MEASUREMENT OF THE REFRACTIVE STATE USING STREAK RETINOSCOPY AND THE "SURE SIGHT ™" AUTOREFRACTOR IN DOGS

A DISSERTATION

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"*No technique in daily use by veterinary ophthalmologists has received less written attention than those of refractive studies.*"

Potest Qui Volt

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DEDICATION

This thesis is dedicated to my beloved parents Dr S Sivagurunathan and Saraspathy K Ponniah, whom have been an invaluable pillar of support, shared my goals and have given me the wings to fly.

DECLARATION

I, **Amilan Sivagurunathan**, do hereby declare

that the experiment presented in this dissertation

is an original manuscript.

That neither the work nor part of it

has been, is being or shall be submitted for another degree

at this or any other university or institution for tertiary education .

February 2011

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

WORD	MEANING
Ametropia	Indicates the presence of refractive errors. An eye with a refractive error, generally results from variations in the axial length of the eye or from inadequate or excessive refractive power within the optical components of the eye.
Anisometropia	When the refractive conditions of two eyes are unequal. The anomaly can be associated with the following variations; when one eye is emmetropic and the other ametropic or when both eyes are ametropic with astigmatic variation. The condition is usually congenital.
Astigmatic refractive error	When refracting a non spherical eye both the meridians (vertical and horizontal streak) are neutralised using different lenses. The difference in refractive power in both meridians refers to the presence of astigmatism.
Autorefractor	A computer controlled machine used in an eye examination to provide an objective measurement of the overall refractive state of the eye.
Cycloplegia	It refers to the pharmacological paralysis of accommodation through relaxation of the ciliary body muscle and contraction of the radial iris dilator muscle. It is the mode of action of parasympatholytic drugs on muscarinic receptor sites.
Diopter(D)	The unit of refractive measurements that can be used to determine a positive or negative spherical and cylindrical power of an eye.
Emmetropia	Refers to an eye without refractive errors where normal refraction through the cornea and the lens converges light rays to a point source on the retina. The term *emmetropization* may include a range of values within -0.5D to +0.5D that may minimally influence visual acuity and can be considered as emmetropic.

End Point of Refraction (EPR)	The point on the optical axis, where a lens is able to neutralise a reflex from the far point.
Far Point of refraction (FP)	Is defined as a location in space on the optical axis where an object should be placed in order to maximise the quality of the retinal image.
Meridian	An imaginary line on the surface of a spherical body. A corneal meridian represents the intersection with the corneal surface passing through the apex on the cornea. The two common meridians measured are 90° and 180°.
Neutralisation	When the retinoscope and the examiner are at the far point of refraction, the pupil appears to fill completely with reflected light and no movement of the streak is seen.
Refractive state	Is the measurement of the end point of refraction when the crystalline lens has minimal refractive power. Three general refractive states are emmetropia, myopia and hyperopia (hypermetropia).
Refraction	The bending of light rays as they pass from one medium through another. Used to describe the action of the cornea and lens on light rays as they enter they eye. Also used to describe the determination and measurement of the eye's focusing system by an optometrist or ophthalmologist.
Reliability value	This is a series of values from 1-9 indicated on the top right corner of the WASS autorefractor display. According to the manufacturer's recommendation, only refractive values with a reliability index of 6 and above are considered acceptable.
Streak retinoscopy (SR)	A manual handheld instrument to provide an objective measurement of the overall refractive state of the eye.

SUMMARY

In medical ophthalmology, refractive studies have become an integral part of a complete ophthalmic examination and second only to a slit-lamp biomicroscopic examination in determining visual function and ability. This study shows that the same ideology applies to refractive studies on dogs. The refraction technique has evolved in process, with refinement of the technology and methods used; with the development of handheld autorefractors utilised in paediatric refraction.

Fifty guide dogs completed this study however five of the dogs were subsequently excluded and replaced because of poor compliance. Forty six of the dogs were Labrador Retrievers; one was a Golden Retriever, one a Great Dane cross, one a Labrador cross and one a cross breed. The median sample age was 17months with an interquartile range (IQR) of13 to 34months. We validated the agreement in refractive error measurement between the Welch Allyn™ "SureSight" (WASS) autorefractor to the traditional Welch Allyn™ handheld streak retinoscope (SR) by two experienced investigators, due to previous studies showing variability in measurement for both instruments. The refractive state for 60% of the guide dogs sampled at South African Guide Dogs Association (SAGDA) were emmetropic (-0.5 to +0.5D), 34% were hypermetropic (>+0.5D) with 6% myopic (<-0.5D). For agreement between the instruments, a wide range of differences using mean spherical equivalence (MSE) was observed between the 95% limits of agreement (-1.911D to 1.698D). On average, measurements with the WASS were slightly lower compared to the SR (mean difference = 0.013). Both instruments showed a better average agreement in determining emmetropia with a tendency to underestimate refractive errors for greater negative and positive diopters. The WASS showed better agreement with the SR for refractive error measurement with higher reliability scale values (8 and above). Clinical astigmatism (>-0.5D cylinder) was detected more readily on the WASS (37 dogs) than on the SR (9 dogs). Between investigators the MSE measurements differed significantly (P = 0.02), with the average agreement on the SR slightly better than the WASS.

Overall, the handheld manual streak retinoscope remains the more practical, cost effective and efficient instrument for objective refraction in dogs. We can also conclude, that current subjective criteriae utilised in the selection of guide dogs at SAGA can be further improved by including objective methods of refraction.

Keywords: Refractive state, handheld autorefractor, manual streak retinoscope, South African Guide Dogs,

CHAPTER 1

INTRODUCTION

1.1 Evolution of Retinoscopy

The first objective diagnosis of refractive errors was by a French ophthalmologist Cuignet (1893) by using a simple mirror ophthalmoscope.[1]Through a peep hole in his mirror he observed a curious reflex that varied among persons with differing refractive errors. He attributed his observations on speed, brightness, size and movement of the reflex to the cornea and termed this technique *keratoscopie*. In spite of his error he was able to classify the refractive errors as myopia (short-sightedness), hyperopia (long-sightedness) and astigmatism (toric curved surface). Landolt, a disciple of Cuignet, later proved that the reflex was in fact originating from the fundus.[1] In1878, Mengin published a clear and simple explanation that helped to popularise this novel refractive technique. The term *keratoscopie* was later refined to *retinoscopie* (role of the retina in the reflex), *skiascopie* (meaning shadow) and finally termed retinoscopy, which was still imprecise as the source of the reflex was not the transparent retina.[1]

In 1903, Duane advocated the use of cylindrical lenses for retinoscopy in astigmatism.[1] Landolt's far point theory, which forms the basis for most of our understanding had been challenged by Wolff's observer-pupil theory and Haas's photokinetic theory.[1] Around the turn of the century, Jackson and Wolff emphasised the importance of the linear fundus reflex and value in enhancing it. In 1902, Copeland designed the modern streak retinoscope using a bulb that produced a linear beam of light that was able to be rotated through all ocular meridians and incorporate variable vergence. His design popularised the streak technique and revolutionised refractive studies on man.[2]

1.2 The clinical importance of refraction.

Of the anomalies of the optical state of the eye, refractive errors are by far the most common cause of defective vision in people.[3] In animals, defective vision can most often be masked by their well developed sense of smell and hearing. The initial subtle loss in visual acuity may not dramatically alter a household's pet behaviour, however it may certainly influence the function of an animal destined for high performance, visually orientated activities.[4] For this reason, an early detection screen for reduced visual acuity in high performance animals should ideally be done prior to breeding, purchasing and training.[4] The characteristic feature of reduced visual acuity is its intermittent nature. Small refractive errors forms little or no reliable guide to the ocular condition.[4-6] It is also important to realise that clinical refraction can be of valuable significance when ruling out refractive error as a primary cause of visual failure.[4-6]

1.3 Justification

The question of how well dogs see is more than a matter of intellectual curiosity. This is because a dog's visual capability directly affects its ability to engage in high performance or visually orientated activities.[4] For example, guide dogs that have passed selection are often assumed to have the best visual acuity for the purpose of guiding blind people. The criteria utilised for selection of guide dogs globally is based on strict international guidelines and recommendations in selection and training.[7]Commonly employed breeds for this purpose include Labrador Retrievers, Labrador crosses and Golden Retrievers, German Shepherds and Poodles.

The refractive state of the guide dog population in South Africa (i.e.: short sighted or myopic, long sighted or hyperopic, normal) has never been objectively measured. The South African Guide Dogs Association (SAGDA) utilises mainly Labrador crosses, Labrador Retrievers, Golden Retrievers, Golden Retriever crosses and occasionally a few crossbreeds. These breeds were selected based on the recommendations by the International Guide Dog Federation which include puppy socialisation at 6-9 weeks, obedience training and task-orientated training.[7] The best dogs are selected based on their temperament and performance, to be introduced into their breeding programme.[7] From this study, we would also wish to extrapolate the accuracy of the current process of selection, and to offer an objective method of refractive state measurement for puppies destined for, and within, the guide dog training programme.

The primary goal of this study was to utilise a sample population of dogs which were assumed to be emmetropic (minimal refractive errors), to compare the accuracy and precision of two objective methods of refraction. The first instrument, the Welch Allyn Sure Sight™(WASS; Welch Allyn®) is a new, handheld portable autorefractor utilised in paediatric refraction. The second instrument is a manual handheld streak retinoscope (SR; Welch Allyn®), commonly employed in objective animal refraction studies. The results obtained in this study will describe the refractive state of South African Guide Dogs, by measuring the extent and prevalence of refractive errors within the population. The latter device has been utilised to determine the refractive state of various animal species.[8-12]

The former device is a new, portable autorefractor developed for quick refractive eye measurements in children and has not been applied in refractive eye measurement in animals. When the WASS was clinically evaluated on cyclopleged and non-cyclopleged children, the autorefractor was shown to be less accurate than a conventional tabletop autorefractor and would prove beneficial in clinical refraction of uncooperative infants.[13] Based on a study by Luorno *etal* in 2004, a statistical difference was indicated between the myopic spherical values of the WASS autorefractor on non-cyclopleged children versus cyclopleged retinoscopic refraction.[14]In contrast, positive cylindrical values of 0.5D or more were statistically similar in the above study.

Guide dogs were chosen as a study model based on five primary considerations. Firstly, the importance of using guide dogs as an animal model would make the study of new refractive measurement techniques less biased and accurate, as they are assumed to have the best visual acuity. Secondly, a comprehensive study defining the visual acuity of South African Guide Dogs has never been described before. Thirdly, the use of refractive devices/instruments to determine refractive errors in guide dogs has not been objectively justified as criteria for selection in South Africa. Fourthly, objective conclusions from this study may prove effective in establishing a quick and accurate system to determine an appropriate breed of dog or subject as a guide dog for the blind. Finally, to determine if the current breeding selection criteriae utilised by the South African Guide Dogs Association are sufficiently adequate, on the basis of visual acuity.

CHAPTER 2

2.1 Objectives of the study

1. To critically and objectively determine the refractive state of the guide dog population utilised by SAGDA.

2. To compare two different methods of refractive measurement between two investigators.

   - Streak retinoscopy (manual device) [Model :18245 Welch Allyn^{R}]

   - Sure Sight^{TM} Autorefractor(digital measurement)[Model :14011 Welch Allyn^{R}]

2.2 Benefits arising from this study

1. This project will attempt to determine the refractive state of guide dogs utilised by the South African Guide Dogs Association (SAGDA).

