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Complicated Full-Thickness Corneal Lacerations and Perforations in Cats

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ABSTRACT

***Background*:** One of the potentially serious eye injuries that can lead to blindness in cats is "full-thickness corneal lacerations and perforations." These injuries require immediate medical intervention, and if left untreated, they can lead to complications such as the risk of infection. Treatment typically depends on the size, depth, and severity of the corneal injury. Small tears and perforations can sometimes be treated with topical antibiotics and eye drops, but larger and deeper injuries may require surgical intervention. Surgical intervention may involve procedures to close the injury and promote the healing process. In the study, the frequency of cats being exposed to full-thickness corneal lacerations and perforations; prevalence by breed; breed, age, and gender predisposition; affected ocular structures; lesion duration; findings of ophthalmological examination; and outcomes of medical and surgical therapies were evaluated in 50 cats (53 eyes).

***Materials, Methods & Results*:** Of the total 50 cats, 74% were Domestic Shorthairs with an average age of 34.8 months. 54% of these were female, and 76% were under 3-year-old. The causes were categorized as traumatic (66%) and non-traumatic (34%). The treatment protocol was categorized as medical treatment alone (n = 16/53) and surgical treatment combined with medical therapy (n = 37/53). Surgical procedures included nictitating membrane flap (NMF; n = 10), conjunctival pedicle flap (CPF) combined with NMF (n = 20), and suture closure combined with NMF (n = 7). Treatment outcomes were evaluated by assessing vision within the initial month and corneal transparency within 1-3 months. The process of epithelization and complete recovery followed distinct timelines: 10 days to 1 month and 1-2 months solely with medical therapy; 3-4 weeks and 5-7 weeks with NMF treatment alone; 2-3 weeks and 4 weeks to 4 months with a combination of CPF and NMF; and 2-5 weeks and 4-8 weeks with suturing combined with NMF, respectively. Out of 45 cats, corneal integrity was successfully restored in 48 eyes (90.56%). Nevertheless, despite various treatment combinations, 5 eyes from 5 cats did not respond to treatment.

***Discussion*:** The findings of this study provide important insights into managing full-thickness corneal lacerations and perforations in cats, emphasizing the significance of prompt intervention to prevent potential vision loss. The prevalence of Domestic Shorthairs among affected cats underscores the importance of understanding breed predispositions in ocular injuries. Traumatic causes are more common than non-traumatic ones, highlighting the necessity of taking preventive measures, especially in environments where cats may be exposed to potential hazards. The wide range of treatments utilized in the study demonstrates the potential effectiveness of both medical therapies and surgical interventions. While treatment outcomes indicate successful restoration of corneal integrity and vision in the majority of cases, the inability to achieve a response in some instances underscores the necessity for better understanding of treatment protocols and factors influencing success. Overall, this study emphasizes the importance of a comprehensive approach to managing full-thickness corneal lacerations and perforations in cats, aiming to preserve vision through early diagnosis, appropriate treatment selection, and vigilant monitoring for optimal outcomes.

Keywords: cat, cornea, laceration, perforation, treatment.

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INTRODUCTION

Full-thickness corneal lacerations and perforations are prevalent in small animal practice and are leading causes of blindness [6,20]. Both humans and companion animals face severe corneal injuries that may result in vision loss, necessitating emergency medical intervention to prevent complications [1]. Treatment protocols aim to restore vision and ocular integrity, utilizing medical and surgical therapies tailored to the injury's cause, extent, and underlying conditions. Treatment options range from simple medical therapy to complex surgical interventions such as soft contact lenses, tarsorrhaphy, and full-thickness corneal grafting [5,7,9,19].

We conducted this study to address the limited research on medical and surgical treatments and post-treatment visual outcomes in cats [2,10,11]. Our focus is on delineating prevalent complications arising from traumatic and non-traumatic penetrating corneal injuries. Additionally, we aim to evaluate the effectiveness of medical and surgical interventions and explore the potential for self-repair supported by medical treatment. Given the constraints of advanced techniques, we also examine the efficacy of commonly used surgical treatments like third eyelid flapping and conjunctival flapping in restoring ocular integrity and vision.

MATERIALS AND METHODS

Animals

This report is a non-comparative, single-centered retrospective study including 50 cats (53 affected eyes) treated for full-thickness corneal lacerations and perforation at the clinics of the Istanbul University-Cerrahpaşa, Faculty of Veterinary Medicine between 2020-2023. The study was approved by the Istanbul University-Cerrahpaşa Ethics Committee for Animal Experiments, with a decision number of 2022/51.

Evaluation of the lesions

The study evaluated full-thickness corneal lacerations and perforations in cats, including incidence, breed-wise prevalence, breed, age, and gender predisposition, affected ocular structures, lesion duration, ophthalmological examination findings, and outcomes of medical and surgical therapies. All patients underwent a comprehensive ophthalmological examination. Treatment protocols included medical therapy alone, NMF alone, suture closure plus NMF, or conjunctival flapping plus NMF, determined by a specialist to restore ocular integrity and vision.

Medical treatment

Perforating lesions with temporary fibrin clotting, small size, absence of active aqueous discharge, and mild iris prolapsus were treated with medical therapy alone [Figure 1 (A,B),(C,D),(E,F),(G,H)]. This therapy included topical ofloxacin drop for antibiotic coverage, sodium hyaluronate for corneal moistening, and dexpanthenol gel for ocular surface lubrication and corneal healing support.

Surgical treatment

The surgical procedure was intraoperatively determined depending on the lesion shape and size, the presence of aqueous humor leakage, the health status of the cornea, the occurrence of iris prolapsus, and the specialist's choice according to their expertise.

All surgical procedures were performed under a binocular surgical microscope, and a lateral position was preferred enabling the affected eye to face the surgical surface of the microscope.

When the iris was partially entrapped without physically protruding up to the ocular surface, when there was no aqueous humor leakage, and the anterior chamber was stabilized, the iris was retracted backward, compressed with tamponing, and sutured with a U-stitch suture pattern applying two-three 2/0 polyglycolic acid stitches[1] (Pegelak rapid®) [Figure 2 (A,B),(C,D),(E,F),(G,H),(I,J)].

When the iris protruded to the corneal surface, entrapped within the lesion for more than 6-8 h, it was gently retracted outward, ensuring fresh uveal tissue was aligned with the corneal surface to prevent penetration of the surface epithelium into the eye globe and potential enophthalmos. Wound debridement involved excising destructed or necrotic corneal tissue encircling the prolapsed iris, followed by irrigation of blood clots in the anterior chamber with lactate Ringer solution and gentle removal using a capsulorhexis scalpel. Adhesions between the prolapsed iris and cornea were separated using saline, viscoelastic material, and/or an iris spatula (Figure 3 A,B,C,D,E,F). In cases of a sinking anterior chamber, the iris was repositioned using viscoelastic material injected along the perforation zone to deepen the anterior chamber and distance the iris from the cornea. The lens was examined for potential traumatic damage, and full-thickness corneal lacerations larger than 2 mm with active aqueous humor leakage and/or shallow anterior chamber were closed with a waterproof corneal suture in the seidel

test-positive non-tissue loss linear perforations (Figure 4 A,B,C,D,E).

A conjunctival flap was applied in the cases with extensive tissue loss and iris staphyloma non-responsive medical therapy to restore the corneal integrity. Viscoelastic material was irrigated by lactate Ringer solution using a 27-30-gauge needle before the last stitch was placed to prevent post-operative ocular hypertension. The suture material was 8/0 polyglactin 910[2] [Ethicon®] was used for this procedure. Then, a nictitating membrane flap was applied to avoid potential damage to the stitches and conjunctival flap during eyelid movements, maintain the ocular surface, thus support healing, and provide corneal merging beneath the flap (Figure 5 A,B,C,D).

