Original Article

Sequelae of carbide-related thermo-chemical injury: A retrospective analysis

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Purpose: To describe the outcomes of eyes with calcium carbide (CaC_2)-related thermo-chemical injury. **Methods:** This study included 28 eyes of 23 patients who presented with calcium carbide-related ocular burns. Only patients with more than three months of follow-up were included. Group A included 16 eyes with Dua's Grade I–III burns, while Group B included 12 eyes with Grade IV–VI burns. Electronic medical records were reviewed to provide data on the etiology of burn, presenting clinical signs and visual acuity, sequelae, and surgical interventions performed, both in the acute and chronic phases. **Results:** The overall mean age was 28.48 ± 11.8 years. Fifteen patients were injured while using carbide to create an explosion to scare away animals on farms. The median presenting BCVA (best-corrected visual acuity) in Group A (20/160) was significantly better than in Group B [(20/2000) ($P = 0.002$)]. Five eyes in Group A and one eye in Group B underwent medical management. There was no difference in the duration of follow-up for both groups ($P = 0.24$). The median final BCVA in Group A (20/32) was significantly better than in Group B [(20/200) ($P = 0.02$)]. Two eyes in Group A and nine eyes in Group B developed LSCD. Two eyes in Group B were phthisical at the last visit. **Conclusion:** Calcium carbide-related ocular injuries can result in significant visual morbidity in young adults. Early presentation and management may improve outcomes. Prevention of these injuries by increasing awareness and increasing advocacy efforts is necessary.

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Ocular burns account for 7.7–18% of ocular trauma.[1] These are ophthalmic emergencies and are associated with significant ocular morbidity.[2] A 50% increase in severe injuries due to fireworks was seen during the Covid-19 pandemic according to a 2021 report by the U.S. Consumer Product Safety Commission.[3] They also found that 15% of firework injuries affect the eye.[4] These ocular injuries can lead to chronic ocular sequelae such as symblepharon, entropion, limbal stem cell deficiency (LSCD), dry eye, and persistent epithelial defects.[5] The prognosis of any ocular burn depends on the severity of the burn, the penetration into the cornea, access to medical care, and the mode of treatment.[6]

Calcium carbide (CaC_2) has been used for multiple purposes across the globe, most commonly for agriculture-related work. It is now increasingly being used for recreational purposes as a firecracker. Calcium carbide, mixed with water, produces a loud explosion along with lime particles and acetylene, a highly inflammable gas. This acetylene has been traditionally used for artificial fruit ripening.[7] In India, calcium carbide is also being used in indigenously made PVC (polyvinyl chloride) guns in rural areas where the main source of income is agriculture. These are mainly used to scare wild or predatory animals away from farms to prevent harm to livestock or agricultural produce. Social media is rife with DIY (do-it-yourself) videos on making PVC guns, and these videos are frequently forwarded and shared on social medial platforms.[8,9] Recently, the use of calcium carbide as a firecracker has increased in India as a ban on the sale of firecrackers was implemented due to increasing pollution levels. A carbide gun as a firecracker is associated with a loud explosion and potentially grievous ocular injuries.[10]

With the increasing use of calcium carbide for multiple such purposes, the incidence of encountering ocular burns secondary to calcium carbide has been on the rise in the last few years. Click or tap here to enter text.[7,10] Carbide-related ocular burns are a serious public health concern as they cause significant ocular morbidity. Appropriate management guidelines are needed to minimize the potentially blinding ocular sequelae such as LSCD. This study aims to analyze the outcomes of calcium carbide-related ocular burns.

Methods

This was a retrospective multicentric case series of patients with ocular chemical burns who presented to our institute between

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July 2018 and April 2022. The ethics committee of the institute approved this study, which was conducted in strict adherence to the tenets of the Declaration of Helsinki.

