European Journal of Ophthalmology / Vol. 18 no. 4, 2008 / pp. 517-528

# Evaluation of therapeutic deep anterior lamellar keratoplasty in acute ocular chemical burns

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PURPOSE. *To evaluate the role of deep anterior lamellar keratoplasty (DALK) in acute ocular chemical burns.*

METHODS. *The study was conducted in 50 eyes of 50 patients (24 male, 26 female) with average age of 38.3±14.3 years. DALK in 5 eyes (10%), DALK with quadrant conjunctivo-limbal graft in 25 eyes (50%), and DALK with amniotic membrane in 20 eyes (40%) were performed along with conventional medical therapy. Controls who were matched in all respects (50 eyes) were given medical therapy only as they refused surgical intervention.*

RESULTS. *Follow-up of cases ranged from 6 to 48 months (mean 21.5±14.18 months). Forty-three eyes (86%) could be restored with clear cornea as compared to 6% in control group. The visual acuity improvement was seen in 100% with good score (0.49±1.46) in DALK group as compared to 18% with low score (0.03±0.01) in control group ($p<0.0001$). Visual acuity improvement in DALK was 6/12 in 19 eyes (38%), 6/24 in 28 eyes (56%), and 6/36 in 3 eyes (6%) but was 3/60–6/60 in 6 eyes (12%) and finger counting only in 3 eyes (6%) in control group. Eyes with advanced grade II and grade III showed better improvement than those with burns of grade IV ($p<0.05$). The discomfort was relieved and epithelial healing was achieved immediately in DALK as compared to a prolonged course in control group ($p<0.0001$). Vascularization presented in 38% in DALK with least score (0.13+0.15) as compared to 100% in control group with high score (2.8±0.30). Perforation of cornea was seen only in 2 cases (4%) in DALK with low score (0.03±0.10) as compared to 88% in control group (1.33±0.20). Symblepharon was seen in 2% in DALK group as compared to 62% in control group.*

CONCLUSIONS. *DALK with and without conjunctival or amniotic membrane transplantation is an effective technique in restoring the integrity of the eye with an excellent graft transparency in 86% and improvement in visual acuity in 100% of the acute chemical burns. (Eur J Ophthalmol 2008; 18: 517-28)*

KEY WORDS. *Chemical burns, Deep anterior lamellar keratoplasty, AMT, Limbal autotransplantation, PKP, Best-corrected visual acuity*

*Accepted: December 19, 2007*

## INTRODUCTION

It is well known that the sequelae which follow an untreated chemical burn constitute limbal cell deficiency, severe dry eyes, persistent epithelial defects, vascularization, corneal perforation, secondary glaucoma, and extensive scarring. It has been noticed that the damage to the eye ensues in its first contact with the chemical and is worst in first few days as the pH of the tears, aqueous, and vitreous gets disturbed within minutes and may normalize within 2 to 7 days (1-3). Similarly, the damage to the conjunctiva and cornea which occurs due to contact of the

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chemical and the by-product of damaged tissues with release of chemical cytokines bring in a cascade of destruction with severe visual loss (4-7). The treatment of chemical burn is a controversial problem in ophthalmology but all agree on the necessity of medical and surgical treatment. Conservative treatment has been carried out in many ways. To prevent progressive tissue melting and vicious cycle of complications, medical therapies such as copious irrigation until pH becomes neutral (8), sodium citrate 10% eyedrops hourly (8, 9), sodium ascorbate 10% eyedrops hourly (10-12), dexamethasone eyedrops hourly (13), EDTA eyedrops hourly (14), topical and oral tetracycline (15-17), systemic progestational steroids (18, 19), timolol eyedrops 0.5% twice a day, and atropine 1% three times a day have been used. In order to correct ischemia, application of glued on hard contact lens have been recommended (20). Many surgical procedures, such as Denig operation (oral mucosa transplantation) (21-23), conjunctival grafting (24), tenonplasty (25-28), amniotic membrane transplantation (29-38), and limbal autotransplantation (39-45), have been tried for the management of chemical burns with an unpredictable outcome. Lamellar keratoplasty (chaud) (46-48) as a therapeutic measure has been used sparingly. There is hardly any recent work which could elaborate the usefulness of such procedure. The purpose of this study was to evaluate the results of combined procedure of an early deep anterior lamellar keratoplasty (DALK) alone or with limbal or amniotic membrane transplantation in acute ocular chemical burns.

## METHODS

The study is retrospective nonrandomized comparative. A prior written consent of the patients was obtained. It included 50 cases of acute fresh chemical burns (10 lime, 15 KOH, and 25 acid). There were 24 male and 26 female patients with an average age of 38.3±14.3 years. Fifty patients with chemical burns, almost with matched lesions (10 lime, 15 alkali, and 25 acid), who refused surgery served as controls and were given only standard protocol treatment (Tab. I).

### *Medical treatment regimen*

All the cases were treated with this standard medical protocol as copious irrigation with ringer lactate solution until pH became neutral. The amount of fluid used ranged from 250 mL to one liter (500±150 cc). The patients were put on EDTA 0.5% drops, sodium ascorbate 10% eyedrops, sodium citrate eyedrops 10%, and 0.1% dexamethasone eyedrops (Syntho Pharmaceutical India) hourly. In addition, tetracycline eyedrops four times a day, timolol eyedrops 0.5% twice a day, and atropine eyedrops three times a day were given. The patients were given tablet doxycycline (Biochem Pharmaceutical India) 100 mg a day and tablet vitamin C 500 mg orally. The study excluded cases that were not due to chemical burn or presented later than 1 week after the accident.