All patients that underwent surgery were administered dexamethasone[3] [Decort®- 2 mg subconjunctival, SID] injection to per eye depending on the patient's clinical status to reduce intraocular inflammation. An Elizabethan collar was prescribed, and all cats were discharged.

Post-operative care

Ceftriaxone sodium[4] [Novosef®- 30 mg/kg IM, SID, 7 days] and meloxicam[5] [Melox®- 0.2 mg/kg SC, SID, 5 days] were administered. Ofloxacin[6] 0.3% [Exocin®- QID], 0.015% sodium hyaluronate[7] [Dryex®- QID] for 1st 2 weeks then 3 times a day for 2 weeks, and 1% tropicamide[8] [Tropamid®, BID] for 1 week was used. A dexpanthenol[9] gel [Recugel®-QID] also was prescribed for 4 weeks to support corneal healing.

Post-surgical follow-up

Stitches were removed at different intervals post-surgery: 3-4 weeks for those with a nictitating membrane flap, 2-3 weeks for conjunctival flap patients, and 2-4 weeks for suture closure cases. Subsequent evaluations included assessing corneal neovascularization and edema, pupil size, anterior or posterior synechiae, anterior chamber depth, and lens structure. After 1.5-2 months, once the flap integrated fully, the intersecting zone was resected under local anesthesia. Post-recovery, topical moxifloxacin-dexamethasone eye drops and dexamethasone pomade were administered, tailored to reduce corneal scarring. Drops were given 3-4 times daily for 2-8 weeks, while the pomade was applied 1-2 times daily for 2-4 weeks, with doses gradually reduced upon healing. Follow-up examinations included neuro-ophthalmological evaluation and assessment of visual function and corneal opacity.

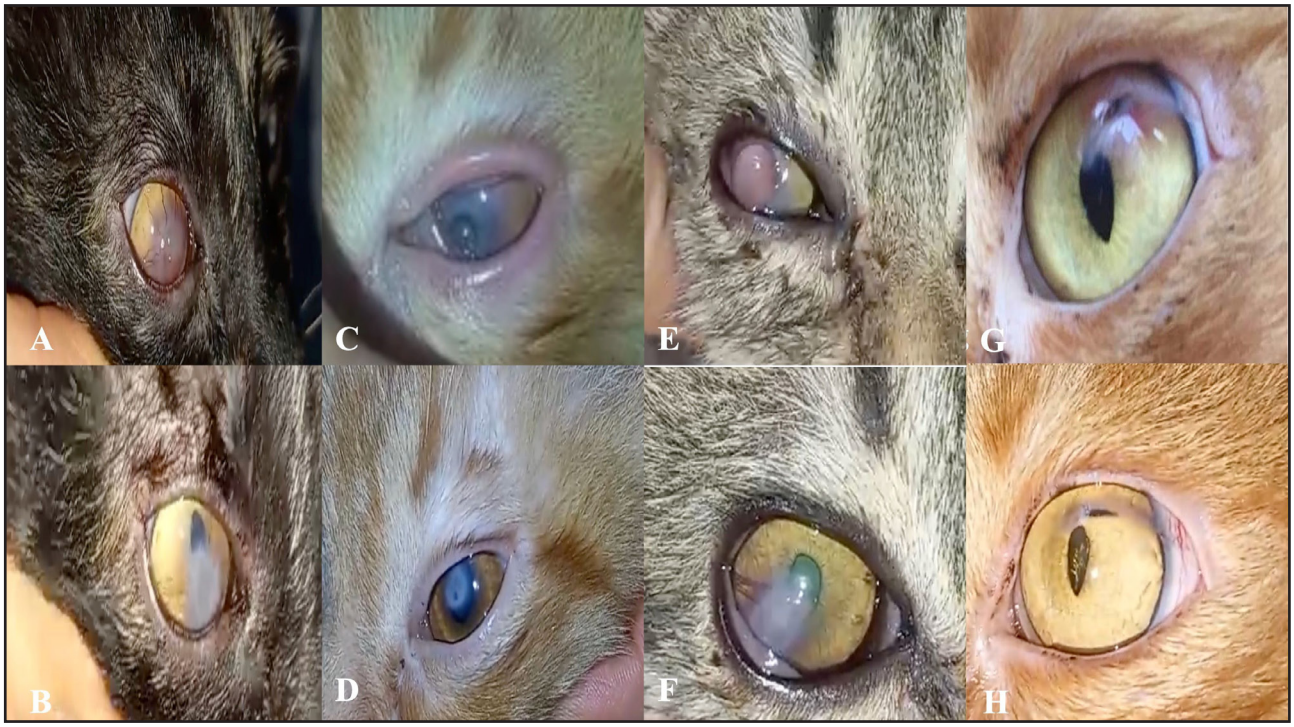

Figure 1. Photographs showing the clinical progression of 4 medically treated cats with corneal perforation. A-B: Right eye of a 5-month-old male Domestic shorthaircat at [no:30] (A) presentation, and on days (B) 21 of medical therapy. C-D: Left eye of a 5-month-old male Domestic shorthaircat at [no:28] (C) presentation, and on days (D) 14 of medical therapy. E-F: Right eye of a 5-month-old female Domestic shorthaircat at [no:23] (E) presentation, and on days (F) 14 of medical therapy. G-H: Left eye of a 2-year-old male Domestic shorthaircat at [no:22] (G) presentation, and on days (H) 30 of medical therapy.

Figure 2. Photographs showing the result of surgical repair of 5 cats with corneal perforation who were treated with NMF and medical methods. A-B: Right eye of an 3-month-old female Domestic shorthair cat with corneal perforation complicated with iris incarceration [no:45] at (A) presentation, and on days (B) 45 of therapy. C-D: Right eye of an 4-month-old female Persian cat with corneal perforation, shallow anterior chamber, fibrin clot [no:46] at (C) presentation, and, on days (D) 35 of therapy. E-F: Right eye of an 7-month-old male Domestic shorthair cat with rupture of Descemet's membrane with the formation of bullae accompanied by corneal vascularization, edema, and lysis at [no: 47] (E) presentation, and on days (F) 30 of therapy. G-H: Left eye of a 3-year-old male Domestic shorthair cat with severe centrally located corneal perforation with iris prolapse [no:48] (G) at presentation and, on days (H) 30 of theraphy. I-J: Corneal perforation in the lefteye of a 4-month-old male Domestic shorthair cat due to infection at [no:49] (I) presentation, and on days (J) 42 of theraphy.

