American Journal of Ophthalmology Case Reports 37 (2025) 102246

Contents lists available at ScienceDirect

American Journal of Ophthalmology Case Reports

journal homepage: www.ajocasereports.com/

Femtosecond laser–assisted large-diameter lamellar corneal-limbal keratoplasty in ocular chemical burns

Lixia Lin [1], Yuwei Xu [1], Zhancong Ou, Kaichen Zhuo, Dongyue Tian, Jiaqi Chen, Jianjun Gu [*]

State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangdong Provincial Key Laboratory of Ophthalmology and Visual Science, Guangzhou, China

ARTICLE INFO

Keywords:
Femtosecond laser
Large-diameter lamellar corneal-limbal keratoplasty
Ocular chemical burns
Limbal stem cell deficiency

ABSTRACT

Purpose: This study highlights the feasibility of femtosecond laser-assisted large-diameter lamellar corneal-limbal keratoplasty and its efficacy in the treatment of ocular surface failure caused by bilateral ocular chemical injury.

Observations: The series included 3 patients with ocular surface failure caused by bilateral ocular chemical burns. After dissection of the host cornea, a femtosecond laser-assisted large-diameter lamellar corneoscleral button, with varying thickness of 250–400 μm, was sutured to the recipient bed. Postoperatively, patients were maintained on topical corticosteroids drops and systemic immunosuppression. Patients were followed up for a minimum of 16 months. The preoperative best corrected visual acuity was counting fingers, hand motions, and hand motions respectively. Postoperatively, the preoperative best corrected visual acuity reached 20/50, 20/50 and 20/40 at the last follow-up, respectively. A stable ocular surface was achieved in all but one eye, due to the cessation of immunosuppressive drugs. Postoperative anterior segment optical coherence tomography revealed well apposed graft interface in all cases.

Conclusions and importance: Compared with conventional techniques, femtosecond laser is useful to create varying thickness corneoscleral graft to rehabilitate ocular surface and visual acuity in patients with bilateral ocular chemical burns.

1. Introduction

Chemical burns to the ocular surface can lead to severe eye damage. These injuries are predominantly caused by acid or alkaline compounds. Ocular chemical injuries represent 0.1%–15 % of all ophthalmic emergencies, with an incidence of 5.1–50 cases per 100,000 population years.[1] Patients may develop severe dry eye due to the loss of goblet cells or lacrimal glands. Rapid conjunctival cicatrization can occur, potentially leading to symblepharon. Immediate treatment focuses on promoting re-epithelialization, reducing inflammation, and preventing infection. In the chronic phase, the primary goal is to prevent and manage scarring of the ocular surface. This is critical as the outcome of ocular chemical burns is evaluated based on both the stabilization of the ocular surface and the restoration of functional vision, particularly in patients with bilateral injuries.

Chemical burns can lead to the depletion of corneal stem cells, potentially causing recurrent corneal epithelial erosions, chronic surface inflammation, and conjunctivalization of the cornea. Penetrating keratoplasty (PK) in eyes with chemical burns shows poor outcomes due to limbal stem cell deficiency (LSCD) and corneal vascularization. For unilateral total LSCD, autologous transplantation of limbal tissue from the healthy contralateral eye is effective.[2] In cases of bilateral LSCD, restoration of stem cells involves using limbal tissue from deceased donor corneas, living-related conjunctival limbal allograft, or cultivated oral mucosal epithelium on human amniotic membrane sheets.[3,4] However, specialized laboratories are required for limbal stem cell culture and transplantation. Additionally, optical corneal transplantation may be necessary in some cases due to significant corneal opacification. When limbal cell transplantation is followed by PK, it necessitates two surgeries and the use of two donor tissues, in a context of limited corneal supply. Large-diameter lamellar corneal-limbal keratoplasty (LKP) has been reported to successfully stabilize the ocular surface and visually rehabilitate cases with bilateral LSCD and stromal scarring.[5] Free-hand dissection has been used to harvest large diameter lamellar corneal grafts,[6] though achieving uniform lamellar dissection at varying thickness remains challenging. This study explores the technical