Only patients with calcium carbide-related ocular burns who presented to us within 6 weeks of the acute burn and patients with a follow-up of ≥3 months were included in the statistical analysis. All patient data from the electronic medical record system was examined including age, gender, mode of injury, initial and final best-corrected visual acuity (BCVA), grade of injury, duration of follow-up, management methods, the clinical outcome based on the final BCVA, and the complications and sequelae of injury. The severity of the ocular chemical injury was graded according to Dua's classification that is based on the extent of limbal involvement in clock hours and conjunctival involvement.[11] The eyes were divided into two groups: Group A: Eyes with Grade I–III ocular injury and Group B: Eyes with Grade IV–VI ocular injury.

In the acute phase, management methods included immediate irrigation after injury and thorough removal of all possible lime particles from the ocular surface at the slit lamp. All patients received intensive topical medications. Most patients with Grade II or a higher grade ocular injury underwent amniotic membrane transplantation (AMT) with or without tarsorrhaphy, to aid in earlier epithelization of the ocular surface. Some patients also underwent simultaneous removal of lime particles from the ocular surface and the fornices. Patients with open globe injury underwent primary repair of the globe.

In the chronic phase, depending upon the extent of sequelae such as symblepharon, partial LSCD, and total LSCD, surgical interventions such as symblepharon release with conjunctival autograft (CAG) or Simple Limbal Epithelial Transplantation (SLET) were performed to restore the ocular surface and to improve the visual outcomes.

Statistical analysis was performed using SPSS version 17.0 software (SPSS Inc., IL, USA). Visual acuities were converted from Snellen to the logarithm of the Minimum Angle of Resolution (logMAR) scale for statistical analysis, using the conversion chart of Holladay.[12] LogMAR scores of 2 and 3 were assigned to Snellen's visual acuities of counting fingers at 2 feet and hand motion at 2 feet, respectively.[12] We arbitrarily assigned values of 4 and 5 to eyes with light perception (LP) and no light perception (NLP), respectively, to also enable comparison between the two groups. A P-value < 0.05 was considered statistically significant.

Results

Records were retrieved from 44 eyes of 39 patients with calcium carbide ocular burns in the study period. The details of all the patients are shown in Supplementary Table 1. Two patients didn't present within 6 weeks of the injury and 14 patients didn't follow-up for more than 3 months. Thus, 28 eyes of 23 patients met the inclusion criteria. Group A included 16 eyes of 12 patients, and Group B included 12 eyes of 12 patients. In Group A, four patients had bilateral burns, while none of the patients in Group B had bilateral burns. One patient had one eye belonging to Group A and the contralateral eye belonging to Group B. Clinical characteristics of both groups are presented in Table 1. In both groups, mostly young males presented with complaints of acute calcium carbide-related ocular burn. In both groups, the most common mode of injury was while using carbide guns in agricultural fields to scare animals. In both groups, the median duration from injury to presentation was 1 day. The right eye was involved in 8/16 eyes in Group A and 11/12 eyes in Group B. The median presenting BCVA was significantly lower in eyes in Group B as compared to Group A (P = 0.002). Seven eyes in Group B could only perceive light or had hand movements/finger counting close to face.

Management in the acute phase

All patients who presented within two days received a thorough eye wash using normal saline. After slit lamp evaluation, 5/16 (31.25%) eyes in Group A and 1/12 (8%) eyes in Group B were managed medically. All patients received topical medications in the form of high-potency corticosteroids (prednisolone acetate 1%), prophylactic antibiotics, cycloplegics, and lubricants. Oral Vitamin C was prescribed to all patients in Group B, and none in Group A. In the acute phase, 11/16 eyes in Group A and 11/12 eyes in Group B underwent surgical intervention. Ten eyes in both groups underwent large AMT along with debridement of the ocular surface. Vitreoretinal surgery for removal of intraocular foreign body and primary globe repair for an open globe injury was done for one eye each of Group A and B respectively. In Group B, one patient with a Grade V chemical burn refused AMT and hence was managed medically.

