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Effectiveness of Diphoterine in Preventing Ocular Alkali Burns damages in Workers in a Brazilian Alumina Refinery

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Abstract

Purpose: *To assess ocular findings after alkali burns and the effects of diphoterine (Diphoterine®) on the injured eyes of twenty-three workers in a Brazilian alumina refinery.*

Participants:*Twenty-three of the 1486 workers who had accidentalocular chemical burns were included in this study.*

Methods: *This is a cross-sectional study over twenty-three of the 1486 workers from an Alumina Company who had accidental ocular chemical burns. The workers were frequently trained to immediately rinse their eyes and skin using diphoterine solutions on the event of exposure to chemical splashes. However, only twenty-two of the twenty-three patients who were exposed in this type of accident, immediately rinsed their eyes and skin with diphoterine solutions after chemical exposure. During ophthalmology consultation, combined corticosteroids and antibiotic eye drops (Moxyfloxacine 0.3% and dexamethasone), preservative-free lubricant eye drops, and 1g daily oral vitamin C were prescribed to all patients. Depending on the presence of de-epithelization and corneal edema, oral doxycycline 100mg twice daily, 1mg/kg oral prednisone, therapeutic contact lenses, and autologous serum eye drops were prescribed.*

Main Outcome Measures: *visual acuity, degree of inflammation, degree of limbal ischemia and deepithelization*

Results

Twenty -two of twenty- three workers who promptly washed their eyes with diphoterine solutionhad no important permanent sequelae and had considerable recovery of vision. One worker who delayed the initial primary care treatment with diphoterine by almost 15 min had permanent corneal opacity and limbal and scleral ischemia, which required further surgeries to improve visual acuity. Four other workers had Autologous Limbal Transplant (CLAU) for Complete improvement of cornea transparency and its visual acuity.

Conclusion: *Diphoterine, when used during the first few seconds after chemical exposure, may reduce the incidence of sequelae of ocular chemical injury. All patients were reconducted to work with restored vision.*

Keywords: *alkali burns, chemical eye burns, diphoterine, ocular surface rehabilitation*

1. Introduction

Chemical burns often occur due to accidents at work and are most often caused by alkalis. Ocular chemical burns cause between 11.5 and 22.1% of eye injuries[1].

Eye injuries are proportional to the toxicity, concentration, volume, penetration, and duration of exposure. Alkalis cause saponification of cell membranes and thus, penetrate the tissue rapidly and profoundly, which often leads to irreversible blindness.

Diphoterine (Diphoterine®; Globaltek®, Salvador, Bahia, Brazil) is an amphoteric, hypertonic, chelating solution used to decontaminate and irrigate the skin and eyes after chemical splashes.[2] Diphoterine has been shown to neutralize acids and bases in vitro, and it is water-soluble.[2] Diphoterine has two modes of action: neutralization of chemicals and removal of chemical aggressors. Thus, the penetration of alkali through the cutaneous and ocular surfaces is interrupted. In 2006, a case series of 24 workers in the German metallurgical industry who were treated with diphoterine shortly after chemical splashes (acids and bases) reported no sequelae, and no further treatment was required.[3] Diphoterine has been tested on more than 880 chemical products representatives of six general classes: acids, bases, oxidizers, reducers, chelators, and solvents.[4]

2. Methods

The Alumina company where the patients included in the present study were working has been in existence since 1984 in the city of São Luis, MA, Brazil. It is one of the largest companies in the world for alumina production. Alumina is produced by bauxite refinement, and during this process, many alkali products, of which caustic soda is the most common, evolve. Workers are constantly trained to protect themselves against chemical burns, and they carry two bottles of diphoterine solution—one each for the skin and eyes—on their waist belts; the solution should be used to rinse the eyes during the first 10s after chemical exposure to avoid further damage.

In this study,we reviewed medical data of Twenty-three workers from an Alumina Company who were exposed to alkali (caustic soda) splashes to their eyes in the last four years and used diphoterine as a primary care treatment during the first hour before assessment by an ophthalmologist.

