

Management of inflammatory corneal melt leading to central perforation in children: a retrospective study and review of literature

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CLINICAL STUDY

Abstract

Purpose To assess the outcome of early therapeutic penetrating keratoplasty (PKP) for corneal melt leading to perforation in children.

Methods Case notes of all the consecutive patients presenting with acute corneal perforation that underwent urgent therapeutic PKP between 2000 and 2010 to the practice of one of the authors, both NHS at Great Ormond Street Hospital for Children and private, were retrospectively reviewed. Onset of perforation, underlying cause, medical and surgical treatment, pre- and post-operative visual acuity, graft clarity, length of follow-up, and post-operative complications were recorded.

Results Four eyes of four consecutive patients (mean age of 9.5 years and median 8.5 years, range 4–17 years) were treated for acquired acute onset corneal perforations. There were three females and one male. Etiologies included herpes simplex keratitis secondary to immune recovery disease post bone marrow transplantation, acanthamoeba keratitis, recessive dystrophic epidermolysis bullosa, and blepharokeratoconjunctivitis with acne rosacea. Pre-operative visual acuity ranged from hand movements to 6/150. All the patients had severe anterior chamber inflammation. All eyes improved in visual acuity ranging from 6/9 to 6/18 with clear grafts at last follow-up. There was no recurrence of melt or perforation. Mean follow-up was 67 months (median 44 months).

Conclusion PKP during the acute phase together with aggressive medical therapy and close follow-up may achieve good visual outcomes in children with corneal melt with perforation and should be considered.

Waiting may sometimes allow the marked inflammatory response seen in children to cause irreversible structural and/or functional damage.

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Introduction

Non-traumatic corneal perforation in children is rare, but may be seen in neurotrophic ulcers,¹ infectious keratitis,² peripheral ulcerative keratitis,^{3–5} ocular surface diseases such as blepharokeratoconjunctivitis (BKC) with or without rosacea,^{6,7} and chemical burns.⁸ Systemic conditions including juvenile rheumatoid arthritis^{9,10} and Stevens Johnson syndrome^{11,12} can rarely cause corneal perforation, while in developing countries, vitamin A deficiency is a common cause of non-infectious corneal melt in children.¹³

The diagnosis and treatment of corneal perforation in children is difficult, because they are often unable to communicate their symptoms clearly, have limited cooperation and many cases present late.

To complicate the issue further, children can lose vision not only from subsequent scarring but also from amblyopia.

Although the literature has reports about management of bacterial and fungal keratitis in mixed cohorts of adults and children,^{2,14–18} especially in developing countries, there is little about the management of protozoal or viral keratitis and even less about non-infectious keratitis leading to perforation in children.

We present four cases of central corneal melt leading to perforation, all secondary to an inflammatory etiology (two infectious and two non-infectious) and all treated successfully with

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Table 1 Demographic profile of the patients

Case no.	Age (years)/ sex	Predisposing condition	BCVA of the affected eye at presentation	BCVA of the affected eye at last FU	Time between perforation and PKP	FU (M)
1	4/F	Acanthamoeba keratitis	HM	6/9	24 h	90 M
2	17/F	Epidermolysis bullosa, MGD	HM	6/9	7 days	26 M
3	12/F	MGD, Blepharokeratoconjunctivitis secondary to acne rosacea	6/150	6/9	Less than 2 weeks	62 M
4	5/M	HSK secondary to immune recovery disease s/p BMT for severe combined immunodeficiency (SCID)	HM	6/18	Less than 2 weeks	90 M

Abbreviations: M, male; F, female; MGD, Meibomian Gland Dysfunction; BCVA, best-corrected visual acuity; HM, hand movements; FU, follow-up; M, months; PKP, penetrating keratoplasty; S/p BMT, status post bone marrow transplantation; ft, feet.

prompt and early therapeutic penetrating keratoplasty (PKP), while the eyes were still inflamed. The degree of inflammation prompted intervention as it was felt that despite anti-inflammatory therapy, damage sustained by inflammation would be too detrimental.

Materials and methods

Case notes of all consecutive patients between 2000 and 2010 with acquired corneal melt and perforation who presented to one surgeon (KKN) in a single tertiary care pediatric hospital or private office (KKN) were retrospectively reviewed. At Great Ormond Street Hospital for Children, this study was considered to be a part of an audit and as such not considered to require ethics committee approval. Onset of perforation, underlying cause, medical and surgical treatment, pre- and post-operative visual acuity, length of follow-up, and post-operative complications were recorded. A literature review was performed using PubMed using the MeSH terms corneal melt, perforation, keratoplasty, and children.

