Faculty of Veterinary Science, Szent István University
Department of Surgery and Ophthalmology

Examination and measurements of the canine lens with B-mode ultrasound

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I: Introduction

This article is enlightening the field of the canine lens and whether there is any correlation between the size of the dog and the diameter of the lens. Is there any correlation between the size of the dogs and their ocular structures at all? May artificial intraocular lens (IOL) replacement surgeries obtain better success rates if veterinary ophthalmologists have greater knowledge to and easier can predict the original size of the canine lens? It is interesting to see if there is any significant difference in the size of the lens in a small dog compared to a large dog. If there is, this might be a valuable tool for a veterinary ophthalmologist in the decision making process on determining the size of the implants in IOL replacement surgeries.

Today there are many different surgical methods and IOL implants veterinarians can choose amongst. The overall diameter of the lens is just one of the main parameters which must be taken into consideration when the implant is chosen for a patient.

"There are no studies that I know of that guide surgeons on deciding what size lens they should use", says veterinary ophthalmologist Rick F Sanchez from the Royal Veterinary Collage in London. It is thereby up to the treating veterinarian to decide all the specifications of the implants, according to what they think or feel is right for the patient.

During my research I discovered that there is very little data to collect regarding correlations between the size of the dog and the diameter of the lens. Therefore I decided to do an examination myself. The aim of my examination is to measure the diameter of the lenses and the axial globe length (AGL) in 25 dogs and on 50 eyes, to see if there is any correlation with the two ocular measurements and the body sizes. The dogs are grouped in categories of "small", "medium" and "large" dogs according to their body weight.

My hypothesis is that most likely are all anatomical structures in a small dog, smaller than in a large dog. It is likely that due to the great size difference in the two individuals, it is reasonable to assume all parts of their anatomy will be in proportionally same difference. The femur is longer, the skull is greater and the heart is bigger in larger dogs. But is this true for the eye and the ocular structures? Is there any direct correlation between the size of the lens and the size of the dog, or may this be an irrelevant factor and have no influence on the ocular structures at all? The lens and its measurements will be of greatest interest, but in this article I will measure the AGL as well. This is to have more information about the actual size-differences of the ocular compartments in the dog, and thereby better references to base my evaluations on.

II: Review of the literature

II. a: Orbital structures of the canine eye

The eye consists of the globe with its intraocular structures and the adnexa including the extraocular structures (1). The adnexa include the extraocular muscles, which keeps the eye in correct place and enables movement of the eye globe. The eyelids and conjunctiva provides protection and support, and the lacrimal system helps keeping the exposed parts of the eye moist and clean. The intraocular structures include mainly the anterior and posterior chambers, the lens, the ciliary bodies, the vitreous body and the retina.

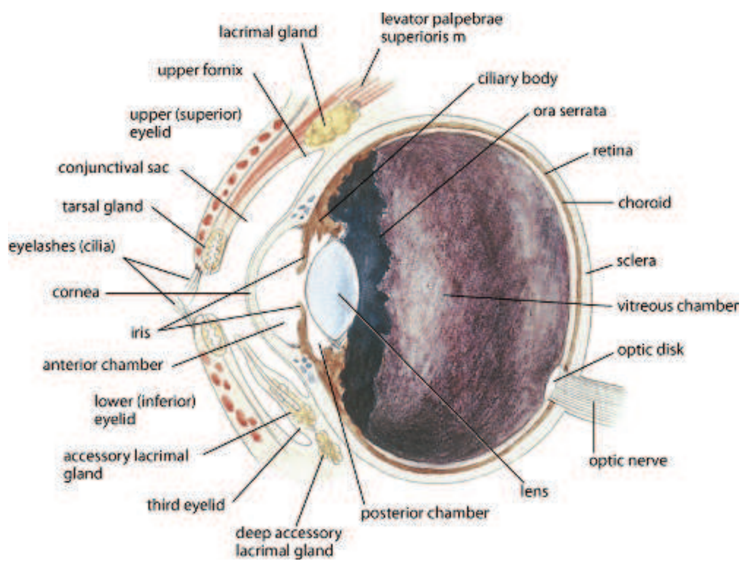


Figure 1. Schematic illustration of the intraorbital structures of the canine eye. (24)

II. a. a: The globe

The canine globe is nearly spherical, and formed by three vascular tunics enclosing the chambers separately. The axial globe length (AGL) is the horizontal length of the globe and is measured from the most rostral part of the cornea to the optical disc on the retina. Previous studies have indicated the mean AGL in the dog to be in a range from 19,1 mm to 21,9 mm (5), with a mean value of 20,8mm (15). It is assumed to vary between breeds and be under great influence of the intra ocular pressure (IOP) (1,15). Meaning that if there is an increase of the IOP it is most likely that the AGL is greater and vice versa.

II. a. b: The chambers

The anterior chamber is lined by the posterior surface of the cornea, the iris and the anterior surface of the lens. The posterior chamber is the space between the iris, the vitreous body and the anterior surface of the lens. The vitreous body is the largest chamber, and accounts approximately 80% of the volume of the globe (1). The retina and the posterior surface of the lens line the vitreous body.

II. a. c: The lens

The lens is a transparent and elastic structure, located between the anterior surface of the vitreous body and the posterior surface of the iris (6). It mainly consists of proteins and structural elements. It is kept in place by the by zonular fibers from the ciliary bodies, which inserts on the superficial layers of the peripheral parts of the lens capsule (1). The lens is spherical and surrounded by two capsules usually identified as the anterior (ALC) and posterior (PLC) lens capsules. The anterioposterior length is estimated to be approximately 7-7,5 mm, and the total volume is about 0,5 ml (26). The diameter of the canine lens at its equator is estimated to be approximately 10-11 mm (26). To compare, the feline lens is slightly larger, with a diameter of 12-13 mm and a thickness of 8 mm (26).

II. a. d: The orbit

The orbit is a mainly osseous cavity with a protective and stabilizing function. It consists of different bony structures and one thick fibrous ligament. The structures provide attachment for other ligaments and muscles, supporting the position of the globe.

The orbit varies greatly among different breeds, depending on several factors like the confirmation of the skull. The orbit is for example more shallow in brachycephalic breeds than in dolichocephalic breeds (11).

II. b: Ocular ultrasonography in veterinary practice

II. b. a: A non-invasive imaging technique

Veterinarians may today choose amongst several different high-technological imaging methods to obtain information of diagnostic value. Radiography, magnetic resonance (MR), computed tomography (CT) and ultrasonography (US) are commonly used in veterinary practices (4). Using noninvasive techniques, or methods causing the least harm possible, to obtain detailed diagnostic information are always favorable. Ocular ultrasonography allows a detailed visualization of intra- and extraocular structures with minimal stress for the tissue and the patient (3,13). Sedation or other medication is usually not required, only local anesthesia on the cornea is necessary. Ultrasonography is efficient, gentle and precise. It is easy to perform on healthy patients as well as traumatic and other high-risk patient of all age groups.