Sequelae and management in the chronic phase

The median duration of follow-up was 4 months in Group A and 5.75 months in Group B (P = 0.24). A nebulo-macular corneal scar was seen in 11 eyes in Group A and 8 eyes in Group B [Fig. 1a-1c]. White granular foreign body deposits were seen in two and four eyes of Groups A and B respectively. Six out of 16 eyes (37.5%) and 9/12 (75%) developed LSCD in Group A and B respectively. Two eyes of Group B went into phthisis. Fig. 1 (a-i) depicts three different cases with sequelae such as corneal scars and partial LSCD.

Two out of 16 eyes in Group A with partial LSCD and symblepharon underwent symblepharon release and conjunctival autografting (CAG). The graft was harvested from the contralateral eye. In Group B, 1/13 eyes underwent symblepharon release and CAG while 2/13 eyes with total LSCD underwent SLET alone, and 1/13 eyes underwent SLET combined with symblepharon release and CAG. Enucleation with ocular prosthesis was done for one patient with phthisis bulbi. The visual acuity in patients who underwent SLET improved from counting fingers to 20/160–20/400 after 5 weeks to 3 months of surgery. [Fig. 2] Table 2 describes the demographic parameters and the clinical outcome of the patients who underwent SLET.

The median final BCVA was significantly higher in Group A compared to eyes in Group B (P = 0.02). The median BCVA in Group A was significantly improved at the last follow-up visit when compared to the first visit (P = 0.0004). Although there was an improvement in the median BCVA in Group B post-operatively, this improvement was not statistically significant (P = 0.45).

In one case, a patient underwent a combination of SLET and Penetrating Keratoplasty (PK); however, this patient did not follow-up with us beyond 3 months and hence was not included in the analysis. In this case, a descemetocele had occurred after symblepharon release, CAG, and AMG was performed for addressing partial LSCD. The purpose of combining SLET with PK was in view of a thin underlying cornea in the form of a descemetocele that would have perforated if only SLET

Table 1: Demographic characteristics, clinical presentation, and outcome of patients included in the study

	Group A	Group B	*P*
Number of eyes	16 eyes of 12 patients	12 eyes of 12 patients	
Mean Age (Years)	28.42±10.27	28.3±13.14	0.98
Male:Female	11:1	12:0	
Mode of injury			
Agricultural fields	4	11	
Recreational use	7		
Ripening of fruits	1	1	
Median duration between injury and presentation in days (IQR)	1 (1–2.25)	1 (1–3)	0.81
Median presenting BCVA in logMAR (IQR)	0.9 (0.6–1.2) SE=20/160 (20/80–20/320)	2 (1.2–2.25) SE=20/2000 (20/320–CFCF)	0.002
Treatment in Acute Phase			
Medical alone	5	1	
Medical and Surgical	11	11	
AMT	10	10	
Globe repair		1	
VR Surgery for IOFB	1		
Median duration of follow-up in months (IQR)	4 (3.15–11. 25)	5.75 (5–6.9)	0.24
Median final BCVA in logMAR (IQR)	0.15 (0.07–0.33) SE=20/32 (20/25–20/40)	0.95 (0.28–2.25) SE=20/200 (20/40–CFCF)	0.02
Complications and Sequelae			
Corneal scar	11	8	1
Foreign body deposits	2	4	0.64
LSCD	6	9	0.06
<3 clock h	4	1	
3–6 clock h	1	4	
>6 clock h	1	4	
Phthisis bulbi		2	
Treatment in the Chronic Phase			
Symblepharon release + CAG	2	1	
SLET	0	2	
SLET + Symblepharon release + CAG	0	1	

IQR=Inter-quartile range; AMT=Amniotic membrane transplantation, VR=Vitreo-retinal; IOFB=Intra-ocular foreign body; CAG=Conjunctival autograft; SLET=Simple limbal epithelial transplantation; SE=Snellen equivalent; LSCD=Limbal stem cell deficiency; CFCF=Counting fingers close to face

Table 2: Clinical characteristics and long-term outcome of patients who underwent SLET