Results

Four eyes of four patients (mean age of 9.5 years and median 8.5 years, range 4–17 years) were treated for acquired corneal perforations. There were three females and one male (see Table 1).

The onset of all corneal perforations was acute after progressive corneal melting. PKP was performed in all four eyes while the eyes were still inflamed. All the perforations were central. Two of four eyes showed an aggressive fibrinous reaction at the time of the surgery, involving the lens and necessitating lensectomy. Conservative measures such as bandage contact lens (BCL) and tissue adhesive were used before PKP in the two non-infective cases. The two patients with infective keratitis were treated medically with appropriate antimicrobial agents after microbiological workup. The two patients with non-infectious etiology received

oral steroids postoperatively. All the post-operative medications are shown in Table 2. All the cases were followed up for a mean period of 67 months and median of 44 months (range 26–90 months). Cases are described in detail below. The results of the literature review are summarized in Table 3.

Case 1

A 4-year-old girl was reoffered to GOSH with a diagnosis of left eye Herpes Simplex Virus (HSV) keratitis. Corneal scrapings at the outside hospital did not grow any organisms, and she was treated empirically with topical as well as oral acyclovir and topical steroids. On presentation, her BCVA was hand movements (HM) in the left eye. Right eye was unremarkable. She responded well to the topical treatment with remarkable improvement in vision to 6/12 in 2 weeks. At this stage, the steroids were tapered. Soon after tapering the steroids, the keratitis recurred with a decrease in the visual acuity to counting fingers. She was again started on intensive steroids and her improved to 6/30. Three months after her initial presentation, she developed corneal epithelial defect for which a temporal tarsorrhaphy was performed in addition to the treatment with topical and systemic acyclovir, topical steroids, chloramphenicol, and atropine eye drops. A month later, she developed corneal ulcer with hypopyon with a decrease in visual acuity to HM. Corneal scrapings performed at this stage were positive for acanthamoeba. She was started on polyhexamethylene biguanide (PHMB) and hexamidine eye drops. Two weeks later, the ulcer perforated needing an emergent PKP (Figure 1a). Postoperatively, topical steroid and antibiotic combination drops along with PHMB drops were started. She was evaluated twice a week in the immediate post-operative period; and the drops were tapered gradually to once a day over a period of 4 weeks and PHMB was continued for another 4 weeks. She was also continued on topical and systemic acyclovir until the confirmation of acanthamoeba in the corneal button, and

Table 2 Summary of clinical data and outcome of patients

Case no.	Initial presentation		Initial management		Surgery	Management after PKP		Complications	Final outcome
	Medical	Surgical	Medical	Surgical		Medical	Surgical		
1	Herpes keratitis, corneal epithelial defect hypopyon, ulcer, later diagnosed as acanthamoeba keratitis, perforated ulcer	Tarsorrhaphy	Oral+Topical ACV, PDF, CHL, ATR, PHMB, Cefuroxime	PKP	Sy+topical steroids, ATR, PHMB, Hexamidine, antiglaucoma tear supplements	CE + IOL YAG capsulotomy	1. Graft rejection 2. PSC 3. Glaucoma	Clear graft Controlled IOP	
2 ^a	Corneal infiltrate with perforation, MGD, corneal vascularization	BCL, Histoacrylate glue	Topical EC, AMK, CF	PKP+CE	LVF, ATP, ECZ, CIPRO, IV AMPH B, Syst+Topical steroids, FLCZ	YAG capsulotomy CE+IOL	PCO	Clear graft	
3	Spontaneous corneal perforation 3 mm secondary to melt at the edge of central corneal opacity, MGD	Double layer AMT+BCL +tarsorrhaphy as no graft availability	IV CF, CIPRO Topical EXN, CHL, Topical steroids	PKP	Topical dexamethasone/neomycin/polymyxin b, Syst steroids, antiglaucoma, tacrolimus		1. Epithelial rejection 2. Endothelial rejection 3. PSC 4. HSV keratitis 5. Glaucoma	Clear graft Controlled IOP	
4 ^b	Descemetocoele with spontaneous corneal perforation with iris plugging the wound		Topical ACV, Oral ACV	PKP+CE +PCIOL	Topical and oral ACV, topical and oral steroids	YAG capsulotomy	Mild suture reaction	Clear graft	

