Titulo: Cataract surgery by phacoemulsification with the Tilt and Tumble technique

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Abstract

Cataract surgery by phacoemulsification with the Tilt and Tumble technique is a technique not well known in veterinary medicine, but widely accepted and used in the field of human medicine, due to the learning curve and the advantages attributed to its use.

The main objectives of this work were the description and study of the results of the Tilt and Tumble technique in cataract extraction surgery by phacoemulsification and its implementation in veterinary medicine.

During the study we were able to observe and detail the advantages and disadvantages of the use of this technique. It was observed that the rupture of the posterior capsule of the crystalline lens and the exit of the vitreous, which are the most frequent complications in the other techniques, showed a much lower predisposition, mainly due to the extracapsular extraction of the cataract. In the same way, the incidence of postoperative complications was quite low. In addition to being an excellent option when the cataract extraction is of soft consistency, but not so suitable for mature or large cataracts.

1. Introduction

1.1. Theoretical foundations

1.1.1. Cataracts

The eyes contain a transparent, biconvex, lenticular, flexible and avascular lens called crystalline lens, whose main function is to focus objects depending on their distance. When the transparency of the crystalline lens is totally or partially lost, what we call cataract is formed, preventing light from reaching the retina and thus causing a loss of vision.

This term comes from the Greek katarráktes “waterfall, cascade”, due to its similarity with the white color of water falling vertically.

Cataracts are one of the main causes of vision loss in animals, especially in older dogs and cats. Cataract surgery has become an essential procedure in veterinary medicine, allowing the restoration of vision and improving the quality of life of patients. In addition, failure to surgically treat advanced cataracts can result in a complication rate up to 255 times higher than those who undergo surgery (Yolanda et al, 2021).

1.1.2. Classification of cataracts

Cataracts can be classified according to age, stage of development or etiology.

Age of onset: cataracts can manifest in various forms, including a congenital problem (congenital cataract), develop in young animals (juvenile cataract) or develop in older animals (senile cataract).

- Congenital cataracts: frequently linked to other ocular anomalies, such as microphthalmia, persistent pupillary membrane, retinal dysplasia, among others.
  When several of these ocular anomalies coexist, abnormal eye movements are also often present, going from mild oscillatory nystagmus to more rotational movements.
  It is common for these congenital cataracts to occur in a stationary form and surgery is not necessary for their elimination.

- Juvenile cataract: primary cataracts seen in young animals may be hereditary in some breeds and progress to complete damage to the lens.

- Senile cataract: are quite frequent in elderly animals, being these the main patients when performing cataract surgery. This type of cataract should not be confused with senile sclerosis, which only causes a physical change of the lens fibers, without causing blindness, pain or discomfort.

Development status

- Incipient cataracts: in this type of cataract we will find very early changes in the crystalline lens, affecting only some fibers or small areas of the lens. The presence of vacuoles may indicate that the cataract is developing. However, vision will be barely affected at this point.

- Immature cataracts: even at this point we can observe the reflection of the back of the eye, since not the totality of the crystalline lens is affected. We can use this reflection to highlight the changes that are caused in the crystalline lens, making it easier to see.

- Mature cataracts: the crystalline lens is completely opaque, preventing us from observing the tapetal reflex. It is probable that the affected eye has no visual function. At this point, the cataract may have accumulated fluid, which we call “intumescence”, resulting in a hypermature cataract. This intumescence is typical of rapidly forming cataracts secondary to diabetes mellitus. Occasionally, increased intraocular pressure may be observed due to obstruction of aqueous humor drainage.

- Hypermature cataracts: fluid accumulation can cause the lens to separate along the suture lines, resulting in an outflow pathway for lens proteins. The presence of these proteins in the uvea will cause a response from the immune system, eventually leading to uveitis. Some signs that can be observed are: episcleral congestion, decreased intraocular pressure and darkening of the iris.

Etiological classification

- Hereditary cataracts: there are different breeds of dogs around the world that are suspected to suffer from cataracts in a hereditary form. Most of them follow specific patterns in terms of age at onset, which part of the lens is affected and how it progresses.

