222.
- Campbell, L. & Reed, C., 1975, 'Ocular signs associated with feline infectious peritonitis in two cats', *Feline Practice* 5, 32-35.

- Castro-Prieto, A., Wachter, B. & Sommer, S., 2011, 'Cheetah paradigm revisited: MHC diversity in the world's largest free-ranging population', *Molecular Biology and Evolution* 28(4), 1455-1468.
- Chalmers, W., Truyen, U., Greenwood, N. & Baxendale, W., 1999, 'Efficacy of feline panleucopenia vaccine to prevent infection with an isolate of CPV2b obtained from a cat', *Veterinary Microbiology* 69(1), 41-45.
- Chandran, N., Saravanabava, K., Albert, A. & Venkatesan, R., 1993, 'Occurrence of parvo viral-infection in lions', *Indian Journal Of Animal Sciences* 63(7), 727-728.
- Cheadle, M.A., Spencer, J.A. & Blagburn, B.L., 1999, 'Seroprevalences of *Neospora caninum* and *Toxoplasma gondii* in nondomestic felids from southern Africa', *Journal of Zoo and Wildlife Medicine* 30(2), 248-251.
- Chomel, B.B., Kasten, R.W., Henn, J.B. & Molia, S., 2006, 'Bartonella infection in domestic cats and wild felids', *Annals of the New York Academy of Sciences* 1078,410-415.
- Cottrill, N.B., Banks, W.J. & Pechman, R.D., 1989, 'Ultrasonographic and biometric evaluation of the eye and orbit of dogs', *American Journal of Veterinary Research* 50(6), 898-903.
- Cullen, C.L. & Webb, A.A., 2013, 'Ocular manifestations of systemic disease Part 2: The cat' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 1978-2036, Wiley-Blackwell, Ames, Iowa.
- Cullen, C.L., Lim, C. & Sykes, J., 2005, 'Tear film breakup times in young healthy cats before and after anesthesia', *Veterinary Ophthalmology* 8(3), 159-165.
- Cunningham Jr, E.T. & Koehler, J.E., 2000, 'Ocular bartonellosis', *American Journal of Ophthalmology* 130(3), 340-349.
- Cunningham, A.J. & Barry, P., 1986, 'Intraocular pressure-physiology and implications for anaesthetic management', *Canadian Anaesthetists' Society Journal* 33(2), 195-208.
- Davidson, B.C., Cantrill, R.C. & Varaday, D., 1986, 'The reversal of essential fatty acid deficiency symptoms in the cheetah', *South African Journal of Zoology* 21,161-164.

- Davidson, M. & English, R., 1998, 'Feline ocular toxoplasmosis', *Veterinary Ophthalmology* 1(2-3), 71-80.
- Davidson, M.G. & Nelms, S.R., 2013, 'Diseases of the lens and cataract formation' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 1199-1233, Wiley-Blackwell, Ames, Iowa.
- Del Sole, M.J., Sande, P.H., Bernades, J.M., Aba, M.A. & Rosenstein, R.E., 2007, 'Circadian rhythm of intraocular pressure in cats', *Veterinary Ophthalmology* 10(3), 155-161.
- Dietrich, U.M., 2013, 'Ophthalmic examination and diagnostics Part 3: Diagnostic ultrasonography' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 669-702, Wiley-Blackwell, Ames, Iowa.
- Dodam, J.R., Branson, K.R. & Martin, D.D., 1998, 'Effects of intramuscular sedative and opioid combinations on tear production in dogs', *Veterinary Ophthalmology* 1(1), 57-59.
- Donaldson, D. & Hartley, C., 2013, 'Ophthalmic Examination and Diagnostics Part 2: Ocular Imaging' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 614-668, Wiley-Blackwell, Ames, Iowa.
- Dubey, J., Navarro, I., Sreekumar, C., Dahl, E., Freire, R., Kawabata, H., Vianna, M.C.B., Kwok, O.C.H., Shen, S. & Thulliez, P., 2004, '*Toxoplasma gondii* infections in cats from Parana, Brazil: seroprevalence, tissue distribution, and biologic and genetic characterization of isolates', *Journal of Parasitology* 90(4), 721-726.
- Durant, S., Mitchell, N., Ipavec, A. & Groom, R., 2015., *Acinonyx jubatus*, in: The IUCN Red List of Threatened Species 2015: e.T219A50649567, viewed 18 February 2017 from www.iucnredlist.org<http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T219A50649567.en>.
- Earle, K. & Smith, P., 1991, 'The effect of dietary taurine content on the plasma taurine concentration of the cat', *British Journal of Nutrition* 66(02), 227-235.
- Ekesten, B. & Torrang, I., 1995, 'Age-related changes in ocular distances in normal eyes of Samoyeds', *American Journal of Veterinary Research* 56(1), 127-133.