	Patient 1	Patient 2	Patient 3
Eye involved	RE	RE	RE
Duration between injury and presentation	6 days	3 days	45 days
Grade of injury	VI	V	VI
VA at presentation	CF 1 m	20/320	CFCF
Prior AMG	Performed twice	-	-
Symblepharon +/-	-	+	-
VA before SLET	HM	CF 1 m	CFCF
Duration between presentation and SLET	3 months	6 months	1.6 months
Duration of follow-up post SLET	3 months	6 weeks	5 weeks
VA after SLET on last follow-up	20/160	20/400	20/160

SLET=Simple Limbal Epithelial Transplantation, VA=Visual acuity, AMG=Amniotic Membrane Grafting, HM=Hand Movements, CF 1 m=Counting Fingers at 1 meter, CFCF=Counting fingers close to face

was performed, and which would have led to post-operative recurrence of LSCD if only PK was performed. The corneal button of the patient who underwent PK with SLET was sent for histopathological analysis. It showed a perforated cornea with necrosed stroma. Granular deposits in between the collagen fibers and a few scattered mixed inflammatory cells were noted. Descemet's membrane was fragmented with the loss of endothelial cells [Fig. 3a]. Vonkossa stain for calcium showed brown granular deposits in the cornea favouring the deposition of calcium, produced in the chemical reaction [Fig. 3b]. Pearl's stain for iron was also positive focally that may be due to the blast of the iron cylinder containing calcium carbide [Fig. 3c]. Immune stain for collagen I was negative or not expressed in corneal collagen fibers, and collagen IV was faintly expressed [Fig. 3d-f].