2. The findings of this project will provide objective refractive measurements in guide dogs, and will determine the prevalence of refractive errors within the guide dog population. The conclusions obtained from this study may be used in tandem with current selection criteriae to improve accuracy in selection.

3. The results obtained will determine the precision, accuracy and validity of the WASS autorefractor in objective animal refraction, when compared with the current "gold standard", the SR.

4. The measurement of refractive state using streak retinoscopy (Welch Allyn^{R})(SR) and the "Sure Sight^{TM}" autorefractor (Welch Allyn^{R})(WASS) are not routine procedures used in veterinary ophthalmology, and this project allows the examiners to acquire the necessary skills prior and during this study. This new skill can then be used in routine ophthalmic examinations in other species such as dogs and cats, and can form part of a routine ophthalmologic assessment.

5. The new techniques developed through this study can be employed in objective selection of utility dogs (for example, dogs for the blind, athletic dogs, police dogs, working class dogs) on the basis of visual acuity before initiating training.

6. This project will form part of the research requirements of Dr A Sivagurunathan's MMedVet (Ophthal) degree.

2.3 Hypothesis

Based on the current criteriae used by the Guide Dog Association in the selection of potential candidates, it would be reasonable to assume that the guide dogs are emmetropic [has minimal refractive errors]. This belief is contrary to a study done by Murphy *et al* .[9]

CHAPTER 3

LITERATURE REVIEW

3.1 Historical background

Interest in accommodation and myopia stems from a widespread, controversial history of research into the effect of visual environment on, refractive development of the eye in people, initiated by Donders and Von Helmholtz.[15,16] In large measure, this interest has grown from progressive and common appearance of myopia in children, to the debilitating effect of even modest levels of myopia on visual acuity.[17]

In the field of veterinary science, the use of refractive measurement has only sustained interest in the last 20 years, through the implementation of intraocular lenses (IOL's) in phacoemulsification surgery. Furthermore, the criteria used in the selection of breeding gundogs and working dogs has been regarded as acceptable until recently, where certain breeds of dogs were classified as tending to myopia.[18] From literature concerning ametropias (any form of abnormal refractive power of the eye) in mammals, it is apparent that their effects are largely, if not entirely due to axial change in eye size.[17] At some level the cornea may be responsible for some of the refractive error induced, as in the case of longer periods of form deprivation (i.e. a diffuser was placed on the eye in early development to obliterate vision, which resulted in elongation in the axial length of the eye, myopia) in guinea pigs and in the development of astigmatism in monkeys.[19,20] In various animal models, the visual environment was found to exert an influence on the refractive development of the eye.[17,21] It is widely considered, and it is likely, that both genetics and environment are responsible for the control of eye refractive development.[21]

The traditional gold standard for the determination of refractive error in pre-school children is retinoscopy, using the streak retinoscope (SR). The SR is the most commonly employed instrument, in measuring the refractive state of animal eyes.[8-12] The principle of retinoscopy is based on two assumptions.[3,5,8] First, that light emerging from the eye (i.e. emergent rays) follows the same optical path as the light entering the eye. Secondly, that the fundus reflex originates at the outer level segments. If the two assumptions hold, then emergent rays exit an emmetropic (normal) eye as parallel rays, hypermetropic (long sighted) eye as divergent rays and a myopic (short sighted) eye as converging rays.[5,8] Therefore, the location of the focal point formed by the emergent rays can be used to determine the refractive state of the eye.[5,8] Although retinoscopy has been the “gold standard” in the objective refraction of an animal's eye, it is subject to interobserver variability.[22] Accuracy and reliability in measurement using retinoscopy requires a trained professional and the ability to keep the patient's head steady for long enough to obtain accurate data. The difficulties with retinoscopy in pre-school children have led to the development of objective autorefractors that can be free of operator bias and can be used by lay individuals. One such autorefractor is the Sure Sight™ (WASS; Welch Allyn®).

Most autorefractors currently in use are based on well-known optical principles such as Streak retinoscopy, the Scheiner method or the knife-edge principle.[6,23] Over the last 40 years, these autorefractors have reached a high standard of perfection. The optical construction was further simplified by incorporating modern computer and video technology, increasing the speed and accuracy of measurement without changing the underlying optical principles.[23] We believe that the use of refractive measurements will prove clinically advantageous in the selection of utility breeds based on the principles of refractive state measurements, before initiating training.

3.2 Optics and refraction

The cornea is a transparent, avascular, non-pigmented extension of the fibrous tunic of the globe. The cornea supports the intraocular contents of the eye, and is responsible for 70% of the total refraction of the canine eye (average 43 D).[5]The cornea constitutes 17% of the relative area of the globe.[5]Corneal thickness varies from species to species and from breed to breed. In the dog, the corneal thickness averages 0.45-0.55mm centrally and from 0.50-0.65mm at the periphery. [24] Refraction by the eye therefore, effectively takes place at two structures, the anterior corneal surface and the lens, with the former contributing to the majority of the refraction.[3,6,25]

The optics of the eye can best be understood in terms of the optical characteristics of its components, the cornea, pupil, crystalline lens, and retina, and how they function in combination. The discipline of optical testing is devoted to measuring the aberrations of an existing optical system (cornea, lens, and pupil). Optical testing can be quite complicated, due to the range of factors involved that may influence the optics of a light wave front.

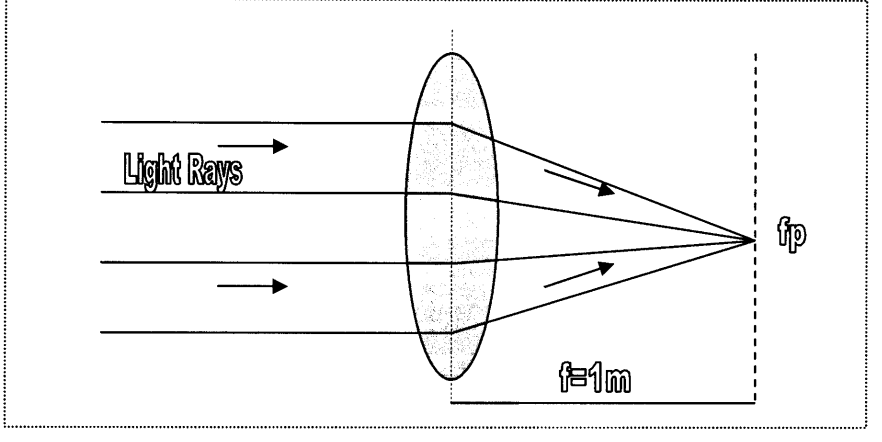


Figure 3.1. A Positive Vergence with a focal length of a 1 dioptre (D) lens; f= focal length/distance; fp= Far point

Diopter (D) measures vergence. According to the wave theory of light, light travels along a wavefront consisting of ray's perpendicular to its surface. Natural light sources emit rays that are *diverging*; which we can call *negative vergence*. The use of a convex lens converges the rays exiting the light source. This is called *positive vergence* as shown in **Figure 3.1**. The curvature of the wavefront determines vergence; this is measured in diopter (D).The greater the curvature, the greater the degree of refraction which increases the dioptric value. Hence we can objectively measure the curvature in diopter (D).[3]

Secondly, a diopter (D) is inversely proportional to the distance ie; focal length (f) and can be used to describe vergence. Positive vergence (convergence) has a positive diopter while negative vergence (divergence) has a negative diopter. Hence distance can be measured in diopter (D) ie; a positive vergence of 4 D is 0.25m.[3]

Thirdly, diopter's (D) measure lens power and the ability of the lens to bend light. When we consider the concept of positive vergence, the greater the positive diopter (D), the greater will be the vergence and lens power. The opposite occurs with negative vergence. The greater the negative vergence, the greater will be the negative diopter (D), hence a weaker lens power.[3]

3.3 Refractive errors

The refractive error of an eye is measured from the outside because we are unable to measure the power of the eye from within. In retinoscopy, we use the reversibility of conjugate points in visual optics when we illuminate the retina and locate the far point (FP).[3]This object point is used to determine the end point of refraction (EPR). The diopter (D) lens required to verge an ametropic eye, from the FP to the EPR, where neutralisation is reached is termed the refractive error. An average series of refractive error measurements determines the refractive state of an eye.[3]

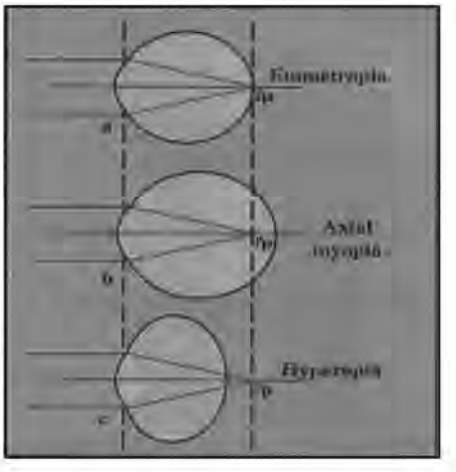
Refractive state is the measurement of the overall refractive ability of the eye. The refractive state of a subject is measured in diopter (D) and can be described as emmetropic (normal, 0 diopter), myopic (short sighted, negative diopter) or hyperopic (long sighted, positive diopter). In clinical animal refractive studies, emmetropia can also be referred to a range of values (-0.5D to 0.5D).

Figure 3.2. A diagram illustrating normal refraction (emmetropia) and abnormal refraction (ametropia) of the eye.

a. Emmetropia

b. Myopia

c. Hyperopia



Emmetropia can be defined as the absence of refractive error or the refractive state for a value or a range of dioptric values that does not produce refractive errors. In terms of visual optics, parallel rays from infinity focus on the fovea, hence the FP of an emmetropic eye is at infinity. Emmetropization is the cooperation of components of the eye (cornea, chamber depth, lens power and axial length) to achieve a higher than expected incidence of emmetropia and lower hyperopia, during the infantile growth of the eye.[3]

Myopia refers to an excessive refractive power with the FP point somewhere between the eye and infinity. It can also be defined as an increase in the axial length of the eye, as a result of lengthening of the posterior segment. This definition can be further subcategorized into physiological and pathological myopia. The term pathological myopia is used specifically in the presence of corneal, choroidal and retinal degenerative changes leading to impaired vision. Physiological myopia is a normal physiological response to the enlargement of the globe, causing the focal beam from distant objects to land before the retina giving the observer a blurred image.[3]

Hyperopia refers to a deficient refractive power that has inadequate positive vergence or plus power. Consequently it can be defined as a shorter than normal axial length, resulting in the inability to focus on a near object. The FP point is beyond infinity. The image is focused behind the retina giving the observer a blurred image.[3]

Ametropia refers to all forms of refractive errors where the FP point is not at infinity (myopia, hyperopia, astigmatism). Ametropias may arise from any of the following:-

- Variations in the axial length of an eye.
- Errors in the curvature of refractive surfaces (astigmatism).
- Variations in indices of refraction
- Shift in the location of the lens.
- Any combinations of the above

Hence ametropia needs a conjugate lens to return the FP to infinity. It is common in the clinical realm to refer to ametropias as either axial or refractive.[3] That is, refractive errors can be the result of an eye that is too long or too short, or the result of an excess or insufficiency in corneal and/or lens refractive powers. In general, research on animal models of ametropia have shown the influence of environment on development and change in the size of the eye.[26,27]

Astigmatism is most often caused by a toric cornea where the radius of curvature at all meridian's are not the same; that is, they are not spherical. Furthermore, the astigmatic effects of the crystalline lens can be subcategorized as regular or irregular. Regular astigmatism is termed "with the rule" or when the steepest corneal meridian is close to 90°and "against the rule "when the steepest meridian is close to 180°. When astigmatism is regular but the principal meridians do not lie close to 90° or 180°, the astigmatism is called oblique.[3] Each of the principle meridians applies a different vergence, which creates two principal focal points in the eye. The principal meridians in astigmatism may be myopic, hyperopic or mixed. "Simple" is a term used when one meridian ie 90° is emmetropic and another, 180° is ametropic. "Compound" is used when both meridians have the same astigmatic error. In general, the end points of refraction will not be same for all meridians of the cornea. The special case of where the refraction in all meridians is the same, is called "spherical" refraction. Where the end points are different for different meridians, the refraction is "astigmatic".