- English, R., Davidson, M., Nasisse, M., Jamieson, V. & Lappin, M., 1990, 'Intraocular disease associated with feline immunodeficiency virus infection in cats.', *Journal of the American Veterinary Medical Association* 196(7), 1116-1119.
- Erickson-Lamy, K.A., Kaufman, P.L., McDermott, M.L. & France, N.K., 1984, 'Comparative anesthetic effects on aqueous humor dynamics in the cynomolgus monkey', *Archives of Ophthalmology* 102(12), 1815-1820.
- Evermann, J.F., Laurenson, M.K., McKeirnan, A.J. & Caro, T., 1993, 'Infectious disease surveillance in captive and free-living cheetahs: An integral part of the species survival plan', *Zoo Biology* 12(1), 125-133.
- Evermann, J.F., Roelke, M.E. & Briggs, M.B., 1986, 'Feline coronavirus infections of cheetahs', *Feline Practice* 16(3), 21-30.
- Featherstone, H.J. & Heinrich, C.L., 2013, 'Ophthalmic Examination and Diagnostics Part 1: The eye examination and diagnostic procedures' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 533-613, Wiley-Blackwell, Ames, Iowa.
- Filoni, C., Catão-Dias, J.L., Bay, G., Durigon, E.L., Jorge, R.S.P., Lutz, H. & Hofmann-Lehmann, R., 2006, 'First evidence of feline herpesvirus, calicivirus, parvovirus, and Ehrlichia exposure in Brazilian free-ranging felids', *Journal of Wildlife Diseases* 42(2), 470-477.
- Flacke, G.L., Schmidt-Küntzel, A. & Marker, L., 2015, 'Treatment of chronic herpesviral dermatitis in a captive cheetah (*Acinonyx jubatus*) in Namibia', *Journal of Zoo and Wildlife Medicine* 46(3), 641-646.
- Foley, J.E., Lapointe, J., Koblik, P., Poland, A. & Pedersen, N.C., 1998, 'Diagnostic features of clinical neurologic feline infectious peritonitis', *Journal of Veterinary Internal Medicine* 12(6), 415-423.
- Friedman, Y. & Daly, B., 2004, 'Red data book of mammals of South Africa: a conservation assessment: CBSG Southern Africa', *Conservation Breeding Specialist Group (SCC/IUCN)*, Endangered Wildlife Trust, South Africa, pp. 147-149.

- Gabelt, B.T. & Kaufman, P.L., 2003, 'Aqueous humor hydrodynamics' in P.L. Kaufman, A. Alm & F.H. Adler (eds.), *Adler's Physiology of the Eye: Clinical Application*, 10th edn, pp. 237-289, Mosby, St. Louis.
- Gaffney, P.M., Kennedy, M., Terio, K., Gardner, I., Lothamer, C., Coleman, K. & Munson, L., 2012, 'Detection of feline coronavirus in cheetah (*Acinonyx jubatus*) feces by reverse transcription-nested polymerase chain reaction in cheetahs with variable frequency of viral shedding', *Journal of Zoo and Wildlife Medicine* 43(4), 776-786.
- Galín, M.A., McIvor, J.W. & Magruder, G.B., 1963, 'Influence of position on intraocular pressure', *American Journal of Ophthalmology* 55(4), 720-723.
- Gelatt, K.N., Peiffer Jr, R.L., Erickson, J.L. & Gum, G.G., 1975, 'Evaluation of tear formation in the dog, using a modification of the Schirmer tear test', *Journal of the American Veterinary Medical Association* 166(4), 368-370.
- Gerds-Grogan, S. & Dayrell-Hart, B., 1997, 'Feline cryptococcosis: a retrospective evaluation', *Journal of the American Animal Hospital Association* 33(2), 118-122.
- Giannetto, C., Piccione, G. & Giudice, E., 2009, 'Daytime profile of the intraocular pressure and tear production in normal dog', *Veterinary Ophthalmology* 12(5), 302-305.
- Gilger, B.C., Davidson, M.G. & Howard, P.B., 1998, 'Keratometry, ultrasonic biometry, and prediction of intraocular lens power in the feline eye', *American Journal of Veterinary Research* 59(2), 131-134.
- Glaze, M.B., 2005, 'Congenital and hereditary ocular abnormalities in cats', *Clinical Techniques in Small Animal Practice* 20(2), 74-82.
- Gonzalez, E., Rodriguez, A. & Garcia, I., 2001, 'Review of ocular ultrasonography', *Veterinary Radiology & Ultrasound* 42(6), 485-495.
- Gould, D. & Pappasoulotis, K., 2013, 'Clinical microbiology and parasitology' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 300-350, Wiley-Blackwell, Ames, Iowa.
- Graw, J., 1996, 'Genetic aspects of embryonic eye development in vertebrates', *Developmental Genetics* 18(3), 181-197.

- Grinninger, P., Skalicky, M. & Nell, B., 2010, 'Evaluation of healthy equine eyes by use of retinoscopy, keratometry, and ultrasonographic biometry', *American Journal of Veterinary Research* 71(6), 677-681.
- Grundon, R.A., Anderson, G.A., Lynch, M., Hardman, C., O'Reilly, A. & Stanley, R.G., 2011, 'Schirmer tear tests and intraocular pressures in conscious and anesthetized koalas (*Phascolarctus cinereus*)', *Veterinary Ophthalmology* 14(5), 292-295.
- Gum, G.G. & Mackay, E.O., 2013, 'Physiology of the Eye' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 171-207, Wiley-Blackwell, Ames, Iowa.
- Hahnenberger, R.W., 1976, 'Influence of various anesthetic drugs on the intraocular pressure of cats', *Albrecht von Graefes Archiv für klinische und experimentelle Ophthalmologie* 199(2), 179-186.
- Hamidzada, W.A. & Osuobeni, E.P., 1999, 'Agreement between A-mode and B-mode ultrasonography in the measurement of ocular distances', *Veterinary Radiology & Ultrasound* 40(5), 502-507.
- Hargis, A.M. & Ginn, P.E., 1999, 'Feline herpesvirus 1-associated facial and nasal dermatitis and stomatitis in domestic cats', *Veterinary Clinics of North America: Small Animal Practice* 29(6), 1281-1290.
- Hawkins, E.C. & Murphy, C.J., 1986, 'Inconsistencies in the absorptive capacities of Schirmer tear test strips', *Journal of American Veterinary Medical Association* 188(4), 511-513.
- Hedberg, G.E., Dierenfeld, E.S. & Rogers, Q.R., 2007, 'Taurine and zoo felids: considerations of dietary and biological tissue concentrations', *Zoo Biology* 26(6), 517-531.
- Heeney, J.L., Evermann, J.F., McKeirnan, A.J., Marker-Kraus, L., Roelke, M.E., Bush, M., Wildt, D.E., Meltzer, D.G., Colly, L. & Lukas, J., 1990, 'Prevalence and implications of feline coronavirus infections of captive and free-ranging cheetahs (*Acinonyx jubatus*)', *Journal of Virology* 64(5), 1964-1972.