* Corresponding author.
E-mail address: gujj@mail.sysu.edu.cn (J. Gu).
[1] These two authors contributed equally to this work.

https://doi.org/10.1016/j.ajoc.2024.102246
Received 20 May 2024; Received in revised form 16 December 2024; Accepted 22 December 2024
Available online 27 December 2024

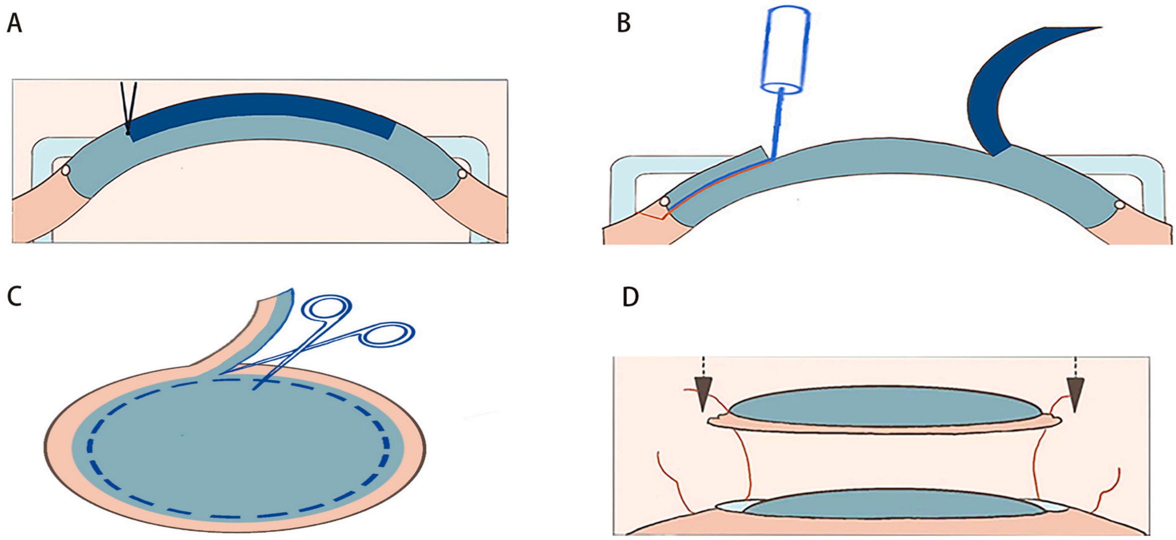

Fig. 1. Schematic diagram showing femtosecond laser–assisted large-diameter lamellar corneal-limbal keratoplasty. (A)The donor cornea was placed onto the artificial anterior chamber with endothelial-side up. An 8 mm lenticule was created with femtosecond laser, with thickness of corneal pachymetry minus 250–400 μm. (B)After the removal of the lenticule, a crescent blade was used to extend the lamellarcut to the periphery of the sclerocorneal rim.(C) The peripheral 2.0mm of the graft with the posterior sclera is partially trimmed with corneal scissors.(D) The lamellar corneoscleral button was sutured to the recipient bed with 10–0 nylon sutures.

