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Comparison of the outcomes of phacoemulsification versus topical medication alone in canine diabetic cataracts: a retrospective study

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ABSTRACT

Background: Long-term comparisons of phacoemulsification with topical medication are limited in canine diabetic cataracts.
Objectives: To compare outcomes of eyes submitted to phacoemulsification with those of topical medication for canine diabetic cataracts and identify risk factors for complications.
Methods: Through medical records review, 150 eyes (76 dogs) with diabetic cataracts were included; 58 eyes (31 dogs) underwent phacoemulsification (phaco-group) and 92 eyes (48 dogs) received ophthalmic solution alone (medication-group). The medication-group was divided into owner-led and vet-led groups depending on who elected not to perform surgery. Comparisons involved time-to-complications, vision, and the number and type of ophthalmic solutions administered. The association between complications and pretreatment clinical findings was investigated.
Results: No difference was found in complication risk between the phaco and owner-led medication groups. Conversely, the vet-led medication-group had a higher complication risk than the other groups. At the last follow-up, 94.8% of the phaco-group had vision, whereas 7.6% of the medication-group restored some visual axis. Poor glycemic control in the medication-group and younger age in the phaco-group increased complication risk. At 1-year post-treatment, the average number of ophthalmic solutions administered was 1.7 and 2.6 in the phaco and medication groups, respectively. The medication-group used anti-inflammatories the most throughout the follow-up, whereas the phaco-group used anti-inflammatories the most until 1-year post-treatment and lacrimostimulants at 1.5-year post-treatment.
Conclusions: For canine diabetic cataracts, phacoemulsification is recommended because it is superior to topical management alone in terms of maintaining vision and reducing the number of ophthalmic solutions required in the long term.

Keywords: Cataract; complications; diabetes mellitus; dogs; glaucoma

INTRODUCTION

Diabetes mellitus (DM) is a common canine endocrine pancreatic disorder [1]. High lenticular glucose levels and osmotic gradient via the sorbitol pathway induce cataracts

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Conflict of interest
The authors declare no conflicts of interest.

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in diabetic dogs [1,2]. Although topical aldose reductase inhibitors can delay the onset or progression of diabetic cataracts with mild lens changes [3], cataract surgery is the best way to restore vision [4].

DM is not a risk factor of complications of cataract surgery [5-7]. Nevertheless, for veterinarians and dog owners, the choice of cataract surgery is more demanding for diabetic cataracts than that for nondiabetic cataracts. In dogs undergoing surgery, glycemic control can be disrupted because of fasting, general anesthetic events, and postoperative topical administration of corticosteroids [1,8,9]. Compared with nondiabetic dogs, diabetic ones are more likely to experience hypotension during general anesthesia for phacoemulsification and tend to have other concurrent systemic diseases leading to anesthetic complications [10]. The costs of cataract surgery and postoperative management are critical for owners who already experience the financial burden of DM management [11,12]. Therefore, some owners may prefer medical therapy or no treatment rather than cataract surgery [12]. Comparative data on the prognosis between surgical and nonsurgical options are required.

A recent study reported that undergoing or not undergoing cataract surgery did not affect long-term complications in dogs [13]. However, this result conflicts with that of another study, which showed a higher failure rate in eyes that received topical medication than in those that received phacoemulsification [14]. Additionally, because earlier studies have included cataracts occurring due to various causes, their results might not align with those from studies focusing exclusively on diabetic cataracts. This is because diabetic cataracts have distinct patterns in pathogenesis and progression compared with other cataracts [2,15]. Canine diabetic cataracts are acute at onset and progress rapidly to mature intumescent cataracts bilaterally [4,15]. Other DM-related ophthalmic diseases, such as diabetic neuropathy, diabetic iridopathy, and diabetic retinopathy, could affect visual outcomes and cause discomfort in diabetic dogs [16,17]. Therefore, there is a need for studies focusing on diabetic cataracts that compare the outcomes of surgical and nonsurgical treatments.

Herein, we aimed to compare the outcomes of phacoemulsification with those of topical medication alone in diabetic dogs and evaluate the relationship between complications and clinical factors, including age and ophthalmic and diabetic conditions. Our findings may provide information to veterinarians and owners for decision-making regarding the management of dogs with diabetic cataracts.

MATERIALS AND METHODS

Study population

Medical records of dogs with diabetic cataracts at Seoul National University Veterinary Medical Teaching Hospital between April 2008 and March 2022 were reviewed. Informed consent was obtained from the owners for the use of medical record data. **Table 1** presents a detailed description of the inclusion and exclusion criteria.