3.4 The nature and incidence of refractive errors

The incidence of refractive errors gives us insight into their biological nature. Steiger, who first studied this subject scientifically by determining the incidence of the spherical refraction in large numbers of people, concluded that hypermetropia, emmetropia and myopia were not separate entities but formed a single series around a common mean; such as the case in physiological variations in height. In young children undergoing objective refraction, it was suggested that an error of 1D spherical may be common due to poor co-operation and restlessness. This is often confirmed with subjective refraction, where an experienced ophthalmologist can rather refract human patients to an accuracy of 0.25D.[28] Because subjective refraction cannot be performed in animals, the accuracy of streak retinoscopy (SR) is difficult to determine with certainty. A goal of 0.5D around the actual refractive state was defined as a reasonable limit for clinical refraction on the SR.[8] Based on this guideline, a subject is considered emmetropic within the range of +0.5D and -0.5D.

Dogs' visual sensitivity in reduced levels of light are quite high and they have relatively good visual acuity under those circumstances.[4] In a survey done on 240 dogs by Murphy *et al*, it was found that the average resting refractive state was within 0.27 diopter of emmetropia.[9] There were individuals in this population that were significantly myopic and there was a greater tendency towards development of myopia with greater age and with the development of nuclear sclerosis.[9]This mild shift in the resting focus of the eye needs to be differentiated from age related presbyopia (loss of focusing or accommodative ability).[4]

In a study by Kubai *et al*, the prevalence and degree of presbyopia in dogs was shown to increase with increasing age across all breeds with a tendency from hyperopia to myopia.[29]In the same study, astigmatism was found to be present in 1% of the adult population of dogs examined, with German Shepherd dogs showing the highest prevalence of astigmatism (3%) and anisometropia (8.9%).[29]

Furthermore, breed predispositions to myopia were found in 53% of German Shepherds and 64% of Rottweilers (myopic of > -0.5 diopter).[9]This study was done at Guide Dogs for the Blind (San Rafael, CA). In another study, myopia in Labrador Retrievers was found to be analogous to human myopia in that it is caused by an elongated vitreous chamber.[18] Of 75 dogs tested 14% were myopic (by at least -0.5D in one eye) and 8% were myopic in both eyes.[18]

Myopia may be induced in various animal species, either by deprivation of form, by optical defocus by the application of negative powered lenses, or by inheritance. Myopia was previously considered to be associated with retinal detachment and skeletal abnormalities.[30] Although the Labrador Retriever is emmetropic on average, naturally occurring vitreal chamber-based myopia was present in a cohort group studied and was shown not to be influenced by excessive crystalline lens or corneal power.[18] The eyes were considered clinically emmetropic when refractive errors measured between -0.5D and +0.5D and when astigmatism was defined as >0.5D difference between refractive errors of the vertical and horizontal meridian for each eye.[28]

It is obvious, therefore, that we cannot consider refraction as a whole, without careful observations of the various component elements which combine to determine the optical system of the eye. Hence, to accurately determine the optical system of an eye, accurate measurement of corneal curvature, axial length of the globe and refractive optics are required. In this study we focus purely on the third component of the optical system to compare the accuracy and precision of the autorefractor.

3.5 Refractive measurement using a streak retinoscope (Model 18245 Welch Allyn^{R})

The retinoscope was invented by ophthalmologist Jack Copeland. The original spot retinoscope has been refined to the modern streak retinoscope.[8] A streak retinoscope is an instrument used to objectively determine the refractive power of the eye. Retinoscopy is a technique to obtain an objective measurement of the refractive state or dioptric power of a patient's eyes and is most accurately done at a fixed distance of 66cm.[8] The technique has been used to define; normal, pathological and surgically induced refractive state of eyes in dogs and numerous other domestic, laboratory and exotic animal species and is considered the "gold standard" in objective refraction.[8-12]

Retinoscopy is performed in a semi-darkened examination room with an assistant steadying the animals head to line its gaze with the examiner.[8]The examiner uses a retinoscope to project a divergent beam of light into the animal's eye and observes the reflection off the subject's retina. This reflex observation requires interpretation by a skilled retinoscopist. While moving the streak or spot of light across the pupil, the examiner observes the relative movement of the reflex, then uses a phoropter (an instrument comprising a series of ophthalmic lenses) or manually places a series of negative or positive lenses over the eye to "neutralize" the reflex.[3,6] Retinoscopy is especially useful in prescribing corrective lenses for patients who are unable to undergo a subjective refraction that requires a judgement and response from the patient. It is also used to evaluate accommodative ability of the eye and detect latent hyperopia. The retinoscope works on a principle called Foucault's principle.[3,6] Basically, it indicates that the examiner should simulate the infinity to obtain the correct refractive power. Hence, a power corresponding to the working distance is subtracted from the gross retinoscope value. Retinoscopy can be subcategorised into dynamic and static retinoscopy.[3,6] Static retinoscopy is performed when the patient has relaxed accommodative status while viewing a distant target. Dynamic retinoscopy is performed when the patient has active accommodation from viewing a near target (ie; without the use of cycloplegia). For the purpose of this study, we will be utilising this technique of dynamic retinoscopy for our refractive measurements.

The meridian is a perpendicular line that an investigator moves the streak along. The axis depends on whether we are using plus-cylinder or minus-cylinder. If the investgator is using plus-cylinder, the axis is 90^{o} from the meridian that the investigator is streaking. However, if the investigator is using minus-cylinder, the axis is the same as the meridian that the investigator is streaking. When performing retinoscopy, if the investigator selects the axis (or the cylinder) at 180^{o}, it refers to detecting astigmatism when streaking the 180^{o} meridian. The actual axis designation (180^{o} or 90^{o}) will depend on whether an investigator is using a plus-cylinder or minus-cylinder.

When using a streak retinoscope, there are several features that aid in making the determination of the refractive state of the eye more accurate, versus the traditional spot retinoscope. These are:

1. Each meridian can be neutralised separately.
2. All errors can be neutralised using either "with" or "against" motion or perhaps using both.
3. The axis of astigmatism is much more apparent versus the spot retinoscope.
4. Streak retinoscopy requires a restrained patient and less time versus the spot retinoscope.
5. Streak retinoscopy can be utilised in patients with non-dilated pupils.

With no lenses between the patient and the streak retinoscope there are three possible initial reflexes that may be observed;

1. "With Motion", where the motion of the reflex is in the same direction with the streak motion. The patient could be hyperopic, emmetropic or less myopic than the dioptric value of the distance. As the streak moves across the pupil, the reflex moves across the pupil in the same direction as the streak.

2. "Neutralization", occurs when the patient's myopia is equivalent to the dioptric value of the working distance. Once the streak touches the pupil, the pupil lights up and remains constant as the streak moves across the pupil.

3. "Against Motion", where the motion of the reflex is in the opposite direction of the streak movement. The patient's myopia is greater than the dioptric value of the working distance. As the streak moves across the pupil, the reflex moves in the opposite direction as the streak.

To identify astigmatism during streak retinoscopy, you will first need to determine neutralization along each of the horizontal and vertical axis meridians. Astigmatism will be present in the following situations:

1. Streaking one meridian gives you with-motion or against-motion, and streaking the meridian 90 degrees away gives you a neutral reflex.
2. Streaking one meridian gives you against- motion, and streaking the meridian 90 degrees away gives you with- motion.
3. Streaking one meridian gives you with-motion (or against- motion) with a wide streak reflex, and streaking the meridian 90 degrees away gives you the same motion

Figure 3.3. A set of spherical lenses of luneau in a retinoscopy rack. The red rack represents negative spherical lenses (divergent). The black rack represents positive spherical lenses (convergent). These lenses have an accuracy of 0.5D.

Figure 3.4. This set of positive and negative spherical lenses were used concurrently with the lens rack in Fig 1.6 to improve the accuracy of streak retinoscopy measurement to 0.25D.

3.6 Refractive measurement using the "Sure Sight^{TM}" Autorefractor (Model 14011 Welch Allyn^{R})- WASS

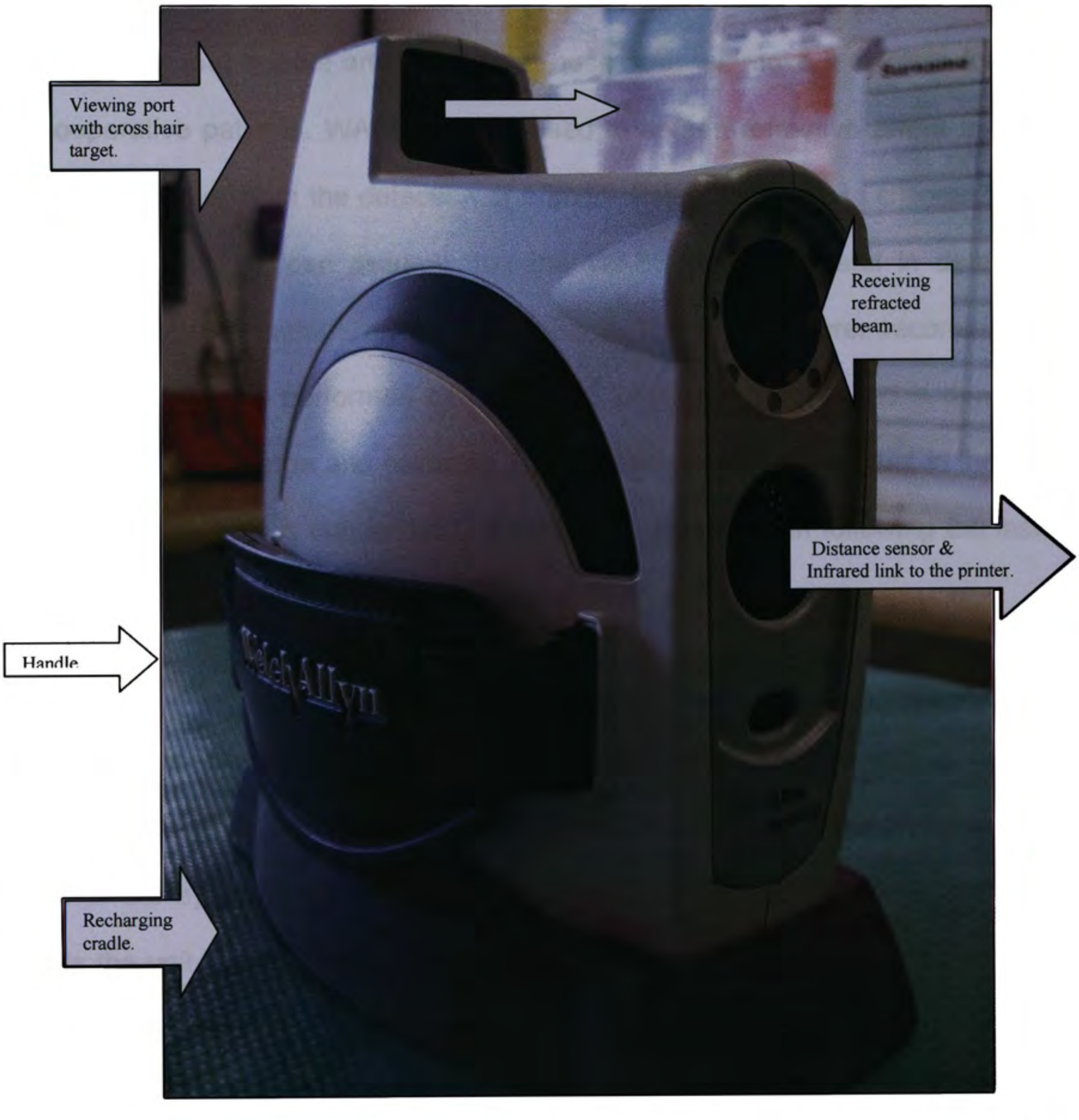


Figure 3.5. The front view of the Welch Allyn^{TM} "Sure Sight" autorefractor (WASS).