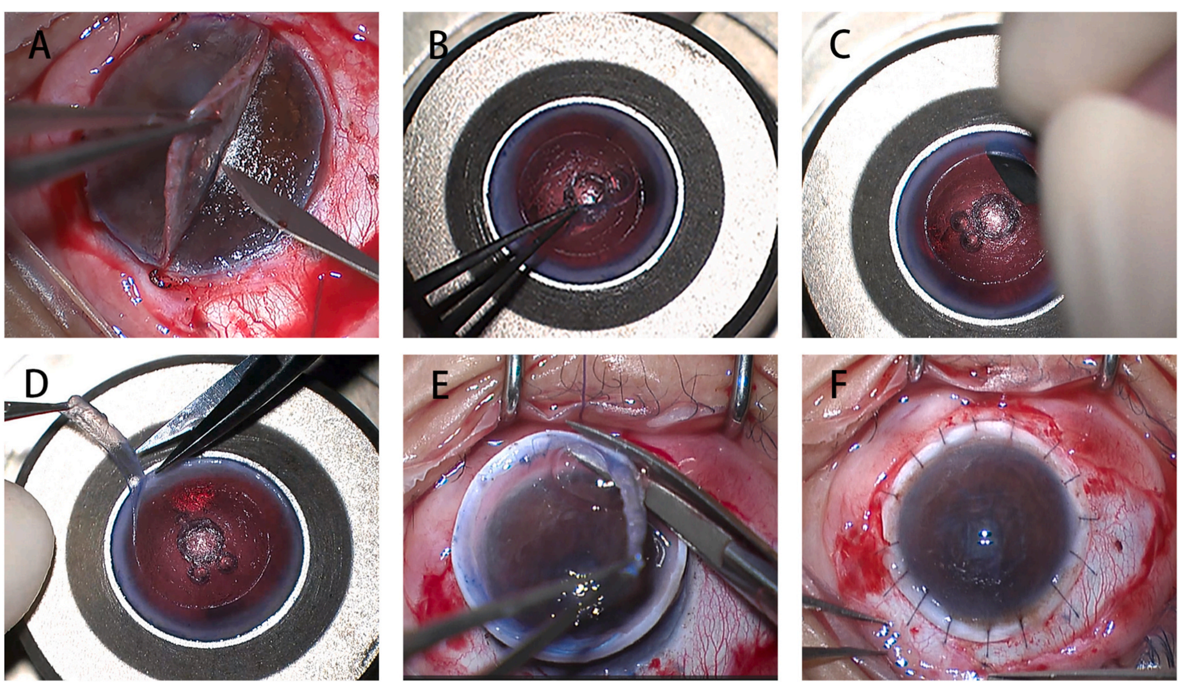

Fig. 2. Surgical procedure of femtosecond laser–assisted large-diameter lamellar corneal-limbal keratoplasty. (A)Dissection of corneal lamellar flap in the recipient eye. (B)The lenticule is removed with the corneoscleral button mounted in an artificial anterior chamber endothelial-side up. (C)Partial-thickness lamellar dissection making multiple central to peripheral incisions with a crescent blade. (D) Peripheral lamellar corneal tissue is removed by corneal scissors. (E)Peripheral sclera tissue is trimmed by corneal scissors to fit the ocular surface. (F) The large-diameter corneal lamellar button is sutured onto the recipient bed.

feasibility of using femtosecond laser-assisted dissection to obtain full-diameter lamellar tissue from a corneoscleral button (Fig. 1), and its therapeutic effect on eyes with LSCD and corneal opacity caused by severe bilateral ocular chemical injuries.

2. Materials and methods

Limbal Stem Cell Deficiency (LSCD) is characterized by chronic epithelial defects, stromal inflammation, corneal vascularization, conjunctival epithelial ingrowth (conjunctivalization), and corneal opacification. Limbal keratoplasty (LKP) is typically performed 12 months or more after injury to allow inflammation to resolve and to increase the likelihood of success. LKP is indicated for the more severely affected eye in bilateral burns when functional vision cannot be restored. The criteria for the operated eyes in all cases are as follows: 1) Patients with severe ocular chemical burns; 2) Tear secretion > 5mm/5min on the Schirmer test; 3) Slit-lamp examination showing LSCD and significant anterior corneal stromal opacity.

2.1. Surgical technique

LKP was conducted under general anesthesia. To assess the depth of corneal pathology requiring removal, anterior segment optical coherence tomography (OCT; Visante OCT, model 1000; Carl Zeiss Meditec, Dublin, CA, USA) was utilized in all cases. The procedure began with a complete 360-degree peritomy, followed by retraction of the conjunctiva. A circular trephine, sized 11–12mm to encompass the limbal area, was employed to mark the sclera using a stain. Lamellar corneoscleral dissection was then performed to a depth of 250–400 μm using a lamellar knife. Care was taken to maintain a consistent plane throughout the dissection, which continued until corneal opacification was fully cleared (Fig. 2A). The size of the recipient bed was measured with calipers to determine the appropriate size for the donor graft. The donor graft was prepared to be oversized by 0.5–1mm relative to the recipient bed and limbal stem cells was included.