- Hernández-Guerra, A., Rodilla, V. & López-Murcia, M., 2007, 'Ocular biometry in the adult anesthetized ferret (*Mustela putorius furo*)', *Veterinary Ophthalmology* 10(1), 50-52.
- Herring, I.P., 2013, 'Clinical Pharmacology and Therapeutics Part 4: Mydriatics/Cyclopegics, Anesthetics and Tear Substitutes and Stimulators' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 423-434, Wiley-Blackwell, Ames, Iowa.
- Herring, I.P., Pickett, J.P., Champagne, E.S. & Marini, M., 2000, 'Evaluation of aqueous tear production in dogs following general anesthesia', *Journal of the American Animal Hospital Association* 36(5), 427-430.
- Hofmeister, E.H., Mosunic, C.B., Torres, B.T., Ralph, A.G., Moore, P.A. & Read, M.R., 2006, 'Effects of ketamine, diazepam, and their combination on intraocular pressures in clinically normal dogs', *American Journal of Veterinary Research* 67(7), 1136-1139.
- Hoover, E.A. & Griesemer, R.A., 1971, 'Experimental feline herpesvirus infection in the pregnant cat', *The American Journal of Pathology* 65(1), 173-188.
- Howard, J., Rogers, Q., Koch, S., Goodrowe, K., Montali, R. & Bush, M., 1987, 'Diet-induced taurine deficiency retinopathy in leopard cats (*Felis bengalensis*)' in *Proceedings of the Annual Meeting of the American Association of Zoo Veterinarians, Turtle Bay, Hawaii, September 6-11, 1987*, pp. 496-498.
- Irby, N., 1983, 'Hereditary cataracts in the British Shorthair cat' in *American College of Veterinary Ophthalmology: Genetic workshop*, Chigaco, Illinois.
- Jang, M., Park, S., Son, W., Jo, S., Hwang, H., Seo, K. & Lee, I., 2015, 'Effect of tiletamine-zolazepam on the intraocular pressure of the dog', *Veterinary Ophthalmology* 18(6), 481-484.
- Jin, Y., Wilson, S., Elko, E.E. & Yorio, T., 1991, 'Ocular hypotensive effects of medetomidine and its analogs', *Journal of Ocular Pharmacology and Therapeutics* 7(4), 285-296.
- Johnson, R.H., 1964, 'Isolation of a virus from a condition simulating feline panleucopaenia in a leopard', *Veterinary Record* 76, 1008-1013.

- Jones, L.T., 1961, 'An anatomical approach to problems of the eyelids and lacrimal apparatus', *Archives of Ophthalmology* 66(1), 111-124.
- Junge, R.E., Miller, R.E., Boever, W.J., Scherba, G. & Sundberg, J., 1991, 'Persistent cutaneous ulcers associated with feline herpesvirus type 1 infection in a cheetah.', *Journal of the American Veterinary Medical Association* 198(6), 1057-1058.
- Kassab, A., 2012, 'Ultrasonographic and macroscopic anatomy of the enucleated eyes of the buffalo (*Bos bubalis*) and the one-humped camel (*Camelus dromedarius*) of different ages', *Anatomia, Histologia, Embryologia* 41(1), 7-11.
- Kennedy, M., Citino, S., McNabb, A.H., Moffatt, A.S., Gertz, K. & Kania, S., 2002, 'Detection of feline coronavirus in captive felidae in the USA.', *Journal of Veterinary Diagnostic Investigation* 14(6), 520-522.
- Klein, H.E., Krohne, S.G., Moore, G.E., Mohamed, A.S. & Stiles, J., 2011, 'Effect of eyelid manipulation and manual jugular compression on intraocular pressure measurement in dogs', *Journal of the American Veterinary Medical Association* 238(10), 1292-1295.
- Knollinger, A.M., La Croix, N.C., Barrett, P.M. & Miller, P.E., 2005, 'Evaluation of a rebound tonometer for measuring intraocular pressure in dogs and horses', *Journal of the American Veterinary Medical Association* 227(2), 244-248.
- Komáromy, A.M., Garg, C.D., Ying, G. & Liu, C., 2006, 'Effect of head position on intraocular pressure in horses', *American Journal of Veterinary Research* 67(7), 1232-1235.
- Kovalcuka, L., Birgele, E., Bandere, D. & Williams, D.L., 2013, 'The effects of ketamine hydrochloride and diazepam on the intraocular pressure and pupil diameter of the dog's eye', *Veterinary Ophthalmology* 16(1), 29-34.
- Krausman, P.R. & Morales, S.M., 2005, '*Acinonyx jubatus*', *Mammalian Species* 771, 1-6.
- Kroll, M.M., Miller, P.E. & Rodan, I., 2001, 'Intraocular pressure measurements obtained as part of a comprehensive geriatric health examination from cats seven years of age or older', *Journal of the American Veterinary Medical Association* 219(10), 1406-1410.

