Femtosecond laser-assisted corneal transplantation

Alireza Baradaran-Rafii, Medi Eslani

INTRODUCTION

The femtosecond laser (FSL) is a focusable infrared laser that delivers ultrashort pulses in the femtosecond duration range. Contiguous pulses are placed at a definite depth within the cornea, thus resecting only targeted tissue. This surgical device allows cutting of corneal tissue in a number of reproducible, customised transplant designs, and allows the use of sagittal plane trephination profiles, such as zigzag, top-hat, Christmas tree and mushroom shapes to improve wound stability and, probably, postoperative astigmatism.[1–5] The unique capability of the FS laser to photodisrupt tissue with minimal collateral damage has made it a promising tool for increasing accuracy and predictability in corneal surgery.[6] It has mainly been used in refractive surgery, for example, for flap preparation in Laser in Situ Keratomileusis (LASIK), for intrastromal corneal ring segments (ICRS) implantation in keratoconus patients[7] or astigmatic keratotomy.

SURGICAL INDICATION

Penetrating keratoplasty (PKP) has been the treatment of choice for advanced cases of keratoconus for a long time. During the past decade, however, deep anterior lamellar keratoplasty (DALK) has regained more popularity in the treatment of keratoconus. The advantages of DALK over PKP surgery are: no corneal endothelial rejection; it is an extraocular procedure; early discontinuation of topical corticosteroids, minor loss of endothelial cells; possible superior resistance to rupture of the globe after blunt trauma; and the potential for early removal of sutures.[8] With the advent of newer techniques and instrumentations, visual and refractive outcomes of DALK have been reported comparable with PKP.[9] Therefore, in moderate keratoconus, cases with clear visual axis and intolerance to contact lenses who do not wish to try ICRS, DALK may be the surgical indication of choice. Overusage of PKP should be avoided. Especially in keratoconus, a very well done DALK may yield the same refractive and visual outcomes as PKP with a lower risk of rejection.

Femtosecond laser-assisted anterior lamellar keratoplasty (F-ALK)

Femtosecond laser ALK surgery with sutures has been previously reported.[10] However, the reproducibility of the lamellar cuts in the donor and recipient corneas may decrease the necessity of corneal suturing. The absence of sutures may allow for early visual rehabilitation, induce less astigmatism, and avoid other suture-related complications. The good fit may also reduce significant refractive shift postoperatively. It has been claimed that postoperative refractive astigmatism in sutureless F-ALK may even be less than that reported in the literature for PKP and various forms of ALK. Future randomised prospective clinical trials with long-term follow-up are needed to test the advantages of using sutures versus sutureless surgery. The question of whether non-suturing of the donor corneal lenticule to the recipient bed increases the risk of donor lenticule loss, dehiscence or epithelial ingrowth should be answered in future studies.

Although ALK may remove the anterior corneal opacity or be used in the surgical treatment of moderate keratoconus, it may not be the surgical treatment of choice in these cases. It has been shown that the quality of vision after microkeratome-assisted ALK is not as good as DALK or PKP. The contrast sensitivity and aberrometric profile after F-ALK, which has not been reported yet, is related to the residual recipient corneal stromal thickness and interface irregularity.[8] Creating a smoother and more regular recipient-donor interface with more advanced femtosecond machines may improve the quality of vision. This issue should be addressed in future studies.

The amount of posterior corneal thickness needed to preserve the tectonic stability of the cornea in sutureless ALK is not yet known. In cases with insufficient amounts of posterior recipient tissue after the cut, or in ectatic conditions, such as keratoconus, suturing the graft might be a logical alternative for protecting the cornea against the induction or exacerbation of ectasia.

Femtosecond laser-assisted deep anterior lamellar keratoplasty (F-DALK)

In the last decade, with the advances in instrumentation and techniques, DALK has regained more popularity as a safer alternative to PKP achieving comparable visual outcomes.[8] Femtosecond laser can be used as a precise surgical knife in deep lamellar dissection of the cornea.[5] However, it can dissect the cornea in a predetermined depth from the surface. Therefore, in cases with irregular corneal thickness, such as keratoconus, the remaining stromal bed would be irregular with an undulating thickness. It is well known that visual acuity is related to the residual recipient corneal stromal thickness.[8] The quality of vision after DALK is comparable with PKP when stromal excision is extended to the Descemet membrane, and inferior to PKP when layers of stroma are left adherent to the Descemet membrane. As a result, F-DALK, generally, should be combined with manual stromal dissection, or air injection into the remaining stroma, to expose the Descemet membrane.

Femtosecond laser-assisted penetrating keratoplasty (F-PKP)

FSLs are capable of creating circular through or multiplanar incisions for corneal trephinations for PKP, which potentially increase graft-host interface surface area, better wound apposition, fit and stability.[11] That is possible only in relatively clear corneas, and not in the limbal region. As a result, F-PKP combines the excellent visual outcomes of PKP with the wound-healing advantages of DALK. In addition, less endothelial damage, less undercutting of the cornea, and more wound healing response occurs with FSLs.[12] Faster healing may lead to an earlier functional recovery.[5]

Several transplant forms including conventional circular, top-hat, mushroom, zigzag, decagonal or Christmas tree designs have been reported in previous studies.[13] It has been claimed that the decagonal shape decreases the torque effect associated with a circular graft during suture placement and allows a stable fitting of the graft into the recipient, because it provides the strength of a circular shape with the stability given by the angles of the polygonal design.[14] The diameter of the posterior surface of the donor can be adjusted in F-PKP according to different purposes. In patients with endothelial insufficiency, the top-hat configuration increases the amount of endothelial cells transplanted. In patients with keratoconus, a mushroom configuration maximises retention of the host's endothelium and minimises the possibility of graft

Ophthalmic Research Center, Labbafinejad Medical Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Correspondence to Professor Alireza Baradaran-Rafii, Department of Ophthalmology, Labbafinejad Medical Center, Boostan 9 Street, Pasdaran Avenue, Tehran 16666, Iran; alirbr@gmail.com

rejection. The top-hat shape is thought to be the most biomechanically stable wound configuration.