Institutional Review Board (IRB)/ Ethics Committee approval was obtained. This Company has 1486 workers who are trained every year in safety drills to avoid skin and eye injuries due to possible accidental alkali splashes. In addition to appropriate clothes, goggles, and face shields, they carry two bottles of diphoterine solutions—one each for the eyes and skin—on their waist belts. They are trained to immediately wash the eyes and skin using the respective diphoterine solution on exposure to chemical splashes. Subsequently, a first-aid team promptly transports the patient to the clinic of an ophthalmologist in an ambulance. During transportation, the eyes are constantly washed with saline solution (0.9%) and diphoterine solution.

At the ophthalmology clinic, the eyes are again washed copiously with 0.9% saline solution using an eye speculum and a topical anesthetic. The superior and inferior for nices are debrided using cotton swabs and washed to remove debris. Subsequently, the eyes are examined to evaluate visual acuity, limbal ischemia, de-epithelization, scleral injury, secondary ocular hypertension, and other signs. The examination is repeated every week for at least 40 days, if necessary. During the last four years (September 2019 to February 2024)only twenty-three of the 1486 workers had accidental chemical burns. We included these patients in the present study.

3. Results

Twenty-two of the twenty-three patients immediately washed their eyes and skin with diphoterine solutions. Only one patient (case n.7) forgot to use the solutions immediately and used them almost 15 min later. This patient washed eyes first with tap water, instead of diphoterine, for 15 min. Patients 8 and 22 had googles ripped off by the force of the impact. Patients 7 and 8 developed 360° limbal ischemia and total corneal opacity. Patient 7 also developed 270°scleral ischemia, cataract, and entropionin the left eye. After two surgeries on Patient 7, the partial limbal surface was restored, total scleral perfusion was reestablished, and palpebral entropion was corrected. The patient had also undergone corneal transplantation and cataract surgery and had a visual acuity of 20/25 with the recovery of the limbal surface onthe last follow-up.Patient 22 had poor visual acuity on the right eye due to previous macular scar. If the patients had an epithelial defect or limbal ischemia at the first follow-up visit, therapeutic contact lenses,100mg oral doxycycline twice daily, along with topical antibiotics combined with dexamethasone eye drops every three hours, preservative-free lubricant eye drops or autologous serum eye drops, and 1g oral vitamin C were prescribed. Oral prednisone 1mg/kg daily was prescribed when corneal edema was observed; in these cases, dexamethasone eye dropswere replaced with 1% prednisolone acetate eye drops.

In twenty-one patients, visual acuity improved to 20/25 or more. In two patients (case n. 6 and n.22),visual acuity did not improve beyond

20/40 OD and 20/30 OS due to preexisting cataracts (case n.6) and residual corneal haze (case n.22)Only 4 patients had autologous limbal surgery for recovering limbal deficiency. At the last follow-up, two patients showedminimal limbal ischemia of less than 60°, which did not compromise the epithelial surface or visual acuity.

Tables 1 and 2 demonstrate the clinical findings at the first and last ophthalmological follow-up visits.

Table 1. *Ophthalmological findings at the first follow-up visit: visual acuity, de-epithelization, limbal ischemia, and corneal edema*