An autorefractor is an instrument that determines the refractive state of the eye by monitoring the retinal image, rather than requiring interpretation of the image by a clinician. The first autorefractor based on the principle of wavefront analysis is the WASS.[31] It is small, light, portable, measures and records data quickly and can be handheld without a table and chin rest. These features make it suitable for measuring uncooperative patients. WASS is often used to screen refractive errors in people and has been employed in the detection of primary vision disorders in children.[31] Based on this observation we can assume that the WASS may be useful in determining the refractive state of various animal populations. The manufacturer recommends that a calibration check be performed on the WASS prior to refraction and is done on a nest that functions to charge and calibrate. Prior to calibration, all switches in the device are turned off. The nest is connected to a computer, and through following the instructions on the software the device can be calibrated.[31]

Based on the Hartman- Shack wavefront analyzer technique, light is sent from an illumination source inside the Sure Sight through a beam splitter and focuses on the back of the eye (retina).[31] The retina, in turn, reflects the light back into the device. Inside the unit, the beam travels through a series of mirrors and is received by a micro-lens array, creating an image which is sent to a CCD camera. The spot pattern of light formed is translated into sphere, cylinder, and axis.[31]

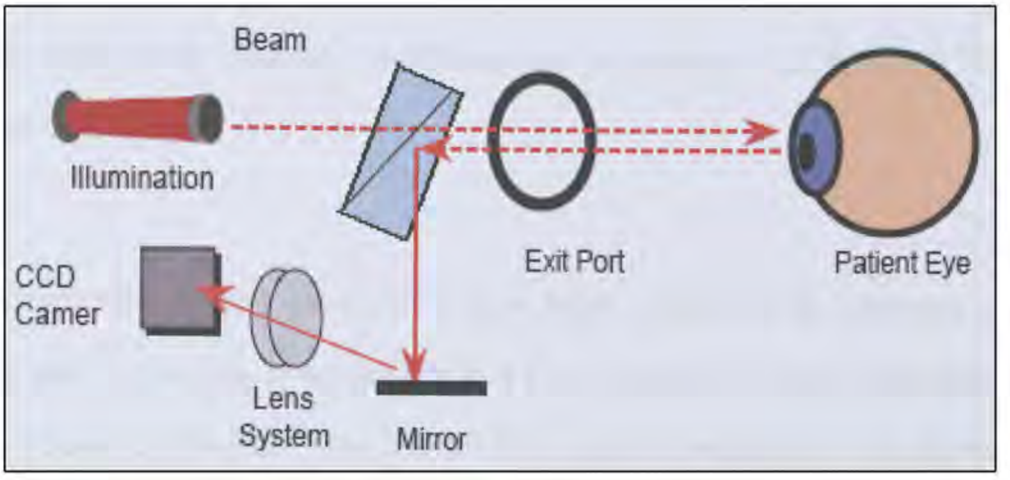


Figure 3.6. Diagram representing the optics utilised by WASS autorefractor, based on the Hartman- Shack Technique. The CCD camera and lens array system forms part of the Hartman- Shack sensor.

During measurement, the WASS presents auditory alignment cues for objectively determining the refractive error at a working distance of 35cm (14 inches). The measurement range according to manufactures specifications is within -5 D to +6 D spheres and 3D for cylinders. There are no specifications concerning minimal required pupil diameter. The instrument measures and averages 5-8 readings per eye. Following which, the results (spheres, cylinders, axis) are displayed on the instrument screen, as illustrated in **Figure 3.9**. A circle of flashing lights around the optics of the patient side of the instrument, is used to maintain fixation in people. Data acquisition time is between 5 to 10 seconds for two eyes. A digital reliability scale on the side of the screen from 1 to 9 indicates the confidence level of this printed measurement. The manufacturer recommends that only reliability scale values of 6 and above to be accepted and recorded. When the refractive values acquired are out of the measurement range on the WASS, the screen displays a -9.99 sphere for severe myopia or +9.99 sphere for severe hyperopia.

The illumination system generates a laser beam which can be projected into the eye under test. The source of illumination is a 5 mW electrical, 3 mW optical semiconductor laser located on the laser mini board.[31]This board is attached to the illumination tube, which houses the optics needed to collect the light emitted by the laser and form it into a beam, which is projected from the end opposite the laser. The drive system monitors the laser output with a photodiode which is physically built into the laser diode. The laser drive system controls the laser output to a particular photodiode level which is set by the DSP board.

Because the laser is invisible, it cannot be used for aligning. Instead, the viewing system produces a visible crosshair target which is aligned so as to be in the same position as the invisible laser beam at the in-range working distance.[31]

The measurement system detects the beam reflected from the patient's eye back toward the unit. This beam enters the product through the one inch port on the front of the unit and is reflected down toward the bottom of the unit by the reflecting side of the beam splitter. This beam passes through a first conjugate lens, to two measurement mirrors, which bend the beam across the bottom of the unit and back up toward the top, where it passes through a second conjugate lens, in to the camera/lenslet assembly. The camera/lenslet assembly consists of the camera board with a lenslet filter mounted to the top of it by a lenslet housing. When the beam passes through this lenslet and IR filter, a group of spots are created, which represent the optics of the eye from which the beam came. If a sufficient number and quality spot pattern images are detected, the DSP computes and reports a reading of the optical power detected. **Figure 3.7A** and **Figure 3.7B** below illustrates two spot pattern images received though the CCD camera.

Figure 3.7A. Emmetropic Eye 0.00 Diopter spot pattern of light is uniform.

Figure 3.7B. Hyperopic Eye +4.24 Diopter spot pattern of light is compacted.

There are two modes for measuring refraction: an adult mode for all cycloplegic measurements and to manifest refraction in adults and children over six years. The child mode is indicated for children aged six or younger. In this mode a constant value of +2.5D is added to the sphere result. This constant correction factor is supposed to compensate for a child focusing on the instrument while positioned 35cm (14 inches) away. For the purpose of this study all eyes refracted with WASS were set on the adult mode.

Figure 3.8. The control toggle indicating the option for adult and child mode on the WASS .

Figure 3.9. Sphero-cylindrical values and axis of astigmatism recorded on the display. The reliability scale value for each eye is displayed on the top right corner as in this figure eg; 4 (right eye), 5 (left eye).

3.7 The effect of cycloplegia on the measurement of refractive errors

The use of cycloplegic agents is routinely adopted to determine the "true" manifestation of refractive errors especially in infants and children. The concept of pharmaceutical paralysis on accommodation is often necessary to relax the habitual accommodative posture in young hyperopes.[32]However, the amount of cycloplegia required to accomplish this has often been debated in literature. Due to the range in activity of various cycloplegic drugs, the use of shorter acting cycloplegic drugs is generally preferred for the purpose of an eye examination.[32]

The ideal cycloplegic agent for clinical and research based studies should reveal the full amount of hyperopia, remove bias due to accommodation of the crystalline lens, remove detrimental effects of accommodation on measurement repeatability, should facilitate testing through a rapid onset of cycloplegic effect and minimize the burden to the subject by limiting the duration of effect and have a high margin of safety.[32]

1% Cyclopentolate (Cyclogel) is probably the most common cycloplegic agent used in the examination of children, providing duration of effect of about an hour. [33]1% Tropicamide (Mydriacyl) is a reputedly weak cycloplegic agent, with a maximum cycloplegic effect at twenty minutes and dissipates within two to six hours.[34]It is at most only recommended for repeated cycloplegic refractions; more often its use is discouraged in pediatric ophthalmology.[35] Based on a study on the effect of cycloplegia on measurement of ocular components by Mutti *et al* they concluded that the effects seen with topical 1% Tropicamide were very similar to that of 1% Cyclopentolate.[32] Although 1% Tropicamide had the tendency of giving a marginally higher dioptric lens power, the bias was nearly equal to the average difference in residual accommodation between the two agents regardless of the method used to measure it.[33] Based on a study by Zadnik *et al* with attention to the repeatability of measurement of ocular components, the most reliable measure of refractive error was autorefraction (Cannon R-1 autorefractor) with cycloplegia, with 95%limits of agreement of +0.32 D.[22] Cycloplegic autorefraction had no statistically significant bias compared to cycloplegic subjective refraction.[22]

For the purpose of this study, non cycloplegic refraction (dynamic retinoscopy) will be measured, based on the manufacturer's recommendation for non cycloplegic refraction with the WASS. Furthermore, the limited accommodative range of dogs as described by Miller *et al*, generally does not exceed 2-3 D.[4] Based on this assumption, the limited range in accommodation should not significantly influence the refractive errors measured.

CHAPTER 4

MATERIALS AND METHODS

4.1 Experiment Model/Subject selection

The model system was based on a cross-sectional study to determine the refractive state of a sample population of guide dogs at SAGA. The subjects were refracted by two experienced investigators, using non cycloplegic refraction. This was performed through a series of planned visits to their premise in Johannesburg.

The subject group consisted of one hundred (100) normal eyes from fifty (50) healthy guide dogs, with normal ophthalmic findings from the age of 8 months to 6 years. To ensure this, both eyes of each dog were screened for ocular abnormalities with a handheld slit-lamp biomicroscope (Carl Zeiss HMNO 100: Germany) and a binocular indirect ophthalmoscope (Heine Omega 200: Hershing, Germany) prior to refractive measurement.

The breed and age of dogs included in this study were limited by availability, during the days of investigation as a result of ongoing puppy socialisation, training programmes and guide service duty. This study included Labrador Retrievers, Labrador crosses, Golden Retriever crosses and cross breeds.

We could not include a comprehensive study on the influence of age related conditions (ie; developmental myopia in young dogs and sclerosis in senior dogs) due to the skewed young population available for refraction at SAGA. The investigators were also limited by the number of available dogs in each age group (puppy, adult, senior), hence subjective analysis of age and breed influences will not be conclusive in this study.

4.2 Experimental design

Healthy dogs without ophthalmologic findings were included in this study. The accuracy and precision of the WASS to the SR were compared using non cycloplegic refraction, performed by two experienced investigators. The subjects were presented randomly to each investigator at two separate stations under ambient light conditions with the assistance of a guide dog handler.

