Evaluation of the Refractive Error in Pseudophakic, Aphakic and Phakic Dogs using Streak Retinoscopy

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ABSTRACT

This study evaluated the refractive error in dogs with intraocular lens (IOL) implants, aphakic dogs and healthy controls. A population of 49 dogs (92 retinoscopies) was divided in 3 groups pseudophakic (n=36 eyes), aphakic (n=4 eyes) and phakic healthy control (n=52 eyes). Streak retinoscopy was performed by horizontal and vertical refraction.

Mean refractive state was: pseudophakic group +3.74 ±5.45D (-3.5; +21.0D); aphakic group +16.94 ±1.39D (+15.5; +18.25D) and phakic group -0.03 ±1.64D (-5.0; +4.0D). On the pseudophakic animals 72.2% were hyperopic, 13.9% were myopic and emmetropic. Astigmatism was diagnosed in 3 eyes. Anisometropia was observed in 10 patients (1; 20.5D) and antimetropia in 2. Correlation between refractive values/optic axial length suggested a tendency towards emmetropia in animals with higher ocular diameter (P= 0.0845; rho= -0.3). On the phakic group 44% were emmetropic, 30% hyperopic and 26% myopic. Low hyperopia predominated on hyperopic eyes (66.7%). No cases of astigmatism, anisometropia or antimetropia were found on the phakic group. All aphakic patients presented with high hyperopia.

An association between refractive state and animal size was found in phakic dogs (P=0.002). On the operated group larger breeds were more adapted to 41D IOLs, with small/medium size breeds presenting high variability in their refractive state. All microphthalmic operated patients showed high hyperopia. More studies should be conducted to evaluate individual biometric characteristics, leading to a wider range of available IOLs.

Keywords: emmetropia, refractive errors, intraocular lens, retinoscopy, dog

INTRODUCTION

Retinoscopy, also known as sciascopy, is the most common objective method for determining the refractive error, with accommodation at rest [1,2]. It allows quantitative estimation of the normal, pathological and surgically induced refractive states of the eye within 0.25-0.5D (diopters) of its true refractive state [3]. Based on the direction and speed of the retinal reflected lights or retinal reflex, trial lenses or a sciascopy bar are placed in front of the patient's eye until the point of reversal or neutralization is reached [4].

In a normal or emmetropic eye, parallel rays from infinity focus on the retina [5,6]. In an ametropic eye, a refractive error is present, thus parallel light rays entering the non accommodating eye will not focus on the retina [7]. Spherical ametropia includes hyperopia and myopia where the focus point is behind the retina and anterior to the retina, respectively [1]. If aspherical ametropia or astigmatism is present, incident light rays have more than one focus point due to irregularities on the refractive surfaces [3]. Anisometropia is a condition where a difference, equal or superior to 1D between two eyes, is present [8]. This concept can be divided into two categories: is anisometropia, where both eyes are either myopic (anisomyopia) or hyperopic (anisohyperopia), and antimetropia where one of the eyes is hyperopic and the contralateral is myopic [9].

Although cycloplegia is important when refracting humans and primates; in domestic animals cycloplegia prior to retinoscopy is often unnecessary since most of them have limited accommodative ability [2,10]. Dogs are reported to have low accommodative range from 2 to 3 diopters [6]. Several studies have shown that there are no significant changes in refractive errors between cycloplegic and noncycloplegic retinoscopies in dogs [11-14]. The use of cycloplegic drugs may cause some ocular discomfort [15] and owners are sometimes unwilling to allow the administration of drugs.

An alternative to the use of cycloplegic drugs, used in human pediatric refraction, is near retinoscopy, also called Mohindra retinoscopy. Like veterinary patients, infants cannot be asked to fixate on a distant target and can sometimes become distressed and uncooperative when restrained. This retinoscopy technique is performed in absolute darkness so the patient's attention is drawn to the light beam [4,15]. The method implies a working distance of 50 cm and the subtraction of a working distance correction of 1.25D, instead of the usual 2.00D [15].