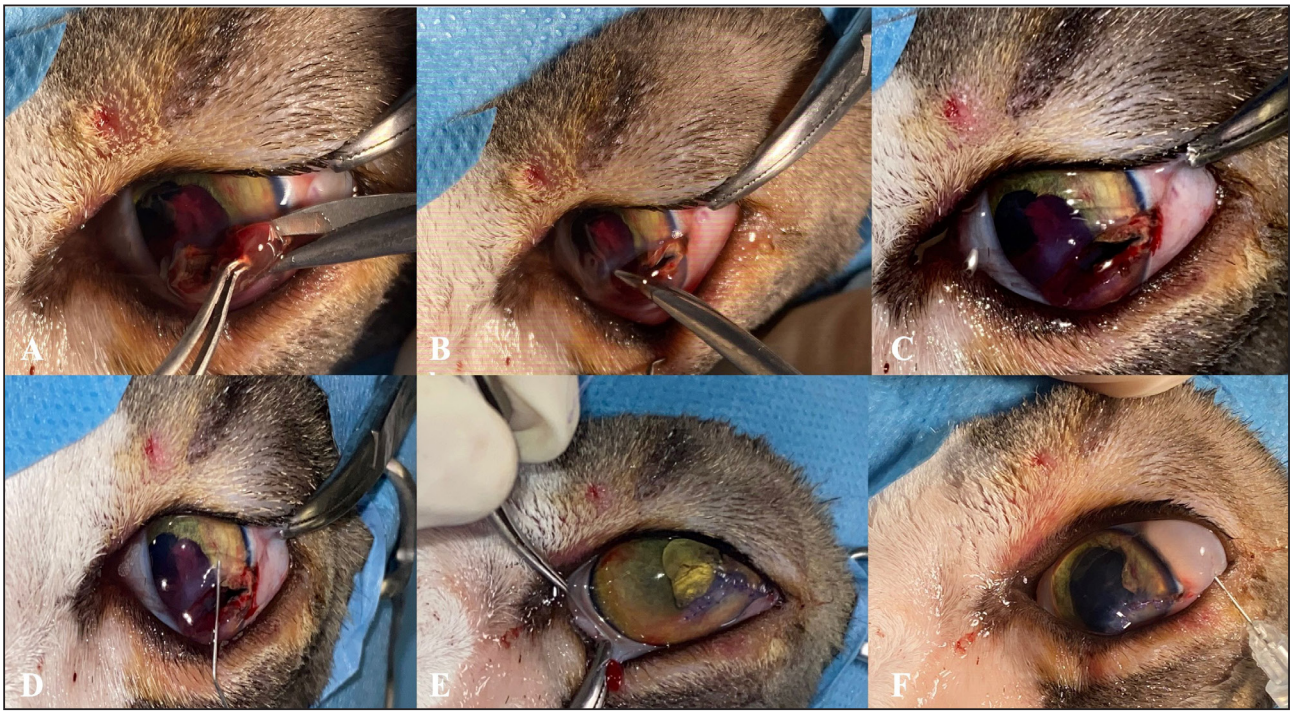

Figure 3. A-F: Images of corneal perforation associated with iris prolapse after falling from a height in a 3-year-old Domestic shorthair cat during intraoperative suture closure [no:37]. A-B: Resection of the prolapsed iris with scissors up to the corneal level; C- Corneal defect and iris appearance after iridectomy; D- Separation of the iris adhesion to the cornea with viscoelastic; E- Suturing of the full-layer corneal laceration and after irrigation of the anterior chamber view; F- Subconjunctival dexamethasone injection after corneal closure.

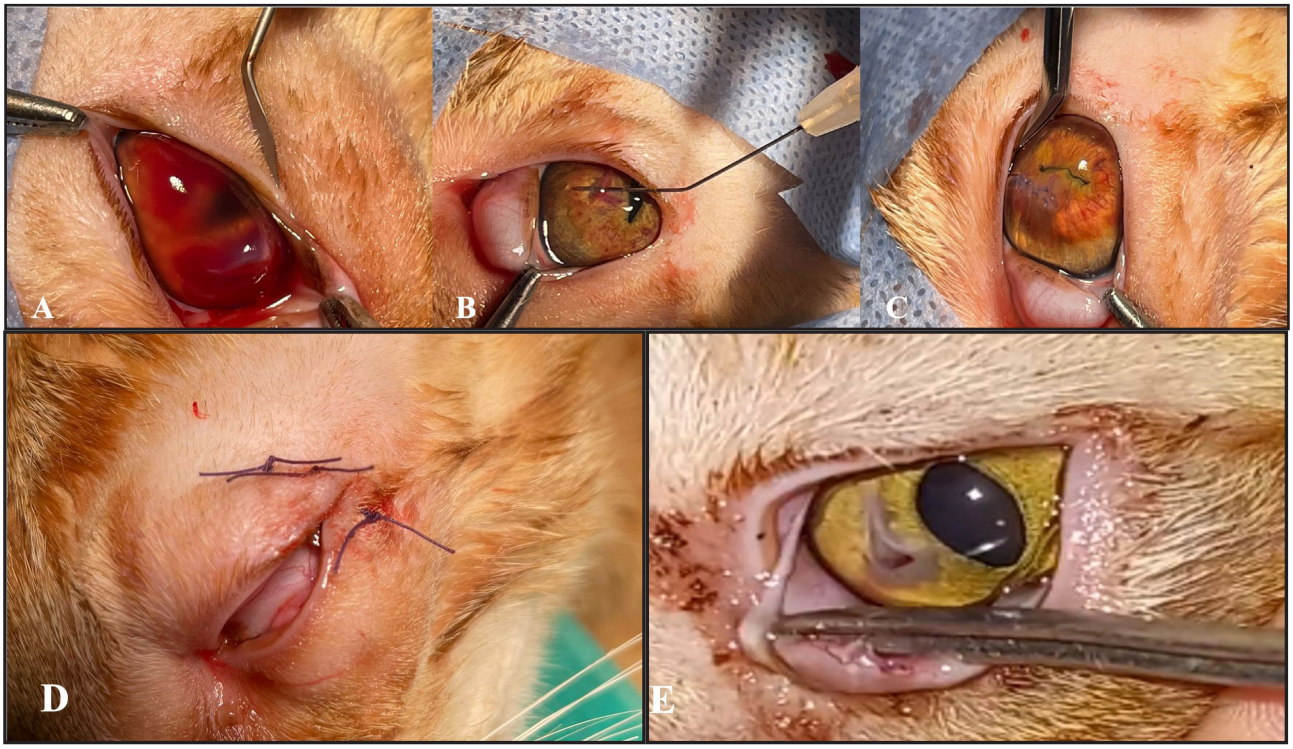

Figure 4. A-E: Treatment of linear full-layer corneal laceration of a 1-year-old Domestic Shorthaircat [no:38] with suture and NMF technique. A- Linear incision and diffuse hyphema in the anterior chamber; B- Irrigation of the anterior chamber with lactated ringer; C- Closure of the corneal defect with simple separate sutures; D- Subsequent application of NMF (4 weeks); E- Linear moderate scar tissue that does not affect vision in the cornea 4 weeks after surgical treatment.