### *Classification of chemical burns*

The severity of the chemical burn was based on Roper Hall and Ballen classifications (6, 49). By using clinical details present in the history, clock hours of the limbal ischemia, corneal clarity, and size of the epithelial defect, the cases were graded. Ischemia was clinically detected by edematous muddiness of limbal or bulbar conjunctiva. Slit lamp examination of the ischemic area revealed pale white color with capillary obliteration and cessation of circulation resulting in blanching and necrosis of the conjunctiva.
Grade I: Epithelial staining of the cornea: no ischemia.

**TABLE I -** DEMOGRAPHIC DATA OF PATIENTS WITH CHEMICAL BURNS

| Factor | No. of cases | DALK mean | Control | Mean | p value |
|---|---|---|---|---|---|
| Age, yr | 50 | 38.3±14.3 | 50 | 38.4±14.02 | 1.000 |
| Sex | | | | | |
| Male | 24 | 0.48±0.54 | 24 | 0.48±0.54 | 1.000 |
| Female | 26 | 0.52±0.54 | 26 | 0.52±0.54 | 1.000 |
| Acid burns | 25 | 0.50±0.53 | 25 | 0.50±0.53 | 1.000 |
| Alkali burns | 20 | 0.40±0.52 | 20 | 0.40±0.52 | 1.000 |
| Lime burns | 5 | 0.20±0.42 | 5 | 0.20±0.42 | 1.000 |
| Follow-up, mo | 50 | 21.5±14.18 | 50 | 21.6±13.93 | <0.987 |

DALK = Deep Anterior Lamellar Keratoplasty

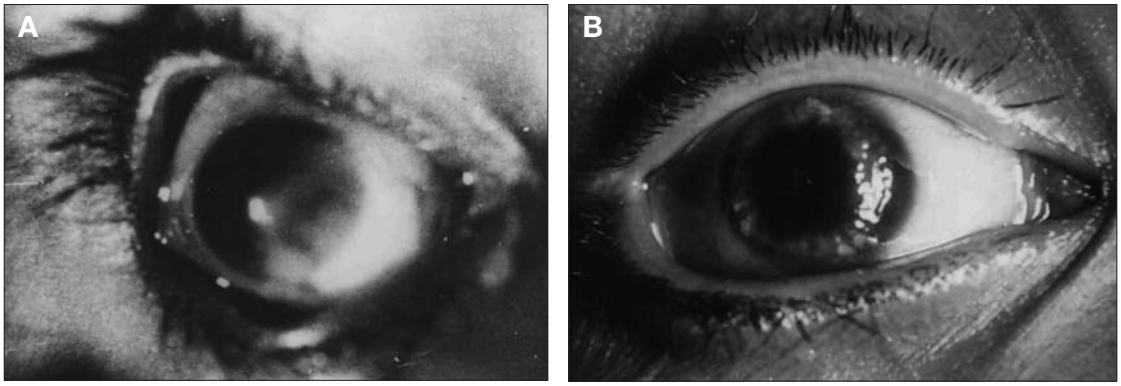


**Fig. 1 - (A)** *Preoperative photograph of eye showing grade II chemical burn with ischemia of conjunctiva in 2 clock hours which was excised and gap filled by sliding the conjunctiva.* **(B)** *Postoperative clear DALK and grade II corneal burn.*

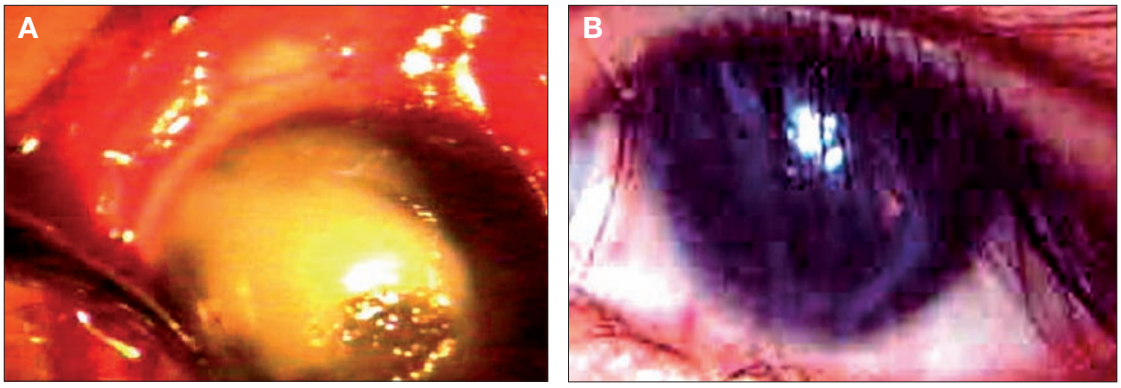


**Fig. 2 - (A)** *Preoperative photograph of grade III of chemical burn (lime) with limbal conjunctival involvement in 4 clock hours. Cornea had dense infiltration with loss of iris details.* **(B)** *Postoperative photograph of grade III chemical burn, clear cornea.*

Grade II: Haziness of cornea but details of the iris are visible. Ischemia less than 1/3 of limbus (Fig. 1A).
Grade III: Total loss of corneal epithelium with stromal haze, non visibility of iris details. Ischemia of 1/3 to 1/2 limbus (Fig. 2A).
Grade IV: Cornea opaque; iris and pupil obscured; ischemia affects more than one half of limbus (Fig. 3A).