Abbreviations: ACL, acyclovir; PDF, pred forte; CHL, chloramphenicol; ATR, atropine; PHMB, polyhexamethylene biguanide; EXN, exocin; EC, econazole; CIPRO, ciprofloxacin; LVF, levofloxacin; AMPH B, amphotericin B; CE, cataract extraction; PCIOL, posterior chamber intraocular lens implantation; PCO, posterior capsule opacification; PSC, posterior subcapsular cataract; IOP, intraocular pressure; syst, systemic; MGD, Meibomian gland dysfunction; IV, Intravenous; BCL, bandage contact lens; AMT, amniotic membrane transplantation; AMK, Amikacin; FLCZ, Fluconazole; Syst, systemic; PKP, penetrating keratoplasty; HSV, Herpes Simplex Virus. ^aIn case 2, the lens was found to be involved at the time of surgery, and lens aspiration was done sparing the posterior capsule. ^bIn case 4, iris and lens were touching the cornea at the time of presentation. Triple procedure with PKP+ CE + PCIOL implantation was performed in the same sitting.

PCR was negative for HSV. One month postoperatively, she developed an increase in intraocular pressure (IOP) with endothelial rejection of the graft. IOP was controlled with topical antiglaucoma medications, and the graft rejection was treated with topical and systemic steroids (1 mg/kg body weight) tailored over a period of 6 weeks. At 12 months follow-up, her BCVA in the left eye was 6/60 with a posterior subcapsular cataract, for which underwent cataract extraction with PCIOL implantation. Ten months after cataract extraction her BCVA improved to 6/24 with +1.5/−6.00 × 80° with graft clear graft and controlled IOP. Four years after cataract surgery, she developed posterior capsular opacification (PCO) for which Neodymium-doped yttrium aluminum garnet (Nd-YAG) capsulotomy was performed with improvement in visual acuity to 6/15. She continued to use topical steroids, lubricants, and antiglaucoma medications. Seven years after the PKP; she was again successfully treated for early endothelial graft rejection with topical steroids. At the last follow-up, 90 months after PKP, her BCVA in the left eye was 6/9, with IOP of 11 mm Hg and clear graft (Figure 1b).

Case 2

Seventeen years old girl, a known case of recessive dystrophic epidermolysis bullosa (RDEB) with meibomian gland dysfunction (MGD), developed corneal melt in the right eye; and she was referred to GOSH from other hospital for further evaluation and management. She had a history of bilateral astigmatism with posterior blepharitis, corneal scars, and recurrent corneal epithelial erosions. At presentation, her BCVA was HM with 0/−2.5 × 10° and 6/24 with 0/−2.00 × 100° in the right and left eyes, respectively. She was on preservative-free econazole (1%), amikacin (2.5%), and ceftazidime (5%) in the right eye. On exam, she was noted to have marked meibomian gland dysfunction, inflamed lid margins 4mm of central corneal infiltrate with shallow anterior chamber. Corneal scrapings were negative for any growth. BCL was placed in the right eye, and all the topical treatment was continued. Next day, the anterior chamber was flat and histoacrylate glue was applied. On close follow-up, it was noted that the anterior chamber had formed but the keratitis failed to respond to the antimicrobial treatment and PKP was performed 6th day after the presentation. At the time of PKP, it was found that her lens was involved and a lens aspiration was done sparing the posterior capsule (Figures 2a and b). Her post-operative course was uneventful. She was continued on topical econazol (1%) two hourly, and also received topical levofloxacin two hourly, preservative-free dexamethasone 1% 2 hourly, atropine 1% 3 times/day. Systemically, she received amphotericin B 3 mg/kg once-daily intravenously (IV)

Table 3 Results of non-traumatic corneal perforation in children reported in literature