The eyes were divided into two groups depending on whether phacoemulsification was performed (phaco group) or only ophthalmic solution was administered without surgery (medication group). Phacoemulsification was performed with or without intraocular lens (IOL) placement. Eyes that underwent phacoemulsification combined with endoscopic cyclophotocoagulation (ECP) were included. The medication group was further divided into

Table 1. Inclusion and exclusion criteria used in this study

Criteria	Description
Inclusion criteria	(1) Dogs with previously diagnosed DM or with newly diagnosed DM owing to the suspicion of diabetic cataract at the initial presentation
	(2) Cataractous eyes with the intumescent appearance of being secondary to DM
	(3) Dogs with a follow-up period of at least 2 months from the treatment initiation
Exclusion criteria	(1) Eyes with concurrent ophthalmic diseases including glaucoma, lens instability, retinal detachment, and severe corneal disease at the initial presentation
	(2) Cataracts attributable to other reasons such as progressive retinal atrophy, trauma, uveitis, and senile or genetic causes, based on the results of complete ophthalmic examinations and history taking
	(3) Dogs of owners with poor compliance with administering prescribed ophthalmic solutions
	(4) Eyes with no lens changes or incipient cataract, which did not require surgical intervention or administration of ophthalmic solutions

DM, diabetes mellitus.

two subgroups as follows: eyes suitable for surgery under veterinarian judgment, but wherein the owners did not consent to the surgery (owner-led medication group) and eyes without surgery not suitable for surgery according to veterinarian judgment (vet-led medication group).

Data collection

Data collected from the records included signalment, treatment type, follow-up time, vision at the last follow-up, pretreatment clinical findings (cataract stage, aqueous flare, lens capsule rupture, glycemic control status, concurrent systemic disease other than DM, and DM duration) at initial diagnosis of diabetic cataracts, number and type of ophthalmic solutions administered at specific time intervals (3, 6, and 9 months, 1 year, and 1.5, 2, 2.5, and 3 years after treatment), and post-treatment complications. The DM duration was estimated from the diagnosis of DM to that of diabetic cataracts. Vision was assessed using a menace response test in both groups. Poor glycemic control was characterized by a serum fructosamine concentration of > 500 μmol/L, blood glycated hemoglobin concentration of > 7%, or blood glucose nadir of < 80 mg/dL accompanied by classic symptoms of DM (weight loss, polyuria, and polydipsia) [1]. Dogs with a history of insulin dosage adjustments at the most recent DM assessment by their attending veterinarians were included as poor glycemic controls. In both groups, ophthalmic complications defined as failures included glaucoma, retinal detachment, uncontrolled severe uveitis, lens (or IOL) instability, and severe ocular surface diseases, including deep ulcers or corneal perforation. Glaucoma was defined as intraocular pressure (IOP) of > 25 mmHg with optic nerve cupping or retinal hyperreflectivity (if possible to examine), which necessitated persistent antiglaucoma treatment, including at least one topical prostaglandin analogue [13,18]. Severe anterior uveitis was defined as a grade ≥ 2+ aqueous flare and/or keratic precipitates, extensive iris synechiae, or iris bombe. Aqueous flare was graded based on a 4-grade clinical scoring system [19]; however, due to the absence of eyes with grade 4+ in the study groups, the 4-grade scoring system was modified to a 3-grade scoring system for application in this study.

Statistical analyses

Data analyses and representation were performed using RStudio version 2022.2.3.492 (RStudio, USA), SPSS version 28 (IBM, USA), and GraphPad Prism 8.0 (GraphPad Software, USA). Demographic factors and follow-up times were compared between the two treatment groups using the chi-squared test or Fisher's exact test for categorical variables and a two-sample *t*-test for continuous variables. Demographic factors and follow-up time were analyzed at the dog and eye levels, respectively. The Kaplan–Meier survival curve was used to estimate the 2-year survival rates. A Cox proportional hazard frailty model was used to compare survival curves while accounting for the cluster effect—potential inter-eye correlations of the same individual. Pretreatment clinical findings were compared between

the two treatment groups using a generalized linear mixed model. To evaluate the possible association with the outcomes in each group, pretreatment clinical findings were investigated using a Cox proportional hazard frailty model. The Mann–Whitney *U* test was used to compare the number of ophthalmic solutions administered in the two groups at the eye level. For all statistical analyses, a *p* value of < 0.05 was considered statistically significant.

RESULTS

Demographic data

In total, 150 eyes of 76 dogs fulfilled the inclusion criteria for this study. Bilateral eyes of 74 dogs were included. Unilateral eye was included in two dogs due to glaucoma development and phacoemulsification surgery in the contralateral eye before the first examination. In the study population, 58 eyes of 31 dogs underwent phacoemulsification (phaco group), while 92 eyes of 48 dogs received continuous administration of ophthalmic solution and did not undergo cataract surgery (medication group). Three dogs were included in both groups, and each eye was included in each group. Two of the three dogs underwent unilateral cataract surgery to shorten the anesthesia times. In the third dog, during preoperative lens-induced uveitis (LIU) management, retinal detachment occurred in one eye. Demographic data of the two groups are shown in **Table 2**. No significant differences were found in age ($p = 0.112$), sex (male vs. female; $p = 0.626$), or breed distribution ($p = 0.567$). However, the medication group comprised all non-neutered dogs ($p < 0.001$). The phaco group (median, 410 days; interquartile range [IQR], 203–882) had a significantly longer follow-up time than the medication group (median, 239 days; IQR, 104–467; $p = 0.010$).