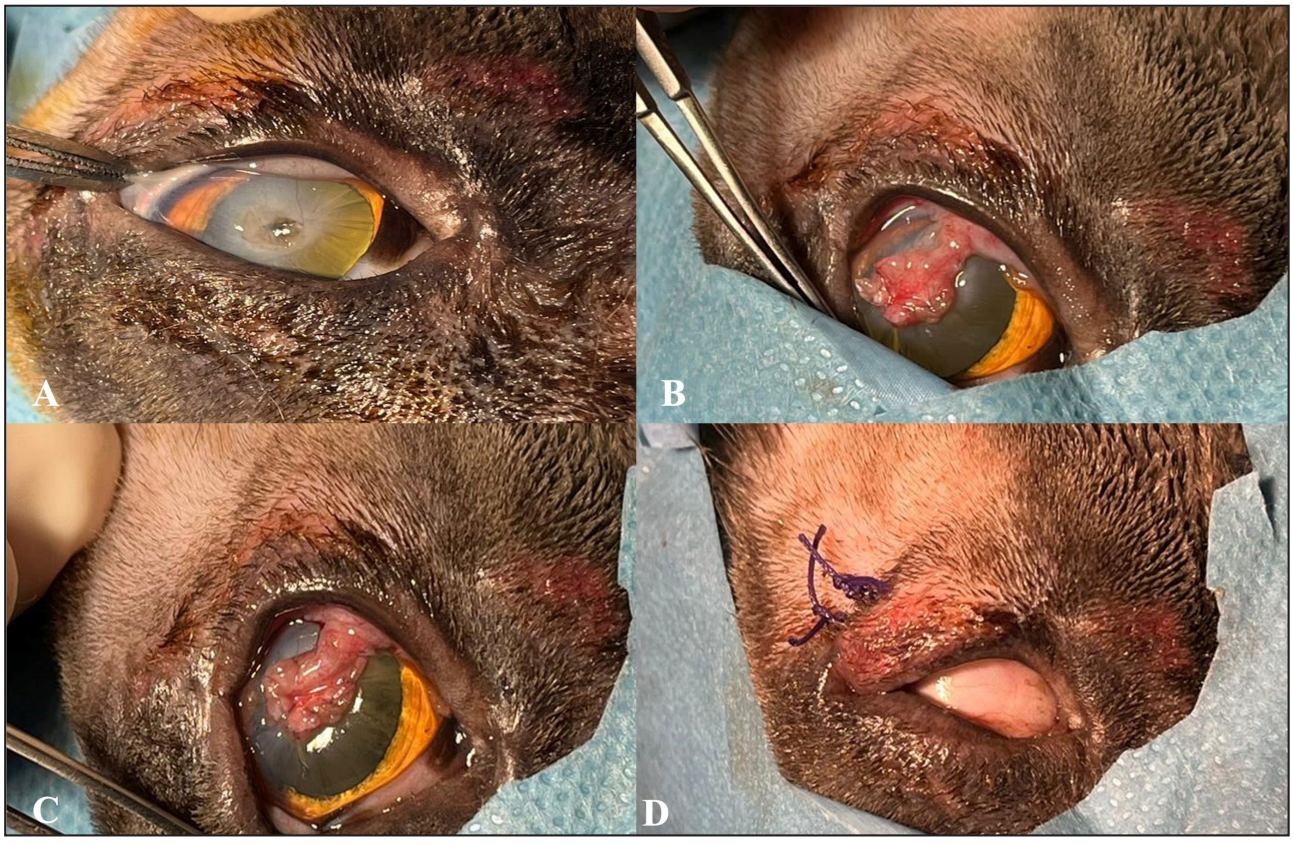

Figure 5. A-D: The photographs show presentation of a 8-year-old British Shorthair cat [no:9]. A- With corneal perforation; B- Suturing of the conjunctival pedicle flap to the cornea with simple separate sutures; C- Appearance of the stable flap; D- Residual NMF for 3 weeks.

RESULTS

Animals

Fifty cats (53 eyes) participating in the study comprised of 4 breeds, including Domestic Shorthair (DSH; n = 37), Persian (n = 10), British Shorthair (BSH; n = 2), and Domestic Longhair (DLH; n = 1). Patient age at initial admission ranged between 3 months of age and 14 years, with an average age of 34.8 months (2.9 years). 76% (38/50) of the cats were ≤ 3 years old, 10% (5/50) were between 3-8, and 14% (7/50) were older than 8-year-old. 27 cats were female (13 intact and 24 spayed), while 23 were male (11 intact and 12 neutered). The average time between the occurrence of the corneal perforation and initial admission to the hospital was 8.90 days (1-60). The findings are listed in Table 1.

Clinical findings

The study examined corneal perforations in cats, finding that 66% were traumatic in nature. Among the non-traumatic cases, 34% were associated with infections, and 6 were due to advanced ulcers. Traumatic causes included cat scratches, foreign body penetrations (such as grass awns and sharp objects), blunt trauma from falls, and unknown sources.

The main clinical signs of corneal perforation included whitish discoloration of the eye (84.90%), decreased visual function and swelling (81.13%), lacrimation (69.81%), pain (62.26%), blepharospasm (52.83%), nictitating membrane protrusion (41.50%), and photophobia (26.41%). Upon initial admission, prevalent clinical findings included corneal edema (84.90%), corneal vascularization (56.60%), shallow anterior chamber (54.71%), iris prolapse (41.50%) [Figure 6 (A,B),(C,D)], discoria (30.18%), and iris incarceration (26.41%) [Table 1].

In infectious corneal perforations, central perforation sites were significantly more common (78.57%) compared to non-infectious cases (38.46%). Traumatic lesions predominantly exhibited paracentral (42.42%) and peripheral (21.21%) perforation sites (Table 1).

Topical medical treatment was administered to all study patients, resulting in successful outcomes in 16 eyes (30.18%) of 13 cats, with 2 showing weak vision and 14 normal vision (Figure 7 A,B,C,D,E,F). Vision was restored in 6 eyes with ambiguous function, maintained in 7 eyes with normal preoperative vision, and not recovered in 3 eyes lacking vision. Posterior synechiae and focal capsular opacification occurred in 3 of 8 eyes with corneal perforation occluded by fibrin clots. Corneal fibrosis with anterior synechiae was observed in 1 eye with iris prolapse and in 8 eyes with iris incarceration. Conjunctival and corneal adhesion occurred in the left eyes of 2 cats, while corneal fibrosis with anterior synechiae, corneal vascularization, and granulation tissue developed in the right eye.

The CPF plus NMF combination was the most commonly performed surgical technique, showing success in 20 patients (40%), especially with paracentral medium to extensive perforations. Nineteen cases (95%) had fully integrated grafts with intact sutures (Figure 8 A,B,C,D,E,F). Among the patients, 17 underwent the procedure once, while 3 required it twice for corneal integrity. In one instance, a 8/0 multifilament suture separated due to corneal melting, necessitating re-suturing and iris repositioning. Enucleation was performed in cases with unrecovered visual function and progressive defects after secondary glaucoma developed post-surgery.

After a successful conjunctival flap, mild, moderate, and severe corneal opacity developed in 11.76% (n = 2/17), 29.4% (n = 5/17), and 58.82% (n = 10/17) of the cases with potential vision, respectively. Clinical examinations revealed corneal vascularization and granulation tissue in four, adhesions between the conjunctiva and cornea in one, and anterior synechia accompanied by corneal fibrosis in 11 cats. Except for 3 cases in which glaucoma developed due to pupillary adhesions despite a successful conjunctival flap, menace response and pupillary light and dazzle reflexes could be received in 17 (85%) cases.

The stitches remained intact, and no aqueous humor leakage was detected in all 7 cases with linear full-thickness lacerations that underwent suturing plus NMF combination. The stitches were removed in none of the cases, and the defective area healed in all patients, with varying degrees of corneal fibrosis (Figure 9 A,B,C,D). Phthisis bulbi requiring enucleation developed in 2 cases (2 eyes) with no preoperative vision, and visual function could not be postoperatively restored. Except for these 2, the vision was restored in 71.42% of the cases despite varying degrees of corneal scarring in 2 of 5, anterior synechia and mild fibrosis in 1 of 5, and anterior synechia, corneal fibrosis, and focal lens opacity in another one of 5 cases. Corneal opacity developed with mild, moderate and high severity in 20%, 60%, and 20% of the cases in which vision was retrieved, respectively. Anatomical integrity was achieved with varying scarring in 10 cases

with small-sized and extensive centrally located (70%) perforations where the iris was partially entrapped after the NMF procedure alone. Vision was successfully restored in all patients despite varying degrees of corneal fibrosis, including anterior synechia, vascularization, and mild ocular shrinkage. Corneal opacity ranged from mild to severe in 30%, 50%, and 20% of the patients, respectively. The follow-up period ranged from 0 to 2 years.

