

Femtosecond laser-assisted deep anterior lamellar keratoplasty with big-bubble technique for keratoconus

Yan Lu^{1,*}, Xiangfei Chen^{1,2,*}, Liping Yang¹, Chunyan Xue¹, Zhenping Huang¹

Purpose: The purpose of this study was to evaluate the clinical results after deep anterior lamellar keratoplasty (DALK) assisted by the femtosecond laser with big-bubble technique for keratoconus. **Methods:** A case series of 22 eyes in 19 patients with keratoconus was enrolled in the study. The 500-kHz VisuMax femtosecond laser (Carl Zeiss Meditec AG, Jena, Germany) was used to create a vertical side cut on donor and recipient corneas. Intraoperative and postoperative complications, uncorrected visual acuity, best-corrected visual acuity, corneal curvature, and central corneal thickness were evaluated in all patients. **Results:** Big-bubble and naked Descemet's membrane (DM) were successfully achieved in twenty eyes (90.9%). Intraoperative macroporation of DM occurred in two cases and converted to full-thickness keratoplasty. The mean follow-up time was 18.8 ± 5.3 months. The best-corrected visual acuity was increased from 0.3 to 1.0, mean corneal curvature was 43.0 ± 2.3D, and mean central corneal thickness was 508.9 ± 60.1 μm (range, from 430 to 600 μm) postoperatively. **Conclusion:** Our results indicate that femtosecond laser-assisted DALK with big-bubble technique is an accurate, safe, and effective method to treat the patients with keratoconus.

Key words: Big-bubble deep anterior lamellar keratoplasty, femtosecond laser, keratoconus

Deep anterior lamellar keratoplasty (DALK) is the procedure to replace the recipient's corneal stroma, leaving healthy Descemet's membrane (DM) and endothelium, which is an alternative procedure to treat keratoconus with stable visual outcomes. In addition, it can decrease the risk of graft rejection, postoperative complication, and delayed endothelial cell density decay compared to penetrating keratoplasty (PKP).^[1]

Big-bubble technique induced by Anwar and Teichmann^[2] in DALK operation has become the most popular procedure among the various surgical techniques described with shortening surgical time and reducing the risk of perforation. It can achieve good long-term visual outcomes while it could delay the recovery time when separating the DM manually in DALK.

The femtosecond laser has been used in corneal transplantation in recent years because of its high precision in corneal incisions.^[3] A femtosecond laser-assisted keratoplasty procedure has been developed to produce bladeless, precise, and predefined lamellar cuts with minimal tissue injury.^[4-7]

The combination of femtosecond laser and diagnostic imaging technology could improve outcomes following DALK in keratoconus.

Here, we report the outcomes in the patients with keratoconus that receive the DALK surgery with big-bubble

technique with the 500-kHz VisuMax femtosecond laser system (Carl Zeiss Meditec AG, Jena, Germany).

Methods

DALK procedure using the big-bubble technique with the VisuMax femtosecond laser system (Carl Zeiss Meditec AG, Jena, Germany) with a 500-kHz repetition rate to treat the moderate to advanced keratoconus was performed in 22 eyes in 19 patients (17 males and 2 females) with the mean age of 22.2 ± 6.6 years (range, from 15 to 41 years) between May 2013 and September 2014 at the our center. The study was approved by the Medical Ethics Committee of our hospital and adhered to the tenets of the Declaration of Helsinki. All patients have signed the informed consent.

All treated eyes received the examination of the uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) with the standard logarithm of the minimum angle of resolution chart preoperatively and postoperatively. Anterior segment optical coherence tomography (Carl Zeiss Meditec, Jena, Germany) combined with the 50-MHz ultrasound corneal pachymetry was used for all patients to evaluate the thinnest corneal thickness in the recipient cornea. Moreover, we have performed the examination of slit-lamp microscopy, corneal topography, and direct ophthalmoscope in dilated pupils. The inclusion criteria were as follows: with more than 200 μm

*These authors contributed equally to this work.