- Cataracts secondary to other ocular problems: may form as a result of diseases that affect the lens environment or damage it directly. They are caused by other ocular conditions such as uveitis or glaucoma, or diseases such as diabetes (Maryland, 2023).

- Traumatic cataracts: are cataracts that develop following physical trauma or injury to the eye, and may even develop years after the injury (Maryland, 2023).

- Metabolic cataracts: a common cause of cataracts is diabetes mellitus (Basher and Robert, 1995). There is an increase of glucose in the aqueous humor and lens due to an increase in blood glucose levels. Because of this, aldose reductase converts glucose to sorbitol. As this molecule is larger than glucose, it cannot diffuse through the lens fibers and therefore accumulates and generates an osmotic gradient. This results in fluid entry into the lens causing distortion of the lens fibers, vacuolization and cataracts.

- Toxic and dietary cataracts: there are several cataractogenic drugs and toxins, as well as exposure to radiation during the treatment of neoplasias or to the sun, can cause the development of cataracts.

- Senile cataracts: there is a high prevalence of cataracts in older animals, being these the main patients for cataract surgery, commonly without an apparent cause (Mailen, 2020).

1.2. Treatment

Cataract management is mainly surgical. Occasionally there have been cases of spontaneously resolved lens opacities, but most of the time this does not occur.

On the other hand, there is no evidence to date that medical treatment is effective against cataracts, since the drugs studied have been used only experimentally and with questionable results.

For a long time, intracapsular cataract extraction has been the technique most commonly used for this type of surgery, however, a trend has developed towards the use of extracapsular techniques as the method of choice.

Phacoemulsification is a surgical technique for cataract extraction based on making a small incision in the cornea and removing the crystalline lens by disintegrating it using high-frequency ultrasonic vibrations to fragment it and then aspirate it.

For this procedure, a phacoemulsifier is used, an instrument responsible for fragmenting the cataract by means of a titanium probe, which emits ultrasonic vibrations.

1.3. Techniques

Nowadays there are several techniques for the extraction of cataracts in small animals, among the most commonly used are:

- Divide and Conquer Phaco
- Stop and Chop Phaco
- Phaco Chop
- Irrigation and Aspiration (I&A)
- Vitrectomy
- Tilt and Tumble Phaco

1.3.1. Divide and Conquer Phaco

In this technique, the phacoemulsification probe is used to sculpt a longitudinal groove in the lens with cataract, and subsequently a second groove perpendicular to the initial one (Uday, 2018), and then a second instrument is used to break the nucleus into several pieces or quadrants that can be easily extracted (Figure 1).

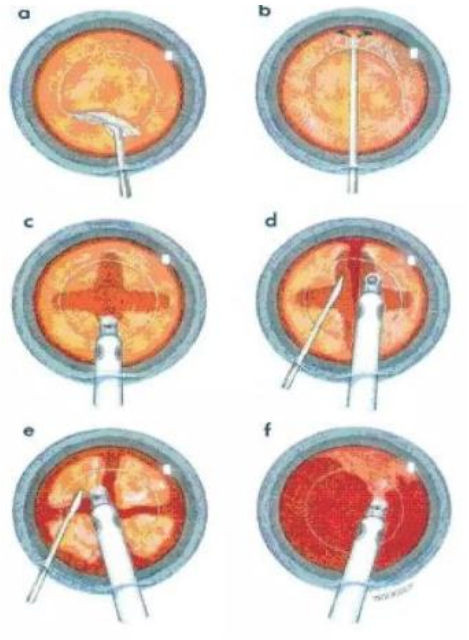

Figure 1: Outline of steps to be followed for the Divide and Conquer Phaco technique. a) Capsulorrehxis. b) Hydrodissection. c) Sculpting of nucleus. d) Cracking of nucleus. e) emulsification of each cuadrant. f) Cortical cleanup and insertion of IOL. Image extracted from the University of Zaragoza website, 2008.