Treatment outcomes were classified based on vision within the 1st month and corneal transparency within 1-3 months. Epithelization and full recovery occurred within specific time frames: 10 days-1 month and 1-2 months with medical therapy alone; 3-4 weeks and 5-7 weeks with NMF alone; 2-3 weeks and 4 weeks-4 months with CPF plus NMF; and 2-5 weeks and 4-8 weeks with suturing plus NMF, respectively. Corneal integrity was restored in 48 (90.56%) eyes of 45 cats; however, treatment failed in 5 eyes of 5 cats despite different combinations.

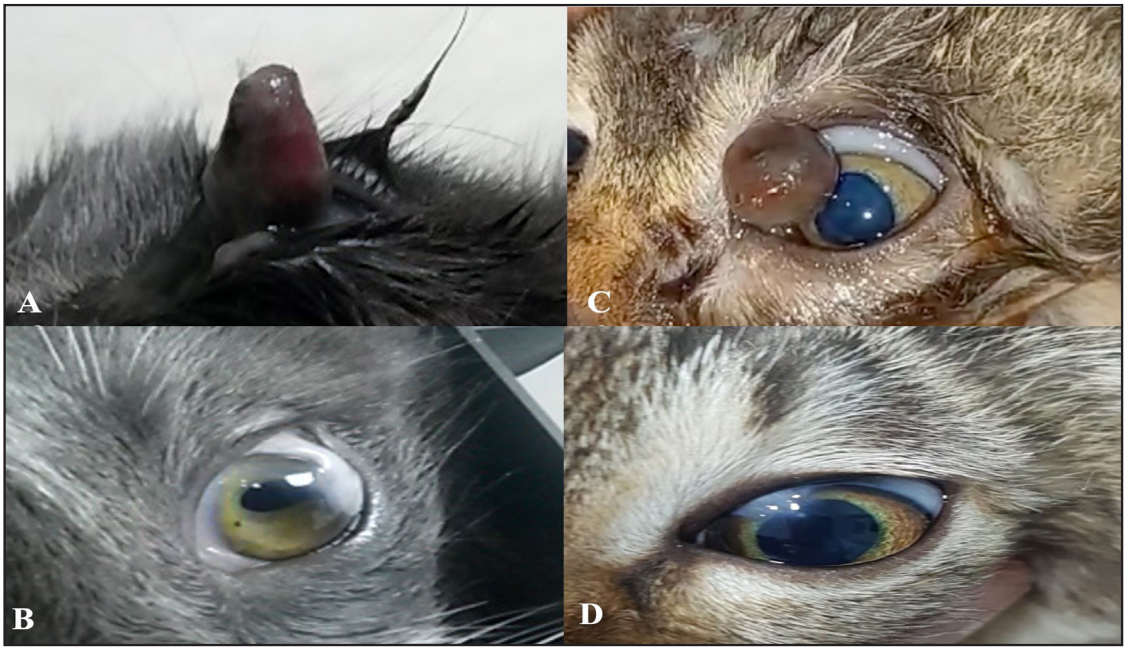

Figure 6. Photographs showing the surgical results of 2 cats with corneal perforation accompanied by iris staphyloma and undergoing conjunctival pedicle flap. A-B: Presentation of corneal perforation with severe iris staphyloma due to a sharp object injury in an 8-month-old cat [no:6] (A), and on days (B) 45 of surgery theraphy. C-D: Presentation of peripherally located corneal perforation with iris staphyloma after trauma due to fighting in a 3-month-old cat [no:13] (C); and on days (D) 30 of surgery theraphy.

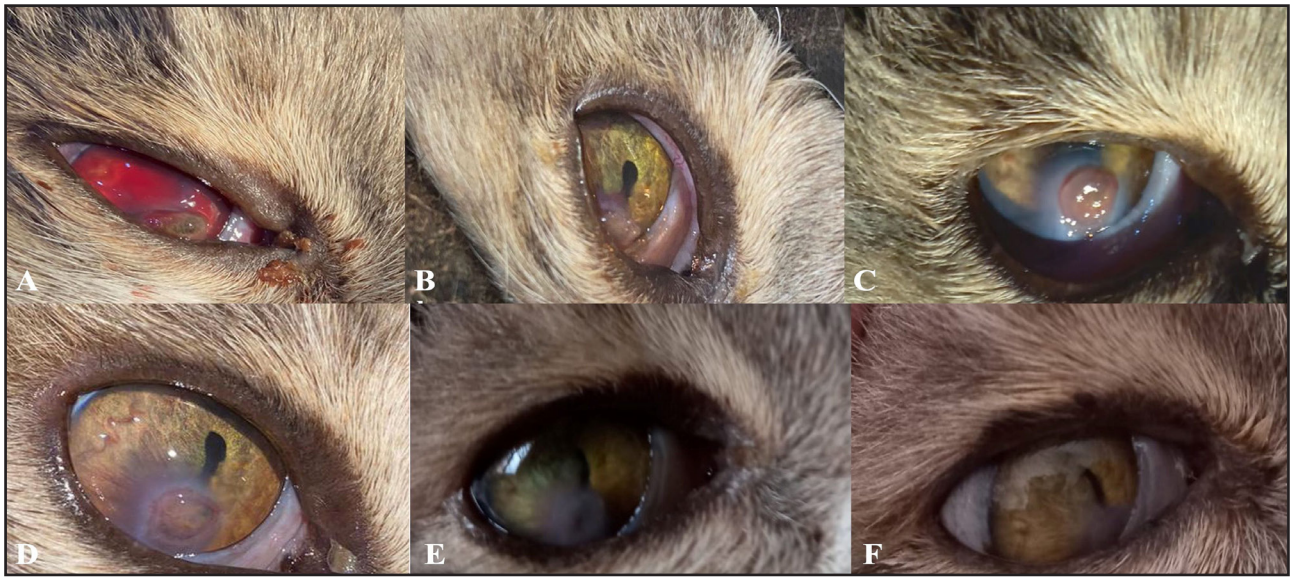

Figure 7. A-F: Medical treatment of post-traumatic corneal perforation in a 13-year-old Domestic Shorthair female cat [no:21]. A- Iris incarceration, diffuse hyphema, shallow anterior chamber presence during presentation, and on days: 2 (B); 10 (C); 14 (D); 21 (E), and 60 (F) of medical therapy.