Case number	VA OD	VA OS	Cornea Epithelial defect OD	Cornea Epithelial defect OS	Limbalis chemia OD	Limbalis chemia OS	Corneal edema OD	Corneal edema OS
1	20/30	20/30	N	180°	N	180°	N	2+
2	20/80	20/30	360°	60°	270°	60°	3+	N
3	20/25	20/25	N	N	N	N	N	N
4	20/20	20/20	N	60°	N	N	N	N
5	20/20	20/20	30°	N	N	N	N	N
6	20/80	20/40	180°	120°	N	N	2+	1+
7	20/20	CF	N	360°	N	360°	N	4+
8	20/30	20/60p	270°	360°	180°	360°	1+	4+
9	20/30	2040p	330°	360°	60°	250°	1+	2+
10	20/20	20/20p	N	N	N	30°	N	N
11	20/20	20/30	N	PSK	N	N	N	N
12	20/20	20/20	PSK	PSK	N	N	N	N
13	20/20	20/20	N	N	N	N	N	N
14	20/20	20/20	N	N	N	N	N	N
15	20/20	20/20	PSK	PSK	N	N	N	N
16	20/20	20/30	PSK	PSK	N	N	N	N
17	20/20	20/20	N	N	N	N	N	N
18	20/20	20/20	N	N	N	N	N	N
19	20/30	20/20	30°	N	10°	N	N	N
20	20/25	20/40	N	50°	N	30°	N	N
21	20/25	20/20	N	N	30°	N	N	N
22*	20/200	20/50	N	360°	N	330°	N	3+
23	20/40	20/20	120°	N	60°	N	2+	N

CF, count fingers; N, not present; VA (Best Corrected visual Acuity), visual acuity; PSK: Punctate superficial Keratitis; 22 Poor OD visual acuity due to macular scar*

Cornea edema grading: +1: thickness increasement; +2 thickness increasement with difficulty for viewing anterior chamber; +3 partial loss of cornea transparency; +4 total loss of cornea transparency

Table 2. *Ophthalmological findings at the last follow-up visit: visual acuity, limbal ischemia, and corneal surface regularity*

Case number	VA OD	VA OS	Limbal Loss OD	Limbal Loss OS	Corneal surface regularity/ opacity OD	Corneal surface regularity/ opacity OS
1	20/20	20/20	N	N	Regular/N	Regular/N
2	20/25	20/25	30°	N	Regular/N	Regular/N
3	20/25	20/25	N	N	Regular/N	Regular/N
4	20/20	20/20	N	N	Regular/N	Regular/N
5	20/20	20/20	N	N	Regular/N	Regular/N
6	20/40	20/30	N	N	Regular/N	Regular/N
***7**	20/20	20/20	N	90°	Regular/N	Regular/N
***8**	20/20	20/25	N	60°	Regular/N	Regular/+
***9**	20/20	20/25	N	30°	Regular/N	Regular/+
10	20/20	20/20	N	N	Regular/N	Regular/N
11	20/20	20/20	N	N	Regular/N	Regular/N
12	20/20	20/20	N	N	Regular/N	Regular/N
13	20/20	20/20	N	N	Regular/N	Regular/N
13	20/20	20/20	N	N	Regular/N	Regular/N

15	20/20	20/20	N	N	Regular/N	Regular/N
16	20/20	20/20	N	N	Regular/N	Regular/N
17	20/20	20/20	N	N	Regular/N	Regular/N
18	20/20	20/20	N	N	Regular/N	Regular/N
19	20/20	20/20	N	N	Regular/N	Regular/N
20	20/20	20/20	N	N	Regular/N	Regular/N
21	20/20	20/20	N	N	Regular/N	Regular/N
***22**	20/200	20/30	N	60°	Regular/N	Regular/2+
23	20/20	20/20	N	N	Regular/N	Regular/N

CF, count fingers; N, not present; VA, visual acuity

**Case7 had CLAU (corneal limbal autologous transplantation), cornea transplant and Cataract extraction. Case 8had CLAU. Case 9 had CLAU surgery. Case 22had CLAU and cataract surgery*