For each dog, a microchip was scanned to confirm their identification. With each investigator there was no specific order in the use of WASS or SR, while the guide dog handler assisted in keeping the head steady (**Figure 4.1**). 2 dogs were refracted at the same time at 2 different stations. Both investigators would swap stations once the measurements from both instruments were recorded.

All procedures were approved by the ethics review committee from the University of Pretoria, South Africa. Informed consent was obtained from the director of the facility for the dogs participating in this study (**Appendix 2**).

4.3 Optometric measurements.

When the WASS was used, the manufacturer's recommendation for non cycloplegic autorefraction on the subject group was adopted. Both investigators held the instrument approximately 35cm (14 inches) from the dog, guided by the distance sensor through toned beeps. The instrument automatically takes five to eight readings per eye before reporting a composite refraction that is determined by the manufacturer's algorithm.

For the purpose of this study, we set the instrument on adult mode. We followed the manufacturer's recommendation to record values with a reliability scale of 6, 7, 8, or 9 (higher numbers signifying greater reliability). Ideally, reliability values below 6 should be discarded and re-measured. In cases where repeated low reliability values were obtained in some subjects, the highest possible reliability value and measurement were recorded.

Figure 4.1. Illustrates the technique of auto refraction.

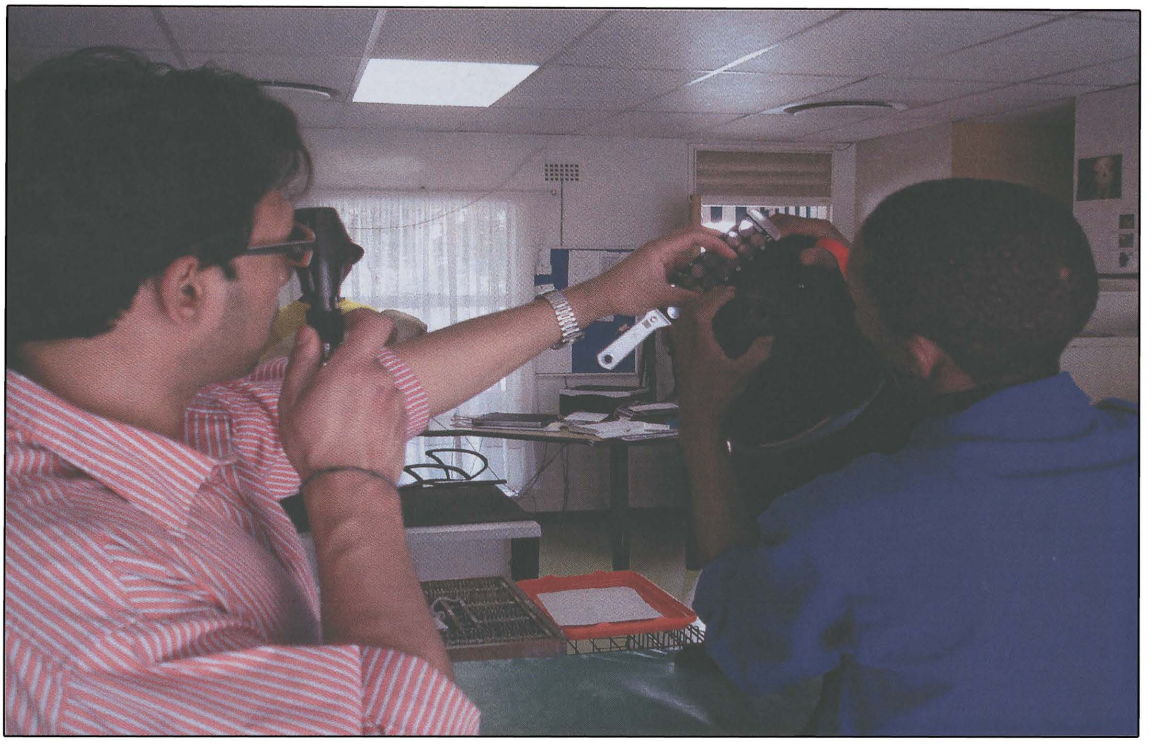


Figure 4.2. Illustrates the technique of retinoscopic refraction by the first investigator and was performed at a fixed distance of 66cm. The dogs were restraint with the help of guide dog handlers.

Figure 4.3. Illustrates the technique of retinoscopic refraction by the second investigator and was performed at a fixed distance of 66cm. The dogs were restrained with the help of guide dog handlers.

For the SR, non cycloplegic refraction were measured at a distance of 66cm, and maintained by a marked string tied from the handle of the retinoscope to a ring placed on the investigator's other thumb which was being used to keep the eyelids open. The string was kept taut to maintain the distance. A series of negative and positive spherical lenses (luneau retinoscopy rack & box of spherical lenses) were placed in front of the eye with both the vertical streak axis (180^{o}) and horizontal streak axis (90^{o}) measured. Lenses that failed to neutralise the refractive error were replaced with the next lens in series and re-evaluated. The end point of refraction in diopter was identified for each eye at neutralisation, to an accuracy of 0.25D. Refractive results with both instruments were recorded on data sheets (**Appendix 1**). The entire procedure was repeated by the second investigator. To minimise the influence of bias, both instruments (ie; SR and WASS) were alternately used as the first refractive instrument of measure.

4.4 Observations

Besides the data collected about the subject as detailed on the patient form (**Appendix 1**), non-cooperative subjects and those identified with ocular abnormalities were removed from the study group and replaced. Both investigators experienced the same difficulty in refracting the subjects. Their hyperactive nature and young age of the subject population resulted in most of the subjects being easily distracted. The restraint offered by guide dog handlers made the measurements possible but not any easier.

4.3 Statistical analysis

The data was entered into a spreadsheet and then analysed using Stata 11.1 statistical software (StataCorp, College Station, TX, U.S.A.) The data was divided into 3 main groups (sphere, cylinder and spherical equivalence).

The mean spherical equivalent (MSE) is the spherical power whose focal point coincides with the circle of least confusion of a sphero-cylindrical lens. Hence, the spherical equivalent of a prescription is equal to the algebraic sum of the value of the sphere and half the cylindrical value, i.e. sphere + cylinder/2. The mean spherical equivalence and spherical values for each instrument were then used to assess between instruments and between investigators.

Medians and interquartile ranges were calculated for sphere, cylindrical and MSE values, and medians were compared between instruments and between investigators using the Wilcoxon matched-pairs signed-ranks test. To assess agreement between instruments and between investigators, scatterplots were generated and Lin's concordance correlation coefficient was calculated.[36]This combines measures of both precision and accuracy to determine how far the observed data deviate from the line of perfect concordance (i.e., the line at 45 degrees on a square scatterplot). Lin's coefficient (r_c) is a function of the nearness of the data's reduced major axis to the line of perfect concordance (the accuracy of the data) and of the tightness of the data about its reduced major axis (the precision of the data). It is the product of the Pearson correlation coefficient (*r*, the measure of precision) and a bias correction factor (C_b, the measure of accuracy). Agreement was also assessed by calculating the mean difference between pairs of measurements and Bland and Altman's 95% limits-of-agreement.[37] The concordance correlation coefficient and limits of agreement were calculated for five subsets of the data: firstly using all observations (i.e., no restriction on reliability scale value); then separately for each investigator; for WASS measurements with the recommended reliability scale value = 6 or greater; and for WASS measurements with a high reliability scale value (8 or greater).

CHAPTER 5

5.0 RESULTS

5.1 Results

Fifty guide dogs completed the study however five of the dogs were subsequently excluded and replaced because of poor compliance. Forty six of the dogs were Labrador Retrievers; one was a Golden Retriever, one a Great Dane cross, one a Labrador cross and one a cross breed. From the data tabulated in **Appendix 2**, we were able to compare 200 pairs of refractive error measurements for spheres and cylinders between two instruments and two investigators. The age of the subjects ranged from 6 to 135 months with an interquartile range (IQR) from 13 to 34 months (median 17 months) illustrated in **Figure 5.1**.

Refractive state of the guide dog population in South Africa

To determine the refractive state of the guide dog population, spherical values tabulated from the SR (ie; average of the horizontal and vertical meridian value); by both investigators were used.

The median refractive error for all dogs was within the range of emmetropia (+0.5D). Labrador retrievers, which was the breed with the largest representation in the sample (46/50), were on average emmetropic (mean 0.48D; median 0.5D, IQR 0D to 1.5D).

Thirty dogs (60%) from the sample were within the range of emmetropia (-0.5D to +0.5D). Seventeen (34%) dogs were hypermetropic (>+0.5D) and three (6%) dogs were myopic (<-0.5D) (**Table 1 & Figure 5.2)**. Furthermore, there was a positive agreement (tendency away from myopia) between the age and spherical values on SR, illustrated in **Figure 5.1**.

When MSE on SR for the left and right eyes were compared, there were 24 occasions (out of 100) on which one or both investigators obtained different results for left and right eyes (anisometropia); representing 20/50 (40%) of the dogs studied. This included 4 dogs (8%) where both investigators found anisometropia.

Comparing astigmatism observed with the WASS and SR.

In this study, we set the limit of clinical astigmatism for values greater (more negative) than -0.5D. With the WASS, astigmatism was observed in 100% of dogs refracted. When we consider the distribution of negative cylindrical values observed, 95% were equal or greater (more negative) than -0.50D, with 37(75%) of the 50 dogs with values greater than -0.75D. In **Table 2** the median cylindrical value observed was -1D with an IQR range of -1.25D to -0.75D. On SR, astigmatism was observed in 9 (18%) of 50 dogs refracted. 25% of the negative cylindrical values were equal or greater (more negative) than -0.5D. The median cylindrical value on SR was 0 D with an IQR range of -0.50D to -0.00D.

Agreement between the WASS and the SR using sphere and MSE

The sphere and mean spherical equivalence (MSE) values obtained using the two instruments for all 200 paired observations are shown in **Table 2**. Sphere values obtained with the WASS (median 0.75 D; IQR 0.5D to 1.5D) were significantly more positive than those obtained using SR (median 0.5 D; IQR 0.0D to 1.5D) ($P < 0.001$). However, the MSE values did not differ significantly between instruments ($P = 0.152$), although the values of the WASS (median 0.38 D; IQR -0.25D to 1.06D) were slightly less positive than the SR (median 0.5 D; IQR 0.0D to 1.5D).

Figure 5.3 shows the agreement between the two instruments by plotting the difference between each pair of measurements against their mean. A wide range of differences was observed between the 95% limits of agreement (-1.911D to 1.698D). On average, measurements obtained with the WASS were slightly lower than the SR (mean difference = -0.106D). The slope in the graph, representing bias in the agreement between instruments, shows that within the range of emmetropia (-0.5D to 0.5D) the average agreement was better (mean difference was closer to zero). On the negative side of emmetropia, the WASS values tended to be more positive, i.e. underestimating refractive error relative to SR. On the positive side of emmetropia, the WASS values tended to be less positive, i.e. again underestimating refractive error relative to SR.

Effect of investigator on agreement between instruments

Table 3 shows the concordance (Lin's coefficient and limits of agreement) between the two instruments for the various subsets of data analysed. There were 132 (66%) paired observations where the WASS measurement had a reliability value of 6 or greater and only 21 (10.5%) pairs with a reliability value of 8 or greater. When we compared reliability values of 6 and greater to all observations, the precision (r = 0.632) and accuracy (C_b = 0.992) in agreement only improved slightly. When we compared reliability values of 8 and greater to all observations, the precision (r = 0.677) and accuracy (C_b = 0.996) in agreement improved somewhat further.