A donor corneoscleral button with a death-to-preservation time of 3 hours, featuring a healthy limbus and corneal epithelium, was selected. The donor tissue was mounted on an artificial anterior chamber, positioned upside down for precise centering. The donor button was inverted into a convex shape to make contact with the flat interface of the laser application head. A lenticule was created using an Intralase FS laser (AMO, Santa Ana, CA, USA) with settings of 160 kHz frequency, 1.8mJ energy, and a 90-degree side-cut angle. The horizontal lamellar cut was intended to be the corneal pachymetry minus 250–400 μm, with lenticule diameters ranging from 8.0 to 8.5mm. After laser application, manual dissection of the lamellar tissue with endothelium using a blunt spatula was performed to loosen any tissue bridges. The lenticule was then removed (Fig. 2B). Partial-thickness lamellar dissection was carried out with a crescent blade, making multiple central to peripheral incisions (Fig. 2C). The posterior doughnut-shaped ring containing the endothelium was excised from the donor tissue using corneal scissors (Fig. 2D). After releasing the pressure in the anterior chamber, the specimen was prepared for punching. A trephine sized 11.5–12.5 mm was used to harvest the donor lamellar graft, based on the diameter of the host cornea. The peripheral 2.0mm of the graft, including the posterior sclera, was partially trimmed to create a thinned flange for improved graft-host apposition (Fig. 2E). The lamellar corneoscleral donor was then secured in place with interrupted 10-0 nylon sutures (Fig. 2F). Horizontal 8-0 Vicryl sutures were used to pass through the conjunctiva, ensuring a well-covered scleral wound. A bandage contact lens was placed on the cornea at the conclusion of the surgery.

2.2. Postoperative immunosuppressive regimens

Postoperatively, patients received topical tobramycin-dexamethasone eye drops six times daily, alongside tacrolimus three times daily. Systemic immunosuppression began with oral prednisone at 0.4mg/Kg for 7 days, and mycophenolate mofetil (MMF) at 0.5g twice daily for 6 months. MMF was then tapered to 0.5g daily for an additional 18 months. Topical 0.1 % flurometholone and tacrolimus were continued three times daily indefinitely. MMF was discontinued if irreversible graft failure or significant adverse effects occurred.

4. Discussion

Limbal allograft procedures are crucial for patients with compromised ocular surfaces due to stem cell abnormalities. Keratolimbal allograft (KLAL) is a useful technique to re-establish a normal corneal phenotype for severe chemical injuries. However, in cases of bilateral LSCD with stromal scarring, subsequent optical keratoplasty is essential which is advised to be performed after at least 3–6 months to achieve a stable ocular surface.[7] In patients with thinning of the cornea due to chemical burns, PK after KLAL is difficult because of the asymmetrical thickness of the donor cornea and the host bed. Allogeneic simple limbal epithelial transplantation (Alloslet) is a simple and fast way to treat LSCD.[8] This surgical technique did not require stem cell laboratory facilities as compared to ex-vivo cultivation of autologous cultivated oral epithelium.[9] However, it is not suggested in eyes with opaque corneal stroma. This is because the limbal transplants placed on the corneal surface are lost after second stage keratoplasty. LKP provides a straightforward, single-stage technique for simultaneously transplanting both the corneal stroma and limbal stem cells.[5,10,11] LKP is the surgical option in cases where the anterior corneal lamellae are opaque. If the cornea is fully opacified, an En Bloc keratolimbal allograft combined with central penetrating keratoplasty may be chosen. Similar to LKP, these procedures require only one donor tissue, which theoretically reduces the antigenic load.[12] Additionally, both surgical approaches alleviate the strain on local eye banks, which often face donor shortages.