¹Department of Ophthalmology, Jinling Hospital, School of Medicine, Nanjing University, ²Department of Endocrinology, Geriatric Research Center, Jinling Hospital, School of Medicine, Nanjing University, Nanjing, Jiangsu, China

Correspondence to: Prof. Zhenping Huang, Department of Ophthalmology, Jinling Hospital, School of Medicine, Nanjing University, Nanjing 210002, Jiangsu, China. E-mail: huangzhenping1963@163.com

Manuscript received: 20.02.16; **Revision accepted:** 08.08.16

Access this article online

Website:
www.ijo.in

DOI:
10.4103/0301-4738.194326

Quick Response Code:



This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

Cite this article as: Lu Y, Chen X, Yang L, Xue C, Huang Z. Femtosecond laser-assisted deep anterior lamellar keratoplasty with big-bubble technique for keratoconus. Indian J Ophthalmol 2016;64:639-42.

of the corneal thickness in the thinnest location, evidence of ongoing keratoconus and intolerance or inefficacy of rigid gas permeable contact lenses. None of the patients had any other coexisting ocular disease.

All surgeries were performed by a sole fully qualified and highly experienced surgeon. The eyeballs of donors were collected and evaluated within 12 h after death. The whole eyeball was placed in the eyeball fixation (which we previously described)^[8] and then received the treatment with the 500-kHz VisuMax femtosecond laser. We use the same laser settings for DALK in donor and recipient corneas to achieve a vertical side incision with the reference of the thinnest corneal thickness. The center of the recipient cornea was marked with a marker after topical anesthesia, then positioned under the curved contact glass of VisuMax femtosecond laser, after which the vacuum suction was activated to perform the treatment. The recipient and donative corneal lamellar were cut with 500-kHz VisuMax femtosecond laser with the following parameters: $360 \pm 58.25 \mu\text{m}$ (range, 200–430 μm) of recipient lenticule; $7.36 \pm 0.08 \text{ mm}$ (range, 7.2–7.5 mm) of recipient diameter; A donative corneal lenticule was produced with the following parameters: The lenticule thickness was $630 \pm 83.72 \mu\text{m}$ (range, 430–800 μm), with $7.47 \pm 0.11 \text{ mm}$ (range, 7.4–7.8 m); 300 nanojoules for side cut, the track distance and spot distance were both 1.5 μm on the graft side, with a 90° side cut angle.

After femtosecond laser procedure, the patient was transferred to the operating room with retrobulbar anesthesia. A 27-gauge needle bent into 60° with a 5 mL syringe filled with air was inserted into the deep stroma [Fig. 1a]. Air was then injected into the stroma to achieve a big-bubble [Fig. 1b] between the DM and posterior stroma. The anterior chamber paracentesis was performed to lower the intraocular pressure, and a small air bubble was injected into the anterior chamber

to check the naked DM. Then, a crescent disposable knife was used to cut the corneal stroma into half [Fig. 1c], and an ophthalmic viscosurgical device was used to refill the space and protect the DM. The residual stroma was excised by corneal scissors to expose the smoothly transparent DM [Fig. 1d]. After peeling off DM and endothelium using forceps from the donor lamella [Fig. 2b], prepared by femtosecond laser [Fig. 2a], the donor lamella was placed on the host stromal bed [Fig. 1e] and sutured by 16 interrupted stitches with 10-0 nylon sutures [Fig. 1f].

The antibiotics and corticosteroids of intravenous injection were used once a day for 3 days. Tobramycin-dexamethasone and ofloxacin eye drops were applied six times and four times/day for 2 weeks, respectively. Flumetholone and cyclosporine A eye drops were instilled three times/day for 3 months to prevent graft rejection.

The mean follow-up period was 18.8 ± 5.3 months (range, from 12 to 26 months). Sutures were removed at the 6th month postoperatively. Removal sutures beforehand were performed in the cases which the sutures have loosened. Data of the last visit in each patient were recorded and selected for further analysis; two cases which converted to PKP surgery were excluded from analysis.

Results

Twenty eyes were uneventful, and no definite intraoperative complications were observed, while there were two eyes converted to PKP surgery because of DM intraoperative tearing and macroporation. Excellent alignment of DM with the donor tissue was observed in the early postoperative period [Fig. 3], and a normal corneal pattern was detected.