## *Surgical technique of DALK*

The cases of advanced Grade II, Grade III, and Grade IV were subjected to the surgery.
Grade II burns: Only DALK was carried out and the ischemic conjunctiva was excised and the defect was repaired by mobilizing surrounding conjunctiva.
Grade III burns: DALK was carried out after assessing the damage to underlying sclera at the sight of the ischemic or necrotic conjunctiva. The damaged area was replaced by LAT and the cornea and sclera was replaced by fresh corneal tissue.
Grade IV burns: The ischemic and necrotic conjunctiva was excised and underlying scleral damage was assessed. First DALK covering the scleral damage with the appropriate diameter trephine was carried out followed by AMT transplantation.
The corneo-scleral tissue was trephined with an appropriate diameter trephine (9.0–12.5 mm) through three quarters of its depth and a lamellar keratectomy was performed. It was ensured that the necrotic area on the sclera was enclosed for removal with the trephine mark irrespective of the size of graft. Sterile air was injected by using a sharp 27-gauge needle bent at 90º, 5 mm from the tip and connected with a 2 mL syringe. The needle tip was introduced through the edge of the partial thickness trephination deep into the cornea stroma and gradually advanced to mid-peripheral cornea while keeping the tip under direct visualization. The plunger of the air filled syringe is pressed forcibly until entry of air into the stroma is noted. A sudden easing of resistance is accompanied with the appearance of a whitish circular semi opaque disc (large bubble). Air is further injected gradually to enlarge this disc reaching up to the edge of trephination mark. Peripheral paracentesis is performed at this stage to lower the intraocular pressure. The stromal collagen fibers were lifted carefully by the tip of a very fine forceps and were removed step by step with a Paufique or Gill knife peeling away until a small amount of stroma was

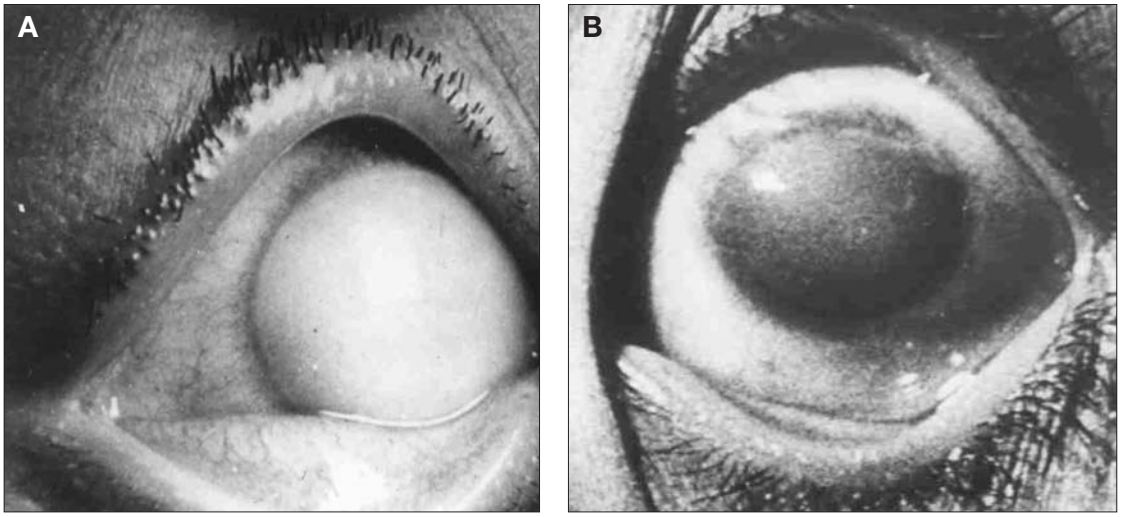


**Fig. 3 - (A)** *Preoperative grade IV burn with total opacification conjunctival ischemia.*
**(B)** *Postoperative opacity in the bed of DALK.*

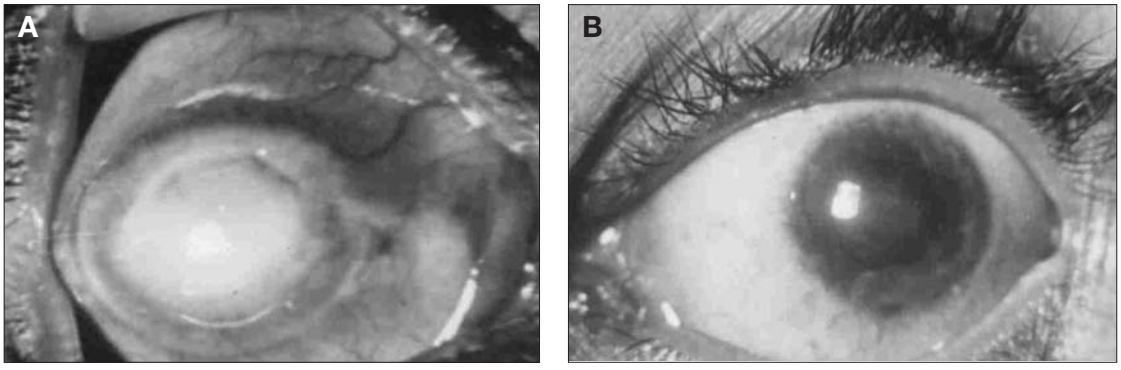


**Fig. 4 - (A)** *Preoperative grade IV burns with ischemia of limbus in 9 clock hours. The excised conjunctiva was replaced with AMT.*
**(B)** *Postoperative view of above case showing a clear DALK.*

left. After this a small exposure of Descemet membrane was made, the stroma and Descemet membrane were separated carefully by inserting the tip of a very fine scissors between them, and stromal membrane was lifted slightly and was cut along the pupillary margin. During the deep stromal peeling, if there was any micropuncture in Descemet membrane but no significant aqueous humor leak resulting from Descemet membrane puncture causing a shallow anterior chamber, the procedure was stopped. A small air bubble was injected into anterior chamber, and corneal grafting was carried out. If there was a large Descemet membrane tear during deep stromal peeling, the surgery was shifted to the opposite quadrant of the dissection. We have not come across a situation where surgery had to be converted to penetrating keratoplasty. A full thickness corneal button with a diameter 0.5 mm larger than the bed was grafted on the Descemet membrane exposed bed after removing Descemet membrane and endothelium. The button was sutured by continuous 10-0 monofilament suture. The donor cornea button was taken from preserved whole eye at 4 ºC.