Several studies have been conducted in an attempt to restore emmetropia in dogs that underwent phacoemulsification. Initially, it was suggested that +30D lens would be sufficient to bring the patient close to emmetropia [16]. More recent studies have shown that +41.5D IOL implants would best approximate emmetropia [14].

Although many studies have already extensively evaluated the refractive state of phakic dogs, revealing the species' prevalence and breed inheritance, fewer articles are found referring to the refractive state on a diverse group of pseudophakic dogs.

The purposes of this study were to evaluate the refractive error in patients subject to phacoemulsification, with and without IOL implants, to assess the efficacy of the diopter power used in current IOL implants, and to establish a correlation between axial length and refractive values in pseudophakic eyes. In parallel, we intended to evaluate the refractive state on a control population of healthy dogs and correlate the refracted values with animal size and age.

MATERIALS AND METHODS

Study Population

The study population included 49 dogs (92 eyes) from several different canine breeds. Animals included in the pseudophakic and aphakic group were patients from the Veterinary Teaching Hospital of Lisbon University that underwent phacoemulsification for cataract surgery between 2011 and 2017 and were not lost on follow up. The phakic group comprised canine patients from the Veterinary Teaching Hospital of Lisbon University. Age, breed or sex were not considered on the selection of patients. The only inclusion criteria for the phakic group was that animals were healthy and had no ocular condition that would modify the refractive media or surfaces.

Patients were divided into three major groups: pseudophakic (14 dogs with intraocular lenses in both eyes, 8 dogs with only one operated eye; total n=36 eyes), aphakic (3 dogs where intraocular lens placement was not possible in at least one of the eyes, total n=4 eyes) and phakic dogs (24 dogs from which both eyes were considered, plus 4 remaining healthy non-operated eyes from pseudophakic dogs; n=52 eyes).

Pseudophakic dogs received foldable IOL implants of +41 (Figure 1) (Acrivet® 60-V, square-edged hydrophilic acrylate) or +42 (Medicontur® PFIS4, square-edged hydrophilic-hydrophobic copolymer acrylate) diopter power randomly, according to the IOL available at the time of the surgery.

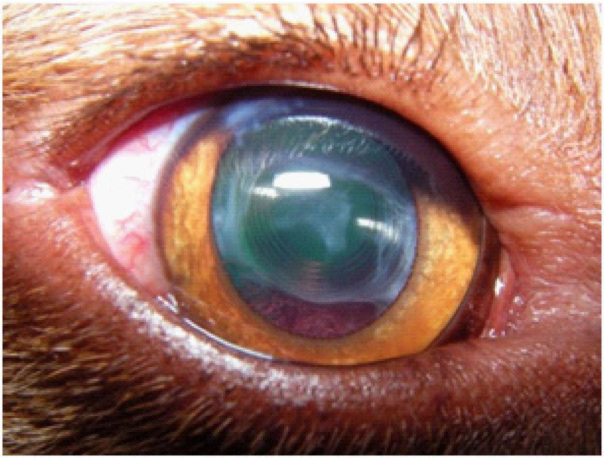

Figure 1: Photograph of the IOL implant (Acrivet +41D model) inside the capsular bag on a post-phacoemulsification follow up.

Optical Methods

Streak retinoscopy was done on dog eyes by refracting both horizontal and vertical meridians with a Beta 200 Heine retinoscope® (Heine Optotechnik, Herrsching Germany) and trial lens bars including spherical plus or minus lenses (Figure 2) (no cylindrical lenses were used).