1.3.2. Stop and Chop Phaco

Based on the creation of grooves as mentioned above, under divide and conquer sculpting techniques. It is a method of phacoemulsification within the capsular bag, where sculpting is performed to provide space for nuclear manipulation and subsequently splitting the posterior plate into two halves (Paul et al, 1994). The nuclear rim is fractionated into pieces of a size to allow its removal using a modified lens hook that is buried in the nuclear periphery and pulled toward the center (Figure 2).

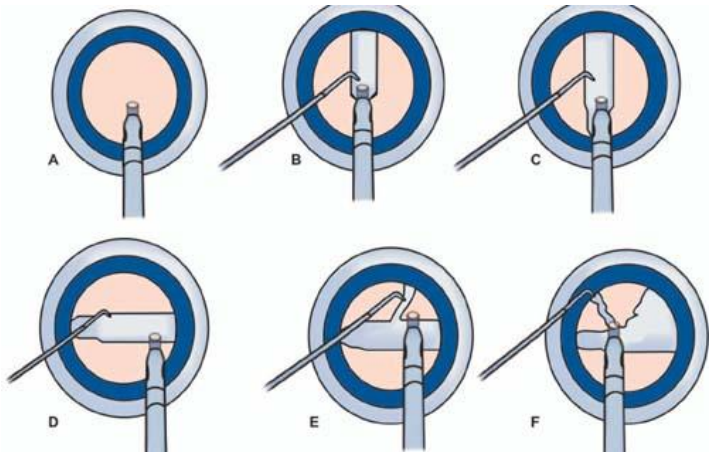

Figure 2: Steps to follow for the Stop and Chop Phaco technique. A, B, C) Longitudinal sculpting of a groove. D) Rotation of the nucleus. E) Division into smaller pieces and phacoemulsification. Image recovered from Mastering the PHACO CHOP 2007.

1.3.3. Phaco Chop

It is one of the most effective, safe and efficient nucleus-fractis techniques, but it has a more complex learning curve for beginner surgeons. It is a bimanual phacoemulsification technique where cutting forces are applied parallel to the natural planes of the lens lamellae, thus splitting the nucleus with less force and time (Christi, 2004). It has been shown that, compared to the Divide and Conquer method, damage to endothelial cells is significantly reduced (Figure 3, Ding et al, 2019).

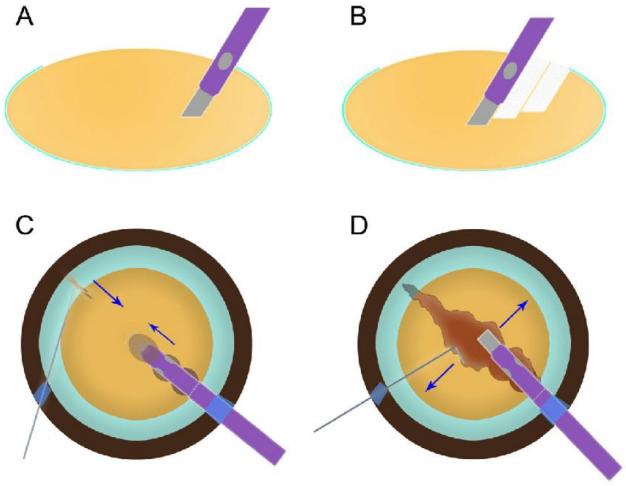

Figure 3: Performance of the Phaco Chop technique. A, B, C, D) Division of the nucleus by ultrasound.

1.3.4. Irrigation and Aspiration (I&A)

Similar to phacoemulsification, the stability of the anterior chamber during incision and opening is due to the balance between inflow and outflow. This technique allows the injection of a saline solution to maintain the depth of the anterior chamber and avoid collapse (Figure 4), while removing material by aspiration (WSVA, 2008).

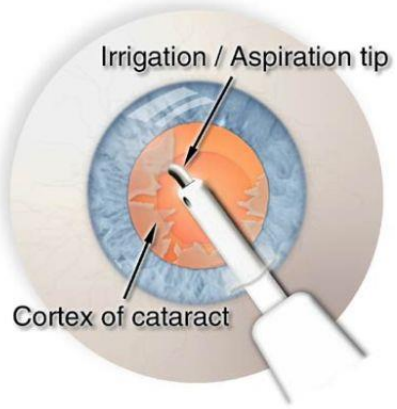

Figure 4: Irrigation and Aspiration in a cataract surgery.