### *Autologous limbal epithelial grafts transplantation*

The epithelial grafts were obtained from the undamaged or mildly damaged contralateral eye. Injection of 2% lidocaine solution or balanced salt solution was given into the subconjunctival epithelial layer close to the limbus, and the epithelium was separated from the tenon capsule. After a small epithelial incision was made, blunt dissection of conjunctival epithelium from Tenon capsule was performed with a scissors tip, and a 4 x 6 mm limbal based conjunctival flap was produced. After peeling centripetally 0.5 mm into the clear cornea the limbal epithelial graft was cut along the corneal side margin. Two limbal epithelial grafts were obtained from the superior and inferior limbus area at the 12 and 6 o'clock positions. Each limbal epithelial graft was fixed around the recipient corneal limbus at the four corners, and its posterior margin was sutured to the recipient conjunctival epithelial margin using 10-0 interrupted Perlon sutures. Because the two limbal grafts covered only one half to two thirds of the recipient's

limbus, the remnant limbus was surrounded by autologous conjunctival fornix, or tissue from the contralateral fellow eye.

### *Preparation of amniotic membrane*

Amniotic membrane was obtained under sterile conditions after an elective caesarean delivery from the women whose serum was negative for human immunodeficiency virus, syphilis, hepatitis B virus, and hepatitis C virus. Under sterile conditions, the placenta was first washed free of blood clot with sterile saline. The inner amniotic membrane was separated from the rest of chorion by blunt dissection through the potential spaces between these two tissues and rinsed in sterile saline (2 liters) and later in 4%, 8%, 10% dimethyl sulfoxide (DMSO) phosphate buffer saline (PBS) for 5 minutes each. It was then cleaned, processed, and preserved following the method described by Dua and Azuara Blanco (61). The membrane was then flattened onto a nitrocellulose paper, with epithelial/basement membrane surface up. The amniotic membrane was then cut into 5 x 5 cm pieces. Each of them was placed in sterile vial containing 10% DMSO medium. The vials were frozen at –80 °c.

### *Transplantation of amniotic membrane*

The membrane was defrosted immediately before use by warming the vial to room temperature for 10 minutes and rinsed three times in saline. A small piece was sent for repeat microbial culture, and the rest of the membrane was rinsed in sterile ringer solution. Surgery was performed under general anesthesia for children and peribulbar anesthesia in adults. The membrane was transferred onto the operative field and the nitroglycerin paper was peeled off, and the membrane was arranged to cover the entire ocular surface with stromal side touching the eye. Interrupted 10-0 Vicryl suture (Ethicon Inc., Johnson & Johnson, India) were initially applied to anchor the underlying conjunctiva and episclera to the membrane around the limbus. A symblepharon ring was inserted to spread the membrane and to flatten it against the surface of the eye especially the fornices and along the palpebral conjunctiva. 6-0 Vicryl sutures were applied to anchor the membrane along the lid margins, the symblepharon ring was removed and suture applied to fix the membrane to the underlying tissues in the bulbar area and to anchor it deep into the fornices.

### *Postoperative care*

Local dressing was done using local antibiotics as ciprofloxacin hydrochloride 0.3% (Ciplox-Cipla Pharmaceutical, India) and corticosteroid eyedrops (0.1% dexamethasone drops, M/s. Syntho Pharmaceutical, India), starting from five times daily and then tapering over several months. Supportive therapy as artificial tears (Just Tears, Sunways Pvt. Ltd. India) sodium citrate 10%, ascorbate 10% were given four times a day for 3 to 4 months along with timolol maleate 0.5% (Glucomol, Cipla Pharmaceutical, India) and atropine eyedrops twice a day postoperatively. Orally the patients were given tablet doxycycline 100 mg daily along with acetazolamide 250 mg 8 hourly and vitamin C 500 mg daily.
When pseudo chamber formation was observed, extent and location determined whether it should be treated immediately or kept under observation. When detachment of Descemet membrane was extensive and central, it was treated with air or 20% of sulfurhexafluoride injection into the anterior chamber. Patients who underwent air or gas injections were instructed to remain supine overnight.

### *Follow-up schedule*

The cases were dressed daily postoperatively for 5 days and weekly until 1 month, biweekly until 3 months, and monthly thereafter. Patients were told that in case of appearance of pain, decrease in visual acuity, or discharge, they should report to the eye center immediately. However, they were given a bandage extended wear contact lens (M/s. Venu Contact Lens, Delhi, India).
At each examination, visual acuity, reduction of pain, status of grafting tissue, corneal epithelial defect, extent of vascularization, and anterior chamber inflammation were assessed. Digital photograph of each visit was obtained and stored for independent comparative assessment by masked observers. The results of various parameters analysis on day 1, day 7, and months 1, 2, 3, 12, 18, 24, and 48 were presented.

### *Statistical analysis*

For convenience of statistical evaluation all the variable factors conjunctival involvement, corneal haze, scleral involvement, perforation, and vascularization were graded to numerical value from 0–4 (0=no lesion,1=1/4 lesion, 2=1/2 lesion, 3=3/4 lesion, 4= total lesion). However, visual acuity was measured in decimal values and score was

graded from 0–1 (1.0=6/6, 0.05=3/60, 0=nil). All statistical data were recorded on a spreadsheet and analyzed using Microsoft Excel (Microsoft Corporation, Redmond, WA), Software Version 9.0. All entries were checked for error. Quantitative variables such as age, sex, discomfort, visual acuity, epithelial defect, corneal transparency, perforation, symblepharon, and vascularization were summarized by mean and standard deviation in the two groups. Before comparing the abovementioned variables between the DALK and control groups at various time points, baseline values in the groups were compared. We computed the mean change from baseline to various follow-up points for discomfort and epithelial ulcer and summarized the *p* value change by mean and standard deviation. Student *t* test and Wilcoxon rank-sum test were used to compare mean variable change between the groups. In this study value less than 0.05 was considered statistically significant.