In the medication group, 44 eyes of 24 dogs were determined as unsuitable candidates for cataract surgery by veterinarians because of posterior synechia, narrow ciliary cleft, poor glycemic control, old age, and suspected cognitive dysfunction. In 48 eyes of 24 dogs, owners chose to manage diabetic cataracts with ophthalmic solutions rather than surgery, owing

Table 2. Demographic data and follow-up time of the study population

Factors	All (76 dogs, 150 eyes)	Phaco group (31 dogs, 58 eyes)	Medication group (48 dogs, 92 eyes)
Age (yr)[a]	10 (8–11)	9 (7–11)	10 (8–12)
Sex			
Male castrated	44 (57.9)	19 (61.3)	27 (56.3)
Female spayed	22 (28.9)	12 (38.7)	11 (22.9)
Male	5 (6.6)	0 (0)	5 (10.4)
Female	5 (6.6)	0 (0)	5 (10.4)
Breed			
Maltese	19 (25.0)	8 (25.8)	12 (25.0)
Miniature poodle	18 (23.7)	8 (25.8)	10 (20.8)
Miniature schnauzer	10 (13.2)	1 (3.2)	9 (18.8)
Yorkshire terrier	8 (10.5)	3 (9.7)	5 (10.4)
Mixed breed	6 (7.9)	4 (12.9)	3 (6.3)
Miniature pinscher	4 (5.3)	2 (6.5)	2 (4.2)
Pomeranian	3 (3.9)	1 (3.2)	2 (4.2)
Others[b]	8 (10.5)	4 (12.9)	5 (10.4)
Follow-up time (days)[c]	321 (119–588)	410 (203–882)	239 (104–467)

Values are presented as median (interquartile range) or number of dogs (%).
[a]Dog-level.
[b]The following breeds with n = 1 were included: Chihuahua, Dachshund, English Cocker Spaniel, Jindo Dog, Pug, Shar Pei, Shih Tzu, and Spitz.
[c]Eye-level.

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to concerns about the deterioration of DM management and postoperative complications, possible exacerbation of concurrent systemic disease after general anesthesia, adaptation to vision loss, and difficulty in postoperative care.

Complication and survival analysis

The overall complication risk was higher for the medication group than for the phaco group (hazard ratio [HR], 3.88; 95% confidence interval [CI], 1.14–13.21; $p = 0.030$). However, there was no significant difference in the risk of complications between the phaco group and the owner-led medication group (HR, 1.70; 95% CI, 0.30–9.58; $p = 0.55$). The vet-led medication group exhibited a significantly higher risk of complications than the owner-led medication group (HR, 16.79; 95% CI, 3.59–78.49; $p < 0.001$) and the phaco group (HR, 8.39; 95% CI, 2.61–26.94; $p < 0.001$). The 2-year survival rates were the highest in the phaco group (84.1%), followed by the owner-led (82.3%), and vet-led (11.2%) medication groups (**Fig. 1**). **Table 3** shows the absolute frequency of failure. In the phaco group, all failures were due to glaucoma (8/58, 13.8%). In the medication group, glaucoma (10/92, 10.9%) was the most common, followed by uncontrolled uveitis (4/92, 4.3%), retinal detachment (4/92, 4.3%), lens luxation (3/92, 3.3%), and severe corneal disease (2/92, 2.2%). For eyes with failure, the median time to failure was 400.5 (range, 9–955) days in the phaco group and 188 (range, 10–903) days in the medication group.

Pretreatment clinical findings

No significant difference was observed between the two treatment groups in cataract stage ($p = 0.076$), presence of aqueous flare ($p = 0.312$), or DM duration ($p = 0.129$; **Table 4**). However, the phaco group had significantly more cases of lens capsule rupture than the medication group ($p = 0.009$). The medication group had more cases of poor glycemic control ($p = 0.042$) and concurrent systemic disease other than DM ($p = 0.001$) at the time of cataract diagnosis than the phaco group.

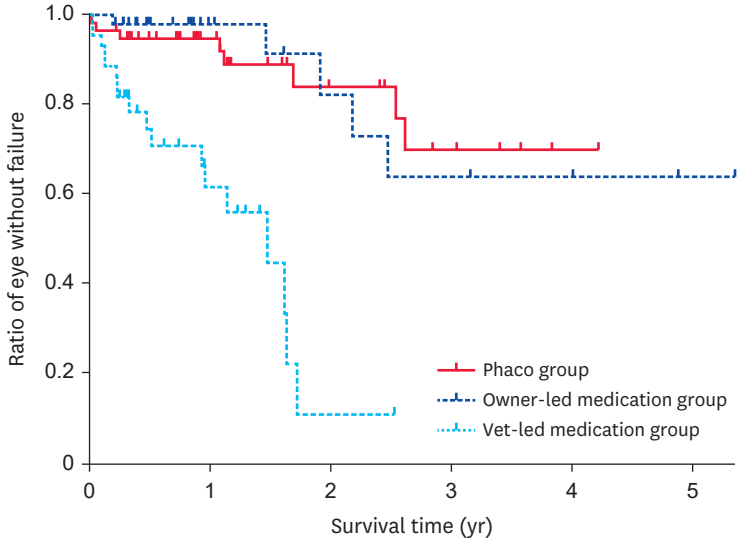

Fig. 1. Kaplan–Meier survival curves in diabetic cataractous eyes in the phaco group, vet-led medication group, and owner-led medication groups. A cox proportional hazard frailty model revealed a higher risk of complications in the vet-led medication group than in both the owner-led medication group (HR, 16.79; 95% CI, 3.59–78.49; $p < 0.001$) and the phaco group (HR, 8.39; 95% CI, 2.61–26.94; $p < 0.001$). There were no significant differences in the risk of complications between the phaco group and the owner-led medication group (HR, 1.70; 95% CI, 0.30–9.58; $p = 0.55$).
HR, hazard ratio; CI, confidence interval.