- Lane, E.P., Brettschneider, H., Oosthuizen, A., Dalton, D.L., Kotze, A., Caldwell, P., Du Plessis, L. & Steyl, J., 2016, 'Feline panleukopaenia virus in captive non-domestic felids in South Africa: original research', *Onderstepoort Journal of Veterinary Research* 83(1), 1-8.
- Lappin, M.R. & Powell, C.C., 1991, 'Comparison of Latex Agglutination, Indirect Hemagglutination, and ELISA Techniques for the Detection of *Toxoplasma gondii*-specific Antibodies in the Serum of Cats', *Journal of Veterinary Internal Medicine* 5(5), 299-301.
- Lappin, M.R. & Black, J.C., 1999, 'Bartonella spp infection as a possible cause of uveitis in a cat', *Journal of the American Veterinary Medical Association* 214(8), 1205-1207.
- Larsen, J.S., 1971, 'The sagittal growth of the eye', *Acta Ophthalmologica* 49(2), 239-262.
- Linberg, K.A., Lewis, G.P., Shaaw, C., Rex, T.S. & Fisher, S.K., 2001, 'Distribution of S-and M-cones in normal and experimentally detached cat retina', *Journal of Comparative Neurology* 430(3), 343-356.
- Lloyd, C. & Stidworthy, M.F., 2007, 'Acute disseminated toxoplasmosis in a juvenile cheetah (*Acinonyx jubatus*)', *Journal of Zoo and Wildlife Medicine* 38(3), 475-478.
- Lombardini, J.B., 1991, 'Taurine: retinal function', *Brain Research Reviews* 16(2), 151-169.
- Maggs, D.J., 2005, 'Update on pathogenesis, diagnosis, and treatment of feline herpesvirus type 1', *Clinical Techniques in Small Animal Practice* 20(2), 94-101.
- Maggs, D.J., 2013, 'Diagnostic Techniques' in D.J Maggs, P.E. Miller & R. Ofri, (eds.), *Slatter's Fundamentals of Veterinary Ophthalmology*, 5th edn, pp. 79-109, Elsevier Saunders, Missouri.
- Maggs, D.J., Lappin, M.R. & Nasisse, M.P., 1999, 'Detection of feline herpesvirus-specific antibodies and DNA in aqueous humor from cats with or without uveitis', *American Journal of Veterinary Research* 60(8), 932-936.
- Maggs, D.J., Lappin, M.R., Reif, J.S., Collins, J.K., Carman, J., Dawson, D.A. & Bruns, C., 1999, 'Evaluation of serologic and viral detection methods for

- diagnosing feline herpesvirus-1 infection in cats with acute respiratory tract or chronic ocular disease', *Journal of the American Veterinary Medical Association* 214(4), 502-507.
- Margadant, D.J., Kirkby, K., Andrew, S.E & Gelatt, K.N., 2003, 'Effect of topical tropicamide on tear production as measured by Schirmer's tear test in normal dogs and cats', *Veterinary Ophthalmology* 6(4), 315-320.
- Marker, L., Munson, L., Basson, P.A. & Quackenbush, S., 2003, 'Multicentric T-cell lymphoma associated with feline leukemia virus infection in a captive Namibian cheetah (*Acinonyx jubatus*)', *Journal of wildlife diseases* 39(3), 690-695.
- Markwell, P. & Earle, K., 1995, 'Taurine: an essential nutrient for the cat. A brief review of the biochemistry of its requirement and the clinical consequences of deficiency', *Nutrition Research* 15(1), 53-58.
- Marnewick, K., Beckhelling, A., Cilliers, D., Lane, E., Mills, G., Herring, K., Caldwell, P., Hall, R. & Meintjes, S., 2007, 'The status of the cheetah in South Africa', *Cat News* 3, 27-31.
- Martin, C., 2005, 'Anamnesis and the ophthalmic examination', *Ophthalmic Disease in Veterinary Medicine* 1, 11-38.
- Martin-Suarez, E., Molleda, C., Tardon, R., Galan, A., Gallardo, J. & Molleda, J., 2014, 'Diurnal variations of central corneal thickness and intraocular pressure in dogs from 8:00 am to 8:00 pm', *The Canadian veterinary journal = La revue veterinaire canadienne* 55(4), 361-365.
- Marzok, M.A. & El-khodery, S.A., 2015, 'Intraocular pressure in clinically normal dromedary camels (*Camelus dromedarius*)', *American Journal of Veterinary Research* 76(2), 149-154.
- McLaughlin, S.A., Brightman 2nd, A.H., Helper, L.C., Primm, N.D., Brown, M.G. & Greeley, S., 1988, 'Effect of removal of lacrimal and third eyelid glands on Schirmer tear test results in cats', *Journal of the American Veterinary Medical Association* 193(7), 820-822.
- Menotti-Raymond, M. & O'Brien, S.J., 1993, 'Dating the Genetic Bottleneck of the African Cheetah', *Proceedings of the National Academy of Sciences of the United States of America* 90(8), 3172-3176.

- Miller, P.E., 2013, 'The glaucomas' in D.J. Maggs, P.E. Miller & R. Ofri (eds.), *Slatter's Fundamentals of Veterinary Ophthalmology*, 5th edn, pp.247-271, Elsevier Saunders, Missouri.
- Miller, P.E. & Pickett, J.P., 1992, 'Comparison of the human and canine Schiötz tonometry conversion tables in clinically normal cats', *Journal of the American Veterinary Medical Association* 201(7), 1017-1020.
- Millward, I.R. & Williams, M.C., 2005, '*Cryptococcus neoformans* granuloma in the lung and spinal cord of a free-ranging cheetah (*Acinonyx jubatus*). A clinical report and literature review', *Journal of the South African Veterinary Association* 76(4), 228-232.
- Mirshahi, A., Shafigh, S. & Azizzadeh, M., 2014, 'Ultrasonographic biometry of the normal eye of the Persian cat', *Australian Veterinary Journal* 92(7), 246-249.
- Molia, S., Kasten, R.W., Stuckey, M.J., Boulouis, H.J., Allen, J., Borgo, G.M., Koehlers, J.E., Chang, C.C. & Chomel, B.B., 2016, 'Isolation of *Bartonella henselae*, *Bartonella koehlerae* subsp. *koehlerae*, *Bartonella koehlerae* subsp. *bothieri* and a new subspecies of *B. koehlerae* from free-ranging lions (*Panthera leo*) from South Africa, cheetahs (*Acinonyx jubatus*) from Namibia and captive cheetahs from California', *Epidemiology and Infection* 155 (5), 3237-3243.
- Morris, J., Rogers, Q. & Pacioretty, L., 1990, 'Taurine: an essential nutrient for cats', *Journal of Small Animal Practice* 31(10), 502-509.
- Mould, J.R.B., 2002, 'Examination and diagnostic procedures 1a Ophthalmic examination' in S.M. Petersen-Jones & S.M. Crispin (eds.), *BSAVA manual of small animal ophthalmology*, 2nd edn, pp. 1-12, British Small Animal Veterinary Association, Gloucester, UK.
- Müller, K., Mauler, D.A. & Eule, J.C., 2010, 'Reference values for selected ophthalmic diagnostic tests and clinical characteristics of chinchilla eyes (*Chinchilla lanigera*)', *Veterinary Ophthalmology* 13(s1), 29-34.
- Munson, L., Marker, L., Dubovi, E., Spencer, J.A., Evermann, J.F. & O'Brien, S.J., 2004, 'Serosurvey of viral infections in free-ranging Namibian cheetahs (*Acinonyx jubatus*)', *Journal of Wildlife Diseases* 40(1), 23-31.