## RESULTS

### *Grade II acute chemical burns*

There were 10 cases (5 control and 5 DALK) of grade II burns. There was corneal haze with epithelial defect in all cases with 3/4 to full corneal involvement (3.6±0.420). There was an equal number of control cases matched in diameter of the corneal defect (3.6±0.42). In cases of DALK, discomfort was relieved instantaneously and was statistically significant ($p<0.005$) as compared to control group which took 3–6 months (Tab. IV).

Epithelial defect was relieved immediately in all cases of DALK and improvement was statistically significant ($p<0.002$) as compared to control group which took almost 12 months to heal (Tab. V).

Visual acuity achieved in DALK group was 100% with better score (0.65±0.22, $p\leq0.0001$), as compared to 80% in the control group with low score (0.04±0.022), which was statistically significant ($p<0.0001$) (Tabs. II, VI).

Corneal transparency in DALK group was 100% (Fig. 1B) with better score (4.0±0.00) as compared to 20% in control group with low score (1.4±0.02), which was statistically significant ($p<0.0001$).

Vascularization was 20% in DALK group with low score (0.10±0.14) as compared to 100% in control group with higher score (1.7±0.27) which was statistically significant ($p<0.0001$).

### *Grade III chemical burns*

There were 50 cases of grade III burns (25=control; 25=DALK) and discomfort score on first day was the same in both groups (3.8±0.38). However, there was instantaneous relief in discomfort in the DALK group (100%) as compared to no relief (0%) in control group on the second day onwards ($p<0.0001$) (Tabs. II, IV).

Epithelial defect in DALK group was cured instantaneously, which was statistically significant ($p<0.001$) compared to delayed healing in control group with more severity of grade (control mean 2.73, DALK mean 0.31).

Corneal transparency in DALK group (Fig. 2B) with better score (4.0±0.00) was 88% as compared to 8% in control group with low score (1.40±0.022), which was statistically significant ($p<0.0001$).

Visual acuity improvement was seen in 100% of DALK group and had a statistically significant high score (0.45±0.25, $p<0.0001$) as compared to 20% in control group with low grade (0.054±0.10) which was statistically significant ($p<0.0001$) (Tabs. II, VI).

Vascularization in DALK group was 32% with low score (0.11±0.23) as compared to 100% in the control group with high grade (2.79±1.49), which was statistically significant ($p< 0.0001$).

### *Grade IV chemical burns*

There were 40 cases of chemical burns (20 control, 20 DALK). Discomfort score was highest (4.0) in both the groups at the time of presentation. However, in DALK case, the discomfort disappeared instantaneously with statistically significant low score ($p<0.001$) as compared to high score (2.5±3.90) in control group (Tab. IV).

Epithelial healing was cured instantaneously in DALK group as compared to much delayed healing in control group ($p<0.0001$).

Corneal transparency achieved (Fig. 3B) in DALK group was 80% with high score (4.0±0.00) as compared to 0% in control group which was statistically significant ($p<0.0001$).

Visual acuity achieved in DALK group was 100% with high score (0.36±0.23) as compared to 0% in control group with least score (0.00±0.000) which was statistically significant ($p<0.0001$) (Tabs. II, III, VI).

Perforation of cornea in DALK was 10% with low score (0.10±0.31) as compared to 100% in control group with high score (4.0±0.00) which was statistically significant ($p<0.0001$).

Similarly, vascularization of the cornea was seen in 100% of control group with higher score (3.9±0.16 ) as compared to 50% with low score (0.20±0.10) in DALK group.
Symblepharon was seen more in control group (100%) as compared to DALK group (5%) and was statistically significant ($p$<0.0001).
Generally it was observed that results were significantly better in grade II and III chemical burns than the grade IV burns and it was further observed that grade II burns provide the best results compared to grade III and grade IV burns (Tab. II).
Collective grades of chemical burns on analysis showed visual acuity improvement from 6/36–6/12 in all the cases in DALK group (100%) as compared to low improvement grade (<3/60–1/60) in 18% of control group. Corneal transparency was seen in 86% of the DALK group as compared to 6% improvement in control group. Vascularization in DALK group was 38% with