The agreement between the WASS and SR is depicted separately for each investigator using MSE measurement is shown in **Figure 5.4A and 5.4B**. On average, measurements obtained by the first investigator (mean difference = -0.226) were slightly lower than the second investigator (mean difference = 0.013D), however the wide distribution of observations were consistent. The slope in the graph, representing bias in the agreement between investigators, shows that within the range of emmetropia (-0.5D to 0.5D) the average agreement was better (mean difference was closer to zero). For both investigators, the negative side of emmetropia, tended to be more positive (i.e. underestimating refractive error) for the WASS and SR. On the positive side of emmetropia, values observed tended to be less positive, i.e. again underestimating refractive error in both instruments.

Table 3, illustrates the 95% limits of agreement for difference in MSE measurement between the WASS and SR for Investigator 1 (-1.88D to 1.43D) and Investigator 2 (-1.91D to 1.93D). In the hands of Investigator 1, agreement between the two instruments was more precise (r = 0.683 vs. 0.531) but less accurate (C_b = 0.956 vs. 0.993) than with Investigator 2. Overall agreement was slightly better for Investigator 1 (r_c = 0.653 vs 0.527).

Agreement between investigators

Agreement between investigators is shown for each of the two instruments in **Table 4**. MSE measurements differed significantly in both cases (P = 0.02). Using the WASS, the MSE values obtained by the first investigator (median 0.37D; IQR -0.19D to 0.87D) were on average lower than the second investigator (median 0.5D; IQR -0.31D to 1.12D). A wide range of differences was observed (95% limits of agreement: -1.26D to 1.02D) (**Figure 5.5A**). The concordance correlation coefficient for agreement between observers using the WASS was r_c = 0.798 (r = 0.806; C_b = 0.991).

For the first investigator, MSE values obtained by the SR (median 0.5D; IQR 0D to 1.5D) were on average higher than the second investigator (median 0D; IQR -0.5D to 1.5D). When the agreement in observations between both investigators were compared on the SR alone (ie; **Figure 5.5B)**, the average difference in MSE of 0.124D was not far from 0D, however a wide range of observations was present within the 95% limit of agreement(-1.02D to 1.20D). Overall agreement between investigators therefore appeared to be slightly better using the SR compared with using the WASS.

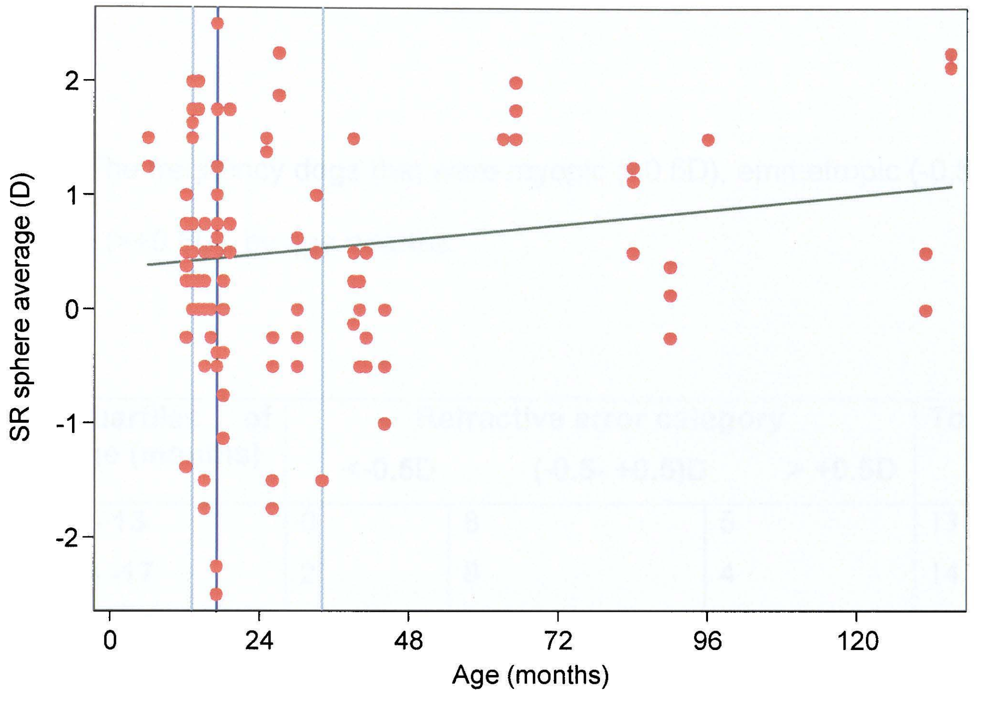


Figure 5.1. Distribution of refractive errors in the sample, plotted against age. Dark blue line represents the median age and light blue lines the 25th and 75th percentiles. Green line represents the linear fit (R^2 = 0.042, P = 0.029).

Table 1. The frequency dogs that were myopic (<0.5D), emmetropic (-0.5 to +0.5D) and hyperopic (>+0.5D), by age quartile.

Quartiles of age (months)	**Refractive error category**			**Total**
	<-0.5D	**(-0.5- +0.5)D**	**> +0.5D**	
6 - 13	0	8	5	13
14 -17	2	8	4	14
18 -34	1	7	3	11
39-135	0	7	5	12
Total	3	30	17	50

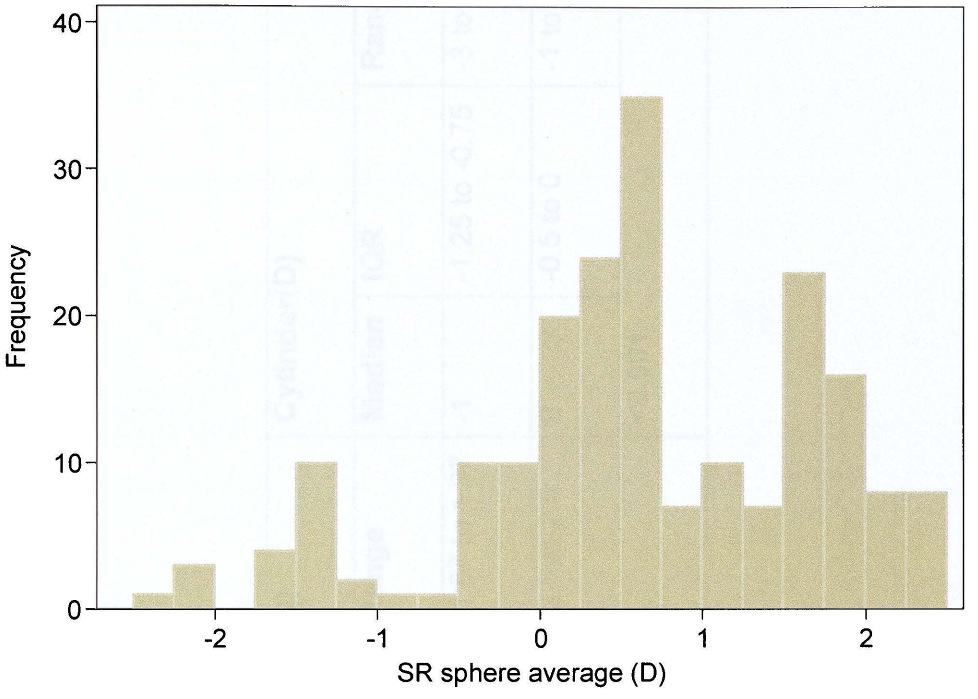


Figure 5.2. Histogram of refractive errors obtained by both investigators using SR. The SR average was calculated by averaging the sphere values from the vertical and horizontal meridian.

Table 2, Comparison between the WASS and SR of sphere, spherical equivalence and cylinder values in dogs with non-cycloplegic refraction.

	Sphere(D)			Spherical equivalence(D)			Cylinder(D)		
Variables	**Median**	**IQR**	**Range**	**Median**	**IQR**	**Range**	**Median**	**IQR**	**Range**
WASS	0.75	0.5 to 1.5	-1.75 to 3.00	0.37	-0.25 to 1.06	-1.87 to 1.87	-1	-1.25 to -0.75	-3 to -0.25
SR	0.50	0 to 1.5	-2.50 to 2.50	0.50	0 to 1.5	-2.5 to 2.5	0	-0.5 to 0	-1 to 0
***P*-value**	**<0.001**			**0.152**			**<0.001**		

Range = Represents the smallest and largest values recorded

D = diopter

Median = 50th percentile

WASS = Welch Allyn™ "Sure Sight"

SR = Welch Allyn™ Streak Retinoscope

IQR = Interquartile range (25th to 75th percentiles)

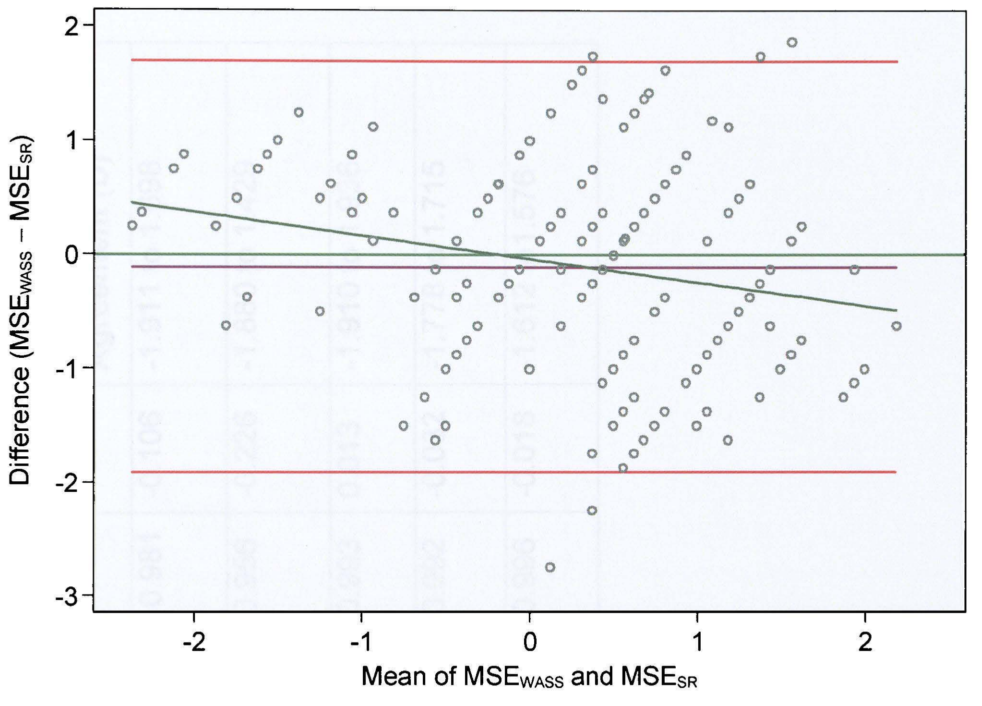


Figure 5.3, Differences between instruments (MSE_{WASS} – MSE_{STREAK}) obtained by both investigators. Purple line indicates observed average agreement; red lines indicate 95% limits of agreement; green line indicates linear fit; y = 0 indicates line of perfect average agreement

Table 3, Agreement between WASS and SR using mean spherical equivalence observed from dogs.