- Munson, L., Terio, K.A., Worley, M., Jago, M., Bagot-Smith, A. & Marker, L., 2005, 'Extrinsic factors significantly affect patterns of disease in free-ranging and captive cheetah (*Acinonyx jubatus*) populations.', *Journal of Wildlife Diseases* 41(3), 542-548.
- Munson, L., Wack, R., Duncan, M., Montali, R.J., Boon, D., Stalis, I., Crawshaw, G.J., Cameron, K.N., Mortenson, J., Citino, S., Zuba, J. & Junge, R.E., 2004, 'Chronic eosinophilic dermatitis associated with persistent feline herpes virus infection in cheetahs (*Acinonyx jubatus*)', *Veterinary Pathology* 41(2), 170-176.
- Murphy, D.F., 1985, 'Anesthesia and intraocular pressure', *Anesthesia & Analgesia* 64(5), 520-530.
- Nakamura, K., Ikeda, Y., Miyazawa, T., Tohya, Y., Takahashi, E. & Mochizuki, M., 2001, 'Characterisation of cross-reactivity of virus neutralising antibodies induced by feline panleukopenia virus and canine parvoviruses', *Research in Veterinary Science* 71(3), 219-222.
- Narfstrom, K., 1999, 'Hereditary and congenital ocular disease in the cat.', *Journal of Feline Medicine and Surgery* 1(3), 135-41.
- Narfstrom, K. & Peterson-Jones, S.M., 2013 'Diseases of the canine ocular fundus' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp. 1303-1392, Wiley-Blackwell, Ames, Iowa.
- O'Brien, C., Krockenberger, M., Wigney, D., Martin, P. & Malik, R., 2004, 'Retrospective study of feline and canine cryptococcosis in Australia from 1981 to 2001: 195 cases', *Medical Mycology* 42(5), 449-460.
- O'Brien, S.J., Roelke, M., Marker, L., Hart, F., Goldman, D.G., Merrill, C., Howard, J.G., Meltzer, D. & van Dyk, A., 1983, 'The South African cheetah: a multidisciplinary approach reveals a provocative genetic status and natural history.', *American Association of Zoo Veterinarians Annual Proceedings*, Tampa, Florida, October 23-27, 1983, vol.16.
- Ofri, R., Horowitz, I., Jacobson, S. & Kass, P., 1997, 'Tear production in lions (*Panthera leo*): the effect of two anesthetic protocols', *Veterinary and Comparative Ophthalmology* 7(3), 173-179.

- Ofri, R., Shore, L., Kass, P. & Horowitz, I., 1999, 'The effect of elevated progesterone levels on intraocular pressure in lions (*Panthera leo*)', *Research in Veterinary Science* 67(2), 121-123.
- Ofri, R., 2013, 'Lens' in D.J. Maggs, P.E. Miller & R. Ofri (eds.), *Slatter's Fundamentals of Veterinary Ophthalmology*, 5th edn, pp. 272-290, Elsevier Saunders, Missouri
- Ofri, R., Horowitz, I., Jacobson, S. & Kass, P.H., 1998, 'The effects of anesthesia and gender on intraocular pressure in lions (*Panthera leo*)', *Journal of Zoo and Wildlife Medicine* 29(3), 307-310.
- Ofri, R., Shub, N., Galin, Z., Shemesh, M. & Shore, L.S., 2002, 'Effect of reproductive status on intraocular pressure in cats', *Journal of the American Veterinary Medical Association* 63(2), 159-162.
- Ofri, R., Steinmetz, A., Thielebein, J., Horowitz, I.H., Oechtering, G. & Kass, P.H., 2008, 'Factors affecting intraocular pressure in lions', *The Veterinary Journal* 177(1), 124-129.
- Ofri, R., Barishak, R.Y., Eshkar, G. & Aizenberg, I., 1996, 'Feline central retinal degeneration in captive cheetahs (*Acinonyx jubatus*).', *Journal of Zoo and Wildlife Medicine* 27(1), 101-108.
- Ofri, R., Horowitz, I.H., Raz, D., Shvartsman, E. & Kass, P.H., 2002, 'Intraocular pressure and tear production in five herbivorous wildlife species', *The Veterinary Record* 151(9), 265-268.
- O'Neil, S., Lappin, M., Reif, J., Marks, A. & Greene, C., 1991, 'Clinical and epidemiological aspects of feline immunodeficiency virus and *Toxoplasma gondii* coinfections in cats', *The Journal of the American Animal Hospital Association (USA)* 27, 211-220.
- Osuobeni, E. & Hamidzada, W., 1999, 'Ultrasonographic determination of the dimensions of ocular components in enucleated eyes of the one-humped camel (*Camelus dromedarius*)', *Research in Veterinary Science* 67(2), 125-129.
- Park, Y., Jeong, M., Kim, T., Ahn, J., Ahn, J., Park, S., Kim, S. & Seo, K., 2011, 'Effect of central corneal thickness on intraocular pressure with the rebound