Obtaining a lamellar corneoscleral button from cadaveric allografts has posed challenges. Traditionally, partial-thickness large-diameter corneal buttons were prepared from whole eyeballs using either manual dissection or a mechanical microkeratome with an oversized head.[13,14] While microkeratomes reduce the time required for harvesting, they necessitate a whole globe, which is not commercially available from eye banks today. Corneoscleral donor buttons from modern eye banks offer advantages like assured tissue quality, serological testing, and a lower risk of infection. Lamellar graft harvesting using a corneoscleral button sutured onto a sterile fabric-covered glass ball implant with manual dissection has been reported.[6] However, this method is technically challenging and time-consuming, especially for inexperienced surgeons. Moreover, manually-dissected lamellar interfaces often exhibit topographical irregularities, potentially impacting visual acuity. Martin Grueterich introduced a technique for harvesting eccentric keratolimbal grafts from donor corneoscleral buttons in a one-step procedure using a single graft. This method only enables the acquisition of approximately 3–4 clock hours of limbal tissue, suggesting its potential use for cases of partial LSCD with superficial scarring but not for cases of total LSCD.[15]

Femtosecond lasers represent a significant advancement in keratoplasty, offering increased precision and accuracy in donor corneal dissections at greater depths.[16–18] This technology has been effectively employed in anterior lamellar keratoplasty, facilitating rapid visual rehabilitation and minimal induced astigmatism.[17] Traditional femtosecond laser procedures, however, are limited to creating lamellar dissections ranging from 5 to 9 mm in diameter, excluding the limbus. Utilizing a corneoscleral button mounted in an artificial anterior chamber with the endothelial side facing up, the femtosecond laser's capacity for precise corneal dissections at varied depths is instrumental in creating large lamellar grafts of varying thickness, suitable for replacing the dissected host cornea. A potential drawback of this approach is the manual dissection required for the peripheral portion of the graft. Nevertheless, the straight edges created by the femtosecond laser, along with multiple central to peripheral incisions made with a crescent blade, result in smooth cut surfaces. This smoothness aids in the proper apposition of the graft to the ocular surface.

In conclusion, femtosecond laser-assisted LKP shows promise as a surgical option for patients with bilateral ocular chemical injuries and corneal opacities of varying thickness. However, the necessity for further studies, more cases, safer systemic immunosuppression protocol and extended follow-up analyses remains to fully establish its long-term efficacy.

CRediT authorship contribution statement

Lixia Lin: Data curation, Conceptualization. **Yuwei Xu:** Writing – original draft, Visualization, Data curation. **Zhancong Ou:** Data curation. **Kaichen Zhuo:** Data curation. **Dongyue Tian:** Data curation. **Jiaqi Chen:** Methodology, Conceptualization. **Jianjun Gu:** Writing – review & editing, Validation, Supervision, Project administration, Data curation, Conceptualization.