Data used	*n*	r_c	*r*	C_b	*msd*	95% Limits of Agreement (D)[37]
All observations with no limit on the reliability scale value	200	0.591	0.602	0.981	-0.106	-1.911 to 1.698
First investigator only	100	0.653	0.683	0.956	-0.226	-1.880 to 1.429
Second investigator only	100	0.527	0.531	0.993	0.013	-1.910 to 1.936
Reliability scale limits with the WASS of 6 and greater	132	0.627	0.632	0.992	-0.032	-1.778 to 1.715
Reliability scale limits with the WASS of 8 and greater	21	0.677	0.679	0.996	-0.018	-1.612 to1.576

MSE = Mean spherical equivalent

r_c = Concordance correlation coefficient

n = Number of paired observational values

r = Pearson's coefficient (measure of precision)

C_b = Bias correction factor (measure of accuracy)

msd = Average difference in mean spherical equivalence (ie: MSE_{WASS}-MSE_{SR})

Table 4, Mean spherical equivalence (MSE) obtained with each instrument, compared between investigators using the Wilcoxon signed-rank test

	WASS			**SR**		
Variables	**Median**	**IQR**	**Range**	**Median**	**IQR**	**Range**
Investigator 1 [MSE; (D)]	0.37	-0.18 to 1.37	-2.12 to1.87	0.50	0.00 to 1.50	-2.50 to 2.50
Investigator 2 [MSE; (D)]	0.50	-0.31 to 1.12	-2.25 to1.62	0.00	-0.50 to1.50	-2.50 to 2.50
***P*-value**	**0.023**			**0.020**		

Range = Represents the smallest and largest values recorded

D = diopter

Median = 50th percentile

WASS = Welch Allyn™ "Sure Sight"

SR = Welch Allyn™ Streak Retinoscope

IQR = The interquartile range is the 25th to the 75th percentile

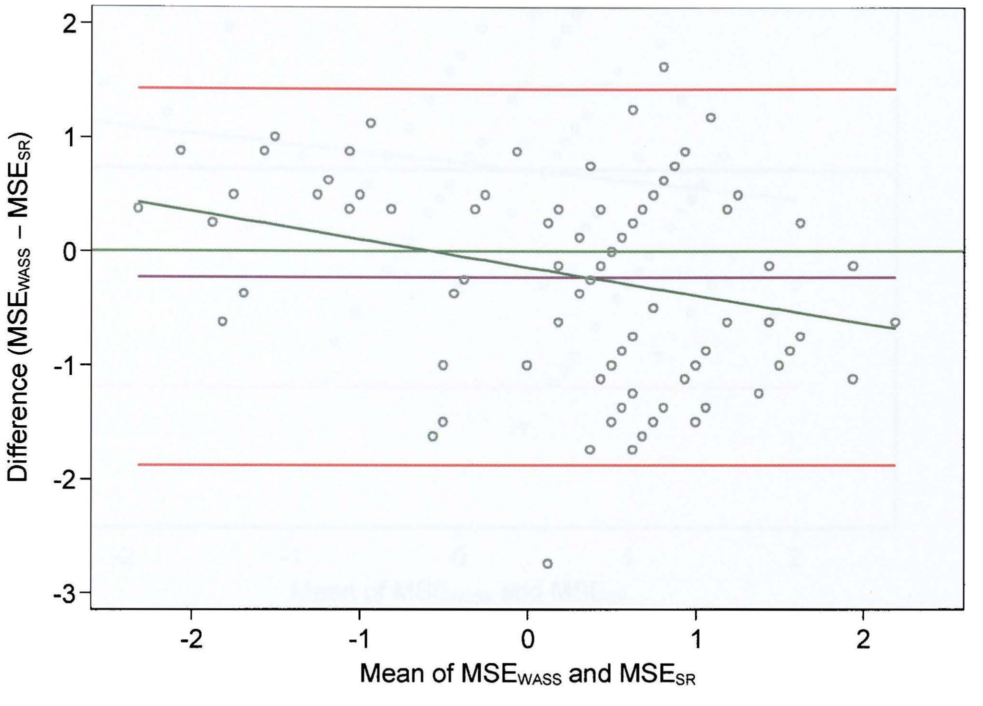


Figure 5.4A. Differences between instruments (MSE_{WASS} – MSE_{STREAK}) obtained by investigator 1. Purple line indicates observed average agreement; red lines indicate 95% limits of agreement; green line indicates linear fit; y = 0 indicates line of perfect average agreement.

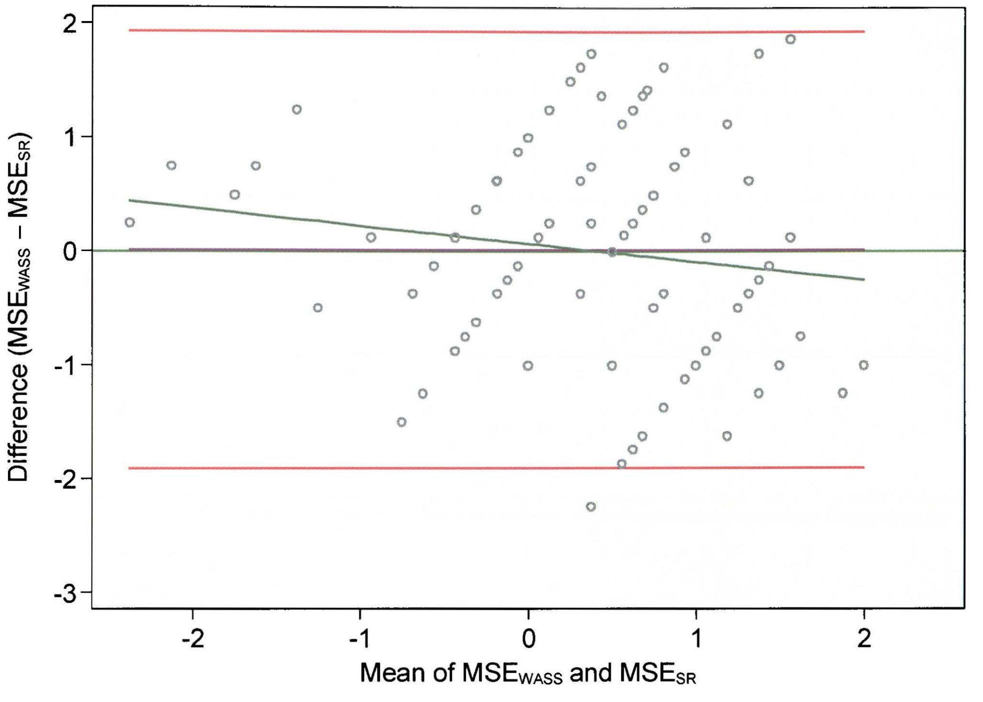


Figure 5.4B, Differences between instruments (MSE_{WASS} – MSE_{STREAK}) obtained by investigator 2. Purple line indicates observed average agreement; red lines indicate 95% limits of agreement; green line indicates linear fit; y = 0 indicates line of perfect average agreement.

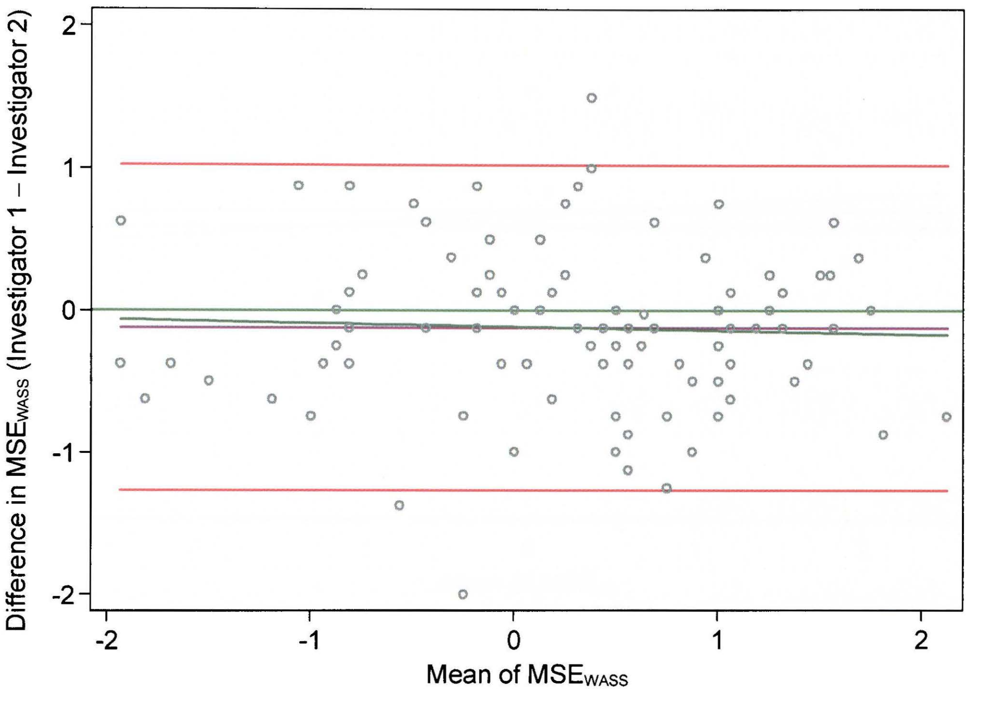


Figure 5.5A, Differences between WASS MSE measurements obtained by both investigators (Investigator 1 MSE_{WASS} – Investigator 2 MSE_{WASS}). Purple line indicates observed average agreement; red lines indicate 95% limits of agreement; green line indicates linear fit; y = 0 indicates line of perfect average agreement.

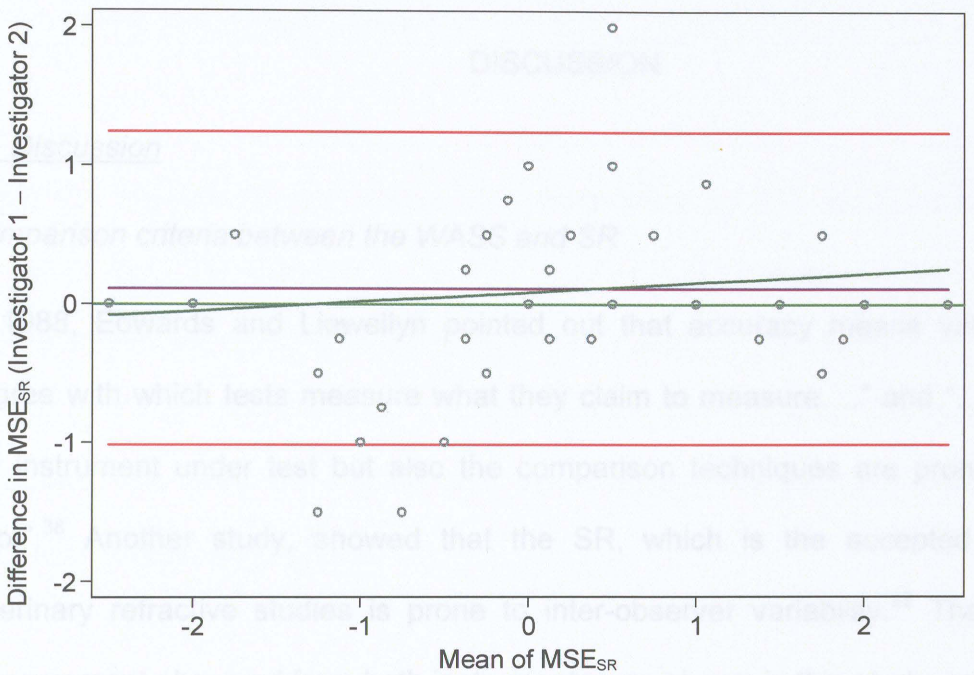


Figure 5.5B, Differences between SR MSE measurements obtained by both investigators (Investigator 1 MSE_{SR} – Investigator 2 MSE_{SR}). Purple line indicates observed average agreement; red lines indicate 95% limits of agreement; green line indicates linear fit; y = 0 indicates line of perfect average agreement.