**TABLE II -** COMPARATIVE EVALUATION OF VARIOUS FACTORS IN CHEMICAL BURNS

| Factor | Pretreatment | | | Post-treatment | | |
|---|---|---|---|---|---|---|
| | DALK | Control | p value | DALK | Control | p value |
| Conjunctival involvement (0–4 grade) | | | | | | |
| Grade II | 1.04±0.16 | 0.88±1.08 | 0.114 | 0.000±0.00 | 0.000±0.00 | — |
| Grade III | 1.44±0.20 | 1.40±1.76 | 0.740 | 0.000±0.00 | 2.04±0.20 | <0.00001 |
| Grade IV | 2.08±0.20 | 2.12±0.08 | 0.998 | 0.20±0.40 | 2.08±0.08 | <0.00001 |
| Corneal haze/opacity (0–4 grade) | | | | | | |
| Grade II | 0.360±0.42 | 0.32±0.45 | 0.182 | 0.000±0.00 | 2.20±0.27 | <0.00001 |
| Grade III | 3.44±0.40 | 3.49±0.95 | 0.627 | 0.340±1.05 | 3.39±0.95 | <0.00001 |
| Grade IV | 4.00±0.00 | 4.00±0.00 | 0.000 | 0.05±0.10 | 3.89±0.19 | <0.00001 |
| Corneal transparency (0–4 grade) | | | | | | |
| Grade II | 0.80±0.00 | 0.40±0.00 | 0.182 | 4.00±0.00 | 1.40±0.022 | <0.00001 |
| Grade III | 0.00±0.00 | 0.00±0.00 | — | 3.66±0.06 | 0.60±0.15 | <0.00001 |
| Grade IV | 0.00±0.00 | 0.00±0.00 | — | 4.00±0.00 | 0.000±0.00 | <0.00001 |
| Scleral involvement (0–4 grade) | | | | | | |
| Grade II | 0.00±0.00 | 0.00±0.00 | — | 0.00±0.00 | 0.000±0.00 | — |
| Grade III | 0.04±0.00 | 0.08±0.00 | 0.560 | 0.00±0.00 | 2.00±0.20 | <0.00001 |
| Grade IV | 1.56±0.44 | 1.48±0.36 | 0.585 | 0.00±0.00 | 0.00±0.00 | <0.00001 |
| Visual acuity (0–1 grade) | | | | | | |
| Grade II | 0.73±0.31 | 0.65±0.032 | 0.735 | 0.65±0.22 | 0.04±0.022 | <0.00001 |
| Grade III | 0.05±0.12 | 0.05±0.12 | 0.859 | 0.45±0.25 | 0.054±0.10 | <0.00001 |
| Grade IV | 0.00±0.00 | 0.00±0.00 | 1.000 | 0.36±0.23 | 0.00±0.00 | <0.00001 |
| Perforation (0–4 grade) | | | | | | |
| Grade II | 0.00±0.00 | 0.00±0.00 | — | 0.00±0.00 | 0.00±0.00 | <0.00001 |
| Grade III | 0.00±0.00 | 0.00±0.00 | — | 0.00±0.00 | 0.00±0.00 | — |
| Grade IV | 0.00±0.00 | 0.00±0.00 | — | 0.10±0.31 | 4.00±0.00 | <0.00001 |
| Symblepharon (0–4 grade) | | | | | | |
| Grade II | 0.00±0.00 | 0.00±0.00 | — | 0.00±0.00 | 0.00±0.00 | <0.00001 |
| Grade III | 0.00±0.00 | 0.00±0.00 | — | 0.00±0.00 | 0.110±0.00 | <0.00001 |
| Grade IV | 0.00±0.00 | 0.00±0.00 | — | 0.08±0.09 | 4.00±0.00 | 0.00000 |
| Vascularization (0–4 grade) | | | | | | |
| Grade II | 0.00±0.00 | 0.00±0.00 | — | 0.100±0.14 | 1.7±0.27 | <0.00001 |
| Grade III | 0.00±0.00 | 0.00±0.00 | — | 0.11±0.23 | 2.79±1.49 | <0.00001 |
| Grade IV | 0.00±0.00 | 0.00±0.00 | — | 0.20±0.10 | 3.93±0.16 | <0.00001 |

No lesion = 0, 1/4 lesion = 1, 1/2 lesion = 2, 2/3 lesion = 3, 4/4 lesion = 4, 0 = no vision, 0.05 = 3/60, 0.1 = 6/60, 0.2 = 6/36, 1 = 6/6
DALK = Deep Anterior Lamellar Keratoplasty

mild grade as compared to 100% in control group. Perforation of cornea was seen in 4% of DALK group as compared to 88% of the control group. Similarly, symblepharon was seen in 2% of the DALK group as compared to 62% in the control group.

## DISCUSSION

The treatment of chemical burn consists of various modalities. Brodovsky et al (50) reported good results in all grades of chemical burns with rigorous conservative medical treatment which included in addition to conventional treatment the use of sodium citrate 10%, sodium ascorbate10%, and corticosteroid drops given hourly. The results were better in grade II burns that involved partial stem cell loss and had a good prognosis with conventional treatments (4, 5, 49, 50). They achieved best-corrected visual acuity (BCVA) more than 6/18 in 60% in grade IV, 93% in grade III, and 92% in grade II. They, however, have reported many fallacies in their retrospective study as imperfect recording of ischemia and grading of the burns. In our study we achieved improvement in the visual acuity from finger counting to 6/60 in 18% of control group in which standard medical protocol was given. Davis and associates (13) reported complications even in grade II chemical burn as delayed healing, perforation, and corneal opacity with medical treatment.

Many authors (29-36) resorted to the use of AMT in acute chemical burns and reported its usefulness. Meller et al (31) believed that AMT not only serves as a sort of internal splint, that is, pure mechanical barrier, as originally proposed by Brown (60) and adopted by Sorsby and colleagues (30), but it possess potent desirable biologic activities. They further noted that the AMT exerted anti-inflammatory actions, promoted epithelialization, helped expand limbal epithelial stem cells in partial limbal deficiency (31), and was effective in preventing the forma-

**TABLE III -** COMPARATIVE ANALYSIS OF PARAMETERS IN DALK AND CONTROL GROUP IN ACUTE CHEMICAL BURNS

| | Group II | Group III | Group IV | Total % |
|---|---|---|---|---|
| Visual acuity | | | | |
| DALK, n (%) | 5/5 (100) | 25/25 (100) | 20/20 (100) | 50/50 (100) |
| Control, n (%) | 4/5 (80) | 5/25 (20) | 0/20 (0) | 9/50 (18) |
| Corneal transparency | | | | |
| DALK, n (%) | 5/5 (100) | 22/25 (88) | 16/20 (80) | 43/50 (86) |
| Control, n (%) | 1/5 (20) | 2/25 (8) | 0/20 (0) | 3/50 (6) |
| Vascularization | | | | |
| DALK, n (%) | 1/5 (20) | 8/25 (32) | 10/20 (50) | 19/50 (38) |
| Control, n (%) | 5/5 (100) | 25/25 (100) | 20/20 (100) | 50/50 (100) |
| Perforation | | | | |
| DALK, n (%) | 0/5 (0) | 0/25 (0) | 2/20 (10) | 2/50 (4) |
| Control, n (%) | 0/5 (0) | 2/25 (8) | 20/20 (100) | 22/50 (88) |
| Symblepharon | | | | |
| DALK, n (%) | 0/5 (0) | 0/25 (0) | 1/20 (5) | 1/50 (2) |
| Control, n (%) | 0/5 (0) | 11/25 (44) | 20/20 (100) | 31/50 (62) |