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Table 3. Causes of failures in the phaco and medication groups

Causes of failures	Phaco group (58 eyes)	Medication group		
		Owner-led (48 eyes)	Vet-led (44 eyes)	Total (92 eyes)
Glaucoma	8 (13.8)	3 (6.3)	7 (15.9)	10 (10.9)
Lens (or IOL) instability	0 (0.0)	2 (4.2)	1 (2.3)	3 (3.3)
Severe corneal disease	0 (0.0)	0 (0.0)	2 (4.5)	2 (2.2)
Uncontrolled uveitis	0 (0.0)	0 (0.0)	4 (9.1)	4 (4.3)
Retinal detachment	0 (0.0)	0 (0.0)	4 (9.1)	4 (4.3)
Total failures	8 (13.8)	5 (10.4)	18 (40.9)	23 (25.0)

Values are presented as number of eyes (%).
IOL, intraocular lens.

Table 4. Pretreatment clinical findings of the study population

Causes of failures	Phaco group (58 eyes)	Medication group			*p* value
		Owner-led (48 eyes)	Vet-led (44 eyes)	Total (92 eyes)	
Cataract stage					0.076
Immature	17 (29.3)	7 (14.6)	5 (11.4)	12 (13.0)	
Mature	41 (70.7)	37 (77.1)	35 (79.5)	72 (78.3)	
Hypermature	0 (0.0)	4 (8.3)	4 (9.1)	8 (8.7)	
Presence of aqueous flare	21 (36.2)	17 (35.4)	24 (54.5)	41 (44.6)	0.312
Presence of lens capsule rupture	9 (15.5)	0 (0.0)	2 (4.5)	2 (2.2)	**0.009**
Poor glycemic control	32 (55.2)	28 (58.3)	38 (86.4)	66 (71.7)	**0.042**
Concurrent systemic disease	22 (37.9)	30 (62.5)	31 (70.5)	61 (66.3)	**0.001**
Diabetes duration (months)	2 (0.75–4)	4 (1–11)	3 (0.25–6)	3 (1–8)	0.129

Values are presented as median (interquartile range) or number of eyes (%).
Statistically significant ($p < 0.05$) associations between the phaco group and medication group using a generalized linear mixed model are shown in bold.

In the phaco group, age was the only significant risk factor, and the risk of complications decreased by 32% with a 1-year increase in age (HR, 0.68; 95% CI, 0.51–0.91; $p = 0.008$; **Table 5**). Conversely, age was not a significant risk factor ($p = 0.73$) in the medication group. Poor glycemic control status increased the risk of complications in the medication group by 10.69 times (HR, 10.69; 95% CI, 1.39–82.24; $p = 0.023$); however, it was not a significant risk factor in the phaco group ($p = 0.28$). All intact female dogs had poor glycemic control; however, no complications occurred. Statistical analyses revealed no significant differences in cataract stage ($p = 0.12$, phaco group; $p = 0.95$, medication group), presence of aqueous flare ($p = 0.16$; $p = 0.40$), presence of lens capsule rupture ($p = 0.21$; $p = 0.300$), concurrent systemic diseases other than DM ($p = 0.42$; $p = 0.200$), and DM duration ($p = 0.55$; $p = 0.088$) between the two treatment groups.

Table 5. Pretreatment clinical findings analyzed for potential risk factors in the phaco and medication groups

Group	Pretreatment clinical findings	HR (95% CI)	*p* value
Phaco group	Age (per yr)	0.68 (0.51–0.91)	**0.008**
	Cataract stage	0.22 (0.03–1.49)	0.120
	Presence of aqueous flare	0.19 (0.02–1.89)	0.160
	Presence of lens capsule rupture	4.05 (0.45–36.76)	0.210
	Poor glycemic control	0.30 (0.03–2.61)	0.280
	Concurrent systemic disease	0.35 (0.03–4.46)	0.420
	Diabetes duration, per month	1.03 (0.93–1.15)	0.550
Medication group	Age (per yr)	1.04 (0.82–1.32)	0.730
	Cataract stage	0.95 (0.19–4.71)	0.950
	Presence of aqueous flare	1.70 (0.49–5.87)	0.400
	Presence of lens capsule rupture	4.08 (0.29–58.08)	0.300
	Poor glycemic control	10.69 (1.39–82.24)	**0.023**
	Concurrent systemic disease	2.74 (0.59–12.78)	0.200
	Diabetes duration, per month	0.81 (0.63–1.03)	0.088

Factors that significantly ($p < 0.05$) altered the likelihood of complications in each group using a Cox proportional hazard frailty model are shown in bold.
HR, hazard ratio; CI, confidence interval.