Biometric measurements of ocular structures are routinely obtained by A-mode ultrasonography both in human and canine patients. However, B-mode ultrasonography is more commonly used in veterinary practice (1). Several ultrasound machines are available on the marked, each model specially developed to suit the practitioners needs. Stationary ultrasound machines in clinics provide extremely detailed images, taking the diagnostic process to a higher level. For veterinarians practicing in the field or under other circumstances where dragging a huge apparatus is less convenient, smaller portable machines are available. Practitioners may choose machines meeting the exact requirements needed. Some machines on the marked are easy to handle, have simple technology and less advanced programs, while others are of high-technological quality with exceptional imaging-techniques and creates detailed pictures of high resolution. This makes is possible for practitioners to obtain diagnostic information with ultrasound technique, all depending on their needs, knowledge and economy.

II. b. b: Indications and performance of ophthalmic ultrasound examination

A wide range of diseases and abnormalities in dogs may lead to various disorders, which may exhibit ocular symptoms (1). The major causes of blindness in small animals are corneal diseases, cataracts, glaucomas and retinal degenerations (26).

Ocular ultrasound examinations are most useful when direct visualization of the intraocular structures is difficult or impossible (43). In situations when normal ocular examinations are prevented, like in corneal opacities, lid problems (partial or total tarsorrhaphy), dense cataracts, hyphema or vitreous opacities, is B-mode ultrasound very useful (43). Some patients may exhibit ocular symptoms without any obvious indication for a definite diagnosis. In such cases, accurately imaging by the help of ultrasound can give valuable information about the ocular structures, especially the lens, choroid, sclera, vitreous and retina (43). More precisely the thickness and surface of the cornea, depth of the anterior and posterior chambers, lens thickness and capsule, iridocorneal angles (ICA), the axial globe length (AGL), the retinal surface and the shape of the globe are of great interest to be examine d precisely (5,6). Detailed information about these ocular structures may have great diagnostic influence.

The examination is usually done with a few drops of local anesthetics 0,5% proparacaine hydrochloride or 4 mg/ml oxibuprocain hydrochloride on each eye (5,6). Standing position or sternal recumbency, with manual restraining, allows best natural picture and is least stressful for the dog. By carefully withdrawing the eyelids manually, the probe may easily be placed directly on the corneal surface. Sterile ultrasonography gel on the tip of the probe provides sufficient contact surface and helps creating optimal pictures. The probe is disinfected and cleaned before and after use. When best possible image is obtained, the picture is frozen and analyzed.

To obtain best possible results from an ocular ultrasonographic examination a few guidelines must be kept in mind. The dog is positioned steady, sitting or standing with manual restraining. Often is lateral or sternal recumbency the best position of choice to make sure the dog stays calm, and thereby make the examination easier to perform. Depending on the technique performed and the cooperative properties of the patient, the veterinarian will decide if sedation is necessary.

II. b. c: A- mode ultrasonography

When A-mode ultrasonography is used in ocular examination is it usually performed using a transducer of 10-12 MHz placed directly on the cornea. A small pencil-beam of ultrasound is sent out from the transducer. A picture with spikes of different height and with, pending on the strength of the returning echo, is visible on the screen. A-mode is mainly used in ocular examinations, believed to be more accurate than B-mode (1). Especially in human medicine is A-mode used for accurate measurements of the axial length of the eye to provide information required to decide the size of the intraocular lens implants of cataract patients (1). Together with this, A-mode ultrasonography is used for preoperative examination of ocular dimensions, detection of ocular oncology and for research purposes (1). This useful knowledge has been adapted to the veterinary practice and is today of great diagnostic importance.

II. b. d: B- mode ultrasonography

B-mode ocular ultrasonography is usually performed using high resolution 10-12 MHz linear or sector transducers (10). Examinations are preferably done without sedation to prevent rotation and retraction of the eye. After using topical corneal anesthesia, the eyelids are carefully and manually retracted, and both eyes are scanned in horizontal and vertical plane.

When using B-mode US a two-dimensional picture of the eye is created (2). The normal canine eye is characterized by a well-lined round structure with anechoic contents. Rostrally does the cornea appear as two parallel hyperechoic lines, which are slightly curved and follow the shape of the globe. The stroma in between the reflecting epithelial lines, appear anechoic.

The second hyperechoic structure we can see on the image on the screen is the anterior lens capsule. There is also visible a convex curve, indicating where the anterior chamber ends and the lens begins. The next hyperechoic structure is the posterior lens capsule, indicating the end of the lens and the beginning of the vitreous body. The ciliary bodies appear as echogenic structures in the periphery of the lens. It is hard to differentiate the iris, choroid and sclera, so together they are called the scleroretinal rim (1).

The scleroretinal rim, enclosing the shape of the globe, lines the anechoic vitreous body. At the ventrocaudal area of the retina is the optic disc visible as a slightly hyperechoic area.

Figure 2: B-mode ultrasonographic picture of the canine eye (Foto: From personal examination.)

II. b. e: High-resolution ultrasonography

"High-resolution ultrasound fills a niche in ophthalmology in that it allows evaluation of ocular structures that cannot be fully examined by use of slit-lamp biomicroscopy or that are obscured by opacities in the aqueous humor or vitreous humor" (3). For the high-resolution technique (HRUS) is a probe of 20 MHz used and for the ultrasound biomicroscopy (UBM) is a probe of 60 MHz used (1,3,8). The tissue penetration is limited to 5 to 10 mm (3), but provides extremely detailed images. Sometimes is the probe too close to the tissue being examined, for the ultrasound machine to create a clear picture. A standoff pad provides more space between the tissue and the probe, and will allow a sharper image to be created. These pads may be home made versions, or commercially produced sterile and bacteriostatic gel pads. These pads may also be useful in A- and B-mode US as well. UBM usually requires heavily sedated patients due to the images being highly sensitive to movements, but HRUS only requires local anesthesia. Today is HRUS and UBM mainly used in human medicine to evaluate tumors and cysts in the chambers, intraocular assessment of the lens, scleral diseases and differentiation of the various forms of glaucoma (3). However an increasing interest of these two methods has been seen in veterinary medicine, especially to determine the pathogenesis of canine glaucoma (3).

II. c: Factors interfering with the ultrasound results

II. c. a: Ultrasound machine and technical errors

II. c. a. a: Ultrasound probe

Mechanical or chemical impact may damage fine sensors in the probe, which may result in sending and receiving ultrasound waves not being accurate enough. The probe and its fine components are especially sensitive to mechanical damage. If the probe accidently falls and hits the table or other solid sobjects, dislocations and small damages to the fine structures and crystals inside the probe may lead to incorrect images or no image at all. Damaged probes may create incorrect images, which makes the diagnostic value of the picture remarkably decreased. The use of proper and correct ultrasound gel is important to prevent damages to the probe. When cleaning the probe it is important to use proper disinfectants and soft cotton for best protection both to the probe it self and the rubber coat on the tip of the probe.