DALK = Deep Anterior Lamellar Keratoplasty

**TABLE IV -** DISCOMFORT RELIEF RELATIONSHIP WITH TIME IN ACUTE CHEMICAL BURNS

| Grade | 1 d | 7 d | 14 d | 1 mo | 2 mo | 3 mo | 6 mo | 12 mo | 24 mo | 48 mo |
|---|---|---|---|---|---|---|---|---|---|---|
| G-II DALK | 3.0 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Control | 3.0 | 2.78 | 2.5 | 1.5 | 1.4 | 1.4 | 1.0 | 0.00 | 0.00 | 0.00 |
| p value | 1.0 | <0.005 | <0.002 | <0.006 | <0.0002 | <0.0001 | <0.00008 | — | — | — |
| G-III DALK | 3.8 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Control | 3.8 | 3.75 | 3.75 | 3.50 | 3.0 | 2.75 | 2.50 | 1.00 | 1.50 | 1.0 |
| p value | 1.0 | <0.002 | <0.002 | <0.0006 | <0.0002 | <0.0002 | <0.00008 | <0.00001 | <0.00001 | <0.00001 |
| G-IV DALK | 4.0 | 0.00 | 0.00 | 0.00 | 0.05 | 0.05 | 0.10 | 0.10 | 0.10 | 0.10 |
| Control | 4.0 | 3.90 | 3.90 | 3.85 | 3.80 | 3.90 | 3.80 | 2.75 | 2.50 | 2.50 |
| p value | 1.0 | <0.002 | <0.002 | <0.00006 | <0.0002 | <0.0001 | <0.00008 | <0.00001 | <0.00001 | <0.00001 |

DALK = Deep Anterior Lamellar Keratoplasty

tion of symblepharon (29, 30). The action of AMT to promote epithelialization, suppress inflammation, and prevent scarring is due to various forms of protein inhibitors, including alpha 1-anti trypsin, alpha-2 plasmin inhibitor, and alpha-2 anti-chymotrypsin. Meller et al (31) carried out AMT in 13 eyes and achieved good visual and structural results in 10/13 eyes with grade II–IV burns and recommended the use of AMT in acute chemical burns. Similarly, Ucakhan et al (32) achieved good results with nonpreserved AMT in four eyes with acute consecutive chemical burns. Arora et al (33) achieved good results with AMT in 15 acute burn cases of grade II–IV with early epithelialization and improvement in visual acuity in 10 out of 15 eyes (60.6%); Kobyashi et al (34) achieved good results in five eyes with acute chemical burns greater than grade II with AMT. Sridhar et al (35) noted good results with AMT in one case of grade III–IV chemical and one of thermal burns. Tamhane et al (36) tried the AMT with the specific medical protocol in 37 eyes and only medical treatment in 44 eyes in grade II–IV burns within 3 weeks of the injury and noted relief in symptomatology. They found it inefficacious in grade III–IV corneal burn cases because of deep stromal ischemia (36, 37, 41). We, however, do not completely agree with above authors that AMT alone can lead to dramatic visual results in all grades of acute chemical burns (41) (Tabs. II–III) In our opinion, the cornea which is drenched with chemical should also be replaced with fresh healthy tissue in the acute stage of ocular burns. It is conceivable that there remain some conjunctival and epithelial stem cells at the basal level, even though fluorescein depicts a large ocular surface defect. Without effective measures to suppress such inflammation in the acute stage, the population of these epithelial stem cells declines, paving a difficult way to recovery. Furthermore, leukocyte infiltration comes in two waves in burns (1, 5, 55, 56): the first within 12 to 24 hours and the second starting at day 7 reaching peak in 14–21 days. Wagoner (5) reported that the first wave is crucial for the recruitment of the second; thus, DALK alone or with supportive therapy performed at an early stage may help suppress the gradual requirement of more inflammatory infiltration, and collectively may shorten the duration and extent of inflammation further. The progress of AMT in grade III chemical burns had been reported to be guarded by many workers (5, 6, 29, 30) due to a potential risk of corneal ulceration, perforation, and conjunctivalization of the cornea. A similar experience has been reported in acute chemical burns by Azuara-Blanco et al (37), Joseph et al (38), Wagoner (5), and Davis et al (13), who noted sterile perforation or corneal ulcerations in untreated grade II–IV chemical burns.

**TABLE V -** EPITHELIAL HEALING RELATIONSHIP WITH TIME IN ACUTE CHEMICAL BURNS

| Grade | 1 d | 7 d | 14 d | 1 mo | 2 mo | 3 mo | 6 mo | 12 mo | 24 mo | 48 mo |
|---|---|---|---|---|---|---|---|---|---|---|
| G-II | | | | | | | | | | |
| DALK | 4.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 |
| Control | 4.0 | 3.75 | 3.75 | 3.50 | 3.25 | 3.00 | 2.70 | 2.6 | 1.50 | 1.50 |
| p value | 1.0 | <0.002 | <0.0015 | <0.0006 | <0.0002 | <0.0001 | <0.0000 | <0.00006 | <0.00001 | <0.00001 |
| G-III | | | | | | | | | | |
| DALK | 4.0 | 0.00 | 0.00 | 0.00 | 0.05 | 0.05 | 0.05 | 0.05 | 0.00 | 0.00 |
| Control | 4.0 | 4.00 | 3.75 | 3.75 | 3.50 | 3.50 | 3.5 | 3.0 | 2.50 | 2.50 |
| p value | 1.0 | <0.002 | <0.002 | <0.0006 | <0.0002 | <0.0001 | <0.00001 | <0.00001 | <0.00001 | <0.00001 |
| G-IV | | | | | | | | | | |
| DALK | 4.0 | 0.00 | 0.00 | 0.00 | 0.05 | 0.10 | 0.050 | 0.10 | 0.00 | 0.00 |
| Control | 4.0 | 3.75 | 3.75 | 3.75 | 3.75 | 3.75 | 3.75 | 3.75 | 3.75 | 3.75 |
| p value | 1.0 | <0.0021 | <0.0025 | <0.0006 | <0.0002 | <0.0001 | <0.0008 | <0.00001 | <0.00001 | <0.00001 |