Study	Surgical procedure	Total No of patients age (range)	No of pediatric patients with corneal perforation (%)	Age/diagnosis of pediatric patients	Location of perforation	Outcome	Follow-up	Comments
Lifshitz et al ³⁴	Tectonic epikeratoplasty	9 (2-76 y)	2 (22.2%)	a. 7 y/Indifferent to pain (Descemetocoele) b. 2 y/Corneal melt	NA NA	Corneal scar VA CF 1 FT	Mean 33M 12 M	None 2 AMT, PKP 5 months later after resolution of inflammation None
Soloman et al ²³	AMT	33 (7-87y)	3 (9.09%)	a. 7 y/Corneal perforation s/p HSK neurotrophic ulcer, secondary bacterial infection b. 17 y/decematocele s/p necrotizing keratitis, contact lens wearer	NA NA	VA 20/100 Vascularized corneal scar Graft failed VA 6/9	10 M NA 6 M	None None None
Nobe et al ¹⁸	PKP	46 (7 M-87 y)	2 (4.34%)	a. 6 M/Pseudomonas keratitis b. 5 y/Herpetic keratitis	NA NA	Clear graft VA 6/9	NA	None None
Vanathi et al ¹²	Tectonic grafts	40 (mean 38.04±19.96 y)	3 (7.5%)	a. 18 y/steroid induced melting with perforation b. 4 y/Keratomalacia with perforation	Paracentral and peripheral Paracentral, limbal NA	Clear graft VA 6/18 Clear graft	18 M 11 M	None None
Utine et al ²⁴	LK using γ-irradiated corneal lenticule	10 (7-80 y)	1 (10%)	7 y/Corneal perforation/p bacterial keratitis	Paracentral	VA 20/30	10 M	None
Shi et al ⁶²	PKP with small diameter glycerin cytopreserved graft	15 (7-45 y)	1 (6.6%)	11 y/Chronically inflamed eye with midperipheral perforation	Mid periphery	VA 6/36	3 M	Initial treatment with BCL Clear graft
Bhatt et al ²⁵	Therapeutic DLK	4 (11-70 y)	1 (25%)	9 y/HSK with perforation 15 y/severe blepharitis with non-infectious perforated corneal ulcer	Paracentral Paracentral	VA 18/20 VA 20/40	10 M 18 M	None None
Savino et al ²⁸	AMT with patch graft	1	1 (100%)	a. 12 y/Chronic corneal ulcer s/p tuberculosis with perforation	NA	Healed corneal scar	4 M	None
Shimamura et al ³¹	Therapeutic DLK	2	1 (50%)	b. 3 M/corneal perforation with Goldenhar syndrome	NA	Healed corneal perforation	NA	AMT was performed later Blepharoplasty was performed
Muller et al ⁶³	Corneal crosslinking in melting keratitis	6 (16-73 y)	1 (16.6%)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	VA 20/125 Corneal scar	4 M	None
Bendoriene et al ⁶⁵	Silicone hydrogel contact lenses	21 (2 M-17 y)	(9.5%)	9 M/keratomalacia induced by Phenyl ketonuria Keratomalacia	NA NA	Clear corneas Clear graft in 5 out of 15 eyes	4 M Mean 7.3 M	None 15 eyes underwent emergency tectonic PKP None None
Habot-Wilner et al ³⁶	AMT and PKP	1	1 (100%) (both eyes)	11 y/PUK in JRA with corneal perforation	NA	Melting of graft recurrent perforation	12 M	Infliximab, cyclosporine as systemic t/t
Valpayee et al ¹⁵	PKP	29 (2 M-5 y)	29 (100%)	5 M/Advanced keratomalacia with descemetocoele with cystic fibrosis NA/BJC	Paracentral	Clear graft VA CSM	18 M	One rejection episode
Mathur et al ⁶	Patch graft	11 (10-18 y)	1 (9.09%)	16.3 y/BJC 10 y/Cockayne's syndrome with exposure keratopathy	Central	Clear graft VA 20/60 NA	17 M Mean 58.9±44M	Glaucoma, cataract None
Singh et al ⁶⁵	PKP	6 (9 M-4.5 y)	6 (100%)	5 y/Gonococcal keratoconjunctivitis NA/BJC	1-Paracentral 1-NA	VA: 6/24 OD 6/9 OS Perforation healed	2 W 2 W	None None
Oh et al ¹⁰	Corneoscleral Patch graft +conj resection+AMT	1	1 (100%)	16.3 y/BJC 10 y/Cockayne's syndrome with exposure keratopathy	Central	Phthisis Enucleation	6 W	None None Absolute glaucoma +Buphthalmos
Wamsley et al ⁶⁷	Corneal gluing PKP	5 (5-29 y)	1 (20%)	5 y/Smith-Lemli-Opitz syndrome with neurotrophic keratopathy	Paracentral	Perforation healed	1 y	Corneal scarring
Kawashima et al ³⁸	PKP	51 (2-16 y)	2 (3.9%)	9 M/Congenital alacrima	Paracentral	Perforation healed	1 y	Corneal scarring
Teo et al ¹²	Corneal gluing	10 (6-27 y)	1 (10%) (both eyes)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	Perforation healed	1 y	Corneal scarring
Hamada et al ⁷	Corneal gluing	1	1 (100%)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	Perforation healed	1 y	Corneal scarring
Yamaguchi et al ¹	TSCLs	1	1 (100%)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	Perforation healed	1 y	Corneal scarring
Wong et al ³⁹	Corneal gluing	1 (20 days)	1 (100%)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	Perforation healed	1 y	Corneal scarring
Zaegelbaum et al ⁴⁰	PKP	2	1 (50%)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	Perforation healed	1 y	Corneal scarring
Nuyts et al ⁴¹	Polyurethane patch	2 (5 y and 84 y)	1 (50%)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	Perforation healed	1 y	Corneal scarring
Yoshita et al ⁴²	TSCLs	1	1 (100%) (both eyes)	10 y/Total corneal involvement with perforation Keratomalacia	Paracentral	Perforation healed	1 y	Corneal scarring