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Visual outcomes and prognoses

In the phaco group, 94.8% of eyes (55/58) had restored vision at the end of the study period and 84.5% (49/58) of eyes had vision without any complications. All eyes without complications had restored vision except for one eye. The eye had retained vision for 3.4 years after surgery but had vision loss because of meningoencephalitis of unknown etiology. The eye was classified as censored because the cause of vision loss was not ophthalmic-related. In the eight eyes that developed glaucoma in the phaco group, IOP-lowering medications were initially used after glaucoma diagnosis. Three eyes (3/8, 37.5%) of two dogs underwent gonioimplantation to preserve sight. At the last follow-up, only one eye had maintained vision without topical antiglaucoma medications, and another eye had maintained normal IOP with topical antiglaucoma medications, although it had no vision. The other eye was enucleated because of constant intraocular inflammation. In five eyes (5/8, 62.5%) whose IOP was controlled using topical antiglaucoma medications without glaucoma surgery until the last follow-up, menace responses were all positive; however, retinal degeneration was confirmed via indirect ophthalmoscopy.

Conversely, in the medication group, 7.6% of eyes (7/92) restored some visual axis because of the resorption of the hypermature cataract after vision loss. All eyes with complications in the medication group exhibited no menace response. In the 10 eyes with glaucoma in the medication group, 5 (50%) required topical antiglaucoma medications at the last follow-up and 4 (40%) received pharmacologic cycloablation with intravitreal cidofovir injection. One eye (10%) was enucleated. In 13 eyes with complications other than glaucoma, 8 (61.5%) developed phthisis bulbi, 3 (23.1%) were managed with topical medications, 1 (7.7%) received intravitreal cidofovir injection, and 1 (7.7%) was enucleated at the last follow-up.

Number and type of ophthalmic solutions administered to nonfailure eyes

The number and type of ophthalmic solutions administered were recorded for the eyes with available follow-up data at each time point. In the phaco group, 47/50 eyes (94.0%) received at least one ophthalmic solution at 3 months following treatment, 37/44 eyes (84.1%) at 6 months, 29/38 eyes (76.3%) at 9 months, 27/34 eyes (79.4%) at 1 year, 15/21 eyes (71.4%) at 1.5 years, 11/15 eyes (73.3%) at 2 years, 9/12 eyes (75.0%) at 2.5 years, and 5/8 eyes (62.5%) at 3 years following treatment. Three eyes did not receive any ophthalmic solutions from 3 months to 3 years after surgery. In the medication group, all eyes received at least one at least one ophthalmic solution throughout all follow-up periods.

Fig. 2 shows the average number of ophthalmic solutions administered at each time point. Three months following treatment initiation, the average number of ophthalmic solutions administered was 1.8 in the phaco group and 2.0 in the medication group, which are not significantly different ($p = 0.614$). However, the number of ophthalmic solutions administered in the medication group was higher than that in the phaco group from 6 months following treatment. In the phaco group, the average number of ophthalmic solutions administered was 1.5 at 6 months following treatment, 1.4 at 9 months, 1.7 at 1 year, 1.0 at 1.5 years, 1.6 at 2 years, 1.4 at 2.5 years, and 0.9 at 3 years. In the medication group, the average number of ophthalmic solutions administered was 2.2 at 6 months following treatment, 2.3 at 9 months, 2.6 at 1 year, 2.9 at 1.5 years, 2.5 at 2 years, 3.0 at 2.5 years, and 3.1 at 3 years. The number of ophthalmic solutions in the medication group tended to increase over time, whereas that in the phaco group tended to decrease.

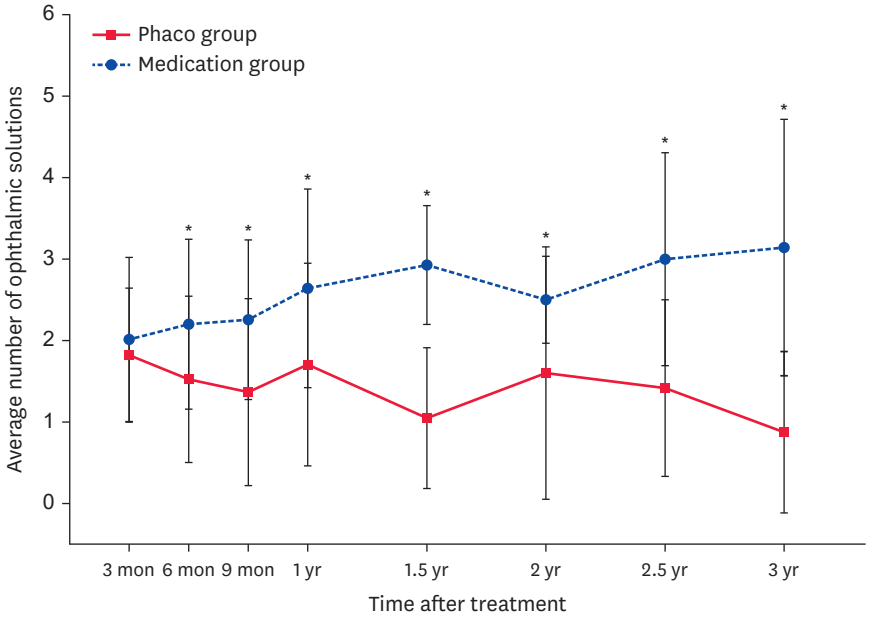

Fig. 2. Time course of changes in the number of ophthalmic solutions administered after treatment. There was no significant difference in the number of ophthalmic solutions administered at 3 months following treatment between the phaco and medication groups ($p = 0.614$). At 6 and 9 months, 1 year, and 1.5, 2, 2.5, and 3 years after treatment, the number of ophthalmic solutions administered to the medication group was higher than that administered to the phaco group ($p = 0.005$, $p = 0.001$, $p = 0.006$, $p < 0.001$, $p = 0.028$, $p = 0.012$, and $p = 0.009$, respectively). Error bar indicates standard deviation. For each time point evaluated, statistically significant differences are represented by an asterisk (*p <0.05).