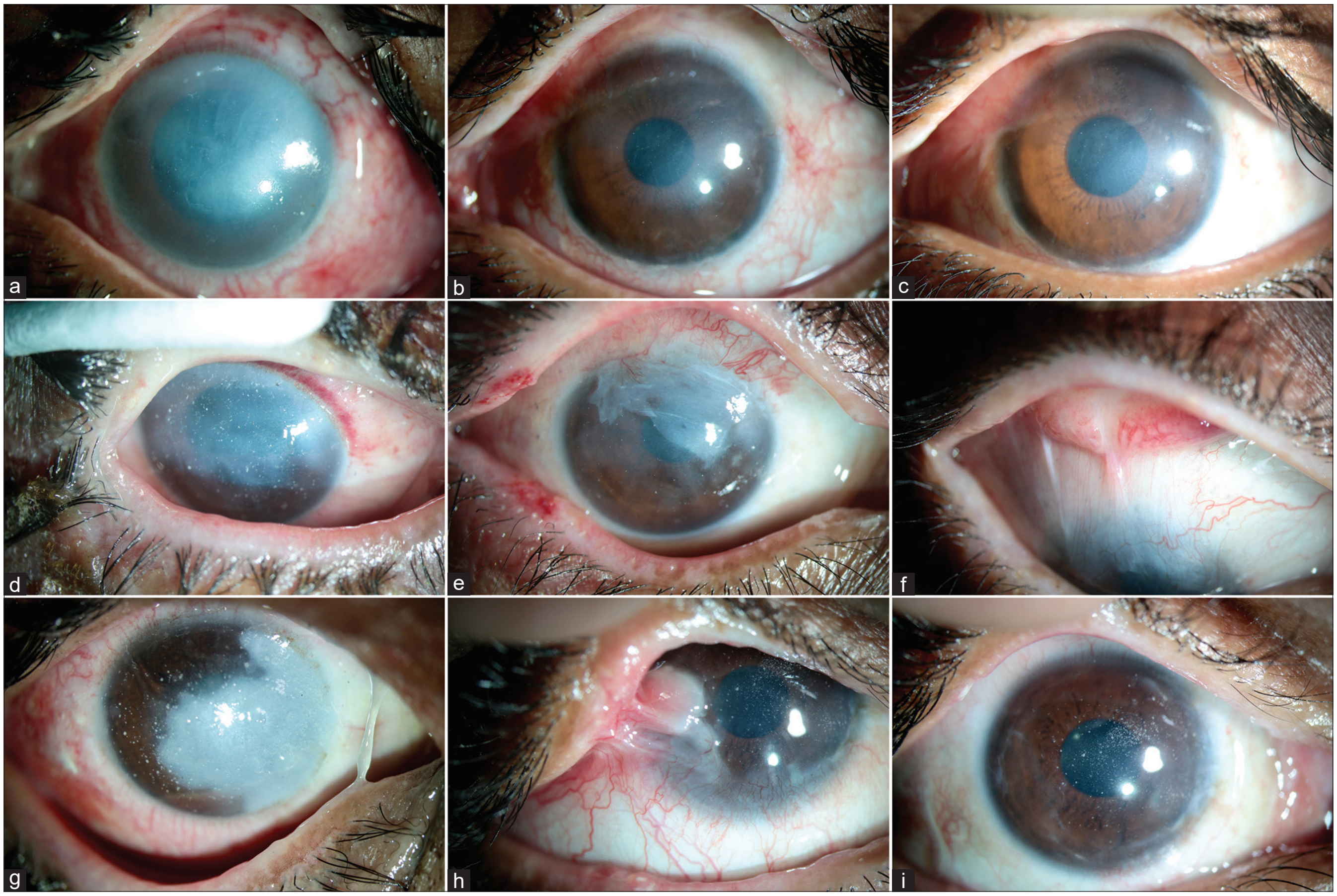

Figure 1: a-c Depicting the same eye, (a) LE Grade III injury, amniotic membrane transplantation (AMT) performed; (b) At 5 months follow-up, central nebulo-macular corneal scar seen with early partial LSCD superonasally; (c) Corneal scar with partial LSCD superonasally at 8 months follow-up post-injury, managed conservatively. d–f depicting the same eye, (d) RE, Grade III injury with multiple corneal foreign bodies noted, AMT and tarsorrhaphy performed; (e) At 6 weeks follow-up, retained AM noted superiorly with underlying corneal scarring with a superior symblepharon; (f) At 4 months follow-up, superior corneal scar with partial LSCD and superior symblepharon; g-i depicting the same eye, (g) RE, Grade III injury, AMT and tarsorrhaphy performed; (h) At 1-year follow-up, a supertemporal symblepharon, partial LSCD was noted, symblepharon release with conjunctival autografting was done; (i) At 15 months, the stable ocular surface was noted

Discussion

Carbide guns, historically used to scare away animals from fields, and artificial fruit ripening has recently gained popularity as a firecracker in India.[10] Using carbide guns in this manner can result in ocular morbidity in various scenarios.[7,13] The present study describes the demographic parameters, long-term outcomes, and sequelae of 28 eyes of 23 patients with ocular burns due to calcium carbide over 4 years.

Calcium carbide-related ocular burns were commonly seen in young males in our study, similar to previous studies describing carbide gun-related ocular burns.[7,13] Most patients gave a history of sustaining an injury while trying to peep into the gun uniocularly from the muzzle side to find the cause of the delayed explosion.[10] Most humans are right-handed; hence, most people prefer to use the right eye for monocular viewing.[14,15] This was hypothesized to be the reason for our study's increased incidence of right-sided ocular burns. Bilateral ocular burns were seen in five patients, and these eyes had a lesser grade of injury, with firecrackers being the most common cause. The less severity of bilateral burns may be attributed to the increased eye-to-blast distance. Most of the higher-grade injuries were unilateral. Thus, we inferred that uniocular right-sided injuries were more common and severe than bilateral ones. In contrast, Bandyopadhyay *et al*.[7] reported bilateral injuries in 66.6% of cases, and there was no significant difference in the incidence of right/left-sided injuries in their study.