1.3.5. Vitrectomy

The majority of phacoemulsification machines are equipped with a vitreous cutter, which is activated by compressed air or an electric motor. It is important to preserve the depth of the anterior chamber, and this is achieved by balancing the inflow and outflow. During this procedure, some or all of the vitreous humor is removed. The vitreous should be removed down to the level of the posterior capsule (WSVA, 2008).

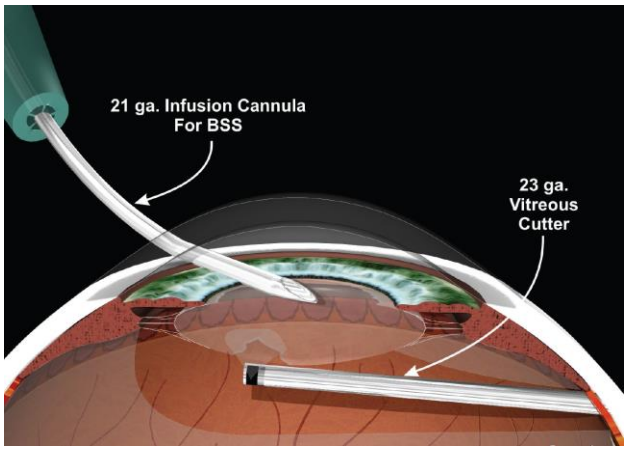

Figure 5: Bimanual anterior vitrectomy. Image recovered from Tip son managing this complication during cataratc surgery, 2009.

1.3.6. Tilt and Tumble

This technique was first described by Dr. Richard Lindstrom in the mid 1990's, founder and surgeon of the Department of Ophthalmology at the University of Minnesota, being a board certified and internationally recognized ophthalmologist in cataract, refractive, glaucoma and laser-assisted surgery.

Cataract surgery using the Tilt and Tumble technique is a type of supracapsular phacoemulsification, that is, cataract extraction is performed outside the capsular bag.

1.4. Approach and objectives

1.4.1. Approach

Cataracts are one of the most common affections in pets and that is why cataract surgery is so important.

Performing a surgical technique with minimal complications is essential for the welfare of the animal. Therefore, after describing the Tilt and Tumble technique, which is not very well known in veterinary medicine, we will carry out a study to find the incidence and severity of the complications of this technique.

1.4.2. Objectives

- To describe and study the results of complications, advantages and disadvantages of phacoemulsification using the Tilt and Tumble technique in cataract extraction surgery.

2. Materials and methods

A descriptive observational study was carried out on 500 patients who underwent cataract surgery by phacoemulsification with the Tilt and Tumble technique. We mainly analyzed the complications, advantages and disadvantages that dogs and cats presented with the use of this technique in the Oftalvet Veterinary Specialties Clinic.

Dogs and cats presenting with cataracts unilaterally or bilaterally were included in the study, independent of the age of the animal and the consistency of the cataract. Patients who would subsequently have an IOL placed after cataract removal were also included.

Procedure

First of all, when the patient has undergone anesthetic induction, we proceed to place a few drops of Betadine 5% before performing any other procedure, as this will act as an antiseptic and disinfectant of the area and thus avoid any possible contamination.

Next, we made a small 1.2 mm incision in the cornea (Figure 6), through which we introduced Trypan Blue intracamerally (Figure 7). This dye does not damage the ocular structures and stains perfectly the subcapsular cells. We should not apply an excessive amount, and we should be especially cautious in case of suspected subluxation, since the dye may pass into the vitreous space and complicate the surgery.

After waiting 10 to 15 seconds, we apply viscoelastic to remove the dye from the anterior chamber and keep the anterior capsule stained. Dye remaining for an excessive amount of time before applying viscoelastic could cause corneal staining. We introduce cohesive viscoelastic through the same incision in order to maintain the depth of the anterior chamber and protect the corneal endothelium.