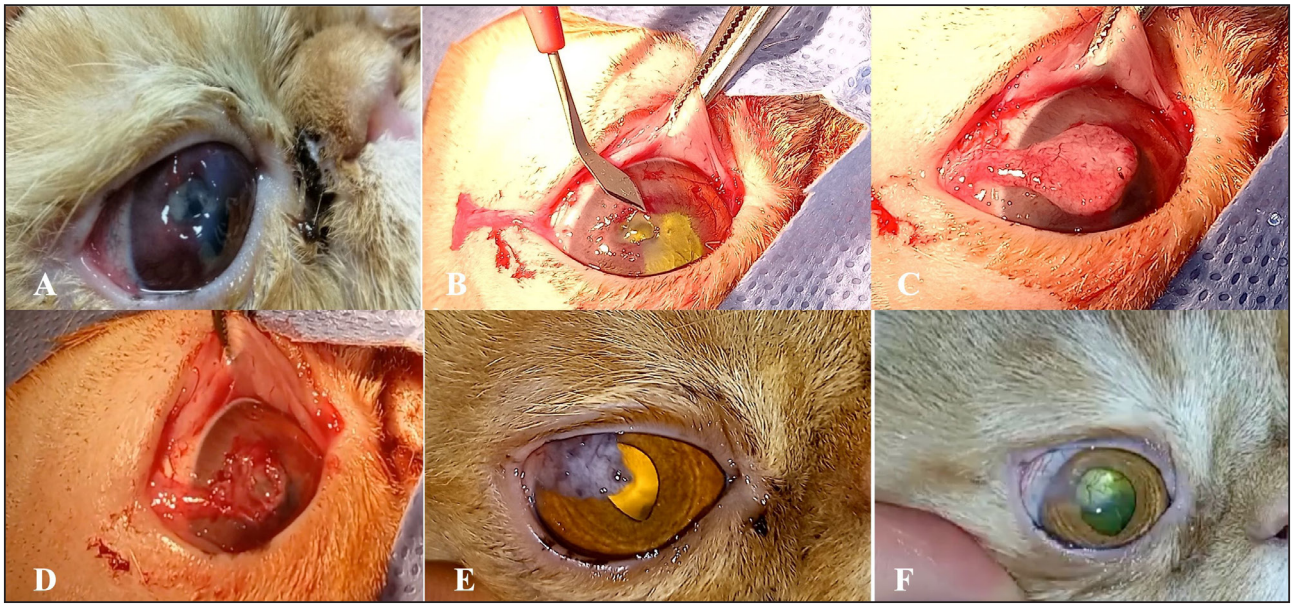

Figure 8. A-F: Photographs showing corneal perforation and conjunctival pedicle flap used to close it, steps and the result of surgical repair in a 6-year-old Persian cat [no:11]. A- Presentation; B- Debridement of the periphery of the lesion; C- Placement of the conjunctival pedicle flap; D- Appearance after the flap has been fixed with sutures; E- Immediately after NMF opening (3 weeks); F- 1.5 years later.

Figure 9. A-D: Limbal-located corneal perforation, fibrin and hyphema in the anterior chamber after falling from a height in a 2-year-old Persian cat [no:36]. A-B: View of the anterior chamber after removal of fibrin and hyphema in the anterior chamber; C- Closure of linear full-thickness corneal laceration with simple separate sutures; D- Control photo 6 weeks after surgical treatment.

Table 1. Summary of all patients' signalement, clinical findings, location, diameter, duration and etiology of the lesion, treatment administered, and visual results.

Case No	Breed, Age, Sex	Eye; Etiology, Localisation, Diameter and Duration of the Lesion	Preop. Vision			Preop. Clinical Findings	Treatment Method	Postop. Vision			Postop. Clinical Findings	Outcomes
			PLR	MNC	DZL			PLR	MNC	DZL		
1	DS,1yrs,M	OS; T(Un), C, La, 5days	?	-	+	IP, CE, SAC, CV	CPF+NMF	-	-	+	Pupillary occlusion, buphthalmos, AS	Enucleation
2	DS;3yrs;M	OS; NT(U), C, La, 7days	?	-	+	IP, CE, SAC, CV	CPF+NMF	+	+	+	Severe and wide corneal scar, granulation tissue, CV	Visual
3	DS;8mths;M	OS; T(Fi), Pa, La, 3days	+	+	+	IP, CE, SAC, Dyscoria	CPF+NMF	+	+	+	Moderatecorneal scar	Visual
4	DS;6mths;F	OS; T(Fi), Pe, La, 2days	?	-		IP, CE, Hyphema	CPF+NMF	+	+	+	Moderate corneal fibrosis, dyscoria	Visual
5	DS;1,5yrs;F	OD; T(Fi), Pa, La, 2days	+	-		IP, CE, SAC, AHL	CPF+NMF	+	+	+	Severe corneal scar	Visual
6	DL;8mths;M	OS; T(SOC), Pa, La,1day	?	-		IP, SAC, Dyscoria	CPF+NMF	+	+	+	Severe corneal fibrosis, AS, dyscoria	Visual
7	DS;4mths;F	OD; T (Un), Pa, Med, 8days	+	+	+	IP, CE, SAC, CV, Dyscoria	CPF+NMF	+	+	+	Moderate corneal fibrosis, AS, dyscoria	Visual
8	DS;1yr;F	OD; NT(U), C, La, 10 days	?	-	+	CE, CV, SAC	CPF+NMF	-	-	+	Wound dehiscence, IP, buphthalmos	Enucleation
9	BS;8yrs;M	OD; NT(U), C, Med, 20days	+	+	+	SAC, CV, CE, Hypotonia	CPF+NMF	+	+	+	Moderate corneal scar, CV, granulation tissue, AS	Visual
10	BS;5yrs;F	OS; NT(U), C,Med, 5 hours	+	+	+	Collabe AC, Hypotonia, AHL	CPF+NMF	+	+	+	Mild corneal scar	Visual
11	P;6yrs;F	OD; NT(U), Pa, La, 1mth	+	+	+	SAC, CV, CE, Hypotonia	CPF+NMF	+	+	+	Mild corneal scar,CV, granulation tissue	Visual
12	P; 3yrs; F	OD; T(Fi), Pe, La, 1day	+	+	+	II, CE, Hypotonia, Collabe AC	CPF+NMF	+	+	+	Severe corneal scar, CV, granulation tissue, cornea-conjunctival adhesion	Visual
13	DS;3mths; F	OS; T(Fi), Pe, Med, 2weeks	+	+	+	IP, SAC, Dyscoria	CPF+NMF	+	+	+	Severe corneal scar, CV, granulation tissue	Visual
14	P; 13yrs; F	OS; T(Un), Pa, La, 3days	+	+	+	IP, CE, CV, SAC	CPF+NMF	+	+	+	Severe corneal fibrosis, AS	Visual
15	DS; 7yrs; M	OS; T(Fi), Pa, La, 2mths	+	+	+	IP, CE,CV, SAC	CPF+NMF	+	+	+	Severe corneal fibrosis, AS, dyscoria	Visual
16	P; 7mths; M	OD; NT(I), C,La, 1week	?	-	+	IP, CE, CV, SAC	CPF+NMF	-	-	+	Pupillary occlusion, buphthalmos, AS	Enucleation
17	DS; 6mths;F	OS; T(Fi), Pa, La, 5days	?	-	+	IP, CE, SAC	CPF+NMF	+	+	+	Moderate corneal fibrosis, AS, dyscoria	Visual
18	DS;2yrs;F	OS; T(Fi), Pe, La, 10days	+	+	+	IP, Dyscoria, SAC	CPF+NMF	+	+	+	Severe corneal fibrosis, AS, dyscoria	Visual
19	DS;5yrs; F	OD; T(Fi), Pa, La, 2weeks	+	+	+	IP, CE, SAC, Dyscoria	CPF+NMF	+	+	+	Severe corneal fibrosis, AS, dyscoria	Visual
20	DS;5mths; F	OS; T(Fi), Pe, La, 3weeks	+	+	+	IP, Dyscoria, SAC	CPF+NMF	+	+	+	Severe corneal fibrosis, AS, dyscoria	Visual
21	DS;13yrs; F	OD; T(Fi), Pa, La, 1day	?	-	+	II, Hyphema, SAC, CE	Me	+	+	+	Moderate corneal fibrosis, AS and PS, discoria, lenticular opacity	Visual
22	DS;2yrs; M	OS; T(Fi), Pa, La, 1week	+	+	+	CV, CE, Hypotonia	Me	+	+	+	Mild corneal scar	Visual
23	DS;5mths; F	OD; T(Fi), Pa, La, 2weeks	+	+	+	II, CE, CV, Dyscoria	Me	+	+	+	Moderate corneal fibrosis, dyscoria,AS	Visual
24	P;14yrs; F	OS; T(Fi), C, Med, 3days	+	-	+	Hyphema, ALCD, hypotonia, SAC, Fibrin clot	Me	+	+	+	Mild corneal scar, PS, lenticular opacity	Visual
25	DS;4 mths;F	OD; T(Fi), Pa, Med, 1week	+	+	+	II, CE, CV, Dyscoria	Me	+	+	+	Mild corneal fibrosis, AS	Visual
26	P;14yrs; M	OD; T(Fi), C, Med, 4days	+	-	+	CE, CV, Fibrin clot, Hyphema	Me	+	+	+	Mild corneal scar, PS, lenticular opacity	Visual
27	DS; 3mths;F	B; NT(I), C,La, 1week	?	-	+	II, CV (B)	Me	+	+	+	R: Severe corneal fibrosis, AS L: Severe corneal fibrosis, AS, cornea-conjunctival adhesion	Visual
28	DS;5mths;M	OS; T(Fi), C,Med, 1week	+	-	+	CE, Hypotonia, Fibrin clot	Me	+	+	+	Moderate corneal scar	Visual
29	P;10yrs; F	OD; T(Un), C, La, 2weeks	+	+	+	CE, CV, II, SAC	Me	+	+	+	Moderate corneal scar	Visual
30	DS;5mths;M	OD; T(Fi), C,La, 2weeks	+	+	+	II, CE, CV, Dyscoria	Me	+	+	+	Moderate corneal scar, AS, dyscoria	Visual