- tonometer and the applanation tonometer in normal dogs', *Veterinary Ophthalmology* 14(3), 169-173.
- Parrish, C.R., 1995, '3 Pathogenesis of feline panleukopenia virus and canine parvovirus', *Baillière's Clinical Haematology* 8(1), 57-71.
- Pauli, A.M., Bentley, E., Diehl, K.A. & Miller, P.E., 2006, 'Effects of the application of neck pressure by a collar or harness on intraocular pressure in dogs', *Journal of the American Animal Hospital Association* 42(3), 207-211.
- Pedersen, N., Yamamoto, J.K., Ishida, T. & Hansen, H., 1989, 'Feline immunodeficiency virus infection', *Veterinary Immunology and Immunopathology* 21(1), 111-129.
- Pedersen, N.C., 2009, 'A review of feline infectious peritonitis virus infection: 1963-2008', *Journal of Feline Medicine and Surgery* 11(4), 225-258.
- Peiffer Jr, R.L., & Gelatt, K.N., 1975, 'Congenital cataracts in a Persian kitten.', *Veterinary Medicine & Small Animal Clinician* 70(11), 1334-1335.
- Percy, D., Scott, F. & Albert, D., 1975, 'Retinal dysplasia due to feline panleukopenia virus infection [Cats]', *Journal American Veterinary Medical Association* 167, 935-937.
- Pesteanu-Somogyi, L.D., Radzai, C. & Pressler, B.M., 2006, 'Prevalence of feline infectious peritonitis in specific cat breeds', *Journal of Feline Medicine & Surgery* 8(1), 1-5.
- Petersen-Jones, S., 2002, 'The lens' in S.M. Petersen-Jones & S.M. Crispin (eds.), *BSAVA Manual of Small Animal Ophthalmology*, 2nd edn, pp. 204-218, British Small Animal Veterinary Association, Gloucester, UK.
- Pfeifer, M.L., Evermann, J.F., Roelke, M.E., Gallina, A.M., Ott, R.L. & McKeirnan, A.J., 1983, 'Feline infectious peritonitis in a captive cheetah', *Journal of the American Veterinary Medical Association* 183(11), 1317-1319.
- Plummer, C.E., Regnier, A. & Gelatt, K.N., 2013, 'The canine glaucomas' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary Ophthalmology*, 5th edn, pp.1050-1145, Wiley-Blackwell, Ames, Iowa.
- Plummer, C.E., Ramsey, D.T. & Hauptman, J.G., 2003, 'Assessment of corneal thickness, intraocular pressure, optical corneal diameter, and axial globe

- dimensions in Miniature Horses', *American Journal of Veterinary Research* 64(6), 661-665.
- Potter, T.J., Hallowell, G.D. & Bowen, I., 2008, 'Ultrasonographic anatomy of the bovine eye', *Veterinary Radiology & Ultrasound* 49(2), 172-175.
- Povey, R. & Davis, E., 1977, 'Panleucopenia and respiratory virus infection in wild felids', *The World's Cats* 3(3), 120-128.
- Quam, D.D., Morris, J.G. & Rogers, Q.R., 1987, 'Histidine requirement of kittens for growth, haematopoiesis and prevention of cataracts', *British Journal of Nutrition* 58(03), 521-532.
- Remillard, R.L., Pickett, J.P., Thatcher, C.D. & Davenport, D.J., 1993, 'Comparison of kittens fed queen's milk with those fed milk replacers', *American Journal of Veterinary Research* 54(6), 901-907.
- Ribeiro, A.P., Silva, M.L., Rosa, J.P., Souza, S.F., Teixeira, I.A. & Laus, J.L., 2009, 'Ultrasonographic and echobiometric findings in the eyes of Saanen goats of different ages', *Veterinary Ophthalmology* 12(5), 313-317.
- Risi, E., Agoulon, A., Allaire, F., Le Dréan-Quéneq'hdu, S., Martin, V. & Mahl, P., 2012, 'Antibody response to vaccines for rhinotracheitis, caliciviral disease, panleukopenia, feline leukemia, and rabies in tigers (*Panthera tigris*) and lions (*Panthera leo*)', *Journal of Zoo and Wildlife Medicine* 43(2), 248-255.
- Roberts, S.M., Lavach, J.D., Severin, G.A., Withrow, S.J. & Gillette, E.L., 1987, 'Ophthalmic complications following megavoltage irradiation of the nasal and paranasal cavities in dogs', *Journal of the American Veterinary Medical Association* 190(1), 43-47.
- Rogers, M., Cartee, R.E., Miller, W. & Ibrahim, A.K., 1986, 'Evaluation of the Extirpated Equine Eye using B-Mode Ultrasonography', *Veterinary Radiology* 27(1), 24-29.
- Rowland, J., Potter, D. & Reiter, R., 1981, 'Circadian rhythm in intraocular pressure: a rabbit model', *Current Eye Research* 1(3), 169-173.
- Rubin, L., 1986, 'Hereditary cataract in Himalayan cats', *Feline Practice* 16(1), 14-15.
- Rubin, L.F. & Koch, S.A., 1968, 'Ocular diagnostic ultrasonography', *Journal of the American Veterinary Medical Association* 153(12), 1706-1716.