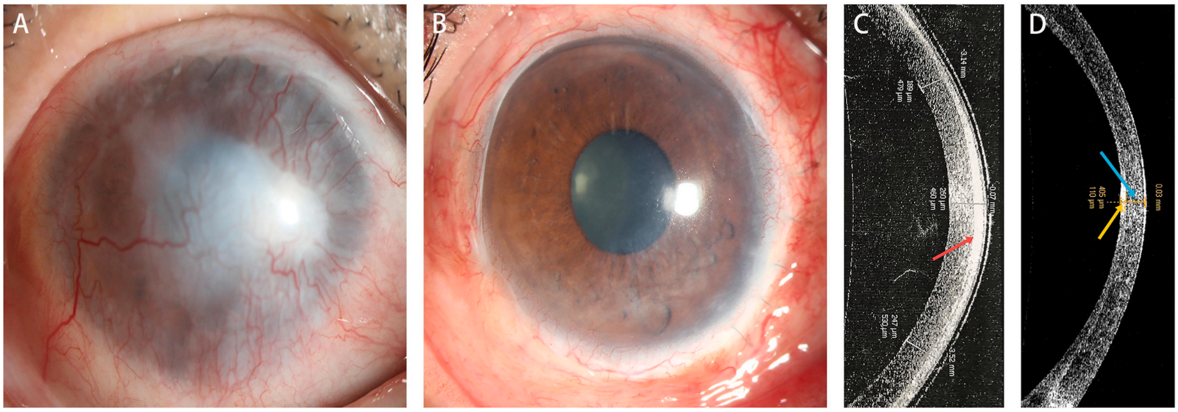

Fig. 3. Case 1, a 31-year-old male with a bilateral alkali burn from 4 years prior. (A) Preoperative slit-lamp biomicroscopy showed total limbal stem cell deficiency and a macular grade corneal scar of the right eye. (B) Postoperative slit-lamp biomicroscopy showed stable ocular surface with clear graft 20 months after surgery. (C) Preoperative AS-OCT revealed corneal pannus and hyperreflective corneal stroma (red arrow) around visual axis of the right eye. (D)Postoperative AS-OCT revealed a well apposed interface of the corneal graft (blue arrow), with donor thickness of 405 μm. The yellow arrow indicates the host cornea. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

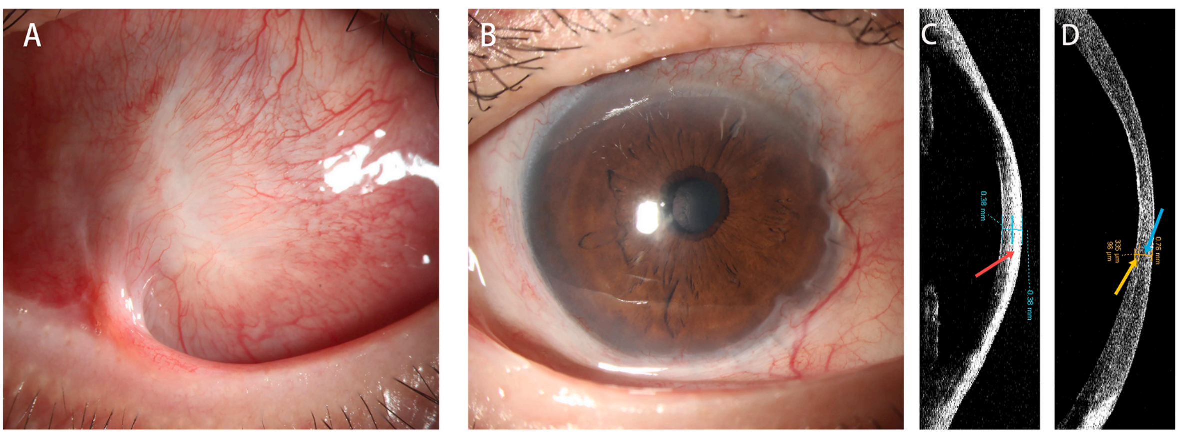

Fig. 4. Case 2, a 32-year-old male with a bilateral alkali burn from 2 years prior. (A) Preoperative slit-lamp biomicroscopy showed 360-degree limbal stem cell deficiency with inferior symblepharon affecting the right eye. (B) Postoperative slit-lamp biomicroscopy showed stable ocular surface with clear cornea of the right eye, postoperative year 2. (C) Preoperative AS-OCT revealed corneal pannus and hyperreflective corneal stroma (red arrow). (D) Postoperative AS-OCT revealed a compact stroma with a hyporeflective epithelium (blue arrow). The yellow arrow indicates the host cornea. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Statement

There is no funding or conflict to disclose.

3. Case report

3.1. Case 1

A 31-year-old male patient presented with severe bilateral ocular chemical burns due to an accidental lime injury four years earlier. His visual acuity was limited to counting fingers in the right eye and hand motions in the left eye. The intraocular pressure (IOP) of the right eye was normal preoperatively. Slit lamp examination revealed total limbal stem cell deficiency and corneal scar with vascularization in both eyes (Fig. 3A–C). After completing preoperative preparations, the patient underwent femtosecond laser-assisted LKP. The graft had a diameter of 12mm and thickness of 400 μm. Postoperatively, he was treated with topical tobramycin dexamethasone eye drops six times daily and tacrolimus three times daily. Systemic immunosuppression was initiated with oral prednisone 30mg for 7 days and MMF 0.5g twice daily for 6 months. Subsequently, MMF was tapered to 0.5g daily and 0.1 % flurometholone and tacrolimus were administered topically three times daily. Twenty months post-surgery, the patient demonstrated a clear graft with a stable ocular surface, and his best corrected visual acuity (BCVA) improved to 20/50 (Fig. 3B–D).