Now we make a second temporary corneal incision of 2.7mm (Figure 8), and then a continuous curvilinear capsulorhexis, between 5-5.5mm in diameter depending on the density of the cataract, and thus generate a window in the lens capsule large enough to allow the nucleus to exit through the rhexis and tilt it out of the capsular bag towards the plane of the iris (Figure 9). A correct capsulorhexis will allow us to perform the hydrodissection more safely and with a

much lower risk of capsular rupture. It is important to maintain anterior chamber depth by using cohesive viscoelastic when necessary.

Figure 6: 1.2mm corneal incision.

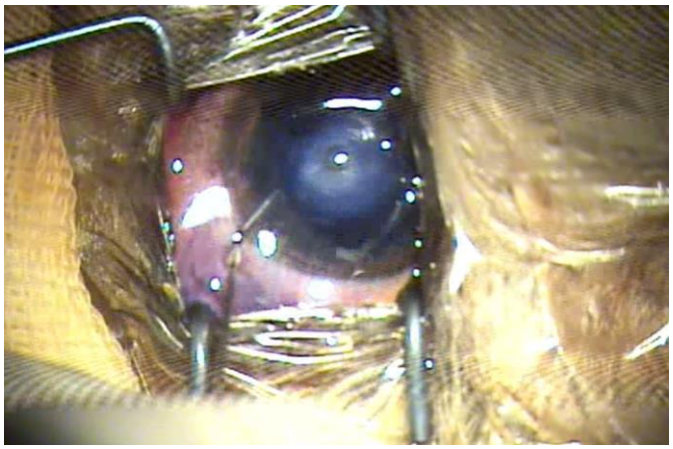

Figure 7: Application of Trypan Blue.

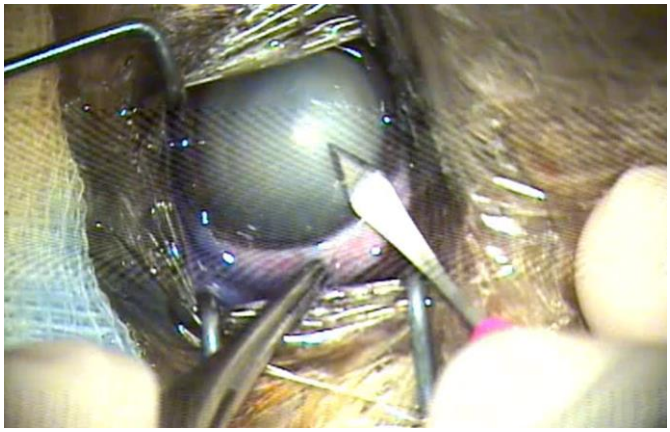

Figure 8: Corneal incision of 2.7mm.

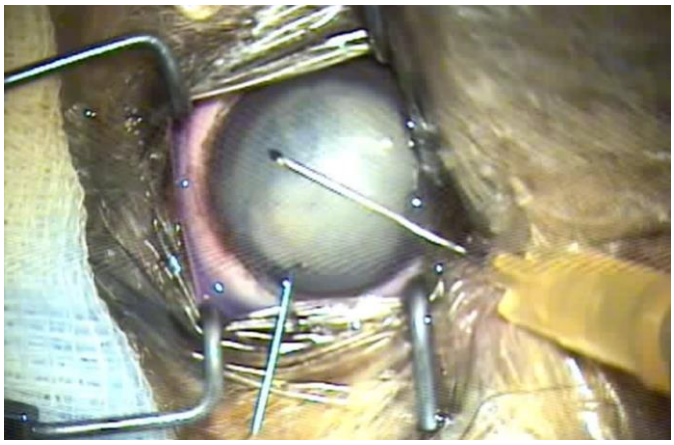

Figure 9: Capsulorhexis 5-5.5mm in diameter.

After capsulorhexis, hydrodissection is performed slowly and constantly, lifting the anterior capsular rim, in order to prolapse the nucleus by tilting it out of the capsular bag (Figure 10). The goal of hydrodissection is to break capsulo-cortical adhesions and decrease traction on the zonule during surgery. Additional viscoelastic can be applied over the nuclear rim to protect the endothelium.