The types of ophthalmic solutions administered at each time point are presented in **Table 6**. From 3 months to 1 year after treatment, topical anti-inflammatory medications for uveitis, including corticosteroids and nonsteroidal anti-inflammatory drugs, were the most commonly used topical medications in both groups. Immunomodulating lacrimostimulants (cyclosporine and tacrolimus) for keratoconjunctivitis sicca was the second most commonly used topical medication. The third most commonly used topical medications were antibiotics for corneal ulcer or conjunctivitis in the medication group and hyperosmotic agents (5% sodium chloride) for corneal endothelial decompensation in the phaco group, except for artificial tears. From 1.5 to 3 years of follow-up after treatment, the most frequently used ophthalmic solutions were still anti-inflammatory agents in the medication group and immunomodulating lacrimostimulants in the phaco group. Mydriatics for uveitis, ocular hypotensive agents (betaxolol and dorzolamide) for ocular hypertension, ethylenediaminetetraacetic acid for corneal degeneration, and allogeneic serum for corneal ulcer were also used.

DISCUSSION

This study provided data comparing the prognosis between phacoemulsification surgery and topical management alone in terms of complications, vision, and the number and type of ophthalmic solutions administered in dogs with diabetic cataracts.

Our results revealed that eyes receiving topical management alone without phacoemulsification surgery for diabetic cataracts had 3.88 times higher risk of complications than eyes receiving phacoemulsification surgery. This result is similar to that reported by Lim et al. [14] (HR,

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Table 6. Time course of changes in the types of ophthalmic solutions administered to nonfailure eyes of the phaco and medication groups

Group	Types of ophthalmic solutions	Time following treatment							
		3 mon	6 mon	9 mon	1 yr	1.5 yr	2 yr	2.5 yr	3 yr
Phaco group	Anti-inflammatories	39/50 (78.0)	35/44 (79.5)	22/38 (57.9)	20/34 (58.8)	9/21 (42.9)	7/15 (46.7)	2/12 (16.7)	1/8 (12.5)
	Corticosteroids	7/39 (17.9)	4/35 (11.4)	4/22 (18.2)	5/20 (25.0)	2/9 (22.2)	0/15 (0.0)	0/12 (0.0)	0/8 (0.0)
	NSAIDs	32/39 (82.1)	31/35 (88.6)	18/22 (81.8)	15/20 (75.0)	7/9 (77.8)	7/7 (100.0)	2/2 (100.0)	1/1 (100.0)
	Lacrimostimulants	38/50 (76.0)	22/44 (50.0)	20/38 (52.6)	18/34 (52.9)	10/21 (47.6)	10/15 (66.7)	7/12 (58.3)	3/8 (37.5)
	Hyperosmotic agents	4/50 (8.0)	2/44 (4.5)	4/38 (10.5)	5/34 (14.7)	3/21 (14.3)	1/15 (6.7)	0/12 (0.0)	0/8 (0.0)
	Antibiotics	4/50 (8.0)	0/44 (0.0)	0/38 (0.0)	1/34 (2.9)	0/21 (0.0)	2/15 (13.3)	0/12 (0.0)	0/8 (0.0)
	Ocular hypotensive agents	2/50 (4.0)	2/44 (4.5)	2/38 (5.3)	1/34 (2.9)	0/21 (0.0)	0/15 (0.0)	3/12 (25.0)	3/8 (37.5)
	EDTA	1/50 (2.0)	1/44 (2.3)	1/38 (2.6)	1/34 (2.9)	0/21 (0.0)	0/15 (0.0)	1/12 (8.3)	0/8 (0.0)
	Mydriatics	0/50 (0.0)	2/44 (4.5)	0/38 (0.0)	1/34 (2.9)	0/21 (0.0)	1/15 (6.7)	0/12 (0.0)	0/8 (0.0)
	Allogenic serum	0/50 (0.0)	0/44 (0.0)	0/38 (0.0)	1/34 (2.9)	0/21 (0.0)	1/15 (6.7)	0/12 (0.0)	0/8 (0.0)
Medication group	Anti-inflammatories	64/69 (92.8)	36/40 (90.0)	32/35 (91.4)	22/25 (88.0)	10/14 (71.4)	7/8 (87.5)	7/8 (87.5)	5/7 (71.4)
	Corticosteroids	4/64 (6.3)	0/36 (0.0)	3/32 (9.4)	0/22 (0.0)	0/10 (0.0)	0/7 (0.0)	0/7 (0.0)	0/5 (0.0)
	NSAIDs	64/64 (100.0)	36/36 (100.0)	31/32 (96.9)	22/22 (100.0)	10/10 (100.0)	7/7 (100.0)	7/7 (100.0)	5/5 (100.0)
	Lacrimostimulants	28/69 (40.6)	20/40 (50.0)	19/35 (54.3)	15/25 (60.0)	9/14 (64.3)	4/8 (50.0)	4/8 (50.0)	4/7 (57.1)
	Hyperosmotic agents	0/69 (0.0)	0/40 (0.0)	0/35 (0.0)	2/25 (8.0)	2/14 (14.3)	0/8 (0.0)	1/8 (12.5)	2/7 (28.6)
	Antibiotics	13/69 (18.8)	11/40 (27.5)	9/35 (25.7)	8/25 (32.0)	4/14 (28.6)	4/8 (50.0)	5/8 (62.5)	4/7 (57.1)
	Ocular hypotensive agents	3/69 (4.3)	4/40 (10.0)	4/35 (11.4)	2/25 (8.0)	2/14 (14.3)	2/8 (25.0)	3/8 (37.5)	3/7 (42.9)
	EDTA	3/69 (4.3)	4/40 (10.0)	3/35 (8.6)	4/25 (16.0)	2/14 (14.3)	0/8 (0.0)	0/8 (0.0)	0/7 (0.0)
	Mydriatics	6/69 (8.7)	6/40 (15.0)	2/35 (5.7)	4/25 (16.0)	2/14 (14.3)	2/8 (25.0)	2/8 (25.0)	0/7 (0.0)
	Allogenic serum	0/69 (0.0)	1/40 (2.5)	0/35 (0.0)	3/25 (12.0)	1/14 (7.1)	0/8 (0.0)	0/8 (0.0)	0/7 (0.0)