II. c. a. b: Poor quality images

Several of the already mentioned errors contribute to creating unsharp images. To be able to make accurate measurements of the anatomical structures is it absolutely necessary with sharp and readable images. A clear and visible screen as well as high resolution of the pictures, is necessary to obtain images of high quality, and thereby prevents mistakes when pictures are evaluated.

II. c. b: Insufficient contact area

To create an image with the ultrasound machine it is essential to make sufficient contact area between the probe and the tissue. No air must be in between the two surfaces, as this will create blurry images. To prevent this, proper ultrasound gel is used in between the probe and the tissue. Too little amount of gel will lead to poor contact area and unreadable images. When disinfecting the probe is alcohol is the best choice, other stronger chemicals may damage the rubber and lead to gaps where air can be trapped and disturb the contact area.

II. c. c: Humane errors

II. c. c. a: Same examiner for every patient

In every examination it is important to take into consideration that errors occur. To prevent unnecessary errors caused by humans in the personal experiment done later in relation to this article, it was decided that the same person should examined all the dogs during the whole examination. Procedures and measurements were in this way done as similar in every case as possible. An even better hypothetical situation would be, if two different persons did the same measurements on each dog. Then the mean values of the two measurements would be a more precise guideline to base evaluations on, and many inaccuracies and human errors would be cleared out.

II. c. c. b: Accuracy

To make sure the human errors are reduced to a minimum it is important that the same procedures are done exactly the same way on each dog. To minimize the influence of various errors, must essential criteria and details be kept in mind. Awareness of the animal and its positioning of the head and body, as well as correct imaging and scanning methods, accuracy and interpreting skills, are all important factors to obtain best possible results.

II. c. c. c: Sufficient knowledge and education

It is of great importance that the person handling the ultrasound machine has sufficient knowledge about how to handle it. Different probes and technical adjustments are chosen according to what kind of organ and tissue that is going to be examined. Using the right probe and transducer, frequency and penetration depth is essential to essential to create a picture of diagnostic value.

II. c. d: Behavior of the dog

It is always hard to minimize errors when live animals are playing essential roles in experiments and examinations. We have to take into consideration that some of the individuals are more anxious and skeptical when being examined. The stressful and unnatural situation for the dog, may lead to unexpected movement that may influence the quality of the examination. Insufficient results from the anesthetics, poor restraining methods and stress may contribute to greater movement of the patients. This will lead to blurry and poor images, which makes it harder to evaluate the picture.

II. d: Clinical aspect of ocular and lentil symptoms

A great variation of congenital or acquired diseases may show ocular signs, some more pathognomic than others. The eye is a sensitive organ both to systemic and local changes, and is therefor a useful tool in clinical diagnostics. The major causes of blindness in dogs are corneal diseases, cataracts, glaucoma and retinal degenerations (26).

Many ocular diseases can be diagnosed by direct ophthalmological examination using a slit lamp biomicroscope and direct ophthalmoscope, without the need of additional and specialized procedures (5). In cases where the transparency of the ocular structures is altered, and a clear view of the inner eye by direct ophthalmoscope no longer is possible, further examination is suggested. Information of great diagnostic value may be obtained by performing a thorough ocular examination.

II. d. a: Congenital diseases that may affect the lens

Congenital abnormalities may or may not be associated with other congenital intraocular abnormalities or cataract (26). Congenital abnormalities may involve all of the different structures of the eye. Some breeds are more predisposed to ocular diseases, either due to skull confirmations or inherited characters. Examples of congenital abnormalities that may be associated with cataracts include persistent pupillary membranes, persistent hyaloid artery, persistent hyperplastic primary vitreous/tunica vasculosa lentis (PHPV/PHTVL), posterior lenticonus, microphakia, lens coloboma and microphtalmos (26). For example is it known that Schnauzers and Australian shepherds are predisposed to congenital microphthalmia and microphthalmia associated with other ocular structures (7). Dobberman and Staffortshire terriers are predisposed to persistent hyperplastic tunica vasculosa/persistent hyperplastic primary vitreous (PHTV/PHPV) (7).

II. d. b: Acquired abnormalities that may affect the lens

Acquired diseases may be due to many reasons, most commonly caused by inflammations, trauma, degenerations, and/or neoplastic diseases. Hemorrhages due to high blood pressure or coagulation disorders or of other idiopathic reasons are also possible causes (1). Depending on the extend and duration of the disorder, if and when the dog receives treatment and what kind of treatment and follow up the dog gets is essential for the outcome of the disease. If diseases, trauma or other disorders are ignored and not taken care of, the result may end in permanent damages to anatomical structures in the eye, especially the lens.

II. e: Diseases affecting the lens

When diseases or abnormalities persist for a longer time period chronic damages may lead to irreversible changes of the lens. The final outcome of these changes will most likely result in surgical treatment. Mentioned below are a few of the most common causes to severe lens damage, leading to surgical treatment and possibly IOL replacement.

II. e. a: Lens displacement

Lens luxation (subluxation, anterior and posterior luxation) occurs in all species, but is commonly associated with inherited defects in terriers. Anterior luxation is normally causing acute signs and is frequently accompanied with glaucoma and corneal edema (27). The treatment in this case is surgical removal of the lens. Subluxation and posterior luxation is less acute, and the evaluation if surgery is necessary is based on the severity if the ocular disease.

II. e. b: Chronic anterior uveitis

Anterior uveitis or iridocyclitis is relatively common in dogs and is often confused with other inflammatory conditions of the cornea and/or conjunctiva (28). Anterior uveitis is associated with acute onset of clinical symptoms and is often caused by trauma, systemic diseases, cataracts, neoplasia or other causes (28). The prognosis is usually favorable for acute anterior uveitis, than recurrent or chronic uveitis. If the patient is not responding well to treatment for the anterior uveitis, the recurring and/or chronic uveitis may develop secondary cataracts, refractory glaucoma and phthitis bulbi (28). Inflammatory cells that are present in the eye over a longer time period, which occurs during a chronic uveitis, may interfere with the transparency of the lens, and thereby decrease the vision to the patient.

II. e. c: Glaucomas

The glaucomas are generally related to reduced drainage of aqueous fluid from the eye, resulting in elevated intraocular pressure (IOP) (31). A few breeds are genetically predisposed, such as Samoyeds, Cocker Spaniels, Poodles, Chow Chows and Siberians (29). If the condition persists or becomes chronic, the high IOP will damage components of the eye, especially the optic nerve that results in blindness in short time (29).

II. e. d: Cataracts

Canine cataracts are commonly seen today (14). The lens is a highly cellular structure containing predominantly proteins. What happens during cataractogenesis is, regardless of the cause, the lens fibers die and epithelial cells undergo transformation and proliferation (38).