Once the nucleus has tilted upward and we observe the equator of the lens, we can emulsify half of the nucleus and so, once this is done, we aspirate the second half inferiorly in the plane of the capsular iris (Figure 11). We will do this with the use of a phacoemulsification probe and a second instrument called a manipulator or rotator, which serves to help us stabilize the nucleus and feed the phacoemulsifier with fragments of the nucleus.

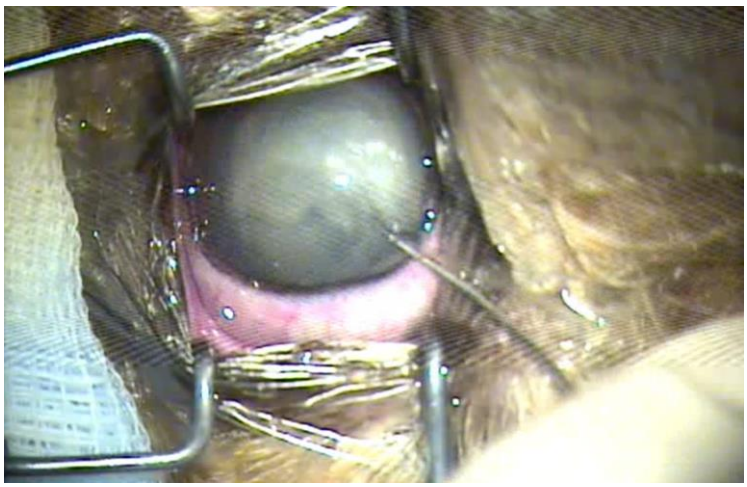

Figure 10: Hydrodissection.

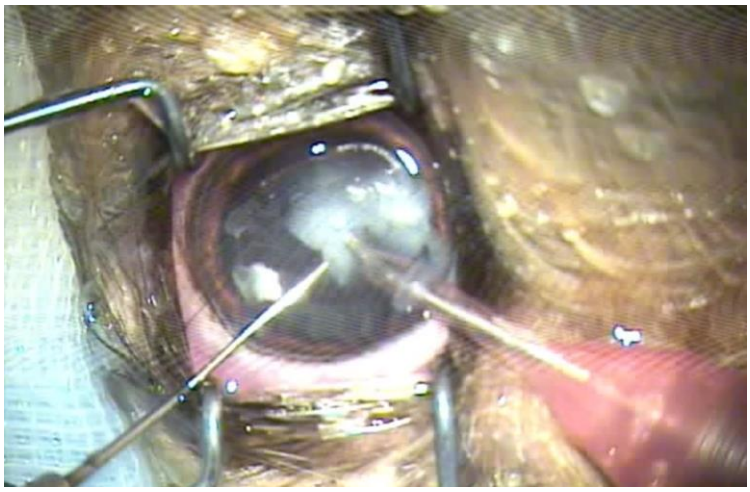

Figure 11: Phacoemulsification of cataract.

After removing the cataract, we perform capsular polishing, with special emphasis on the anterior capsule, since here the presence of epithelium will produce crystallin fibers, which will migrate to the posterior segment generating an opacification of the posterior capsule. With capsular polishing we manage to eliminate this epithelium and avoid opacification of the lens capsule.

Now, if desired, it is time to place the intraocular lens (IOL) in the patient's eye. We use foldable lenses, which can be implanted through really small incisions (Figure 12). The only difference at this point with respect to the other techniques is that the rhexis is slightly wider, but still smaller than the optical part of the IOL. To do this, we first introduce dispersive viscoelastic. Once the IOL is correctly positioned and centered, we remove the dispersive viscoelastic and proceed to suture closure, with previous hydration of the edges of the incisions made in the cornea at the beginning of the surgery (Figure 13). A single surgeon stitch is sufficient in the larger incision (2.7mm), and no sutures will be used in the smaller one (1.2mm), since it will be self-sealed.