- Ruiz, T., Campos, W.N., Peres, T.P., Gonçalves, G.F., Ferraz, R.H., Néspoli, P.E., Sousa, V.R. & Ribeiro, A.P., 2015, 'Intraocular pressure, ultrasonographic and echobiometric findings of juvenile *Yacare caiman* (*Caiman yacare*) eye', *Veterinary Ophthalmology* 18(s1), 40-45.
- Rusanen, E., Florin, M., Hässig, M. & Spiess, B.M., 2010, 'Evaluation of a rebound tonometer (Tonovet®) in clinically normal cat eyes', *Veterinary Ophthalmology* 13(1), 31-36.
- Sanchez, R., Mellor, D. & Mould, J., 2006, 'Effects of medetomidine and medetomidine-butorphanol combination on Schirmer tear test I readings in dogs', *Veterinary Ophthalmology* 9(1), 33-37.
- Schaller, G.B., 1968, 'Hunting behaviour of the cheetah in the Serengeti National Park, Tanzania', *African Journal of Ecology* 6(1), 95-100.
- Schiffer, S.P., Rantanen, N.W., Leary, G.A. & Bryan, G.M., 1982, 'Biometric study of the canine eye, using A-mode ultrasonography', *American Journal of Veterinary Research* 43(5), 826-830.
- Schwink, K., 1986, 'Posterior nuclear cataracts in two Birman kittens', *Feline Practice* 16 (4).
- Sedlák, K. & Bártová, E., 2006, 'Seroprevalences of antibodies to *Neospora caninum* and *Toxoplasma gondii* in zoo animals', *Veterinary Parasitology* 136(3), 223-231.
- Sharp, N., 1997, 'Timed running speed of a cheetah (*Acinonyx jubatus*)', *Journal of Zoology* 241(3), 493-494.
- Spencer, J.A., Higginbotham, M.J. & Blagburn, B.L., 2003, 'Seroprevalence of *Neospora caninum* and *Toxoplasma gondii* in captive and free-ranging nondomestic felids in the United States', *Journal of Zoo and Wildlife Medicine* 34(3), 246-249.
- Stadtbäumer, K., Köstlin, R.G. & Zahn, K.J., 2002, 'Effects of topical 0.5% tropicamide on intraocular pressure in normal cats', *Veterinary Ophthalmology* 5(2), 107-112.
- Steinmetz, A., Eulenberger, K., Thielebein, J., Buschatz, S., Bernhard, A., Wilsdorf, A. & Ofri, R., 2006, 'Lens-anomalies and other ophthalmic findings in a group of

- closely-related angola lions (*Panthera leo bleyenberghi*), *Zoo Biology* 25(5), 433-439.
- Stiles, J., 2014, 'Ocular manifestations of feline viral diseases', *The Veterinary Journal* 201(2), 166-173.
- Stiles, J., 2013, 'Feline ophthalmology' in K.N. Gelatt, B.C. Gilger & T.J. Kern (eds.), *Veterinary ophthalmology*, 5th edn, pp.1477-1559, Wiley-Blackwell, Ames, Iowa.
- Studdert, M., Kelly, C. & Harrigan, K., 1973, 'Isolation of panleucopaenia virus from lions', *Veterinary Record* 93(6), 156-158.
- Toni, M.C., Meirelles, Adriana Érica Wilkes Burton, Gava, F.N., Camacho, A.A., Laus, J.L. & Canola, J.C., 2010, 'Rabbits' eye globe sonographic biometry', *Veterinary Ophthalmology* 13(6), 384-386.
- Tordiffe, A. S.W., Wachter, B., Heinrich, S. K., Reyers, F., & Mienie, L. J., 2016, 'Comparative serum fatty acid profiles of captive and free-ranging cheetahs (*Acinonyx jubatus*) in Namibia', *PloS one*, 11(12), e0167608. doi:10.1371/journal.pone.0167608
- Townsend, W.M., 2008, 'Canine and feline uveitis', *Veterinary Clinics of North America: Small Animal Practice* 38(2), 323-346.
- Townsend, W.M., Stiles, J., Guptill-Yoran, L. & Krohne, S.G., 2004, 'Development of a reverse transcriptase polymerase chain reaction assay to detect feline herpesvirus-1 latency-associated transcripts in the trigeminal ganglia and corneas of cats that did not have clinical signs of ocular disease', *American Journal of Veterinary Research* 65(3), 314-319.
- Trbolova, A. & Ghaffari, M.S., 2012, 'Reference values for Schirmer tear tests I and II in clinically normal pigs', *Veterinary Ophthalmology* 15(3), 180-182.
- Truyen, U., Addie, D., Belák, S., Boucraut-Baralon, C., Egberink, H., Frymus, T., Gruffydd-Jones, T., Hartmann, K., Hosie, M.J. & Lloret, A., 2009, 'Feline panleukopenia. ABCD guidelines on prevention and management', *Journal of Feline Medicine & Surgery* 11(7), 538-546.

- Tuntivanich, N., Petersen-Jones, S.M., Steibel, J.P., Johnson, C. & Forcier, J.Q., 2007, 'Postnatal development of canine axial globe length measured by B-scan ultrasonography', *Veterinary Ophthalmology* 10(1), 2-5.
- Uauy, R.D., Birch, B.B., Birch, D.G., Tyson, E.E. & Hoffman, D.R., 1990, 'Effect of dietary omega-3 fatty acids on retinal function of very-low-birth-weight neonates', *Pediatric Research* 28(5), 485-492.
- Van Rensburg, I.B. & Silkstone, M.A., 1984, 'Concomitant feline infectious peritonitis and toxoplasmosis in a cheetah (*Acinonyx jubatus*)', *Journal of the South African Veterinary Association* 55(4), 205-207.
- Van Vuuren, M., Goosen, T. & Rogers, P., 1999, 'Feline herpesvirus infection in a group of semi-captive cheetahs: case report', *Journal of the South African Veterinary Association* 70(3), 132-134.
- Van Vuuren, M., Steinel, A., Goosen, T., Lane, E., Van der Lugt, J., Pearson, J. & Truyen, U., 2000, 'Feline panleukopenia virus revisited: molecular characteristics and pathological lesions associated with three recent isolates', *Journal of the South African Veterinary Association* 71(3), 140-143.
- Veith, L., Cure, T. & Gelatt, K., 1970, 'The Schirmer tear test in cats', *Modern Veterinary Practice* 51(5), 48-49.
- Verbruggen, A., Akkerdaas, L., Hellebrekers, L. & Stades, F., 2000, 'The effect of intravenous medetomidine on pupil size and intraocular pressure in normotensive dogs', *Veterinary Quarterly* 22(3), 179-180.
- Wack, R.F., Kramer, L.W., Cupps, W.L., Clawson, S. & Hustead, D.R., 1993, 'The response of cheetahs (*Acinonyx jubatus*) to routine vaccination', *Journal of Zoo and Wildlife Medicine* 24(2), 109-117.
- Wallin-Håkanson, N. & Wallin-Håkanson, B., 2001, 'The effects of topical tropicamide and systemic medetomidine, followed by atipamezole reversal, on pupil size and intraocular pressure in normal dogs', *Veterinary Ophthalmology* 4(1), 3-6.
- Walser-Reinhardt, L., Wernick, M.B., Hatt, J.M. & Spiess, B.M., 2010, 'Bilateral vision loss in a captive cheetah (*Acinonyx jubatus*).', *Veterinary Ophthalmology* 13(s1), 128-133.