Preoperative UCVA and BCVA were counting fingers (CF) - 0.1 and CF - 0.12, respectively. Postoperative UCVA and BCVA were increased to 0.1–0.4 and 0.3–1.0,

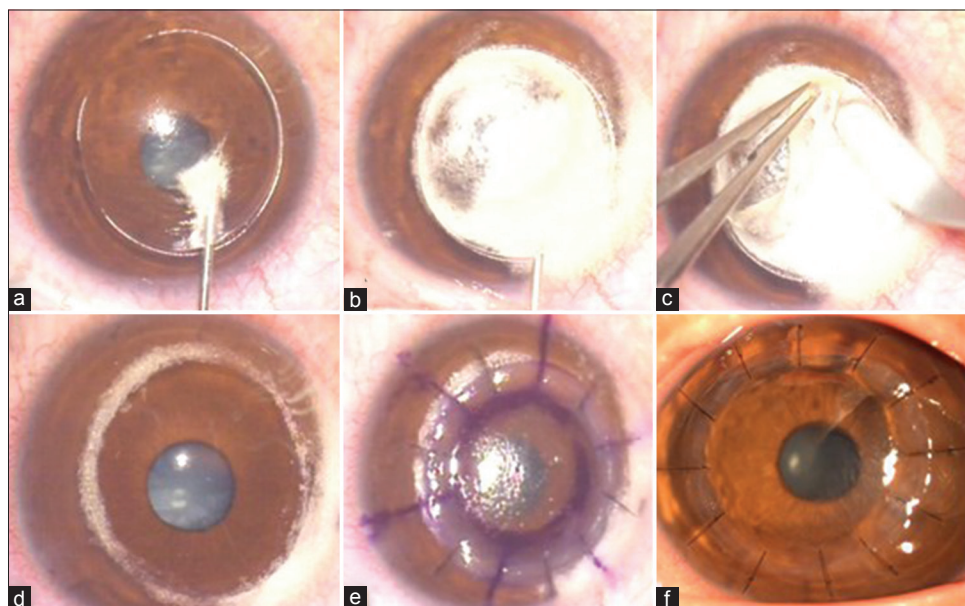


Figure 1: (a) The 27-gauge needle was inserted into the deep stroma through the femtosecond trephination groove. (b) Formation of big-bubble. (c) The crescent disposable knife was used to cut the corneal stroma. (d) Clear Descemet's membrane after removal of an entire stroma. (e) Donor tissue is placed on the host bed and sutured using 10-0 nylon suture. (f) Slit-lamp photograph showing clear corneal graft at 2 days postoperatively

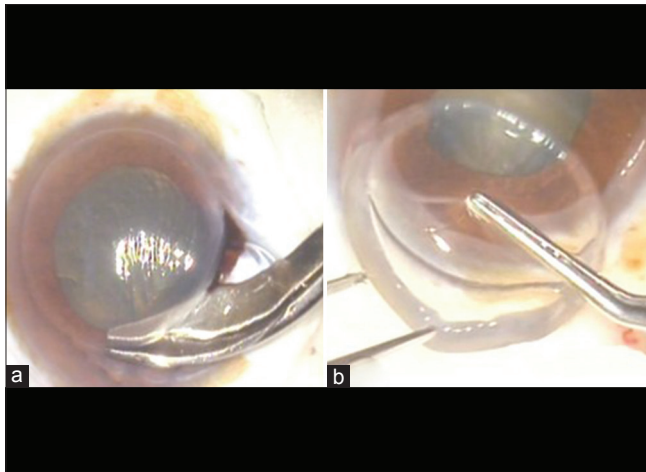


Figure 2: (a) Donor tissue was excised by corneal scissors after femtosecond laser treatment. (b) Peeling off Descemet's membrane and endothelium using forceps from the donor lamella