We administer an antibiotic and anti-inflammatory subconjunctival and place a few drops of Betadine 5% on the ocular surface in order to disinfect and check that there is no leakage of aqueous humor and that the incisions are properly sealed.

Figure 12: Intraocular lens placement.

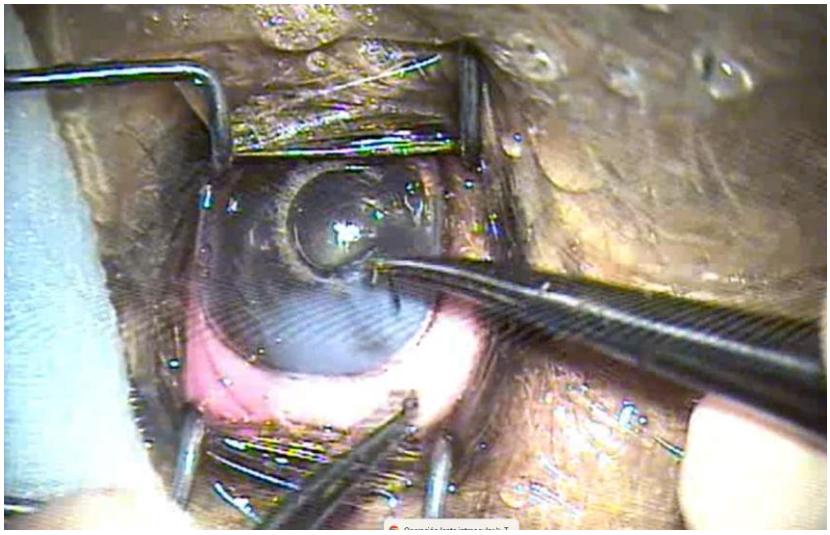

Figure 13: Corneal suture.

3. Results

3.1. Intraoperative complications

Regarding intraoperative complications of cataract surgery with the Tilt and Tumble technique, we can highlight the low incidence of posterior lens capsule rupture and vitreous outflow, being the most common during the performance of other traditional techniques.

3.1.1. Rupture of the posterior capsule of the crystalline lens

It is the most common intraoperative complication during cataract surgery using other phacoemulsification techniques, generating a high risk of a decrease in the patient's visual acuity after surgery (César, 2013). This capsular rupture can occur at any stage of the surgery, both at the beginning, in the middle of the procedure while the nucleus is removed, and at the end when the cortex is aspirated. This complication is most frequently encountered in surgeons who are new to the use of these techniques, although it can also occur in experienced surgeons. The Tilt and Tumble technique has the advantage of performing phacoemulsification and extraction of the cataract outside the capsular bag, considerably reducing the occurrence of this complication in that phase of the surgery; however, it can be present in the rest of the operative phases.

3.1.2. Vitreous outflow

The presence of vitreous humor in the anterior chamber is a fairly common complication during cataract surgery, being of great importance in affecting the patient's vision outcome.
To a large extent, vitreous prolapses are associated with the rupture of the posterior lens capsule, both during phacoemulsification of the nucleus and during irrigation/aspiration, although it can also be associated with zonular alterations (María Teresa, and Juan Carlos, 2013).
Currently, some techniques are used for its recovery such as vitrectomy, heavy fluids and phacofragmentation with or without intraocular lens placement, depending on the capsular status. Therefore, going hand in hand with the previous complication, it will present a lower incidence compared to other traditional techniques, since cataract extraction occurs outside the capsule.

3.2. Post-surgical complications

3.2.1. Mild endotelial edema

Endothelial edema refers to an accumulation of fluid in the cornea and may be the result of preoperative factors such as previous endothelial pathologies or be caused by intraoperative factors specific to the technique such as trauma secondary to irrigation solutions, ultrasound, lens extraction maneuvers or intraocular lens implantation (Belén, 1998).

3.2.2. Mild to moderate uveitis

This is an inflammatory condition affecting the middle layer of the eye: iris, ciliary body and choroid. It can significantly affect the patient's recovery and visual outcomes after surgery. It also causes increased inflammation, delayed healing and a greater probability of developing other conditions such as glaucoma or corneal endothelial edema. Some of the symptoms we will see after surgery include eye pain, high sensitivity to light, blurred vision and ocular redness (Brian, 2024).