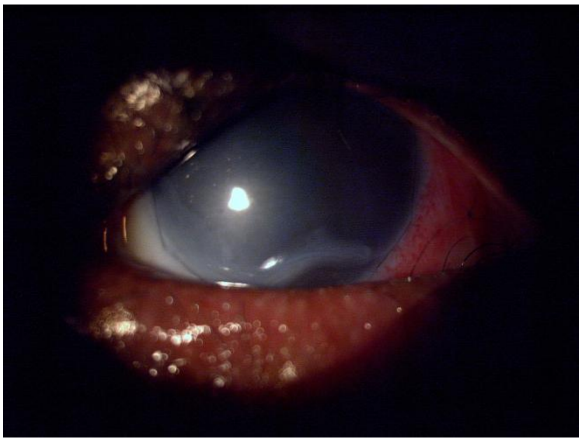

Figure 1

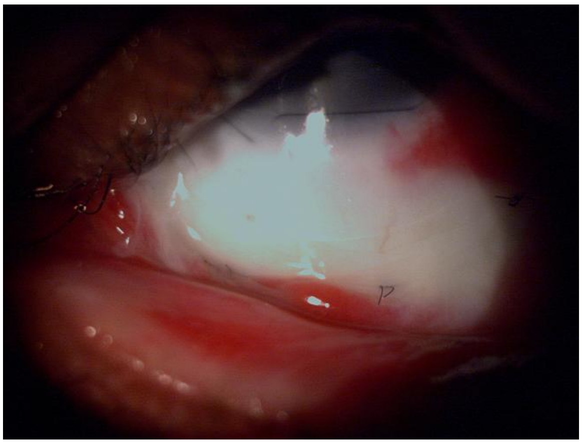

Figure 2

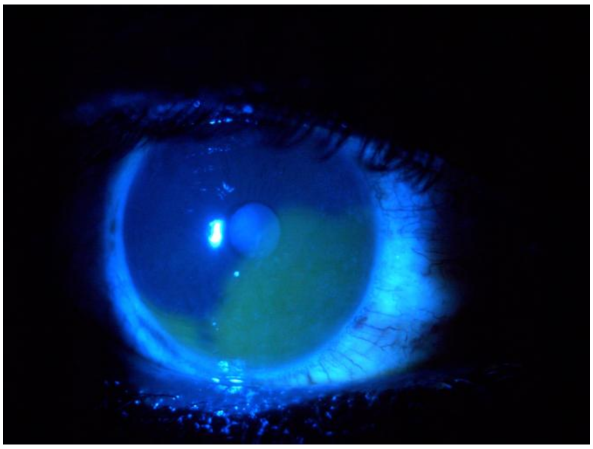

Figure 3

4. Discussion

Early use of diphoterine was found to be effective in reducing the extent of chemical injuries of the eyes, leading to a faster recovery within 10 to 20 days without irreversible sequelae. These findings corroborate those of the study by Donoghue in which no signs of chemical burns on the skin or eyes were found in 52.9% of the group that used diphoterine compared with 21.4% of those who used water first for rinsing.[5]

The osmolarity of the rinsing solution plays a critical role in determining favorable outcomes in patients with ocular burns. Hypoosmotic solutions (e.g., water) can rapidly penetrate the injured cornea, causing cell swelling, edema, and cell death.[7] The use of diphoterine and other high-osmolarity solutions does not have these consequences; these solutions enable healing by mobilizing water and dissolved corrosives from the damaged tissue.[6]This may be the reason for the unfavorable outcome in case 7.

One study comparing diphoterine with a phosphate buffer solution in 10 healthy human volunteers found that both irrigation fluids were equally safe and did not have any harmful effects.[7] Many countries outside the US or Brazil now require hospital staff and firefighters to rinse their eyes and skin with diphoterine solution instead of water after chemical splashes. In Brazil, diphoterine is not essential to be stored in emergency rooms or firefighter cars.

Regarding the choice of rinsing solution, Rihawi et al. observed that amphoteric solutions could neutralize the destructiveness of the substance that caused the burns on the surface of the eyes much better than phosphates or physiological saline solution, which did not show any therapeutic activity in the model of severe alkali eye burns used in that study.[7]Rinsing with tap water had an intermediate position on the scale of efficiency but was much less effective than the amphoteric or buffering solutions in their experiments,[7]corroborating case 7 events.

Treatment using amphoteric rinsing solutions, such as diphoterine, can result in better visual outcomes after ocular chemical burns. On this stydy, due to promptly treating the workers after the accident, all patients were able to be reconducted to work with full restored vision. Emergency room staff, ambulance staff, and firefighters should be advised to use diphoterine as the initial primary care treatment after ocular alkaline chemical burns.

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