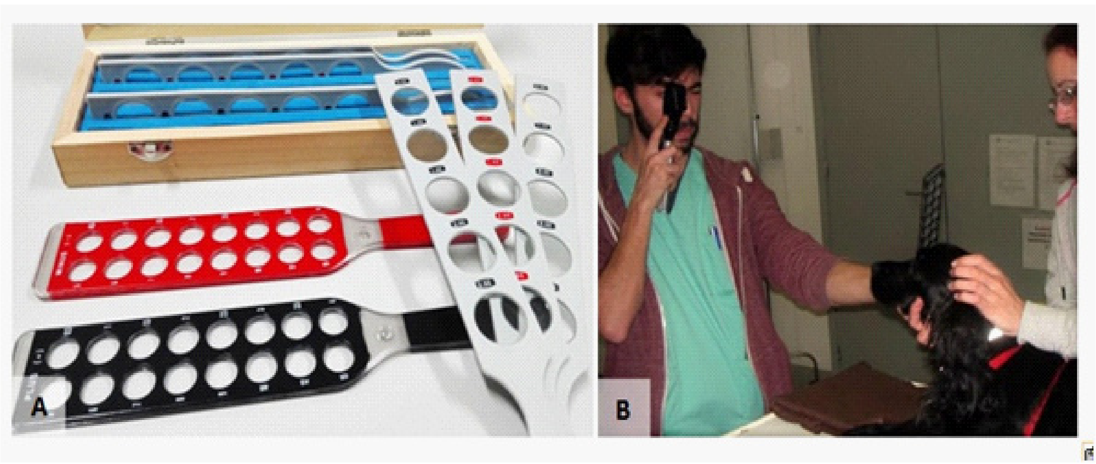

Figure 2: A) Sciascopy bars set used to evaluate the refractive state of the studied animals. **B)** Retinoscopy being performed on one of the pseudophakic dogs included in this study.

Horizontal meridians were refracted first and vertical ones second. Oblique meridians were refracted only when swirling or scissor like reflexes were observed. The trial lenses, or sciascopy bar, were placed 1-2 cm away from the patient's cornea, and the retinoscopy was repeated with each added lens until neutralization was reached. Refractive errors higher than 15D (maximum on a sciascopy bar) were analyzed by addition of separate sciascopy bars.

Retinoscopy on the pseuphakic and aphakic group was performed on a dimmed light room at a working distance of 67cm.

Because non-operated animals still have the ability to accommodate, phakic animals were evaluated in total darkness to eliminate any accommodative stimuli from the room, in resemblance to the Mohindra method. A conventional 67cm working distance with a +1.5D working lens was used. All phakic dogs underwent a complete ophthalmic examination to discard any ophthalmic condition.

No cycloplegic drugs were administered in any group.

Ocular B-scan ultra sonography, using an8MHz probe apparatus, was performed on the pseudophakic group prior to surgery to evaluate the length of the optic axis and lens capsule dimensions for haptic size determination.

Data Analysis

Data concerning the studied population were analyzed by age, breed and dog size, with dog size defined by: small (≤10kg); medium (>10kg ≤ 25kg) and large (>25kg) breed animals. There were two available diopter power IOL implants on pseudophakic patients, +41D and +42D. To uniformize data, 1 diopter was subtracted from all 42D retinoscopy values.

Animals with refractive errors between -0.5D and +0.5 were considered emmetropic, ≤-0.5D myopic and ≥+0.5D hyperopic. Hyperopia was divided in low (≤+2D); moderate (+2.25 to +5D) and high (>+5D) [17]. Anisometropia was considered when refractive values between 2 eyes in the same dog differed more than 1D. If a difference higher to 0.5D was noticed between two different meridians in the same eye, astigmatism was diagnosed.

Spearman's rank correlation test was used to associate refractive errors with age and optic axial length and One-way ANOVA test was used to find correlation between retinoscopy values and size groups. Statistical significance was defined as $P < 0.05$.

RESULTS

Studied Population

Several different canine breeds were included in the study, namely the Australian Shepherd (n=2eyes), Boerboel (n=2 eyes), Beagle (n=2 eyes), Chihuahua (n=4), Cane Corso (n=2 eyes), Dachshund (n=7 eyes), English Cocker Spaniel (n=11 eyes), English Springer Spaniel (n=2 eyes), Fox Terrier (n=2 eyes), Golden Retriever (n=4 eyes), Jack Russel Terrier (n=8 eyes), Labrador Retriever (n=9 eyes), Miniature Schnauzer (n=1 eyes), Portuguese Watchdog (n=2 eyes), Portuguese Water Dog (n=2 eyes), Poodle (n=1 eyes), Rhodesian Ridgeback (n=7)eyes), Saluki (n=2 eyes), Pekingese (n=2 eyes), Weimareiner (n=2 eyes), Yorkshire Terrier (n=10 eyes) and crossbreeds (n=8 eyes). Ages ranged from 0.25 to 15 years old, with a median of 6 years. Post-operative refraction period varied from 0 to 5.2 years.