The patients were divided into Group A and Group B based on Dua's grading. This helped us differentiate the pattern of injuries and the probable change in their management. All patients presented early to us after the acute burn, thus receiving early medical and surgical management. The presenting visual acuity in both groups matched the grade of injury with patients in Group B with higher-grade injuries having poor visual acuity. In the study by Bandyopadhyay *et al*., 20/55 patients had a presenting BCVA of only hand movements to LP, while 18/28 eyes in our study had visual acuity.[7]

Primary medical management in the form of intensive ocular irrigation with fluids may be the single most important factor in determining the outcome of an ocular burn.[16] Delay in ocular irrigation adversely impacts the result of chemical injury.[17] All our patients received thorough irrigation. Only

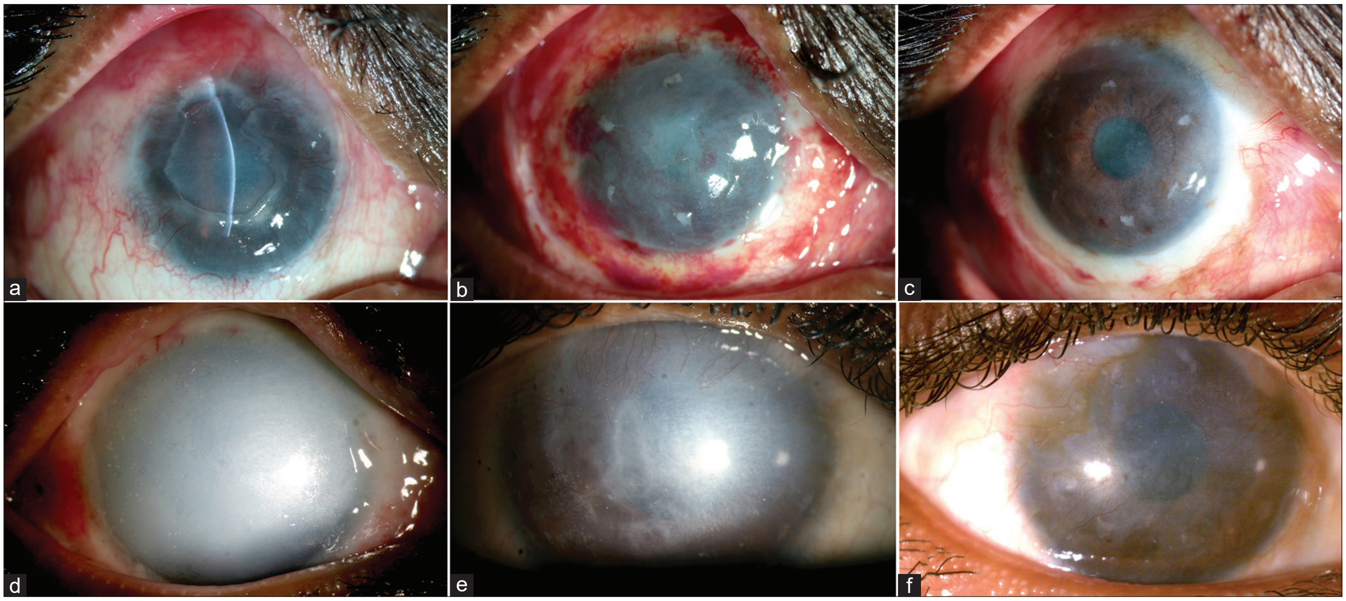

Figure 2: a-c Depicting the same eye; (a) RE Grade VI injury, Persistent epithelial defect noted 2 months post-injury, VA-CFCF; (b) Post SLET, 1-week follow-up; (c) At 5 weeks follow up, epithelised cornea noted with some residual stromal scar, VA-20/160. d–f depicting the same eye; (d) RE Grade VI injury, amniotic membrane transplantation (AMT) done; (b) Total LSCD noted 3 months post-injury, VA-HM, SLET was planned. (c) Three months post SLET, VA of 20/160 recovered with recurrence of partial LSCD superiorly