When this happens the lens osmolarity is altered and results in hydration of the lens, leading to opacity with time (9). Metabolic diseases, trauma, inflammations, degenerations, edema, and neoplastic diseases may cause cataracts (1,4,12,26). Cataracts are one of the most frequently occurring and important complications of canine diabetes mellitus (DM) (4). A few of the congenital abnormalities that may be associated with cataracts are listed earlier. It is important to differentiate between minor lens imperfections in young dogs and normal increase in nuclear density (nuclear sclerosis) in older animals, from the pathological clinical picture of cataracts (27). Cataracts appear in many different forms, and the classification according to the lens changes is the basis for qualifying the opacifications (26). The classification is based on the age of onset of the cataract, the position of the opacification within the lens, the degree of opacification and the possible cause (26). By classifying the clinical picture of the cataracts by using these different categories, a uniform language between veterinarians and surgeons has been formed.

II. f: Intraocular lens implants in dogs

II. f. a: History

The intraocular lens implants (IOL) in the dog has had a remarkable development during the past 50 years. Techniques and ideas was originally imported from the human medicine and tested out on the canine eye.

First IOL cases in humans were reported by Ridley in 1951 in England, and in dogs by Simpson in 1956 in the United States of America (26). The first two IOLs used in dogs were "1) an 11mm diameter IOL for intracapsular placement after an extracapsular lens extraction, and 2) a 14 mm diameter plastic IOL positioned in front of the posterior lens capsule after an extracapsular lens extraction through either a periphery iridotomy or the pupil". These two methods were the basics of the gradually increasing success rate for lens replacement surgeries in later years. During the 1980´s the interest of IOLs in humans increased, making information and techniques accessible for veterinarians to adopt to their medicine.

With careful evaluation of the routine implantation of IOLs, the surgeries were also performed in dogs. It became quickly apparent that the dioptic power used in IOLs in humans (15-20 dioptic power) was not sufficient strength for the canine eye. The IOLs used in dogs today have a dioptic power of 40-42 D (26).

II. f. b: Canine IOL implants today

There are several different IOL implants available for the dog on the marked today. They vary in dioptic power, total diameter, optic diameter, construction, haptical type, materials and manufacturers. Dioptic power varies from 40 D to 45 D, with 40-42 D being considered as optimal (26). Some implants have a power of 26, 30, 32 and 36 D, but these are less used. The optic diameter of the IOLs is referring to the central part of the implant. This diameter varies between 6-8 mm, but implants with diameter of 6 mm and 7 mm is most common. If the haptics of the implants are taken intro consideration, the implants may be up to 18 mm. The construction of the implant is either a 1-piece or a 3-piece construction, where the 3-piece is more flexible. The one-piece IOLs are recommended for dogs (26).

The material the IOLs are made of may influence the development of postoperative complications, especially postoperative capsular opacification (PCO) in dogs. Both soft foldable acrylic and hard polymethylmethacrylate (PMMA) IOLs for dogs are available on the market today. The PMMA IOL was for long time the most popular choice, but currently is the foldable acrylic IOLs the most commonly implanted in dogs. This is mainly due to that it requires a smaller incision for implantation, resulting in less postoperative complications and a shorter surgical time (26).

The size of the IOLs overall diameter in the dog vary from 11-18 mm (26), but "14 mm is used as a standard size" (verbal communication; R. Sanchez, Zs. Szentgáli). The actual lens diameter of the implant is usually between 13 and 16 mm in diameter, but when taking the haptics into consideration the diameter may vary from all the way from 11 to 18 mm in total.

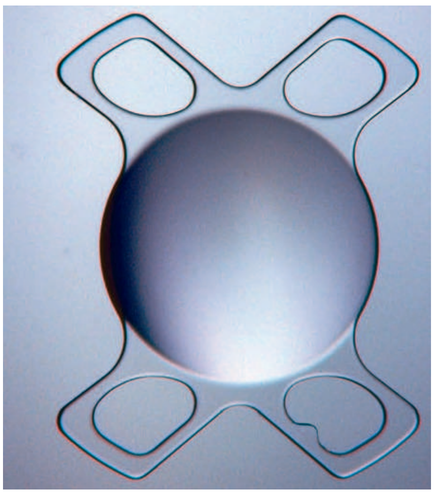


Figure 3: Foldable acrylic IOL implant available for the dog (27).

It is up to the treating veterinarian to decide what kind of implant that is suitable for each patient. Regarding the overall diameter of the lens, ophthalmologist Rich F Sanchez from the Royal Veterinary College (RVC), in London says: "Ophthalmologists normally choose a size they think/feel is right. Personally I will use a smaller lens if I feel I have a lens that is not entirely stable and I feel putting a smaller lens will be physically easier. The main concern in such a case is the risk of lens decenteration if it ends up being too small for the capsular bag." Norwegian ophthalmologist Ernt-Otto Ropstad at the Norwegian Veterinary University (NVH) says that he finds the size of the dog irrelevant for his evaluation of the IOLs, it is the size of the bulbus that matters.

Even though there are several independent veterinary ophthalmologists having various of meanings and thoughts about how they choose the IOL implants and which factors they find most important to take into consideration, it is suggested that a foldable acrylic implant of 14mm is the standard size of IOL implant in dogs (38).

III: Personal examinations

III. a: Materials and methods

In this examination was the main focus the axial globe length (AGL) and the diameter of the lens in the dog. 25 dogs and 50 eyes were examined with ocular B-mode ultrasonography, and the AGL and the lens diameter were measured in both the vertical and horizontal plane. The dogs were categorized in 3 different groups according to their body size, depending on their weight. The aim of this examination was to see if there were any correlation between the size of the dog and the measurements done. It has earlier been mentioned that the average AGL in dogs is measured to be between 19,1 mm and 21,9 mm and the average lens diameter in dogs is 10-11mm at its equator. It has not been specified whether larger dogs may have higher numbers in these measurements than smaller dogs, it has only been enlightened that there might be variations among breeds (26). The purpose of the examination was to find out if there is any obvious indication to use IOL implants of different diameters in dogs of varying sizes.

III. a. a: Criteria of the dogs

The dogs taking part in this study were healthy with no history of ocular diseases. A short ophthalmic examination with slit lamp biomicroscopy and direct ophthalmoscope was performed on every dog, to make sure they were clear for ocular disorders. They were of various age and size, different breeds with different skull confirmations and of both sexes. They were categorized in three different groups according to their body weight. To make sure the groups were in correlation with the actual size of the dog and not mistaking the weight of the dog with increased body fat tissue, the dogs were evaluated to be in the normal range of the body condition scoring.

The dogs were divided in the following groups:

1) <u>Small</u> dogs: less then 10 kg.
2) <u>Medium</u> dogs: between 10 and 30 kg.
3) <u>Large</u> dogs: above 30 kg.

To obtain best possible results with greatest reliability it was favorable to have dogs meeting all the criteria mentioned, in all tree categories. This means that the dogs in every category were both females and males, of various age groups and various breeds.