Abbreviations: M, months; y, years; W, weeks; VA, visual acuity; PKP, penetrating keratoplasty; AMT, amniotic membrane transplantation; AM, amniotic membrane; HSK, herpes simplex keratitis; conj, conjunctival; t/t, treatment; TSCLs, therapeutic soft contact lenses; PUK, peripheral ulcerative keratitis; JRA, juvenile rheumatoid arthritis; CSM, central, steady, maintained; BJC, blepharokeratoconjunctivitis; NA, not available.

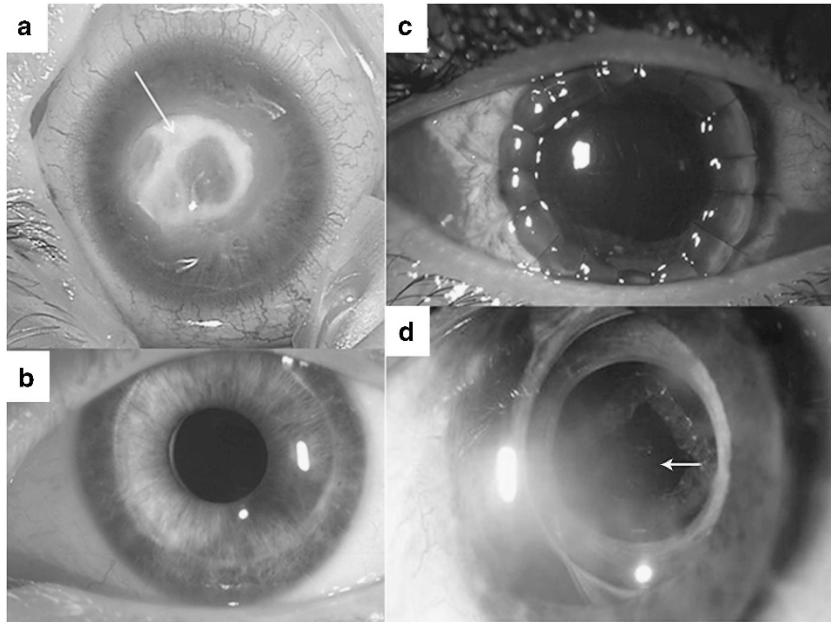


Figure 1 Pre- and post-operative pictures of case 3. (a) Case 1 with acanthamoeba keratitis: Central corneal infiltrate (long arrow) with perforation and thinning, with surrounding inflammation. The anterior chamber is almost flat (small arrow). (b) Case 1 at the last follow-up showing clear cornea after therapeutic penetrating keratoplasty and later cataract extraction with primary intraocular lens implantation. (c) Case 3 with Blepharokeratoconjunctivitis secondary to acne rosacea: At 1 week after therapeutic penetrating keratoplasty showing clear graft. (d) Case 3 at last follow-up showing clear visual axis and capsulotomy opening (arrow).

for 1 week, ciprofloxacin 500 mg twice-daily for 4 days, fluconazole 300 mg once-daily orally for days. Histopathology of corneal button was negative for any organism as well as fungal and acanthamoeba culture. After careful discussion with microbiologists, IV methylprednisolone was started for 24 h. Subsequently, she was put on tapering doses of oral prednisolone (1 mg/kg/day) over a period of 6 weeks. One week postoperatively, her BCVA was 6/60 in the right eye. At 1-year follow-up, she developed PCO and underwent Nd-YAG capsulotomy. At last follow-up, 26 months after the PKP, her BCVA in the right eye was 6/9 with IOP of 12 mm Hg and clear graft.