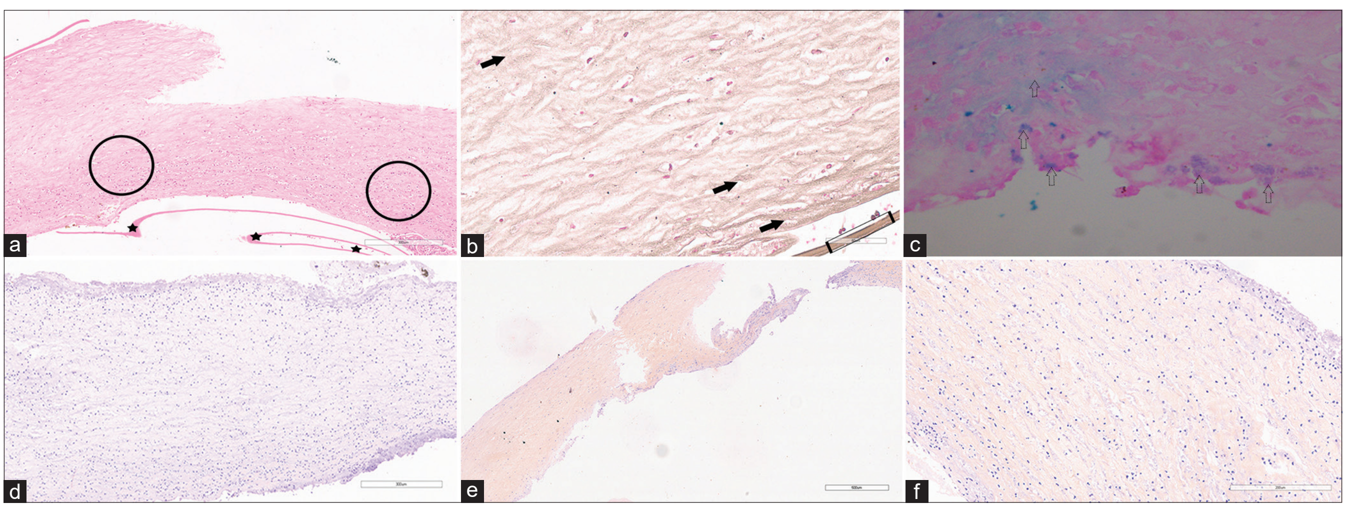

Figure 3: (a) Histopathology of the corneal button after carbide injury (10x, Hematoxylin and eosin stain) showing stromal necrosis and scattered mixed inflammatory cells (encircled). The DM was fragmented and folded (asterisks); (b) Von Kossa Histochemical stain (40x) showed brown calcium deposits in between stromal fibers and over the DM (rectangle); (c) Pearl's stain (40x) for iron showed iron granules in the stroma (arrow); (d) Immunohistochemical stain (10x) showed loss of collagen-I in the stroma (10x); (e and f) Immunohistochemical stain (5x and 20x) showed faint expression of collagen-IV in the stroma (brown discoloration of stroma)

medical management in the form of topical medications was given to a few eyes in Group A with a lower grade of injury. Surgical management in the form of an AMT with or without tarsorrhaphy was the mainstay of our treatment protocol in the acute phase. The amniotic membrane, as an adjunct to medical management, helps to reduce inflammation, accelerates epithelization of the corneal surface, and reduces scarring and corneal vascularization in the acute phase.[18] It improves patient comfort by reducing eyelid friction over the injured surface.[19] Only one patient of Group B had an open globe injury for which a primary repair was done. In contrast, 30.3% of patients had open globe injuries in the study by Bandyopadhyay et al.[7]

In Group A, vision-threatening sequelae were uncommon; hence, the visual outcomes were better than in Group B. Only two patients had partial LSCD requiring symblepharon release with CAG. Symblepharon release with CAG is a useful surgical technique for unilateral partial LSCD and avoids limbal stem cell transplantation in eyes where a healthy limbus exists.[20] In Group B, two eyes had a severe injury in the acute phase leading to phthisis bulbi, despite AMT. Also, more severe grades of LSCD were seen in a higher number of eyes, necessitating SLET in three eyes.[21] The mechanism of action of SLET is through multidirectional growth of epithelial cells from each transplant until all epithelial islands merge and create a confluent sheet of epithelium on the corneal surface.[22] Successful remodeling of the ocular surface with remarkable improvement in vision in patients with LSCD has been reported with SLET previously.[23] In Group B, the visual outcomes at the final follow-up did not improve significantly, and this could be secondary to the severity of the acute burn, causing corneal scars and LSCD despite appropriate and timely medical and surgical intervention.