Dogs were divided in three major groups: pseudophakic (n=36 eyes), aphakic (n=4 eyes) and phakic dogs (n=50 eyes). From the initial phakic group (52), one eight month Beagle dog was excluded from statistical analysis for not fulfilling the entire inclusion criteria. He had several ocular abnormalities: microphthalmos, cortical congenital cataracts, nystagmus and persistent pupillary membrane.

Retinoscopy Results

Mean refractive error for the pseudophakic group was +3.74 ±5.45D (range from -3.5 to +21D), aphakic group +16.94 ±1.39D (range from +15.5 to +18.25D) and for the phakic group -0.03 ±1.64D (range -5.0 to +4.0D) (Table 1). Mean optic axial length on operated animals was 17.27 ±1.60mm (range 14.00 to 20.90mm).

Table 1: Refracted error on Pseudophakic, Aphakic and Phakic canine eyes.

Group	No.	Mean ± SD	Min	Max
Pseudophakic	36	+3.74 ±5.45D	-3.5D	+21D
Phakic	50	-0.03 ±1.64D	-5.0D	+4D
Aphakic	4	+16.94 ±1.39D	+15.5D	+18.25D

Pseudophakic Group

In the pseudophakic group, hyperopia had a higher prevalence (Figure 3) as identified in 72.2% of the eyes (low-30.8%; moderate-38.4%; high-30.8%) with only 13.9% being myopic and emmetropic. Astigmatism, with a prevalence of 8.33%, was diagnosed in 3 eyes (+2.5+1x180º; +3+1x90º; +5+3x135º). Out of 20 dogs that we were able to perform retinoscopy in both eyes (including patients with IOL and aphakic eyes), anisometropia was seen in 10, varying from 1 to 20.5D of difference between both eyes, and antimetropia was seen in 2 (-2.5D OD; +18D OS and -5D OD; +0.25D OS).

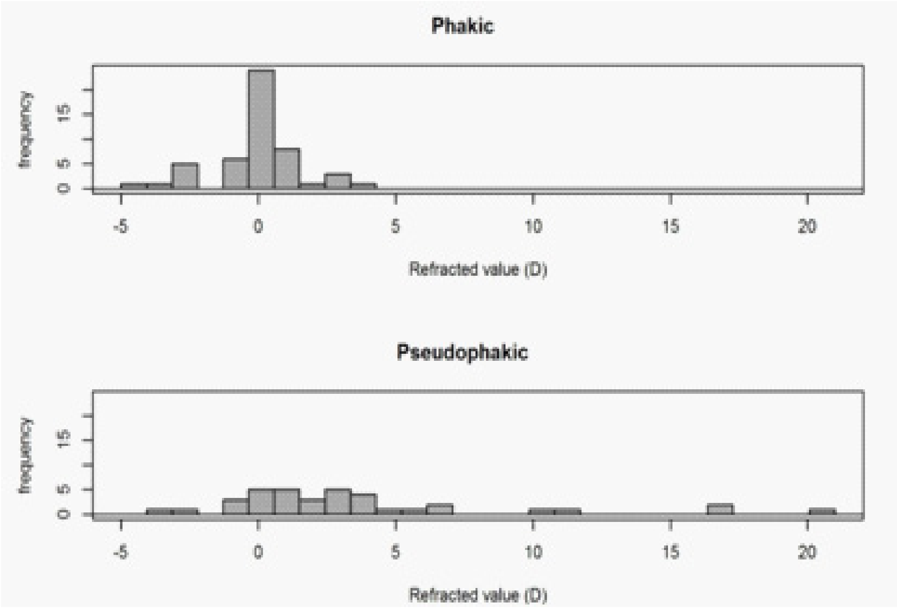

Figure 3: Refracted value distribution on the Pseudophakic and Phakic groups.