- Wasieri, J., Schmiedeknecht, G., Förster, C., König, M. & Reinacher, M., 2009, 'Parvovirus infection in a Eurasian lynx (*Lynx lynx*) and in a European wildcat (*Felis silvestris silvestris*)', *Journal of Comparative Pathology* 140(2), 203-207.
- Waters, L. 1994 'The Schirmer tear test II in cats'. *British Small Animal Association annual conference proceedings*, Birmingham, UK April 6-9,1994.
- Weinreb, R.N., Cook, J. & Friberg, T.R., 1984, 'Effect of inverted body position on intraocular pressure', *American Journal of Ophthalmology* 98(6), 784-787.
- Williams, D.L. & Heath, M.F., 2006, 'Prevalence of feline cataract: results of a cross-sectional study of 2000 normal animals, 50 cats with diabetes and one hundred cats following dehydrational crises', *Veterinary Ophthalmology* 9(5), 341-349.
- Williams, J. & Wilkie, D.A., 1996, 'Ultrasonography of the eye', *The Compendium on continuing education for the practicing veterinarian* 18(6), 667-676.
- Witte, C.L., Lamberski, N., Rideout, B.A., Fields, V., Teare, C.S., Barrie, M., Haefele, H., Junge, R., Murray, S. & Hungerford, L.L., 2013, 'Development of a case definition for clinical feline herpesvirus infection in cheetahs (*Acinonyx jubatus*) housed in zoos', *Journal of Zoo and Wildlife Medicine* 44(3), 634-644.
- Wu, S., Nemesure, B., Hennis, A. & Leske, M.C., 2006, 'Nine-year changes in intraocular pressure: the Barbados Eye Studies', *Archives of Ophthalmology* 124(11), 1631-1636.
- Yadegari, M., Salehi, A., Ashtari, A. & Ashtari, M.S., 2013, 'B-mode ultrasound biometry of intraocular structures in dromedary camels (*Camelus dromedarius*)', *Global Veterinaria* 10(1), 71-74.
- Ye, S., Harasiewicz, K., Pavlin, C. & Foster, F., 1995, 'Ultrasound characterization of normal ocular tissue in the frequency range from 50 MHz to 100 MHz', *IEEE transactions on ultrasonics, ferroelectrics, and frequency control* 42(1), 8-14.

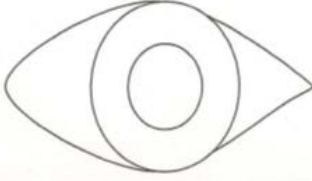
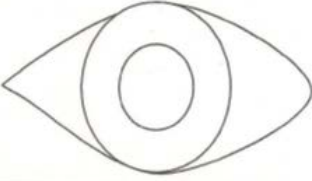

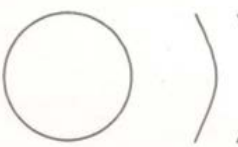
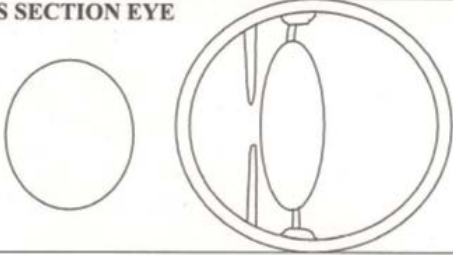
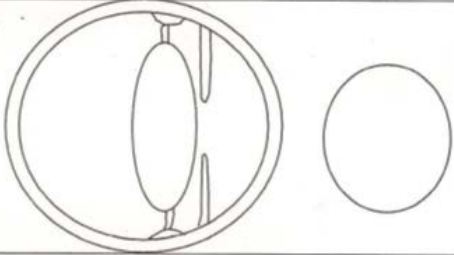

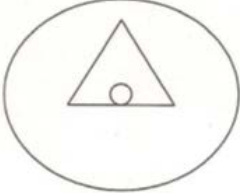


Appendix 3. Examination sheet

Animal: _____ Microchip: _____
 DOB: _____ Place: _____
 Weight: _____ Sex: _____ Date: _____
 Time of sedation: _____
 Schirmer tear test: R _____ L _____ Time: _____
 Tonometry: R _____ L _____ Time: _____

Right eye

Left eye

ADNEXA, CONJUNCTIVA ANTERIOR UVEA 	
CORNEA 	
LENS & CROSS SECTION EYE 	
FUNDUS 	

Biometry:

Axial globe length:
 Axial lens thickness:
 Anterior chamber depth:
 Posterior segment depth
 Other comments:



Appendix 4. Animal Ethics Committee Certificate



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Animal Ethics Committee

PROJECT TITLE	Prevalence of ocular pathology in captive adult cheetahs (<i>Acinonyx jubatus</i>) in South Africa
PROJECT NUMBER	V038-14
RESEARCHER/PRINCIPAL INVESTIGATOR	Dr. CJ Boucher

STUDENT NUMBER (where applicable)	94 288 870
DISSERTATION/THESIS SUBMITTED FOR	MMedVet

ANIMAL SPECIES	Cheetahs (<i>Acinonyx jubatus</i>)	
NUMBER OF ANIMALS	110	
Approval period to use animals for research/testing purposes		June 2014 - September 2016-
SUPERVISOR	Dr. I Venter	

KINDLY NOTE:

Should there be a change in the species or number of animal/s required, or the experimental procedure/s - please submit an amendment form to the UP Animal Ethics Committee for approval before commencing with the experiment

APPROVED	Date	30 June 2014
CHAIRMAN: UP Animal Ethics Committee	Signature	