(continues...)

(...continuation)

31	DS; 8 yrs; M	OS; T(Fi), Pe, Med, 10hours	+	+	+	Hyphema, CE, Fibrin clot	Me	+	+	+	Mild corneal scar	Visual
32	DS; 4mths;F	B; NT(I), C,La, 2weeks	+	-	+	II(L),IP(R), CE,CV	Me	+	+	+	Right: Moderate corneal fibrosis, AS Left: Cornea-conjunctival adhesion, AS	Visual
33	DS; 3mths;F	B; NT(I), C,Med,10 days	? Right	- Left	+	CE,CV,II(R), Fibrin clot(L)	Me	+	+ Left	+	R: Moderate corneal fibrosis,AS L: Mild corneal scar	Visual
34	DS; 3yrs; M	OD; T(Fi), C,La,5days	+	+	+	IP, CE, AHL, Collabe AC	Su+NMF	+	+	+	Diffuse corneal fibrosis, AS, phthisis bulbi	Enucleation
35	P; 7yrs; M	OS; T(Fi), C,La, 12days	?	-	+	IP, CE, CV, SAC	Su +NMF	-	-	-	Severe corneal fibrosis, AS, phthisis bulbi	Enucleation
36	P; 2yrs; F	OD; T(FH), Li, La, 8hours	+	-	+	Hyphema, CE, Fibrin clot	Su +NMF	+	+	+	Mild corneal scar	Visual
37	DS; 3yrs; F	OS; T(FH), Pe, La, 8hours	+	-	+	Hyphema, Dyscoria, IP, CE, SAC	Su +NMF	+	+	+	Moderate corneal fibrosis, AS, dyscoria	Visual
38	DS; 1yr; M	OS; T(SOC), Pa, Med,1day	+	-	+	Hyphema, dyscoria, CE, SAC, hypotonia	Su +NMF	+	+	+	Moderate corneal scar	Visual
39	DS; 7mths; M	OS; T(Fi), Pe, La,1day	+	-	+	Hyphema, CE,SAC, Hypotonia	Su +NMF	+	+	+	Moderate corneal scar	Visual
40	DS; 2yrs; M	OD; T(SOC), C,La,1day	+	-	+	Hyphema, IP, CE, AHL, Collabe AC, ALCD	Su +NMF	+	+	+	Severe corneal fibrosis, focal cataract in the lens, AS, dyscoria	Visual
41	DS; 3mths;F	OD; NT(I), Pa, La, 10days	+	+	+	II, CE, CV, Discoria, SAC	NMF	+	+	+	Moderate corneal fibrosis, AS, dyscoria	Visual
42	DS;4mths;M	OS; NT(I), C,La, 2weeks	?	-	+	II, CE, CV, SAC, Hypotonia	NMF	+	+	+	Mild corneal fibrosis, AS	Visual
43	DS; 7mths;F	OS; NT(I), Pa, La, 10 days	+	-	+	IP, CE, CV, SAC, Cataract	NMF	-	+	+	Severe corneal fibrosis, AS, dyscoria, cataract	Not visual (due to cataract)
44	DS;5mths;M	OD; NT(I), C,La,12days	?	-	+	II, CE, CV	NMF	+	+	+	Moderate corneal scar, CV	Visual
45	DS; 3mths;F	OD; NT(I), Pa,La, 2weeks	+	+	+	II, CV, CE, Dyscoria	NMF	+	+	+	Moderate corneal fibrosis, AS, dyscoria	Visual
46	P; 4mths; F	OD; T(Fi), Pa, S,1day	+	+	+	SAC, Fibrin clot, CE	NMF	+	+	+	Mild corneal fibrosis, AS	Visual
47	DS;7mths;M	OD; T(Gr), C,La,1week	?	-	+	II, CE, CV, Bullae	NMF	+	+	+	Mild corneal fibrosis, CV, AS	Visual
48	DS;3yrs; M	OS; NT(U), C,L,2weeks	?	-	+	IP, CE, CV, SAC	NMF	+	+	+	Severe corneal fibrosis, AS	Visual
49	DS;4mths;M	OS; NT(I), C,La, 1week	?	-	+	CE, CV	NMF	+	+	+	Moderate corneal fibrosis, AS, microophthalmia	Visual
50	DS;3mths;M	OD; NT(I), C,Med,10 days	+	+	+	Fibrin clot, hypotonia, CE, CV, Bullae	NMF	+	+	+	Moderate corneal scar	Visual

DS: Domestic Shorthair; DL: Domestic Longhair; P: Persian; BS:BritishShorthair; F : Female,M: Male ; T: Traumatic, NT: Nontraumatic, Un: Unknown, U: Ulcer, Fi: Fight, Gr: Grass awn, SOC: Sharp object cut, I: Infection, FH: Fallsfromheight, CPF: Conjunctival Pedicle Flap, Me: Medical, Su: Suture, NMF: Nictitans Membrane Flap, IP: Iris prolapsus, II: Iris incarceration, CV: Corneal vascularization,CE: Corneal edema,ALCD: Anterior lens capsule degeneration, AS: Anterior synechia, PS: Posterior Synechia, SAC: Shallow anterior chamber, AHL: Aqueous humor leakage, C: Central, Pe: Peripheral, Pa: Paracentral, Li: Limbal, S: Small, Med: Medium, La: Large, PLR: Pupillary light reflex, MNC: Menace reflex, DZL: Dazzle refleks, R: Right, L: Left, OD: Ocular dexter, OS: Ocular sinister, B: Bilateral,?:Couldn't be assed

DISCUSSION

Perforating corneal defects are open-globe injuries and are significant health issues in veterinary medicine, causing vision loss [1]. Once the lesions have occurred in youth and early adulthood, a severe health issue emerges, threatening the quality of future life of the living thing [5,16]. This study is the most comprehensive retrospective study demonstrating the outcomes and efficacy of different treatment protocols administered in cats with corneal full-thickness lacerations and perforations during the last 3 years at the Animal Research Hospital of the Istanbul University-Cerrahpaşa in comparison with the findings of the previously documented similar studies in the literature.