Correlation between refractive values and optic axial length (Figure 4) suggested a tendency towards emmetropia in animals with higher ocular diameter (P=0.0845; rho=-0.3). When running the same analysis, but separated by breed size, we found statistical significance in the medium size group (P=0.0278; rho=-0.725) showing that, in this group, larger eyes were more adequate to a diopter power of +41D used in current IOL implants (Figure 5).

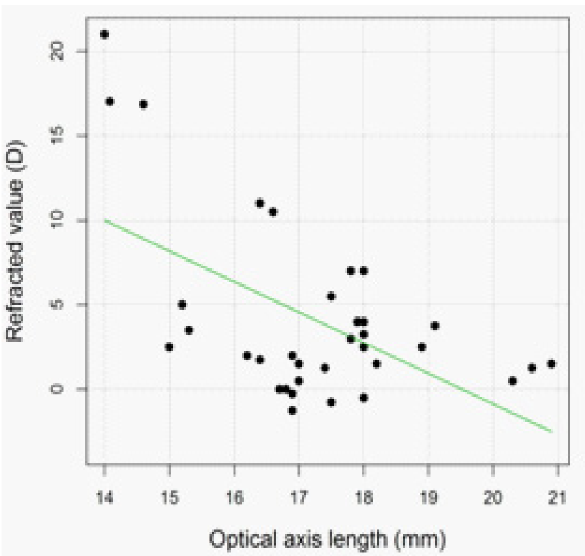

Figure 4: Correlation analysis between refractive values and optic axial length on the pseudophakic group.

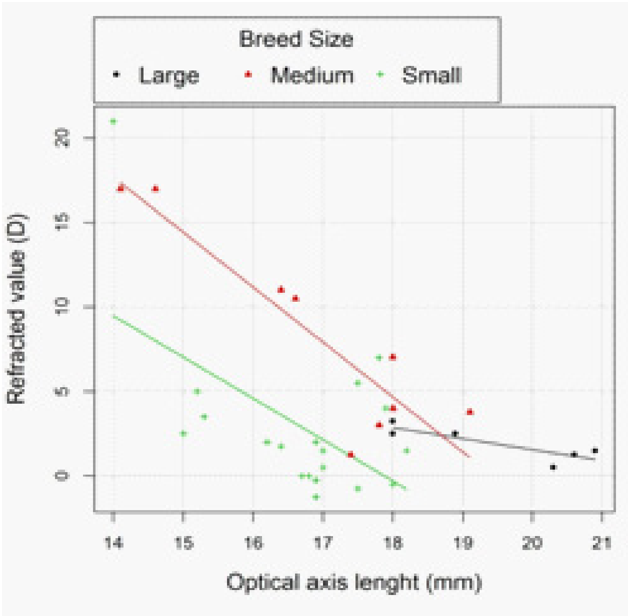

Figure 5: Correlation analysis between refractive values and optic axial length by breed size on the pseudophakic.

Microphthalmos was diagnosed, prior to surgery, in 3 of the pseudophakic patients and 2 of them, both English Cocker Spaniels, had multiple congenital malformations (microphakia, persistent pupillary membrane and nystagmus).

Their refraction values were: +9.5D (42D IOL) in the left eye and +11D (41D IOL) in the right eye, +16D (42D IOL) in both eyes, and +21D (41D IOL) in the right eye of the third patient.

Aphakic Group

In the aphakic group, as expected due to the absence of the lens, all animals presented with high hyperopia with a mean refracted value of +16.94 ±1.39D, ranging from +15.5 to +18.25D.

Phakic Group

In the phakic group 44% of the eyes were emmetropic, 30% hyperopic and 26% were myopic. For the hyperopic eyes, 66.7% had low and 33.3% presented with moderate hyperopia. No cases of high hyperopia, astigmatismor anisometropia were found.