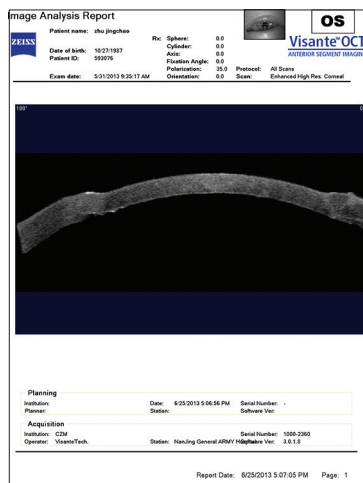


Figure 3: Excellent alignment of Descemet's membrane with the donor tissue was observed by the image of anterior segment optical coherence tomography in the patient's cornea at day 2 postoperatively

respectively. The mean corneal curvature decreased from preoperative $65.4 \pm 8.8\text{D}$ (range, from 48.6D to 75.6D) to postoperative $43.0 \pm 2.3\text{D}$ (range, from 37.2D to 46.5D), and the mean central thickness increased from preoperative $353.2 \pm 55.0 \mu\text{m}$ (range, from 200 to 430 μm) to postoperative $508.9 \pm 60.1 \mu\text{m}$ (range, from 430 to 600 μm), indicating that the corneal curvature and thickness were restored to normal.

One eye developed the steroid-induced high intraocular pressure postoperatively and resolved with steroid withdrawal. Three eyes with loosened sutures had to be removed beforehand. No other postoperative complications were observed.

Discussion

DALK is an alternative procedure to treat keratoconus instead of PKP, which could remove the diseased stroma from the recipient and replace the donor graft, with leaving the recipient DM and endothelial cells, avoiding allograft rejection, preserving the advantages of extraocular surgery,

and achieving good visual outcome.^[9]

However, the successful DALK surgeries were limited by technical difficulties, time-consuming operation, and corneal intraoperative perforation.^[10]

In this study, the 500-kHz VisuMax femtosecond laser-assisted DALK with big-bubble technique and naked DM layer were successfully achieved in 90.9% of keratoconus patients, similar to the results reported by Buzzonetti *et al.*, with the success of 85.7.9%, 73%, 100%, and 84.6% using the 60 kHz IntraLase femtosecond laser (Abbott Medical Optics, Inc., USA).^[11-13] However, it was higher than traditional big-bubble DALK reported by Fontana *et al.* with 64%,^[14] Sarnicola *et al.* 77%,^[15] Huang *et al.* 67%,^[16] and Feizi *et al.* 79.2%, respectively.^[17]

Unlike the big-bubble DALK procedures using 60 kHz IntraLase femtosecond laser with mushroom or zigzag incision on donor and recipient corneas,^[18] and conventional trephine 60%–80% thickness of the cornea by Anwar in which procedure air is injected into the deep stroma in an attempt to achieve a large air bubble between DM and stroma to facilitate pre-Descemet's plane dissection,^[2] the 500-kHz VisuMax femtosecond laser-assisted big-bubble DALK, which creates a vertical side cut on donor and recipient corneas, provides a high percentage of success in achieving the big-bubble and naked DM (90.9%) resulting from the exactly predefined corneal depth. It has been reported that the excellently naked DM will be achieved in the case of inserting the needle into the deeper stroma.^[19] There are two cases converted to PKP surgery in our study, which reduce the risk of intraoperative macroperforation, that is the main complication of DALK. Even if the big-bubble DM dissection was failed, it also provides the smooth incision when converted to PKP.

The improved UCVA and BCVA and normal corneal pattern and thickness were observed postoperatively, which demonstrated that VisuMax femtosecond laser-assisted big-bubble DALK could accelerate visual recovery and achieve good refractive outcomes with the excellent alignment of donor and recipient corneal stromal interface.