The 25 dogs taking part in this examination, were categorized into these three tables:

Table 1: Group 1, "Small" (less than 10 kgs)

Nr	Breed	Sex	Age	Weight, kg
1	Miniatyr dachs	Female, intact	8 y	8,2
2	Mix (dachs, Tibetan spaniel)	Female, spayed	7 y	8,0
3	Mix (tib. Spaniel)	Male, castrated	3,5 y	6,2
4	West Highland White terrier	Female, intact	4 y	7,0
5	Chihuahua	Female, intact	6 y	3,8
6	Chihuahua	Male, intact	5 y	5,9
7	Miniatyr Poodle	Male, intact	4 y	5,0

Table 2: Group 2 "Medium" (between 10 and 30 kg)

Nr	Breed	Sex	Age	Weight, kg
1	Shiba	Male, intact	4 y	12,0
2	WHW terrier	Female, intact	6 y	12,6
3	Terrier mix	Male, castrated	5 y	14,0
4	Viszla	Female, intact	4,5 m	14,0
5	Mix (Terrier, Labrador,)	Female, spayed	6 y	12,0
6	English setter	Male, intact	6 y	25,5
7	Gordon setter	Female, intact	1 y	15,0
8	Flattocated Retriever	Female, intact	2 y	24,0
9	Labrador mix	Female, intact	1 r	18,0
10	Alaskan huskey	Female, intact	3 y	24,0

Table 3: Group 3, "Large" (Above 30 kgs)

Nr	Breed	Sex	Age	Weight, kg
1	Border Collie mix	Male, castrated	2,5 y	30,1
2	Akita	Male, intact	19 m	30,6
3	Yellow lab	Female, intact	4 y	32,0
4	Labrador-viszla mix	Male, intact	7 y	30,0
5	Short haired pointer	Male, intact	12 y	42,0
6	Golden retriever	Male, intact	7 y	34,5
7	English setter	Male, intact	6 y	31,5
8	Alaskan huskey	Male, intact	5 y	30,0

III. a. b: Criteria of the method and equipments

A portable B-mode Linscan Ultrasound machine (Linscan Ultrasound USA) with a 12 MHz sector transducer with 6 cm of tissue penetration was used for the first 12 patients. For the next 13 patients was a GE LOGIQ 200 PRO Series Ultrasound machine (MedCorp, USA) with a probe with a 9 MHz linear transducer used.

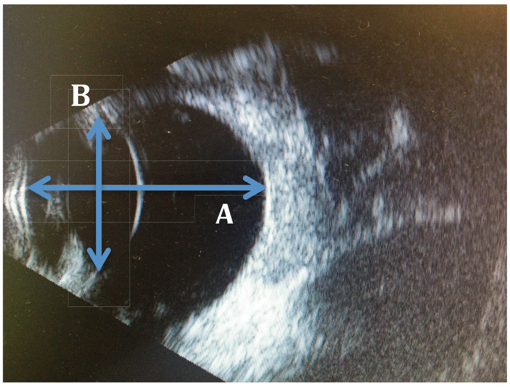
It was used 2-3 drops of local anesthesia (Humacain eyedrop, Richter, Hungary), 3 times with 30 seconds interval on each eye for each dog. The anesthetic effect lasted for approximately 20 min, which was sufficient time to do a thorough examination. After applying the final drops of anesthetics, the dog was placed on an examination table. The owner was supporting the head, and carefully withdrawing the eyelids.

The probe was disinfected before and after use, to prevent contamination between the dogs. During examination the dog was preferably placed in standing position. Sternal recumbency was the second best option if standing was not possible. In these two positions the head and eyes were in most natural positions, and the measurements were performed. A small amount of sterile ultrasonography gel was placed on the probe to obtain sufficient contact area. With this contribution from the owner, the probe was placed directly onto the corneal surface. The ultrasound machines recorded and saved the pictures during the examination. During the examination it was crucial that both dog and owner remained calm and cooperative for the process to be successful.

III. a. c: The measurements

The scanning gave a clear view of the entire eye globe, with clear lines of the borderline between the anterior chamber and the cornea, the anterior and posterior lens capsule, the scleroretinal rim and the optical disc. By rewinding the recorded film, it was possible to find the best picture according to the mentioned criteria and freeze it for further research.

Two measurements were done in each selected picture. The axial globe length (AGL), was measured from the rostral point of the anterior chamber, to the optical disc. And the diameter of the lens was measured from the peripheral point of attachments to the ciliary bodies. The measurements were first done in the vertical plane, then in the horizontal plane on the right eye. Then the same procedure was repeated on the left eye. After all the measurements were done, the eyes and the probe were gently cleaned from excess gel with cotton. The probe was also disinfected with alcohol. The dog was then carefully placed back on the ground and the examination was finished. All the measurements were noted and placed in an excel file.



Figur 4: US picture showing where the AGL (A) and the diameter of the lens (B) are measured. (From personal examination).

III. a. d: Statistical analysis

The program used for the statistical analysis of this study was "R Core Team (2014), Foundation for Statistical Computing, Vienna, Austria". URL: http://www.R-project.org/. All values for continuous variables was given as mean and 95% confidence interval, unless else stated. Probabilities of less than 5% were considered statistically insignificant in this study. Usually is a probability of less than 5% also used, but in smaller studies like this is 5% sufficient as limit of significance.

III. b: Results

The measurements have been summarized in the table below, indicating all the dogs and the data. Table 4 shows the first 12 dogs being examined with a US-machine of 12 MHz, sector transducer and the last 13 dogs being examined with a 9 MHz, linear transducer ultrasound machine.

The first section of the table, "General", is a general description of the dogs taking part in the examination. Here are the breed, sex, age and weight of the different dogs indicated.

For the second section, "Measurements (mm)", are the findings from each dog written.

Table 4 is subdivided into sections of the right and the left eye of each dog. Both sections for right and left eye are then subdivided into the horizontal and vertical plane, which again are divided into sections showing data for the axial globe length and the lens diameter.

Table 4: Overview of collected data from personal examination:

		General				Measurements (mm)							
						Right eye				Left eye			
						Vertical plane		Horizontal plane		Vertical plane		Herizontal plane	
B-mode US machine	Nr	Breed	Sex	Age	Weight, kg	AGL	Lens diameter	AGL	Lens diameter	AGL	Lens diameter	AGL	Lens diameter
12 MHz, sector transducer.	1	Mix (Border collie)	Male, castrated	2,5 y	30,1	19,03	11,05	19,02	11,01	19,31	11,09	19,57	10,71
	2	Akita	Male, intact	19 m	30,6	19,21	10,60	21,96	10,10	19,56	10,70	20,07	12,09
	3	Shiba	Male, intact	4 y	12,0	18,59	10,95	18,84	10,78	18,15	10,84	18,91	10,67
	4	Yellow labrador	Female, intact	4 y	32,0	19,96	11,85	19,74	11,66	22,05	11,93	19,72	11,75
	5	Mix (Viszla)	Male, intact	7 y	30,0	21,85	11,42	21,25	11,76	21,27	11,44	21,29	12,08
	6	Terrier	Male, castrated	3 y	12,6	20,40	10,68	20,29	11,96	19,95	10,62	19,55	10,37
	7	Terrier mix	Male, castrated	5 y	14,0	20,04	10,45	19,88	10,52	19,67	10,93	19,95	10,76
	8	Dachshound	Male, castrated	8 y	8,2	18,43	10,52	18,42	10,46	18,74	10,18	18,34	10,56
	9	Viszla	Female, intact	5 m	14,0	18,94	10,00	18,68	10,14	18,90	10,07	18,89	10,07
	10	Mix	Female, spayed	6 y	12,0	19,73	10,43	19,23	10,78	19,51	10,62	19,07	10,15
	11	Mix (dachs)	Female, spayed	7 y	8,0	18,66	10,53	18,18	10,10	18,47	10,35	18,49	10,81
	12	Mix (tib. Spaniel)	Male castrated	3,5 y	6,2	18,85	11,03	18,81	10,93	19,32	11,10	18,46	10,51
9 MHz, linear transducer.	13	Short haired pointer	Male, intact	12 y	42,0	17,59	12,08	18,02	11,89	18,13	12,05	17,77	11,90
	14	WHW terrier	Female, intact	4 y	7,0	18,58	10,60	18,64	10,58	18,49	10,49	18,67	10,38
	15	Chihuahua	Female, intact	6 y	3,8	19,92	11,05	20,08	11,16	20,11	11,12	19,99	11,18
	16	Chihuahua	Male, intact	5 y	5,9	20,30	11,88	20,48	12,02	20,34	11,93	20,47	12,09
	17	English setter	Male, intact	6 y	25,5	19,78	10,70	20,20	11,30	21,01	11,39	20,98	11,07
	18	Gordon setter	Female, intact	1 y	15,0	18,58	11,26	18,90	11,76	18,98	12,01	19,03	11,89
	19	Fl. Retriever	Female, intact	2 y	24,0	19,58	11,34	19,23	11,05	19,59	11,69	19,62	11,9
	20	Labrador mix	Female, intact	1 y	18,0	19,8	10,56	19,92	11,03	19,43	10,91	19,56	10,98
	21	English setter	Male, intact	6 y	31,5	20,03	11,43	20,15	11,38	20,39	10,98	20,67	11,12
	22	Miniatyr Poodle	Male, intact	4 y	5,0	19,59	10,45	18,79	10,56	19,04	10,89	19,87	11,03
	23	Golden retriever	Male, intact	7 y	34,5	18,98	10,75	19,32	10,43	19,04	11,01	18,87	10,69
	24	Alaska husky	Female, intact	3 y	24,0	20,03	11,56	19,87	11,49	19,89	10,9	20,01	11,12
	25	Alaska husky	Male, intact	5 y	30,0	19,54	10,43	19,78	11,11	20,12	11,34	20,42	11,04

The data from Table 4, was categorized into the different groups, and the mean value in each group was calculated. This was done by first finding the mean between the horizontal and vertical plane for both the AGL and the lens diameter. This was calculated by adding the two data and divide by two. The result indicated the mean values for each of the parameters, in both eyes. Then the average value for both of the eyes was calculated in the same way, so one data for each measurement done in each dog, was the result used for further calculations. This value was placed in Table 5, 6, and 7 and used to calculate the mean value representing the groups. The mean value in each group was calculated.

The values of the different groups is indicated in the tables below:

Table 5: Group 1, "Small dogs", mean AGL and lens diameter in mm:

Nr	Breed	Sex	Age	Weight, kg	Mean AGL	Mean lens diameter
1	Mix dachs	Female, intact	8 y	8,2	18,48	10,62
2	Mix (dachs)	Female, spayed	7 y	8,0	18,45	10,45
3	Mix (Spaniel)	Male, castrated	3,5 y	6,2	18,86	10,71
4	WHW terrier	Female, intact	4 y	7,0	18,60	10,59
5	Chihuahua	Female, intact	6 y	3,8	20,03	11,13
6	Chihuahua	Male, intact	5 y	5,9	20,40	11,38
7	Mix poodle	Male, intact	4 y	5,0	19,32	11,26
Mean value					**19,16**	**10,88**

Table 6: Group 2, "Medium dogs", mean AGL and lens diameter in mm:

Nr	Breed	Sex	Age	Weight, Kg	Mean AGL	Mean lens diameter
1	Shiba	Male, intact	4 y	12,0	18,62	10,81
2	WHW terrier	Female, intact	6 y	12,6	20,05	10,70
3	Terrier mix	Male, castrated	5 y	14,0	19,89	10,67
4	Viszla	Female, intact	4,5 m	14,0	18,85	10,07
5	Mix (Terrier,)	Female, spayed	6 y	12,0	19,39	10,55
6	English setter	Male, intact	6 y	25,5	20,49	11,12
7	Gordon setter	Female, intact	1 y	15,0	18,87	11,23
8	Flatocated Retriever	Female, intact	2 y	24,0	19,51	11,50
9	Labrador mix	Female, intact	1 y	18,0	19,68	11.30
10	Huskey	Female, intact	3 y	24,0	19,95	11,38
Mean value					**19,53**	**10,93**

Table 7: Group 3, "Large dogs", mean AGL and lens diameter in mm:

Nr	Breed	Sex	Age	Weight, kg	Mean AGL	Mean lens diameter
1	Border Collie mix	Male, castrated	2,5 y	30,1	19,23	10,97
2	Akita	Male, intact	19 m	30,6	20,20	11,06
3	Yellow labrador	Female, intact	4 y	32,0	20,37	11,30
4	Lab-viszla mix	Male, intact	7 y	30,0	21,42	11,68
5	Shorthaired pointer	Male, intact	12 y	42,0	17,88	11,98
6	Golden retriever	Male, intact	7 y	34,5	19,05	10,72
7	English setter	Male, intact	6 y	31,5	20,31	11,23
8	Alaskan huskey	Male, intact	5 y	30,0	19,97	10,98
Mean value					**19,80**	**11,24**

After calculating the mean values for each group, the values were placed in a pole chart to give a visual impression of the differences between the groups.