Types of ophthalmic solutions were recorded for the eyes with available follow-up data at each time point. Values are presented as number of eyes (%).
NSAIDs, nonsteroidal anti-inflammatory drugs; EDTA, ethylenediaminetetraacetic acid.

4.0), who included cataracts with different etiologies in their study. However, Krishnan et al. [13] reported that the influence of factors contributing to the decision of not pursuing surgery may have affected the comparison between the two groups. The study demonstrated a significantly greater complication rate in eyes deemed unsuitable candidates for surgery by ophthalmologists than those deemed suitable for surgery according to ophthalmologists but whose owners refused surgery. In our study, there were differences in the distribution of lens capsule rupture, concurrent systemic diseases, and poor glycemic control status between the phaco and medication groups, which could have affected the comparison. Therefore, we divided the medication group into two subgroups: vet-led and owner-led medication groups. The results showed no significant difference in the risk of complications between the phaco group and owner-led medication group, with comparable 2-year survival rates of 84.1% in the phaco group and 82.3% in the owner-led medication group.

Glaucoma is a major complication of phacoemulsification [20], and secondary glaucoma can also develop in eyes with cataracts [21,22]. In diabetic dogs, a swollen and enlarged lens poses an additional risk of secondary glaucoma due to anteriorly displaced peripheral iris and a collapsed iridocorneal angle, resulting in the narrowing of the anterior chamber; this condition is known as phacomorphic glaucoma [20,23,24]. However, despite these additional risk factors, the incidence of glaucoma in the medication group did not differ significantly from that in the phaco group. This result is in close agreement with a previous study showing that a direct association between intumescent cataracts and glaucoma was rarely diagnosed, accounting for only 2% of cases of secondary glaucoma [21]. As the present study did not differentiate among causes of glaucoma, further studies evaluating the anterior chamber depth are needed to clarify the contribution of intumescent cataracts to the development of glaucoma in the medication group.

In the phaco group, glaucoma was the only cause of failure, but in the medication group, complications other than glaucoma occurred. Among them, lens luxation could be attributed

to an intumescent lens that was not surgically removed and remained, as well as the resulting LIU in the eyes of the medication group. Lens luxation is thought to be associated with cataract maturation and chronic uveitis [4,20]. As cataractogenesis becomes chronic, lens shrinking causes secondary zonular stretching and breakage [4,20]. Additionally, the increased weight of the cataractous lens caused by a decrease in the amount of low-molecular-weight proteins of the lens and an increase in that of high-molecular-weight proteins leads to subsequent lens instability [4,25]. Increased levels of matrix metalloproteinases and inflammatory mediators in chronic uveitis can also degrade the zonules [4,26]. Canine breeds with *ADAMTS17* mutation in the primary disease process are more vulnerable to lens luxation [20]. In the phaco group, because relatively lightweight prostheses, IOL, had replaced the cataractous lens, partial or complete luxation of the IOL was rare [27,28].

The incidence rate of postoperative complications in our study was slightly lower than in the previous study by Krishnan et al. [13], reporting that DM is not a risk factor for cataract surgery [5-7]. However, a higher incidence rate of complications was observed in the medication group in our study compared with study by Krishnan et al. [13], regardless of the reason for not undergoing surgery. This result may be attributed to differences in cataract types and stages between the two studies. Specifically, Krishnan et al. [13] included a wide range of cataract types, including incipient cataract, whereas our study included only diabetic cataracts. Unlike the rapidly progressing diabetic cataracts, age-related or hereditary cataracts are often nonprogressive and remain incomplete [29]. Consequently, they may be less likely to develop complications that occur as the cataract matures. Additionally, an intumescent lens or compromised blood-aqueous barrier (BAB) in diabetic cataractous eyes could potentially increase complications. As observed in our study, poor glycemic control particularly was a risk factor in the medication group. However, further studies comparing these two groups under the same conditions are required to assess whether diabetic cataracts have higher complication rates than nondiabetic cataracts without cataract surgery.