In cases of sterile keratolysis following chemical injury, SLET can be combined with PK. This is an emergency surgery to avoid a frank corneal perforation. The inclusion of SLET helps reduce the risk of postoperative epithelial failure and recurrence of LSCD. Simultaneously, PK provides tectonic support to the globe. This has been documented previously with longer follow-ups in two cases.[24,25]

This is the first study describing outcomes and sequelae of calcium carbide-related ocular burns. The retrospective nature of the study is a limitation. The division of the patients into two groups based on the severity of injury helped us understand the prognosis and the required follow-up for these patients. Group B patients had predominantly uniocular right eye injuries. A longer follow-up could give us more insight into sequelae later in the chronic phase of the disease. LSCD in Group B eyes may be progressive needing further surgical interventions. Group B patients should be followed up for at least 6 months for visual rehabilitation. This analysis helped us counsel and prognosticate patients with a severe grade of carbide injury on the required follow-ups, the need for surgery in the future, and the probable visual outcomes.

To conclude, calcium carbide-related ocular injuries are mostly uniocular and severe in nature and affect young males. Loss of vision in this age group can cause a loss of economic productivity and a poor cosmetic outcome. Multiple surgical interventions required in these eyes can increase the burden on the healthcare system and increase the number of follow-up visits for the patient. Prevention of these injuries is the key, and there is a need to increase advocacy efforts and create awareness about such injuries. Such advocacy efforts and awareness campaigns are required in the semi-urban and rural areas of the nation, where agriculture is the largest provider of livelihood.

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Conflicts of interest

There are no conflicts of interest.

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Supplementary Digital Content Legend

Supplementary Table 1: Demographic characteristics, clinical presentation, and outcome of all patients who presented with calcium carbide ocular burn

	Grade I-III	Grade IV-VI
Number of eyes	31 eyes of 27 patients	13 eyes of 13 patients
Mean Age (Years)	27.59±11.90	28.15±12.59
Male:Female	26:1	13:0
RE: LE	14:27	12:1
Mode of injury		
Agricultural fields	6	12
Recreational use	25	
Bystander		1
Median duration of interval between injury and presentation in days (IQR)	1 (1-4)	1 (1-3)
Presenting Visual acuity		
20/20-20/40	3	
20/40-20/200	15	2
<20/200	13	11
Treatment in Acute Phase		
Medical	11	1
Surgical		
AMT	19	11
Globe repair		
VR Surgery for IOFB	1	1
Treatment in Chronic Phase		
Symblepharon release and CAG	2	2
SLET		1
SLET+CAG+Symblepharon release		1
PK SLET, CAG, and Symblepharon release		
Median duration of follow-up in months (IQR)	2.5 (1.5 – 4)	5.75 (5 – 8)
Outcome		
20/20-20/40	21	2
20/40-20/200	5	2
<20/200	4	7
Lost to follow up	1	
Complications and Sequelae		
Resolution	7	
Corneal scar	15	2
Foreign body deposits	2	4
LSCD		
<3 clock h	6	1
3-6 clock h	2	3
>6 clock h	1	5
Phthisis bulbi		2

IQR=Interquartile range, AMT=Amniotic Membrane Tranplantation, VR=Vitreo-retinal, IOFB=Intra-ocular foreign body, CAG=Conjunctival autograft, SLET=Simple Limbal Epithelial Transplantation, PK=Penetrating Keratoplasty, LSCD=Limbal Stem Cell Deficiency