Conclusion

Our preliminary results suggest that the 500-kHz VisuMax femtosecond laser-assisted big-bubble DALK is an accurate, safe, and effective surgical method in the treatment of keratoconus. It seems to be an alternative procedure to treat keratoconus in the patients with healthy endothelium instead of conventional DALK and PKP. However, future prospective, randomized, comparative studies with more patients are needed to be conducted to verify this conclusion.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

- Romano V, Iovieno A, Parente G, Soldani AM, Fontana L. Long-term clinical outcomes of deep anterior lamellar keratoplasty in patients with keratoconus. *Am J Ophthalmol* 2015;159:505-11.
- Anwar M, Teichmann KD. Deep lamellar keratoplasty: Surgical

- techniques for anterior lamellar keratoplasty with and without baring of Descemet's membrane. *Cornea* 2002;21:374-83.
3. Farid M, Pirouzian A, Steinert RF. Femtosecond laser keratoplasty. *Int Ophthalmol Clin* 2013;53:55-64.
 4. Shehadeh-Mashor R, Chan C, Yeung SN, Lichtinger A, Amiran M, Rootman DS. Long-term outcomes of femtosecond laser-assisted mushroom configuration deep anterior lamellar keratoplasty. *Cornea* 2013;32:390-5.
 5. Price FW Jr., Price MO, Grandin JC, Kwon R. Deep anterior lamellar keratoplasty with femtosecond-laser zigzag incisions. *J Cataract Refract Surg* 2009;35:804-8.
 6. Soong HK, Malta JB, Mian SI, Juhasz T. Femtosecond laser-assisted lamellar keratoplasty. *Arq Bras Oftalmol* 2008;71:601-6.
 7. Buzzonetti L, Petrocelli G, Valente P, Iarossi G, Ardia R, Petroni S, *et al.* The big-bubble full femtosecond laser-assisted technique in deep anterior lamellar keratoplasty. *J Refract Surg* 2015;31:830-4.
 8. Lu Y, Yang L, Ge Y, Chen X, Huang Z. Femtosecond laser-assisted anterior lamellar keratoplasty for the treatment of stromal corneal pathology. *BMC Ophthalmol* 2015;15:15.
 9. Lu Y, Shi YH, Yang LP, Ge YR, Chen XF, Wu Y, *et al.* Femtosecond laser-assisted deep anterior lamellar keratoplasty for keratoconus and keratectasia. *Int J Ophthalmol* 2014;7:638-43.
 10. Buzzonetti L, Petrocelli G, Valente P. Femtosecond laser and big-bubble deep anterior lamellar keratoplasty: A new chance. *J Ophthalmol* 2012;2012:264590.
 11. Buzzonetti L, Laborante A, Petrocelli G. Standardized big-bubble technique in deep anterior lamellar keratoplasty assisted by the femtosecond laser. *J Cataract Refract Surg* 2010;36:1631-6.
 12. Buzzonetti L, Petrocelli G, Valente P. Big-bubble deep anterior lamellar keratoplasty assisted by femtosecond laser in children. *Cornea* 2012;31:1083-6.
 13. Buzzonetti L, Laborante A, Petrocelli G. Refractive outcome of keratoconus treated by combined femtosecond laser and big-bubble deep anterior lamellar keratoplasty. *J Refract Surg* 2011;27:189-94.
 14. Fontana L, Parente G, Tassinari G. Clinical outcomes after deep anterior lamellar keratoplasty using the big-bubble technique in patients with keratoconus. *Am J Ophthalmol* 2007;143:117-24.
 15. Sarnicola V, Toro P, Gentile D, Hannush SB. Descemetic DALK and predescemetic DALK: Outcomes in 236 cases of keratoconus. *Cornea* 2010;29:53-9.
 16. Huang T, Zhang X, Wang Y, Zhang H, Huand A, Gao N. Outcomes of deep anterior lamellar keratoplasty using the big-bubble technique in various corneal diseases. *Am J Ophthalmol* 2012;154:282-9.e1.
 17. Feizi S, Javadi MA, Daryabari SH. Factors influencing big-bubble formation during deep anterior lamellar keratoplasty in keratoconus. *Br J Ophthalmol* 2015;8:307111.
 18. Farid M, Steinert RF. Deep anterior lamellar keratoplasty performed with the femtosecond laser zigzag incision for the treatment of stromal corneal pathology and ectatic disease. *J Cataract Refract Surg* 2009;35:809-13.
 19. Vajpayee RB, Tyagi J, Sharma N, Kumar N, Jhanji V, Titiyal JS. Deep anterior lamellar keratoplasty by big-bubble technique for treatment corneal stromal opacities. *Am J Ophthalmol* 2007;143:954-7.