CHAPTER 6

DISCUSSION

6.1 Discussion

Comparison criteria between the WASS and SR

In 1988, Edwards and Llewellyn pointed out that accuracy means validity, i.e, "the degree with which tests measure what they claim to measure…." and "….that not only the instrument under test but also the comparison techniques are prone to bias and error".[38] Another study, showed that the SR, which is the accepted technique in veterinary refractive studies is prone to inter-observer variability.[22] The variability in measurement observed from both instruments was shown in this study, as with previous studies. For these reasons, we are only able to conclude on the agreement of measurement between the two instruments rather than the precision and accuracy of the WASS, when compared to the SR.

In this study, objective refraction using the WASS and SR gave similar results for spherical equivalent refractive error from both investigators. The difference in median spherical equivalent was approximately -0.13D between the instruments and was not significantly different. The median sphere (0.25D) and cylindrical values (-1D) however were significantly different. These observations agree with previous studies using mean spherical equivalence. In the hands of each investigator, the two instruments had similar 95% limits of agreement, with the WASS having a tighter agreement along the interquartile range. Furthermore, in a clinical setting, this difference may not be considered significant with our animal patients. The variability of readings between the two screening instruments makes their value as diagnostic tools questionable.

When the median sphere values was considered for the whole group, a positive difference of 0.25D between the WASS and SR was observed. In addition to this, all sphere values observed on WASS were consistently more positive than with the SR, indicating a slight positive bias in measurement with the WASS. This observation is consistent with previous studies on children where the WASS proved to be more effective in diagnosing myopia.[13,14]

Refractive state of guide dogs in South Africa

We investigated fifty animals consisting of 5 breeds of dog utilised by SAGA, under non cycloplegic conditions. Since SR was considered the traditional gold standard in objective refraction, we defined the refractive state of South African guide dogs based on observations with the SR. We found that although 60% of the guide dogs sampled were within the range of emmetropia (0.5D) and a wide range of ametropias (hyperopia, myopia, anisometropia) within the subject group were present. This observation agrees with the wide range of refractive errors reported in dogs, however, it contradicts a previous study by Murphy *et al*, where specifically all the guide dogs screened were emmetropic. We have shown that the refractive state of guide dogs in South Africa is not completely emmetropic, and the current subjective breeding and selection criteriae was not as effective as previously thought.

When incidence of astigmatism was considered, the WASS detected astigmatism in all eyes refracted and displayed the cylindrical error along with the axis of astigmatism. The SR detected clinical astigmatism of greater than 0.5D cylinders in only 25% of the dogs refracted. The difference in astigmatic observation on SR may be related to the variation in retinoscopic reflex interpreted by each observer. Furthermore, the retinoscopic reflex on SR at or near neutralisation can be misinterpreted when an uncooperative patient precludes careful observation of the “with” or “against” reflexes, especially, when the difference between the vertical and horizontal meridians are close. Although the WASS identifies astigmatism more consistently, we cannot confirm its accuracy. It appears that the SR underestimates astigmatism and further studies are needed to justify this.

Effect of investigator on agreement between instruments

On average, the measurements observed by the first investigator between the instruments were slightly lower than the second investigator; however a wide distribution of observations were consistent. At emmetropia (0 to 0.5D), both investigators were consistent in measurement. For ametropias, a bias in agreement between investigators was consistent throughout measurement with both instruments which sloped towards underestimating refractive error as the diopter of measurement became more positive or more negative. From our observation, the 95% limits of agreement for clinician refraction in dogs (±1.26) was significantly larger that those reported by Zadnik et al on people (±0.5D). This can be explained by the significant influence of patient factors such as pupil fixation and compliance that was difficult to be maintained by both investigators. Furthermore, each investigator had a chance to refract each patient only once. With all factors considered, the overall agreement between investigators appeared to be slightly better with the SR than with the WASS.

As the reliability scale values on the WASS increased, a narrower width in the limits of agreement between instrument measurements was observed. Of all the reliability values observed with the WASS, the agreement between the WASS and SR was most precise (r=0.679) and accurate (C_b=0.996) for confidence values of 8 and greater. Ideally, when the light reflex that the autorefractor is neutralising is bright and stable, the reading should read a 9 confidence value. To obtain consistent high reliability scale values for measurement with the WASS is a challenge in hyperactive dogs.

There are several limitations to keep in mind when generalising the results in the present study. Firstly, due to the limitation in availability of guide dogs during the training season, the sample size obtained for this study was small and skewed to an interquartile range of age 13 to 34 months. Although adequate, a larger and wider sample size would have been more representative of the guide dog population in South Africa. Secondly, the difficulty in obtaining consistent high reliability scale values (6 and above), as recommended by the manufacturer for measurement on the WASS, made it necessary to include lower reliability scale values. This may have further reduced the agreement between instruments as shown in Table 3, where the pearson's coefficient (a measure of precision) and the bias correction factor (a measure of accuracy) improved slightly as the reliability scale limit increased. Furthermore, the elimination of subjects with ocular pathology limits the ability to generalise the measurement of refractive errors in diseased eyes.

6.1 Conclusion

The WASS and SR show acceptable agreement with each other during non cycloplegic conditions, however the traditional retinoscope; SR remains a better tool when the patient has small pupils. This is due to the instrument environment of autorefractors that may over stimulate accommodation, resulting in pseudomyopia. Autorefractor findings need not necessarily replace retinoscopy, but might alert the practitioner for the need to conduct supplemental retinoscopy. Any factor that interferes with accurate fixation, or the state of accommodation, may result in variability of WASS autorefractor readings. When WASS is utilised, the use of the confidence level or reliability scale value is essential in interpreting values displayed on the digital screen. Furthermore, objective refraction is useful to identify and quantify clinical refractive error within the guide dog population prior to selection and breeding. Our results suggest that the WASS autorefractor assessed in this study can serve as an alternative tool to approximate canine refractive error. Further studies are required to validate its precision and accuracy.

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APPENDIX -1

METHODOLOGY IN RECORDING DATA:

1. Each investigator will have their own copy of a recording chart.

2. For completeness sake, all critical information needs to be filled up ie: Location, investigator date, name, age, sex breed, OD 1(D), OD2 (D), OS 1(D), OS 2(D), Astigmatism.

3. Comments – takes into account any ocular findings observed during the eye exam.

4. To calculate astigmatism from the streak horizontal and vertical spherical values, subtract the larger value form the smaller value to obtain values in –ve cylindricals.

5. The autorefractor determines the –ve cylindrical values automatically.

6. With the autorefractor, please record the reliability value in superscript next to your result.

7. For this study, we will adopt the manufacturers recommendations with regards to the Welch Allyn "Sure Sight" autorefractor.
   - Non cycloplegic autorefraction
   - Adult Mode
   - Accept reliability values of 6 and above.

8. Because of the range in reliability values, two autorefarctor values per eye will be recorded on the chart. An average value will be determined as the autorefractor value.

APPENDIX 1. - Data sheet of resting refractive index measurements

LOCATION: INVESTIGATOR: DATE:

Signalment				Refractive state- spherical measurement- (Right eye) (Left eye)						
Name/ID	Age	Sex	Breed	Instrument	OD 1(D) 180°-v	OD 2(D) 90°-h	OS 1(D) 180°-v	OS2 (D) 90°-h	Astigmatism	Comments
1.				A-rv						
1.				SR						
2.				A-rv						
2.				SR						
3.				A-rv						
3.				SR						
4.				A-rv						
4.				SR						
5.				A-rv						
5.				SR						

KEY:- OD 1(D) = Right eye - Vertical axis (Dioptres) OS 2(D) = Left eye –Horizontal axis (Dioptres)
A-rv = "Sure sight^{TM}" Autorefractor S.R = Streak Retinoscope

APPENDIX 2

South African Guide Dogs Association (SAGDA)
To whom it may concern:

Re: Dr Sivagurunathan and Dr Goodhead from the Johannesburg Animal Eye Hospital, have previously submitted a consent form to SAGDA in 2009 , which was subsequently acknowledged and approved by the University of Pretoria Ethics committee and SAGDA administrators. We have finally acquired one of the instruments needed for this study to take place. This document contains a step by step guide which needs to be followed for this research study. This study will be performed on SAGDA's premise.

REFRACTION STUDY PROTOCOL:-

1. For the purpose of this study, we would require adult guide dogs from the age of 2-6 years of age.
2. We are hoping to refract approximately a sample size of 100 dogs to validate this study.
3. 2 instruments available for refraction will be clinically applied and tested by 2 different investigators.
4. For the purpose of this refractive study, topical cycloplegia will not be used as recommended by the autorefractor manufacturer.
5. Two investigators will be performing this study.
6. Two rooms will be needed, that may require dim, ambient conditions for this study.
7. The dogs will be randomly presented to each investigator, one in each room in no particular order. The dog may also be brought from one room to the next to avoid unnecessary inconveniences.
8. No preference to the instrument used first ,
9. Each dog will first be screened for ocular abnormalities before the refractive measurements are taken.
10. One room will have the autorefractor, while the other will have the streak retinoscope.
11. A dog handler will be needed to assist in keeping the patients head steady during the study.
12. The refractive measurements will be tabulated on specific recording sheets (Appendix 2).

ROOM REQUIREMENTS:-

1. Room should have space for a small table to place the dogs on for the study.
2. The room will be dimmed to reduce excessive sunlight.
3. A handler would be needed to keep the dogs head steady
4. Plug point in each room would be needed for the instruments.
5. The refraction measurements should not take more than 10 minutes per patient.
6. We will bring along a table for the study to be performed.

Please advise us on the following:

1. The population of dogs within the age of 2-6 years at SAGDA.
2. The population of dogs outside SAGDA that we may be able to refract at your premise/ or at our practice in Fourways (Johannesburg Animal Eye Hospital)

1. GUIDE DOGS:-
2. We are hoping to collect data from as many dogs as we can refract (minimum no. 60; ideal 100 dogs)
3. We are planning to run these refractive studies on dogs on the weekends.
4. These dogs may need to be kept indoors or in the shade from 6 hours from the moment the drops are placed.
5. The dogs will not experience any form of pain or discomfort during this study.
6. The number of dogs available on site at SAGA over the weekend
7. The number of dogs available for the study from the age of 2 years to 7 years
8. We may require more that a than one visit to obtain sufficient refractive data.
9. The weekends that would be suitable for this study.
10. Would a dog handler from SAGDA be available to us for the study duration. We suspect the study may take more than a day to acquire values from 100 guide dogs.
11. Please advise us on day/days that would be ideal for the study to take place. Would weekends be better?
12. Based on the above information, a timetable will be drawn, and a copy sent to you for your approval.
13. We are hoping to start on the 28th of August 2010

Please contact us if you have any further queries.
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Kind regards,
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