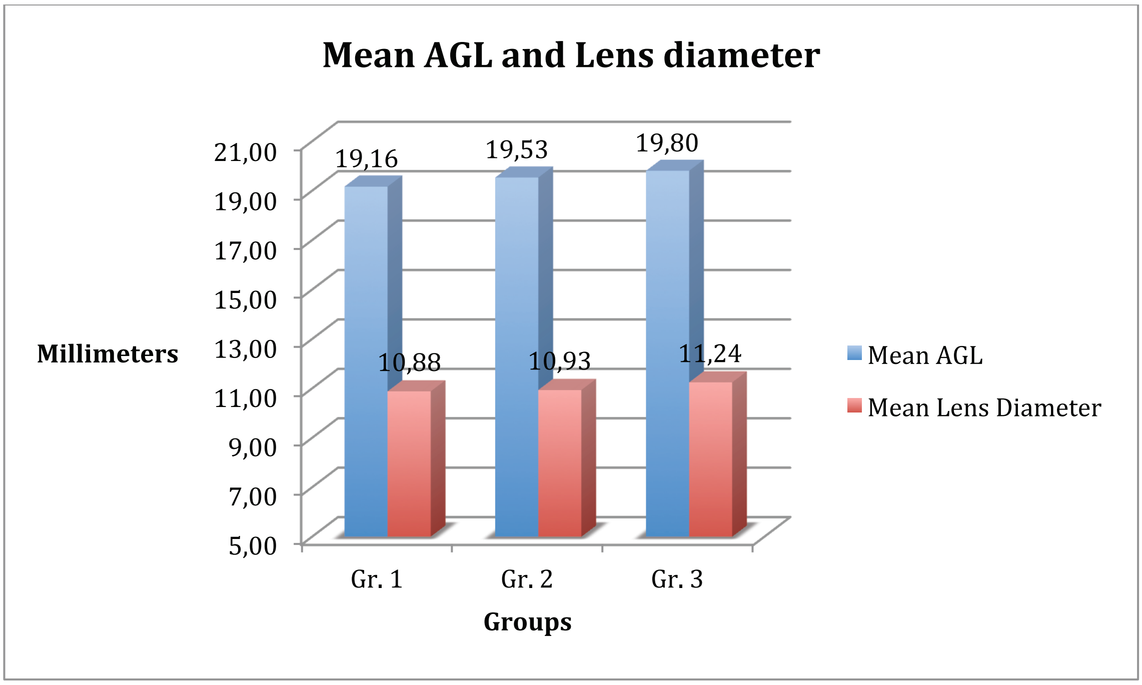


Figure 5: Showing the mean axial globe length (AGL) and lens diameter in millimeters in the different groups. Gr. 1 is representing the group of small dogs, Gr. 2 the medium dogs and Gr. 3 the large dogs.

III. b. a: Statistical analysis, results

III. b. a. a: AGL

The right mean 19,47 ± 0,84 mm

The left mean 19,55 ± 0,87 mm

The overall mean 19,51 ± 0,83 mm

Weight linkage

- Right vertical plane
  Total population: Non significant (p=0,89) association (β = 0,002)
  Population below 30 kg: Non significant (p=0,12) positive association (β= 0,03)
  Population above 30 kg: Non significant (p=0,12) neg. association (β= - 0,23)
- Right horizontal plane
  Total population: Non significant (p=0,24) association (β = 0,0021)
  Population below 30 kg: ***Significant*** (p=0,01) positive association (β= 0,05)

	Population above 30 kg: ***Significant*** (p=0,004) neg. association (β= - 0,17)
- Left vertical plane	Total population: Non significant (p=0,17) association (β = 0,024)
	Population below 30 kg: ***Significant*** (p=0,02) positive association (β= 0,04)
	Population above 30 kg: Non significant (p=0,37) neg. association (β= - 0,33)
- Left horizontal plane	Total population: Non significant (p=0,37) association (β = 0,015)
	Population below 30 kg: ***Significant*** (p=0,003) positive association (β= 0,05)
	Population above 30 kg: Non significant (p=0,13) negative association (β= - 0,18)

III. b. a. b: Lens diameter

The right mean	10,99 ± 0,53 mm
The left mean	11,07 ± 0,56 mm
The overall mean	11,03 ± 0,51 mm

Weight linkage

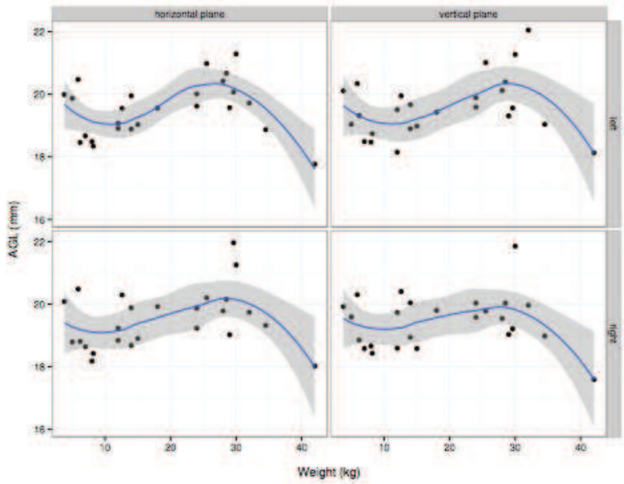
- Right vertical plane	***Significant*** (p=0,04) association (β=0,02)
- Right horizontal plane	Non significant (p=0,2) association (β=0,014)
- Left vertical plane	***Significant*** (p=0,03) association (β=0,022)
- Left horizontal plane	***Significant*** (p=0,03) association (β=0,25)

III. b. b: AGL

The study reveals that the average AGL in “Gr. 1, small dogs” was 19,16 mm, in “Gr. 2, medium dogs” was 19,53mm and in “Gr. 3, large dogs” was 19,80 mm (Figure 5).

The statistical analysis was showing an overall mean of the AGL at 19.51 ± 0,83 mm, with a mean of the right eye of 19,47 ± 0,84 mm and the left eye of 19,55 ± 0,87 mm.

For the weight linkage the statistics were showing a significance of p = 0,01 with association (β = 0,05) in the population below 30 kg, and of p = 0,004 with association (β = -0,17) in the population above 30 kg, both in the right horizontal plane. The population below 30 kg was significant with a p=0,02 with association (β = 0,04) in the left vertical plane with a significance of a p=0,003 with association (β = 0,05) in the left horizontal plane.



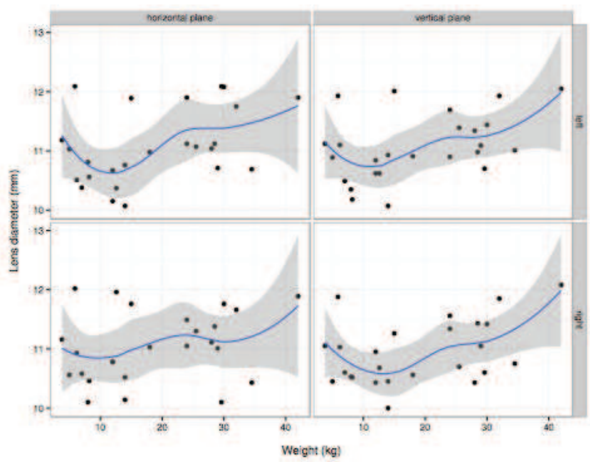
Figur 6: AGL and weight linkage in horizontal and vertical plane of both right and left eye.

III. b. c: Lens diameter

The study reveals that the average lens diameter in Gr. 1 was 10,88 mm, in Gr. 2 was 10,93 mm and in Gr. 3, 11,24 mm. (Figure 5.)