An association between refractive state and breed size was found (P=0.002) (Figure 6). When separated by size, mean refractive state was closer to emmetropia in medium size breeds with -0.27 ±1.03D. Larger breeds had a mean refractive state of +0.82 ±1.52D, and smaller breeds -1.00 ±1.75D.

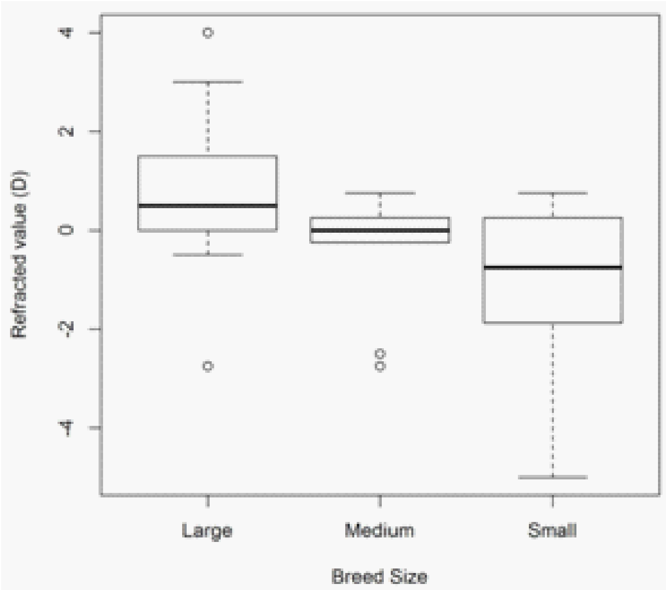

Figure 6: Refractive state distribution by breed size, on the phakic group.

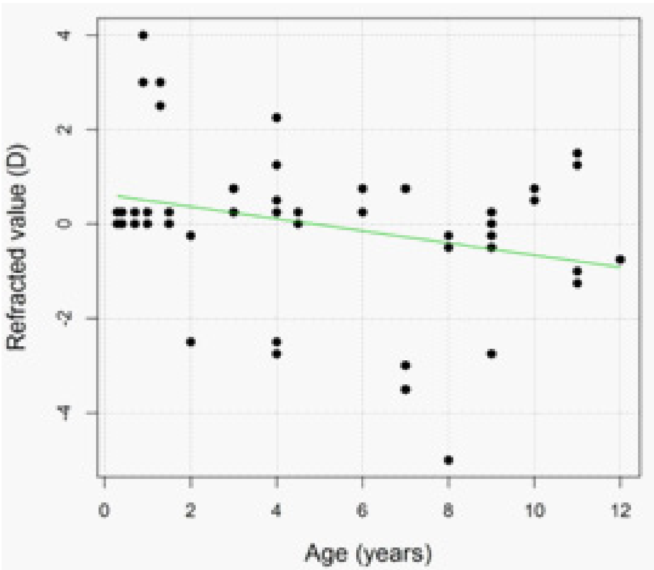

Figure 7: Correlation analysis between retinoscopy values and age on the phakic group.

Correlation analysis between retinoscopy values and age suggested a tendency towards lower hyperopic values or myopia within older animals (P = 0.054; rho = -0.273) (Figure 7).

Most breeds showed consistency in their refracted values (marked with an asterisk) (Table 2).

Table 2: Mean refractive error of breeds included in the phakic group.

Breed	N (eyes)	Breed's mean refractive error (D)
Boerboel	2*	+1.38D
Cane Corso	2*	2.75
Portuguese Water Dog	2	+0.13D
Chiuaua	3	-0.5D
Cocker Spaniel	2*	+0.5D
Dachshund	4*	-0.9D
Fox terrier	1	-5D
Golden Retriever	4*	+2.06D
Jack Russel	5	+0.35D
Labrador Retriever	5*	-0.85D
Rhodesian Ridgeback	6	+0.58D
Australian Shepherd	2*	+0.13D
Saluki	2*	-0.25D
Springer Spaniel	2*	+0.13D
Weimareiner	2	+0.75D
Yorkshire Terrier	2*	-3.25D
Crossbreeds (medium size)	4	-1.25D

The microphthalmic Beagle, excluded from the phakic group statistical analysis, with multiple ocular malformations showed high hyperopia and anisometropia with +13D on the left eye (OS) and +11D on the right eye (OD).