DALK = Deep Anterior Lamellar Keratoplasty

**TABLE VI -** RESULTS OF DALK IN VARIOUS GRADE OF CHEMICAL BURNS

| | | Visual acuity | | |
|---|---|---|---|---|
| **Grade** | **Graft clarity** | **6/12** | **6/24** | **6/36** |
| Grade II | 5 (100%) | 4 (80%) | 1 (20%) | — |
| Grade III | 22 (88%) | 10 (40%) | 15 (60%) | — |
| Grade IV | 16 (80%) | 5 (25%) | 12 (60%) | 3 (15%) |
| Total | 43 (86%) | 19 (38%) | 28 (56%) | 3 (6%) |

DALK = Deep Anterior Lamellar Keratoplasty

Morgan and Murray (39), Chen and Xu (40), Kenyon (41), Gerard et al (42), Gatinel et al (43), and Roa et al (44) have recommended the limbal cell auto transplantation (LAT) in acute burns as this technique promotes epithelialization of ocular surface and early healing. However, Roa et al (44) met with failure in early acute burn cases. Thoft (24) and Kenyon and Tseng (45) also believe that LAT does not restore the limbal landmark when performed in acute stage; hence they do not recommend it. It seems that the AMT, LAT, and fresh corneal tissue posses an anti-inflammatory action. The matrix of these tissues is capable of excluding inflammatory cells (51, 52) and one of the mechanisms may be facilitating their rapid apoptosis. Sorsby and colleagues (30) and Meller et al (31) opined that early intervention is the key to satisfactory visual outcomes in case of chemical burns and Wagoner (5) further observed that an early epithelial replacement has been regarded as essential in ocular chemical burns. Keeping this in mind, various workers tried AMT and LAT in this field but hardly anyone bothered to replace the chemically drenched cornea associated with epithelial loss. In this study, we evaluated the results of an early DALK alone, DALK with LAT of the conjunctiva, and DALK with AMT. DALK with supportive tissue grafting was given to remove all the affected cornea, sclera, or conjunctiva which was drenched with chemicals and replaced it with a fresh donor tissue. We noted that early DALK alone or with supportive procedures could almost save all the eyes with advanced grade II, III, and IV burns with amelioration of the symptoms and could correct the ocular surface disorder resulting in clear grafts in 86% of cases with100% improvement of visual acuity, from 6/24 to 6/12 in 47 eyes (94%) and 6/36 in 3 eyes (6%) (Tab. IV), which was higher than obtained by Kuckelkorn et al (47) and Redbrake et al (48). Our success rate was higher than mentioned earlier (46-48). Kuckelkorn et al (47) recommended LK/PK as an early procedure by a large size graft of 11–12 mm and noted success in 25% of early cases and 36.4% of late operated cases. Immediate actions collectively are desirable for an early restoration of ocular surface in advanced grades of chemical burns. Unlike other authors (36, 50), we did not achieve good results of medical therapy in our control group (Tab. III), which could be due to non-incorporation of the cases in this study beyond 1 week of the chemical injury. Based on a large series of cases and long-term clinical observation, we summarize the benefits of this surgical procedure of a large sized DALK, which would act as the limbal cell transplant and would correct the limbal stem cell deficiency. First, ocular surface reconstruction and corneal clarity recovery were achieved simultaneously by a single stage surgical procedure. The irritation, photophobia, and epithelial defects were resolved earlier. The visual acuity improvement was remarkable in contrast to the results of ALT or AMT performed alone in previous studies reported by others (56) in which a second stage operation such as PK after 6 months was required to recover corneal clarity and visual acuity after the initial ocular reconstruction. Second, there is no doubt that if we choose PK as an alternative to DALK either a single two stage or as second stage surgery combined with ALT, the corneal clarity could recover for some period as large grafts of 9.5 mm do not escape graft reaction onslaught despite the use of postoperative immunomodulators. Third, the large transplant not only provides a new cornea but also removes the chemical-soaked cornea and makes the host cornea fit to retain its functional and structural integrity.

The fresh tissues not only help in the epithelialization of ocular surface but also promote the proliferation of the progenitor cells in vivo (53) and in vitro (57, 58). Other purposes of the fresh tissues are to preserve and expand the slow cycling property of the epithelial progenitor cells (57) and provision of new growth factors (59). In this study, we demonstrated that early DALK alone in grade II or DALK with ALT in grade III DALK, with amniotic membrane in grade IV as a single stage surgical procedure performed simultaneously saved all eyes with an achievement in transparency in 86% of eyes and improvement in visual acuity in 100% of cases ranging from 6/36 to 6/12. The factors leading to greater success in our cases of acute chemical burns were multiple: 1) removing the chemically drenched tissues; 2) replacement with fresh biologically active tissues; 3) cutting of the chain mechanism necessary for inducing first and second stage of inflammation; 4) supplying the tissue growth factors necessary for restoring the integrity of ocular surface; 5) supplying fresh limbal progenitor cells; 6) supporting and prolonging life of the left out progenitor cells; 7) supporting tissues such as AMT and LAT help in restoring the integrity of ocular surface by their biological beneficial effect in promoting epithelialization, anti-inflammatory action, providing growth factors, and mechanical support; 8) anti-adhesive properties; 9) bacteriostatic property; 10) wound protection; and 11) lack of immune reaction.

*Proprietary interest: None.*

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