Case 3

A 12-year-old girl from Namibia presented with acute right eye spontaneous corneal perforation. She was a known case of acne rosacea and MGD with a significant ocular history of bilateral pannus, left conjunctival ulcer with corneal stromal abscess and right eye corneal perforation, which was treated with conjunctival flap 1 year before her presentation to GOSH. She was otherwise healthy child, HIV negative, with a low Basal Metabolic Index, and some unspecified blood abnormality (low CD4 count). On presentation, her BCVA was 6/150 in the right eye and 6/9 in the left eye. Ocular exam of the right eye showed corneal perforation (3 mm in size) secondary

to melt at the edge of central cornea opacity. Left eye showed paracentral cornea scar with nasal pannus. Fundus examination of both eyes was within normal limits. She was on oral erythromycin 250 mg QID, Exocin 3 g/ml eye drops two hourly in the right eye and tear supplements in both eyes.

She was scheduled for PKP in the right eye, but because of the unavailability of appropriate graft material, it was decided to perform double layered amniotic membrane transplantation (AMT) with central tarsorrhaphy in the right eye. Gradually, the anterior chamber had formed and the patient underwent PKP within 7 days to clear the visual axis. Postoperatively, there was mild uveitis and raised IOP was noted in the right eye. She was given topical dexamethasone/neomycin/polymyxin combination drops 6 times/day, antiglaucoma medications, and oral steroids. Ten days postoperatively, her BCVA in the right eye was 6/38 @4 m (Figure 1c).

One month later, she developed corneal erosion and subsequent epithelial rejection which was treated with topical ofloxacin/steroid combination eye drops tapered over a period of 6 weeks. Three months postoperatively, endothelial rejection was noted, which was controlled with systemic steroids (2 mg/kg/day) and topical steroids tapered over a period of 6 weeks and cyclosporine eye drops. Four months later, her steroids were discontinued and she was started on Tacrolimus 150 mg/kg/day. At 12 months follow-up, central graft