DISCUSSION

Emmetropia was the most common refractive state of phakic animals in our study, which correlates with results obtained previously by others [12,13]. However, this differs from the results achieved in similar studies that suggest a tendency toward low hyperopia in phakic patients [18]. Nevertheless, 30% were hyperopic with 66.7% having low hyperopia. Myopia was the least common refractive error with only 26% of cases.

Myopia in dogs has been associated with nuclear sclerosis in older dogs and axial elongation of the vitreous chamber [19,20]. This study suggests a tendency to lower hyperopic values or myopia in older animals. Several studies have tried to relate myopia with breed and myopia inheritability [12,13,21]. A study conducted in 1992 by Murphy et al. showed a higher prevalence of myopia in the German Shepherd, Miniature Schnauzer and Rottweiler. In a survey gathering 1,440 dogs representing 90 breeds, Kubai et al. (2008) proved a higher prevalence of myopia in the breeds cited before plus the Collie and Toy Poodle. Predisposition towards myopia in Labrador Retrievers (due to axial elongation) has been reported [12,19,21]. In conjunction with such reports, in this study 5/5 of the Labradors' eyes were myopic. Due to the small sample size concerning each breed, we could not draw representative conclusions regarding refractive states. However, the breeds Boerboel, Cane Corso, Cocker Spaniel and Golden Retriever (4/4) showed predominantly hyperopic values. Emmetropia was the most common refractive state in the Portuguese Water Dog, Jack Russel Terrier (3/5), Rhodesian Ridgeback (4/6), Australian Shepherd, Saluki and English Springer Spaniel. Myopia was noted in the Dachshund (4/4), Labrador (5/5) and Yorkshire Terrier (Table 2). When comparing our refracted values with breed size, larger breeds proved to be more consistently hyperopic, smaller breeds to be more myopic, and medium size breeds emmetropic (P=0.002). This finding may be explained by the corneal curvature radius. Large breeds are known to have a higher corneal curvature radius (loweroptic power) and smaller breeds to have a shorter one (increased optic power).

Astigmatism is considered rare in veterinary patients with a prevalence of only 1% [12]. In our study no cases of astigmatism or anisometropia were registered on the animals included in the phakic group.

Lens removal translates in a high refractive error resulting in severe hyperopia around +14D, reduction in visual acuity to 20/800 or worse and loss of accommodation ability [6]. Previous studies have showed mean refractive values in aphakic eyes around +18,50D (range, +18 to +19.31D) [22], +14.14 ±2.10D (range, 10.5 to 18.5D) [14] which are similar to ours: +16.94 ±1.39D (range from +15.5 to +18.25D).

In pseudophakic animals there was a high prevalence (72.2%) of hyperopia. Over correction was seen in 6 eyes reaching up to -3.5D. Values reported on a previous study [22] show mean refraction values of +2D in a group of 10 pseudophakic animals. In humans, diopter power calculation formulas are applied to each patient after A-scan ultrasonography or laser interference for optical biometry measurements and keratometry for corneal refractive power contribution [7,23]. A study applying formulas with keratometry and optical biometry has been conducted on veterinary patients to determine the most suitable IOL refractive power. With that, implementing the concept “one-implant-fits-all”, suggested that aphakic dogs require an implant of approximately 40D [24]. Using different power IOLs’ and linear regression analysis Davidson et al. (1993) predicted variations from +39.62 to +43.14 D in IOL powers necessary to approximate emmetropia.

Although having 30.8% with low hyperopia and 38.4% with moderate hyperopia, it is the high hyperopic dogs (30.8%) that deserve special attention. Such hyperopia incidence could be attributed to lens material or design. Foldable hydrophilic acryl implants have been reported to cause a hyperopic shift when compared to polymethylmethacrylate due to haptic angulation, which brings the lens closer to the retina [25]. This doesn’t seem to be the case considering both models used in this study had 0º haptic angulation.