In the phaco group, the complication risk increased with lower age. This finding could be related to the higher proliferative capacity of lens epithelial cells in younger patients. In humans, lens epithelial cells of younger individuals have a higher rate of proliferation and metaplasia and an inflammatory response, leading to higher rates of posterior capsule opacification [30-32], although this has not yet been verified in dogs [33].

In the medication group, poor glycemic control was associated with an increased risk of complications. Hyperglycemia is considered a major contributing factor to cataracts and ocular microangiopathy in DM [1]. A previous study using anterior segment angiography found that diabetic dogs were more likely to have vascular disruption and the severity of structural abnormalities within the iris vasculature was associated with serum fructosamine concentrations [17]. In this study, the higher risk of complications in dogs with poor glycemic control was likely due to a disrupted BAB. However, the significance of glycemic control was limited to the medication group and was not found in the phaco group. This was considered because intensive glycemic control was maintained perioperatively to induce general anesthesia in the phaco group. Not only does poor glycemic control increase the risk of complications, but good glycemic control also has a protective effect against ocular diseases [2,34]. For example, early lens changes, such as small vacuoles, could resolve if hyperglycemia is well-controlled in dogs [2], and improved glucose control reduces the risk of diabetic retinopathy in humans with type 2 DM [34].

The presence of aqueous flare at the initial diagnosis of diabetic cataract did not increase the incidence of complications of diabetic cataracts in either group. In the phaco group, this finding was consistent with those of previous studies that identified the lack of association between preoperative LIU and postoperative glaucoma [7,35]. This could also be related to the exclusion criteria of the study population in both groups. The presence of aqueous flare at the initial diagnosis of diabetic cataract indicated that patients were exposed to untreated LIU. However, as the present study excluded eyes with severe uveitis or secondary complications from chronic LIU at the initial diagnosis, the aqueous flare may not have lasted very long.

Lens capsule rupture did not affect the incidence of complications for both groups. This finding corroborated that of a previous study that spontaneous lens capsule rupture in diabetic cataracts did not affect long-term outcomes of phacoemulsification [15]. However, because most eyes with capsular rupture were included in the phaco group, more data are needed to determine the prognosis of eyes that were managed with topical medications alone.

Continued administration of ophthalmic solutions could affect not only costs but also the quality of life of the owners and diabetic dogs. In both groups, long-term use of lacrimostimulants was associated with reduced tear production in diabetic dogs [36]. Unsurprisingly, anti-inflammatories were used significantly for LIU control in the medication group; however, anti-inflammatories were most often used in the phaco group to prevent adhesions likely caused by intermittent uveitis up to 1 year after surgery. The common use of hyperosmotic agents in the phaco group compared with that in the medication group suggested that corneal endothelial function could be further damaged by cataract surgery, in addition to increased endothelial pleomorphism and polymegathism in diabetic dogs compared with nondiabetic dogs [37]. A difference in one ophthalmic solution may not be clinically significant. However, a slight upward trend was found in the medication group over time, whereas a downward trend was noted in the phaco group. This difference could have been more salient if the frequency of ophthalmic solution administration had been considered.

What makes a clear difference between the phaco and medication groups was the possibility of vision recovery. Owners responded that they were more concerned about vision than costs [11]. Although 7.6% of the eyes in the medication group showed a positive menace response as the cataract resorbed, it cannot be considered that clinical vision was fully restored. Until the last follow-up, 84.5% of eyes in the phaco group had vision without any complications. Additionally, eyes that had already undergone phacoemulsification had a chance to maintain their vision through additional interventions if they developed glaucoma. A total of 94.8% of eyes, including cases in which glaucoma developed but vision was maintained through topical antiglaucoma medications or glaucoma surgery, retained vision at the last follow-up.

This study has several limitations. First, the treatment procedures were not identical because of the retrospective design. Additional surgical interventions such as ECP, vitrectomy, and placement of the capsular tension ring as well as the types of topical anti-inflammatory medications administered varied. However, this study aimed to evaluate the treatment options available to owners and the respective prognosis of these options and not specific treatment methods. Clinicians can identify a suitable treatment option for patients through thorough ophthalmic examinations. Second, the study divided the medication group based on reasons for not undergoing surgery and compared its risks with the phaco group. This approach minimized the effect of eyes considered poor candidates for cataract surgery by veterinarians in the medication group. However, the effect of a significant number of eyes

with lens capsule rupture in the phaco group was not considered. To control all pretreatment clinical findings or account for potential interactions between variables, further studies using multivariate analysis are required.

In conclusion, our findings provide more specific information about diabetic cataracts to owners and veterinarians. Based on the present results, phacoemulsification surgery for canine diabetic cataracts did not demonstrate a higher success rate in terms of complications compared with topical management alone. However, it provided more favorable outcomes in terms of vision and the number of ophthalmic solutions administered, which could improve patients' quality of life. Therefore, phacoemulsification may be recommended for this purpose. Nevertheless, owners should be aware that long-term topical management may be required even after successful surgery.

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