3.2. Case 2

A 32-year-old male patient was diagnosed with bilateral LSCD due to an expansive cement injury two years prior. The BCVA in both eyes was hand motions and the IOP was normal. External examination revealed symblepharon and 360° corneal conjunctivalisation with extensive pannus. The right eye, with relatively less severe symblepharon, was deemed to have better visual potential (Fig. 4A–C). Femtosecond laser-assisted LKP was then performed, utilizing a graft with a diameter of 11.5mm, thickness of 350μm, and including a healthy limbus and corneal epithelium. A lateral tarsorrhaphy was executed using 6–0 prolene sutures to temporarily stabilize the ocular surface. Postoperatively, the patient was prescribed topical tobramycin dexamethasone eye drops six times daily and tacrolimus three times daily in a weekly tapering dose. At the two-year postoperative follow-up, the operated eye maintained clarity with a stable ocular surface (Fig. 4B–D). The patient's BCVA had stabilized at 20/50.

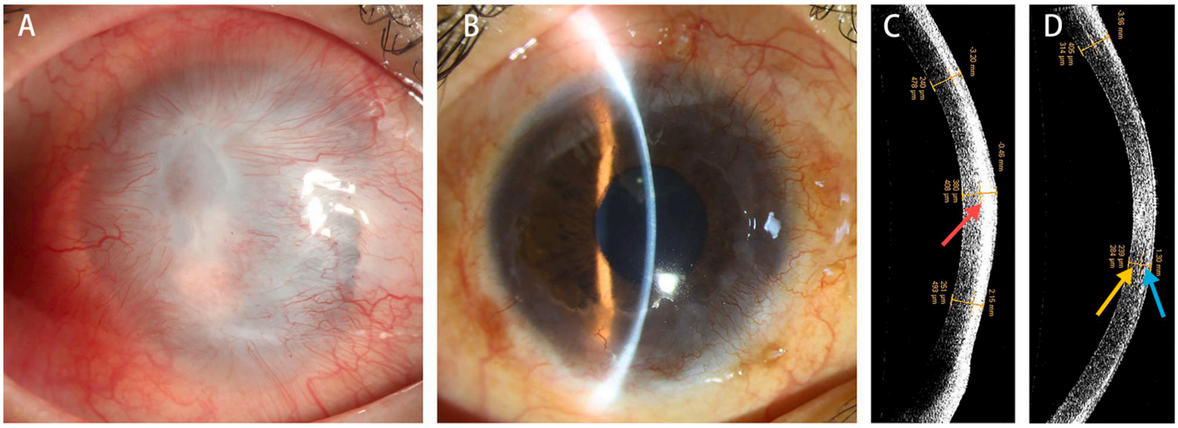

Fig. 5. Case 3, a 25-year-old male with a history of bilateral lye injury from 1 year prior. (A) Preoperative slit-lamp biomicroscopy showed total limbal stem cell deficiency, corneal vascularization and lipid deposition of the right eye. (B) Postoperative slit-lamp biomicroscopy showed central clear graft with peripheral vascularization 16 months after surgery. (C) Preoperative AS-OCT revealed corneal pannus and hyperreflective corneal stroma (red arrow) around visual axis of the right eye. (D) Postoperative AS-OCT revealed a well apposed interface of the corneal graft (blue arrow), with donor thickness of 239μm. The yellow arrow indicates the host cornea. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.3. *Case 3*