3.2.3. Few cases of mild hypertension in the first hours after surgery

It refers to an increase in pressure inside the eyeball, which may occur after cataract surgery due to several factors, such as inflammation, blockage of ocular fluid drainage or excessive fluid production. Normally this process is self-limiting, therefore, it usually normalizes within the first 24-48 hours after surgery without the need for treatment (Aitor et al, 2016).

3.2.4. Some cases of capsule opacification

Capsular opacification is caused by the proliferation and migration of lens epithelial cells that are retained in the capsular bag after surgery, which finally transform into myofibroblasts (David, 1999). There are certain predisposing factors for the appearance of this process, such as glaucoma, diabetes mellitus and uveitis.

3.2.5. Very few cases of decentered IOL

It will be mainly related to an inadequate continuous circular capsulotomy (CCC), which is responsible for the intraocular lens remaining centered. The CCC should remain centered and with its edge overlapping the edge of the intraocular lens. It may also be due to a disproportion

between the size of the capsular bag and the size of the intraocular lens, especially in small eyes (Poyales and Garzón, 2016).

3.2.6. No cases of retinal detachment

There were no cases of retinal detachment after surgery, since the incidence of this condition is lower when extracapsular lens extraction techniques are performed, as in our case.

4. Discussion

The results suggest that cataract extraction with phacoemulsification using the Tilt and Tumble technique is a fairly safe and effective method in the patients who have undergone the study. However, there are also a number of risks that must be taken into account during surgery. The complications reported with the use of this technique have a lower presentation than those shown with other types of cataract extraction techniques.

4.1. Advantages

The Tilt and Tumble phacoemulsification technique is easy to learn and has a relatively short learning curve. In addition, it can be used in a wide variety of cases and has demonstrated great efficacy in the removal of soft or medium-hard cataracts, which are difficult to cut, and cutting within the sac may result in cheese-wiring of the nucleus. If we were to perform soft nucleus emulsification endocapsularly, we would have a higher risk of rupturing the posterior capsule of the lens, since the phacoemulsification probe could cut the soft cataract and also rupture the posterior capsule without giving time for a surgeon response (Arthur, 2015).

It can also be an advantageous technique in subluxated cataracts, where it is recommended to avoid intracapsular cutting and maneuvers such as nucleus rotation, which exerts pressure on the zonules.

Thus, this technique allows the nucleus to be emulsified extracapsularly in a simple and safe way, in addition to the fact that the amount of energy used and surgery time are less than those necessary to emulsify the nucleus inside the capsule.

4.2. Disadvantages

On the other hand, dense nuclei may be too large to be prolapsed out of the rhexis, and therefore may cause a capsular blow-out syndrome and the nucleus to fall out. This is also the case with mature cataracts that completely fill the capsular bag and may not move properly when we apply fluid to try to prolapse it out of the rhexis. In these cases, it is recommended to use the other cataract extraction techniques described.

The size of the rhexis can also be a problem when performing surgery, since a rhexis that is too small can cause a capsular explosion due to excessive pressure behind the nucleus. Even the prolapse of a soft cataract can be compromised by making a rhexis that is too small for that nucleus.

Excessive and repeated hydrodissection can also cause capsule explosion, so in these cases we must decompress the trapped fluid before attempting repeated hydrosurgical procedures (Arthur, 2015).

5. Conclusions

Phacoemulsification using the Tilt and Tumble technique is an excellent method for extracting soft cataracts, but it can present some difficulties when it comes to mature or overly large cataracts. It is then that a correct choice of the patients to whom it is decided to be performed and the experience of the surgeon become fundamental pillars for the success of the surgery.

Complications such as vitreous protrusion or posterior capsule rupture, although still present, can be avoided more frequently since the cataract will be emulsified extracapsularly and, therefore, we will move away from the risk zone.

All of this, together with its short learning curve, makes this technique an interesting option for experienced and less experienced surgeons in the field of phacoemulsification, and even more unknown in terms of veterinary medicine.

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