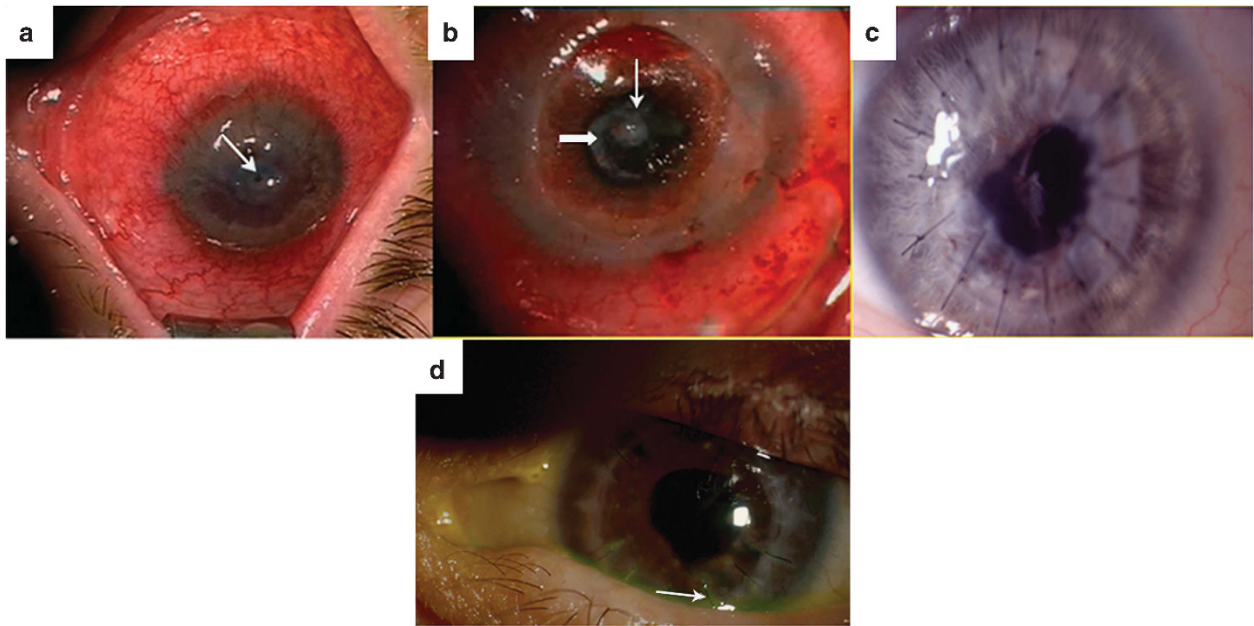


Figure 2 Pre-operative, intraoperative, and post-operative pictures of case 2 with epidermolysis Bullosa and post-operative picture of case 4. (a) Severely inflamed eye with central corneal perforation (arrow) with surrounding infiltrate and shallow anterior chamber. (b) Intraoperative still showing cataractous lens (thin arrow) and fibrin reaction (bold arrow) in the anterior chamber. (c) Clear cornea after therapeutic penetrating keratoplasty. (d) Post-op picture of case 4 with Herpes simplex keratitis secondary to immune recovery disease showing clear cornea with loose sutures (arrow).

haze was noticed along with subcapsular lens opacity in the right eye; with BCVA of 6/48. A diagnosis of herpes keratitis was made and treated with systemic and topical acyclovir. Right eye cataract progressed and a lensectomy with PCIOL was performed 26 months post PKP. Post cataract extraction and PCIOL implantation, her BCVA improved to 6/12 in the right eye. She subsequently had Nd-YAG capsulotomy for the PCO in the right eye. At the last follow-up, 62 months after PKP, her BCVA in the right was 6/9 with clear graft (Figure 1d). She was on tapering doses of tacrolimus.

Case 4

A 5-year-old male child with a significant medical history of immune recovery disease s/p bone marrow transplantation (BMT) for severe combined immunodeficiency (SCID) presented with right eye descemetocoele. He was diagnosed with bilateral herpes simplex keratitis (HSK) secondary to immune recovery disease from his BMT for SCID and was taking topical and oral acyclovir. At presentation, his BCVA was HM in both eyes. On ocular exam, he was noted to have descemetocoele in the left eye with spontaneous corneal perforation which was plugged by the iris. The lens was also touching the cornea. His right eye showed corneal scarring with ghost vessels due to previous episode of

HSK. Fundus evaluation was within normal limits in both eyes.

Because of the involvement of iris and lens, a triple procedure with PKP+CE+PCIOL implantation was performed. Postoperatively, he was continued on topical and oral acyclovir and tapering doses of topical preservative-free dexamethasone 1% eye drops. He was left on dexamethasone 1% eye drops per day and prophylactic dose of oral acyclovir. At the last follow-up, 90 months after PKP, his BCVA in the left eye was 20/60 (Figure 2d). He is reviewed by his immunologist on a regular basis.

Discussion

Inflammatory corneal melting leading to perforation may be due to infectious and non-infectious destructive conditions.^{1-4,14-19} Failure to diagnose and treat a perforation early can lead to further corneal damage, cataract formation, secondary glaucoma due to formation of peripheral anterior synechiae, and loss of the eye, especially if the inflammatory response is marked.¹⁵ Further, a delay in the management could result in amblyopia of the affected eye, especially when the central cornea is involved. In this small case series, an aggressive inflammation of the anterior segment was found in half of the eyes, and conservative measure including anti-

inflammatory treatment failed to allow healing of the perforation in all the eyes.

The diagnosis and treatment of corneal melt with perforation in children is complicated due to limited cooperation and lack of detailed history from the patient. There are numerous medical and surgical options for managing corneal perforation, but surgical procedures in children are technically more difficult than adults.²⁰ The strategy for managing corneal perforation should address the underlying process leading to keratolysis as well as the surgical aspect to restore the integrity of the globe and useful vision. It is our suggestion that the well-documented increased inflammatory response seen in children should also have some consideration in the decision-making algorithm. We report four pediatric cases of corneal melt and perforation with uncommon etiologies. Although each etiology is rare, the case series demonstrated successful outcomes, using an aggressive paradigm of early surgical intervention. To the best of our knowledge, AK has not been previously reported in a 4-year-old child (Figures 1a and b); neither are we aware of any report on corneal perforation secondary to RDEB and HSK secondary to immune recovery disease post-BMT. Perforation in BKC in a 12-year-old child is also extremely rare.