A 25-year-old male worker presented with a history of bilateral chemical injury from lye one year prior. At the time of presentation, he exhibited total LSCD with corneal opacity in both eyes (Fig. 5A–C). In June 2022, a LKP with a donor graft thickness of 250 μm was performed on the right eye, following removal of the pannus and corneal opacity. One year post-surgery, the patient ceased using MMF. Unfortunately, in October 2023, an ocular examination indicated a clear central graft but with a conjunctivalized ocular surface, suggesting a recurrence of LSCD (Fig. 5B). AS-OCT showed a well-apposed graft interface (Fig. 5D). His visual acuity improved from hand movement preoperatively to 20/40 at the last follow-up. The patient was advised to continue using topical flurometholone and to resume oral MMF.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Ahmmed AA, Ting DSJ, Figueiredo FC. Epidemiology, economic and humanistic burdens of Ocular Surface Chemical Injury: a narrative review. *Ocul Surf*. 2021;20: 199–211.
2. Fogla R, Padmanabhan P. Deep anterior lamellar keratoplasty combined with autologous limbal stem cell transplantation in unilateral severe chemical injury. *Cornea*. 2005;24:421–425.
3. Deng SX, Kruse F, Gomes JAP, et al. Global consensus on the management of limbal stem cell deficiency. *Cornea*. 2020;39:1291–1302.
4. Shanbhag SS, Saeed HN, Paschalis EI, Chodosh J. Keratolimbal allograft for limbal stem cell deficiency after severe corneal chemical injury: a systematic review. *Br J Ophthalmol*. 2017;102:1114–1121.
5. Vajpayee RB, Thomas S, Sharma N, et al. Large-diameter lamellar keratoplasty in severe ocular alkali burns: a technique of stem cell transplantation. *Ophthalmology*. 2000;107.
6. Wong DW, Chan WK, Tan DT. Harvesting a lamellar graft from a corneoscleral button: a new technique. *Am J Ophthalmol*. 1997 May;123(5):688–689.
7. Solomon A, Ellies P, Anderson DF, et al. Long-term outcome of keratolimbal allograft with or without penetrating keratoplasty for total limbal stem cell deficiency. *Ophthalmology*. 2002 Jun;109(6):1159–1166.
8. Kaur A, Jamil Z, Priyadarshini SR. Allogeneic simple limbal epithelial transplantation: an appropriate treatment for bilateral stem cell deficiency. *BMJ Case Rep*. 2021 Feb 5;14(2), e239998.
9. Nakamura T, Kinoshita S. Ocular surface reconstruction using cultivated mucosal epithelial stem cells. *Cornea*. 2003;22:S75–S80.
10. Qi X, Xie L, Cheng J, Zhao J. Clinical results and influential factors of modified large-diameter lamellar keratoplasty in the treatment of total limbal stem cell deficiency. *Cornea*. 2013 May;32(5):555–560.
11. Jain N, Kate A, Basu S. Deep anterior lamellar limbo-keratoplasty for bilateral limbal stem cell deficiency with corneal scarring in chemical injury sequelae: two case reports. *Int J Surg Case Rep*. 2022 Aug;97, 107409.
12. Karimian F, Hassanpour K. En Bloc keratolimbal allograft and central penetrating keratoplasty: a novel surgical technique in severe limbal stem cell deficiency. *Cornea*. 2023 May 1;42(5):656–661.
13. Chuck RS, Behrens A, McDonnell PJ. Microkeratome-based limbal harvester for limbal stem cell transplantation: preliminary studies. *Am J Ophthalmol*. 2001 Mar; 131(3):377–378.
14. Sarayba MA, Tungsiripat T, Sweet PM, Chuck RS. A portable microkeratome for harvesting the human anterior corneal surface. *Cornea*. 2004 Jul;23(5):443–446.
15. Grueterich M, Kenyon KR, Priglinger S, Welge-Luessen U, Lackerbauer C, Kampik A. Eccentric lamellar keratolimbal grafts harvested with a manually guided microkeratome. Technical report. *Ophthalmic Res*. 2007;39(3):179–183.
16. Mian SI, Shtein RM. Femtosecond laser-assisted corneal surgery. *Curr Opin Ophthalmol*. 2007 Jul;18(4):295–299.
17. Choi SK, Kim JH, Lee D, Oh SH. A new surgical technique: a femtosecond laser-assisted keratolimbal allograft procedure. *Cornea*. 2010 Aug;29(8):924–929.
18. Shousha MA, Yoo SH, Kymionis GD, et al. Long-term results of femtosecond laser-assisted sutureless anterior lamellar keratoplasty. *Ophthalmology*. 2011 Feb;118(2): 315–323.