In the surgically intervened group, 3 animals had been diagnosed with microphthalmos prior to the surgery and 2 of them, both Cocker Spaniels, had multiple congenital malformations.

Their refraction values varied between +9.5D (42D IOL) and +21D. The patient with the highest refractive error (+21D) was also the one with the smallest optic axial length of 14mm.

From the initial phakic group, one patient was excluded from statistical analysis for not fulfilling the entire inclusion criteria; nevertheless, his retinoscopy was compelling. This 8-month-old dog had several ocular abnormalities: microphthalmos, cortical congenital cataracts, nystagmus and persistent pupillary membrane. Retinoscopy showed anisometropia with +13D in the left eye and +11D in the right eye. In humans, microphthalmia can be responsible for a refractive error as high as +20D. Physiologic hyperopia can be due to axial length of the eye being shorter than the refracting components of the eye [17] which seems to be the case in this animal due to congenital microphthalmos. These findings show that both anatomical and functional optics components are involved in microphthalmic eyes. Microphthalmic eyes lack dioptric strength to their axial length and when operated they require IOLs with increased compensating power comparing to the common +41D lens.

Despite lacking statistical significance for all groups, our results seem to reveal a tendency towards emmetropia in animals with higher ocular diameter suggesting that larger eyes are more adequate to a diopter power of +41D used in current IOL implants. Cataract surgery or other procedures that involve incision of the cornea lead to an uneven corneal surface [26]. The use of sutures for corneal closure has proven to lead to astigmatism [27]; nonetheless, such surgically induced error frequently resolves in 3 or up to 4 weeks [27,28]. Our two cases of regular compound astigmatism (+2.5+1x180º; +3+1x90º) had a post-operative time of 3 and 4 years, respectively. The most severe case of astigmatism in our study, irregular astigmatism, with a difference of 3D between axis (+5+3x135ºD) was evaluated on the same day of the surgery. This meridian in this eye coincided with the main incision site. It is impossible to know how much of the astigmatism would persist after corneal healing.

We registered 10 cases of anisometropia: 1D, 1.25D, 1.5D (2), 2D, 3D, 3.75D, 5.25D*, 15.25D, and 20.5D*. Surgically induced antimetropia was observed in two patients (marked above with an asterisk) with the worst case having -2.5D OD and +18D OS. In minor degrees of anisometropia binocularity is preserved. A difference of 1D causes a difference in size of 2% on the image formed on the retina. A difference up to 5% (2.5D) is well tolerated by the majority of the patients [29]. Severe anisometropia or antimetropia, as seen in some aphakic or pseudophakic veterinary patients, may induce deleterious effects on a patient's vision leading to amblyopia and exclusion of the defective eye [16]. Total suppression of the image of the aphakic eye is described in human pediatric and adult patients [30].

The main limitation to this study was the difficulty to obtain enough operated animals. Another limitation was that some of the pseudophakic dogs, initially included in the pseudophakic group, had optical media opacifications; where refractive evaluation was impossible and therefore removed from this study. Specific biometric measures such as anterior chamber depth, vitreous chamber depth or lens axial length, would have allowed better understanding and evaluation of the refractive error, but only optic axial length was available.

In conclusion, this study demonstrates that phakic dogs present more frequently with emmetropia and all aphakic dogs with hyperopia. When present, hyperopic and myopic errors are more associated with larger and smaller breeds respectively. Pseudophakic dogs show high variability in their refractive errors, being patients with smaller eyes, the ones with the highest refractive error. Intraocular lenses with +41 dioptric power, showed to be suitable for only 13.9% of the animals evaluated, with 74% of the remaining animals having a considerable refractive error (myopic, moderate hyperopic, and high hyperopic patients).

Until ocular biometry or keratometry becomes a current practice amongst veterinary ophthalmologists, more studies should be conducted in an attempt to correlate biometric characteristics between different groups of dogs (optic axial length/vitreous chamber depth) with post phacoemulsification refractive needs, instead of a one size fits all model, leading to a wider range of IOL diopter power availability and a lower incidence of refractive errors.

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