The statistical analysis was showing an overall mean of the lens diameter of 11.03 ± 0,52 mm, with a mean of the right eye of 10,99 ± 0,53 mm and the left eye of 11,07 ± 0,56 mm.

For the weight linkage there was a significance at p = 0,04 with association (β = 0,02) in the right vertical plane and a significance with p = 0,03 with association (β = 0,022) in the left vertical plane. There was also a significance with p=0,03 with association (β=0,25) in the left horizontal plane.



Figur 7: Lens diameter and weight linkage in horizontal and vertical plane of both right and left eye.

III. c: Discussion

The aim of this study was to evaluate if it was possible to detect any direct correlations between the body size of the dog and the lens diameter by using B-mode ocular ultrasonography. After categorizing the 25 dogs taking part in the study into 3 different groups and performing the measurements, the data from the different groups was compared.

As both eyes were measured and no significant difference existed between the two eyes in either of the AGL or the diameter of the lens in either of the dogs, the average values between the two eyes were used in this study. There was no indication to believe there was of any great significance of what transducer that was used. Both ultrasound machines with different transducers and different megahertz values gave satisfactory images to make precise measurements in this examination. The portable US machine with a sector transducer was easier to handle and thereby created a picture of better quality. The sector transducer was also contributing to a better visualization of the ocular structures of interest.

The interval of the reference values for the AGL indicated in the literature is from 19.1mm to 21,9 mm with 20,8 mm being the average value. The results from the examination were revealing that according to these values, all three groups were measured to be in the reference interval. It was detected a slight increase of a total 0,64 mm from Gr. 1 to Gr. 3. There was a slight increase from Gr. 1 to Gr. 2 of 0,37mm, and from Gr. 2 to Gr. 3 of 0,27 mm (Figure 5). The total increase from Gr. 1 to Gr. 3 was of 0,64mm. It seems like the AGL is increasing linearly as the weight increases, up to a certain point. In figure 6., this point seems to be around 30 kg. Kept in mind that only one dogs is representing 40 kg.

It seems like there is no connection or any significant difference of the parameters between females and males regarding the AGL.

The statistical analysis were also showing interesting data relating the AGL and the age, however this is not a part of the topic in this article, and will not be discussed further here.

The reference value of the lens diameter is 10-11 mm. The overall diameter of the lens in the examined dogs was measured to be 11,03±0,51 mm. The results were showing that Gr. 1 and Gr. 2 were within the normal range, but Gr. 3 was 0,24 mm above. There was also a slight increase in the measurement between Gr. 1 and Gr. 2 of 0,05 mm, and a greater increase from Gr.2 to Gr. 3 with 0,31mm. (Figure 5.) There was a total difference of 0,36 mm between Gr. 1

and Gr. 3. There was a slight increase in the lens diameter, which gradually increases as the weight of the dogs increases.

The hypothesis of this study was that the diameter of the lens would most likely be greater in larger dogs compared to smaller dogs. The findings are revealing a slightly larger diameter of the lens in Gr. 3 compared to the other groups, but no significant difference between Gr. 1 and 2. It seems like there is no linear correlation between the diameter of the lens and the weight of the dogs. Even though is it visible that the lens diameter is slightly bigger in large dogs.

The literature supports the theory that the axial globe length and the diameter of the lens in the dog is being set to 19,1-21,9mm with 20,8mm as an average (5,15) and 10-11mm (26) respectively. These tendencies we can see in this study as well.

The overall results from this examination are revealing a slight increase in both the AGL and the lens diameter for the Group 3, largest dogs. The results were expected to show an even more symmetrical increase in *both* measurements as the weight of the dogs increased. Instead, only a marked increase for the diameter of the lens in Gr.3, and not a marked increase in Gr. 2, compared to Gr. 1 is shown. The findings are showing a more or less proportional increase in the AGL in the three groups, as the weight increases.

There is a reason to believe there might be interactions with some errors or inaccuracy that gave these results, because there is no such clear difference form the first and the second group, as there is from the second and the third group. If the study was done with more than 25 dogs, this inaccuracy might even out.
In further studies regarding this topic, I would consider using both of the ultrasound machines on a limited number dogs, to evaluate the validity of the machines. There is a reason to believe that ocular structures are in correlation with the size of the dog, but there is no clear indication that this is the most crucial factor for determining the diameter of the lens. The bulbus and the AGL are probably better indications to predict ocular structures, including the lens diameter. This study indicated an increase in the AGL, which was in correlation with the increase of the dogs' body weight. It seems like there is reason to believe that the size of the bulbus and thereby the AGL might be a factor of greater importance than the weight of the dog.

IV: Summary

This article is enlightening questions about correlations between the diameter of the lens, the axial global length and the body size of dogs. Larger dogs have larger anatomically structures than smaller dogs, and the hypothesis in this article was that this was true for the ocular structures as well. By accurate determination of the canine lens sizes, the success rate of IOL replacement surgeries may be greatly improved. Determination of the IOL implants must be done with great care and accuracy. By easy being able to predict the size of the lens in the patients is beneficial for the further determination of the IOL implants.

This study is therefor investigating if there is any direct correlation with the size of the dog and the diameter of the lens, and thereby making it easier to predict the size of the IOL implant to be chosen. In this examination were 25 dogs categorized into 3 groups according to their body weight. Group 1 being under 10 kg, Group 2 being between 10 and 30 kg and group 3 more than 30 kg. The dogs were clinically healthy with no history of ocular diseases. Both the lens diameter and the axial globe length were measured by using B-mode ocular ultrasound. All three groups are showing results for the AGL matching the reference values given by the literature, with a slight increase of 0,64 mm from the group of smallest candidates to the group of largest. The results for the lens diameter in Group 1 and 2 was in between the reference interval, but for group 3 was the lens diameter measured to be 0,24 mm above. Comparing the three groups to each other we can see that the largest group has a larger lens diameter and a greater AGL.

This study gives an impression that the ocular structures are in no direct correlation with the actual size of the dogs. There is a tendency, showing that a slight increase in the size of structures may be reasonable, but the differences are not significant. When the size of the IOL implants are to be chosen for todays patients, it might of greater importance to measure the bulbus of the dog to determine the size of the lens.

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VI: List of abbreviations

- Ultrasonography - US
- Magnetic resonance - MR
- Computed tomography – CT
- Persistent hyperplastic tunica vasculosa / persistent hyperplastic primary vitreous - PHTV/PHPV
- Diabetes Mellitus – DM
- High-resolution ultrasound technique – HRUS
- Ultrasound biomicroscopy – UBM
- Axil globe length - AGL
- Iridocorneal angle – ICA
- Intraocular lens – IOL
- Body condition score – BCS
- Intra ocular pressure – IOP
- Polymethylmethacrylate – PMMA
- Intra capsular opacification - ICO
- The Norvegian Veterinary College – NVH
- The Royal Veterienary Collge, University of London – RVC
- Anterior lens capsule – ALC
- Posterior lens capsule – PLC

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