Corneal perforations commonly occur during youth and adulthood, as these are the times when people are more likely to experience trauma and infections [5,11]. Some studies have reported different average ages for lesions. For instance, one study found an average lesion age of 5.9 years [2], while another found it to be 7.56 years [12]. In our study, the mean age was 2.9 years, aligning with previous findings. Most cases (76%) were ≤ 3-year-old, with a peak at 3-4 months. Trauma-related injuries (63.15%; n = 24/38) were more common than infection-related ones in this age group. However, infection-associated corneal perforations (n = 10/17) also occurred mainly in individuals ≤ 3-year-old, particularly in those 7 months old or younger. The high incidence in young cats is attributed to their active behavior, curiosity, and susceptibility to infections.

In the evaluation of etiological factors contributing to perforating ocular defects, cat scratches emerge as the most prevalent traumatic cause, with reported prevalence rates of 58.33% [12], and 70% [16]. In our study, cat scratches ranked highest among traumatic causes of perforating corneal lesions, accounting for 69.69% of cases (Table 1). The prevalence of non-traumatic corneal perforations was found to be 34%, which aligns with the reported prevalence of 33.33% [1]. In a study, it was noted that all cats referred with corneal perforation complaints had a 1-week history of deep corneal ulcers [2]. Similarly, we found that 35.29% (n = 6/17) of non-traumatic corneal perforation cases were admitted due to pre-existing corneal ulcers.

Some studies have reported that 94.5% of individuals with penetrating object-related ocular injuries were referred to medical centers within the 1st 12 h, and 81.2-85% within the first 24 h, highlighting the importance of early intervention [14,15]. In a study, it was found that 20% of patients were referred within the 1st 24 h, emphasizing the success of rapid medical intervention [1], while another study suggested that the time between corneal trauma and surgical intervention did not significantly impact patient outcomes [3]. In our study, only 22% were referred within 24 h, with an average referral time of 8.90 days. Despite varied timeframes between the incident and medical intervention, outcomes remained favorable overall. Treatment protocols were successful in 77.27% of patients with compromised vision at admission, with 22.72% showing poor response. Unfavorable outcomes were primarily attributed to corneal perforation-related complications rather than delays in medical care.

In perforating corneal lacerations, prognosis is influenced by injury-associated complications [8,15]. Studies in humans show that complications like iris prolapse, lens injury, retinal detachment, and intraocular foreign bodies negatively impact prognosis, with prevalence rates ranging from 11-68%, 1.7-28%, and 15-22%, respectively. Previous studies identified corneal edema and vascularization, iris prolapse and corneal melting, and corneal edema with vascularization and iris prolapse as prevalent complications [1,7,8], contrasting with the findings of another study [15]. In our study, anterior synechia and dyscoria were the most prevalent complications, occurring in 18 cases with iris prolapse (15 after iridectomy, 3 without). Additionally, 12 cases with iris incarceration (without iridectomy) experienced dyscoria. In cases, endophthalmitis was reported in 24.44%, and phthisis bulbi in 11.11% [1]. In our study, 6% developed secondary buphthalmos, causing vision loss, and 4% developed phthisis bulbi, with no cases of endophthalmitis. The relatively low prevalence of phthisis bulbi and absence of endophthalmitis may be attributed to early-phase administration of wide-spectrum antibiotics, promoting primary wound healing. Common complications leading to vision loss and requiring enucleation included pupillary occlusion, secondary glaucoma, and phthisis bulbi, despite medical and surgical interventions.

Lesion size and site significantly influence the outcome of perforating corneal injuries [13]. Paulsen *et al*. [16] noted a direct correlation between corneal laceration extent, time to initial admission, and potential vision loss, contrasting Braus *et al*. [3] findings. Central corneal wounds, particularly affecting the

pupil, pose a greater threat to visual function than paracentral or peripheral lesions [17]. In the study, 83.33% of traumatic corneal perforations involved the central cornea, with no asserted association between lesion site and treatment outcome [1]. Our study aligned with literature, with 49.05% centrally located defects. Infection-related wounds mainly affected the central cornea (78.57%), while cat scratch-induced lesions occurred paracentrally (42.42%). Poor prognosis cases often had centrally located, extensive perforating corneal defects, often accompanied by iris staphyloma and buphthalmos. Phthisis bulbi cases also stemmed from severe central lesions and ocular inflammation, resulting in relatively low conclusive visual function.

Various surgical techniques are utilized to repair corneal perforations, with the approach depending on the extent of the lesion. Primary wound closure is preferred for linear and relatively uncomplicated corneal lacerations, especially when the iris isn't entrapped [21]. In some studies, it has been reported that primary closure achieves a 100% success rate in vision restoration in cats [1,3]. reported 100% success rates for vision restoration with primary closure in cats. In our study, vision was regained in 71.42% of patients undergoing suture closure. However, 28.57% experienced failure, often due to severe corneal damage or post-operative complications like uveitis leading to phthisis bulbi.

Conjunctival flapping has been endorsed for traumatic corneal perforations due to its efficacy and feasibility, maintaining a high-quality ocular surface despite corneal morphological changes [22]. A study reported favorable outcomes in 80% of traumatic and 26.66% of non-traumatic wounds, with a 20% failure rate attributed to corneal melting [1]. In our study, conjunctival flap was the most common surgical procedure, succeeding in 85% of cases (70% traumatic, 30% non-traumatic). Failures (5%) were attributed to corneal melting and (10%) to complications like pupillary block and secondary glaucoma after iridectomy, hindering anatomical and physical restoration of the ocular structure.

A study argued against the efficiency of conjunctival flapping for centrally located deep and perforating corneal ulcers due to oversized tissue obstructing the visual axis [12]. Another study achieved success with medical treatment alone in traumatic corneal and lens wounds, with success rates of 81% and 100% at 2-6 months and 6-12 months, respectively [3]. In our study, medical therapy alone restored ocular integrity and vision in all 13 cases of central and paracentral lesions without active aqueous humor leakage or severe iris prolapse. Though not compared directly, medical therapy alone showed comparable or superior results to combined medical and surgical treatments. Thus, medical therapy alone was deemed optimal for managing corneal lacerations and perforations without aqueous humor leakage, fibrin clot, or severe iris incarceration.

The efficacy of the NMF technique in managing various ocular conditions remains debated [4]. However, in our cases, the NMF technique yielded favorable results for iris prolapse, both in cases with no preoperative vision and those with normal preoperative vision. Despite previous reports of its inconvenience and inefficacy as a single treatment option for deep perforating corneal ulcers, the NMF technique proved beneficial in our study. The NMF flap, typically applied for superficial lesions or defects with moderate depth, has been recognized as an efficient tool, acting as a compressive bandage supporting corneal healing in cats [16,18]. In our study, consistent with existing literature, the flap served as a compressing tampon, leveling herniated iris with the corneal surface in cases with severe iris prolapse.

CONCLUSION

In conclusion, 90.56% of 50 cats treated for perforating corneal wounds regained vision successfully. Vision loss, observed in 10% of cases, was more common with centrally located lesions and complete pupillary iris prolapse. Medical therapy alone achieved satisfactory outcomes in all 13 cases treated, while 86.48% of those treated with medical therapy plus various surgeries experienced cosmetically and functionally acceptable results. Aggressive medical therapy proved equally effective as surgical interventions for penetrating corneal wounds without aqueous humor leakage or incarcerated iris staphyloma, offering a convenient therapeutic option, especially for patients unsuitable for anesthesia, to restore ocular integrity.

MANUFACTURES

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