Corneal perforations not due to bacterial keratitis are rare in children. This would explain why only four cases were seen during a 10-year period. Treatment options for corneal melt and perforations include medical therapy of underlying diseases and; simple measures such as BCL, corneal gluing, and tarsorrhaphy.²¹ If these methods fail, then authors have described the use of conjunctival flaps,²² AMT,²³ lamellar keratoplasty (LK),²⁴ deep lamellar keratoplasty (DLK),²⁵ patch graft,¹² or PKP.^{18,19}

Tissue adhesives can be used to close small perforation (up to 3 mm in diameter) and may slow down stromal melting.^{21,26} Although Leahey *et al*²¹ in a series of 44 patients (3 children) used cyanoacrylate glue to treat perforations, 2 children needed a subsequent conjunctival flap and PKP, resulting in poor visual outcome (see Table 3). We used histoacrylate glue and BCL in case 2 (Figure 2a), but the aggressive inflammatory reaction with a non-healing perforation prompted a therapeutic PKP immediately (Figures 2b and c).

Although conjunctival flaps have been used in corneal perforations, as a temporary measure in an inflamed eye, they often result in a vascularized cornea scar. All our cases had central corneal perforation which would have resulted in central scar if we had used conjunctival flaps, with subsequent likely deprivation amblyopia.

Although AMT has also been employed in patients with corneal perforations in cases with central corneal perforation, published data suggest poor visual

outcome with PKP being needed later almost invariably (see Table 3).^{23,27}

In the only report of good visual outcome using simultaneous patch graft and AMT in a 9-year-old girl, the perforation was midperipheral and not central.²⁸ In our series case 3, with acne rosacea, AMT was utilized to treat the central corneal perforation purely because the appropriate graft material was not available. After the formation of anterior chamber, PKP was performed within 7 days to clear the optical axis (Figures 1c and d).

Historically, therapeutic PKP has been discouraged in inflamed perforated eye because of increased complication rates and poor visual outcomes.²⁹ In this series, it was the senior surgeon's assessment that in at least two of four cases secondary inflammation was thought potentially to be irreversibly damaging.

Therapeutic PKP in inflamed eyes with corneal perforation secondary to microbial keratitis (especially bacterial and fungal) is well described in developing countries.^{16,17} In one such series of 46 eyes of 46 patients, only 2 were children and both had therapeutic PKP; 1 child had a failed PKP but was 6 months old and another child (5 years old) had successful PKP after initial glue for perforation due to HSK.¹⁸ In one of the largest pediatric specific series of microbial keratitis, only 2 patients out of 78 presented with perforation.³⁰

Other techniques described to treat corneal perforations include LK or DLK, PKP with glycerin cryopreserved grafts and most recently crosslinking.^{24,25,31–33} All these have limited experience in children.

It is apparent that perforation of cornea in developed countries is rare. This is reflected by the unique etiology in 3 of 4 cases namely AK in a 4-year-old child, RDEB, HSK secondary to immune recovery disease post bone marrow transplantation and BKC secondary to acne rosacea. All our cases had central corneal perforation and either showed failure to heal and/or had aggressive anterior chamber inflammation. Therapeutic PKP even during an inflamed stage resulted in visual outcome that varied from 6/9 to 6/18.

In two of our patients (cases 1 and 3), the post-operative course was complicated by increased IOP and graft rejection which were managed successfully medically. These two patients also developed posterior subcapsular lens opacity and underwent cataract extraction with intraocular lens implantation. In two cases (2 and 4), the lens was found to be involved at the time of surgery and lens aspiration was done sparing the posterior capsule (Figure 2d). Three patients (cases 1–3) subsequently developed posterior capsule opacification and underwent YAG capsulotomies. Despite the complicated post-operative course, the final visual outcome was good. All four patients had lens removal either subsequent to

PKP or at the time of PKP. Three had an IOL and one remained aphakic (patient with RDEB).

We conclude that while published reports describe poor outcomes generally in children with corneal perforation, this may be because the increased intraocular inflammation known to occur in children may have been overlooked. We suggest therapeutic intervention during the inflamed stage even for non-infectious cases should be considered.

Summary

What was known before

- Inflammatory cornea melt leading perforation is rare in children.
- The outcomes are generally poor.
- Penetrating keratoplasty for acute corneal perforation in an inflamed eye has rarely been performed in children.
- The literature does not describe this mode of management especially in children.

What this study adds

- This study shows that penetrating keratoplasty (PKP) during the acute phase together with aggressive medical therapy and close follow-up may achieve good visual outcomes in children with corneal melt.
- This study suggests that therapeutic intervention in the form of PKP during the inflamed stage even for non-infectious cases should be considered in children.

Conflict of interest

The authors declare no conflict of interest.

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