Postoperative astigmatism is the most important limiting factor for visual recovery after PKP.[15] In theory, performing same-cut profile on both donor and recipient cornea may reduce corneal astigmatism. However, different levels of astigmatism have been reported after F-PKP,[4 16 17] which may be due to different follow-up periods, surgeon experiences, different incision profiles, suture removal status and so on. There are many factors contributing to surgical astigmatism, among them suturing technique and surgeon expertise are very important. These issues still exist after FSL-assisted corneal transplantation. Despite the dramatic increase in incision accuracy and profile with FSLs, surgeon factor still plays a very important role in postoperative astigmatism. At the present time, it seems that visual and refractive outcomes are comparable with outcomes after conventional trephination techniques.[4]

There are many unidentified issues that should be evaluated in future studies, including best donor-recipient disparity, best incision profile for specific indications, its strength and stability versus conventional PKP, overlap width, average graft diameter and so on.

Femtosecond laser-assisted Descemet stripping automated endothelial keratoplasty (F-DSAEK)

The FSL also has been used to prepare lamellar donor buttons for DSAEK.[18 19] Old-generation FSLs for DSAEK caused poorer cut quality than microkeratomes.[20] Therefore, the visual acuity after F-DSAEK was reported to be lower than that after conventional DSAEK. Lamellar cuts are restricted to depth adjustments by microkeratome head sizes, and the button thickness is poorly reproducible. Buttons created with FSL are more planar shaped and thinner which could be beneficial for visual outcomes. New-generation high-frequency FSLs can create much smoother buttons.[21] However, the smoothness and regularity of the stromal interface still need to be optimised with better laser settings.[21] With appropriate FS settings, the double-layer profile may create smoother and more even interfaces across both the mid-stroma and the buttons' side.[21] With newer-generation FSLs, there is no significant difference in contrast sensitivity, stray light and Best Spectacle-Corrected Visual Acuity (BSCVA) between the F-DSAEK and PKP.[19 22]

A high frequency allows a decrease in spot size and steps. This lowers the energy required to achieve the lamellar cut effectively and preserve endothelial cell viability.[21] The deeper into the corneal stroma the full lamellar cut, the rougher the interface created. The double-layer profile can create reproducible lenticules less than 150 μm thick with little energy and less gas diffusing, thus preventing possible endothelial toxicity.[21] Curved corneal applanators that induce less distortion to the anterior surface of the cornea, could, theoretically, reduce concentric ridges reported in the tissue interfaces prepared by the FSL with flat applanators.

Future horizon

Newer faster-generation machines enable decreasing the relatively long FSL operative time and, most importantly, allowing the placement of more spots with less spacing in between. This results in faster and sharper cutting machines that produce smoother interfaces and probably better visual outcomes. In addition, increasing the density of the laser spots allows using lower energy that can, theoretically, minimise the FSL complications related to the use of high-energy laser spots. The high costs and lack of portability are currently the most important limiting factors for widespread use of this technique.

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REFERENCES

1 Tan DT, Dart JK, Holland EJ, *et al*. Corneal transplantation. *Lancet* 2012;379:1749–61.
2 Farid M, Steinert RF. Femtosecond laser-assisted corneal surgery. *Curr Opin Ophthalmol* 2010;21:288–92.
3 Bahar I, Kaiserman I, Lange AP, *et al*. Femtosecond laser versus manual dissection for top hat penetrating keratoplasty. *Br J Ophthalmol* 2009;93:73–8.
4 Birnbaum F, Wiggermann A, Maier PC, *et al*. Clinical results of 123 femtosecond laser-assisted penetrating keratoplasties. *Graefes Arch Clin Exp Ophthalmol* Published Online First: 11 May 2012. doi:10.1007/s00417-012-2054-0
5 Price FW Jr, Price MO. Femtosecond laser shaped penetrating keratoplasty: one-year results utilizing a top-hat configuration. *Am J Ophthalmol* 2008;145:210–14.
6 Shousha MA, Yoo SH. New therapeutic modalities in femtosecond laser-assisted corneal surgery. *Int Ophthalmol Clin* 2010;50:149–60.
7 Ertan A, Kamburoglu G. Intacs implantation using a femtosecond laser for management of keratoconus: Comparison of 306 cases in different stages. *J Cataract Refract Surg* 2008;34:1521–6.
8 Reinhart WJ, Musch DC, Jacobs DS, *et al*. Deep anterior lamellar keratoplasty as an alternative to penetrating keratoplasty a report by the american academy of ophthalmology. *Ophthalmology* 2011;118:209–18.
9 Funnell CL, Ball J, Noble BA. Comparative cohort study of the outcomes of deep lamellar keratoplasty and penetrating keratoplasty for keratoconus. *Eye (Lond)* 2006;20:527–32.
10 Mosca L, Fasciani R, Tamburelli C, *et al*. Femtosecond laser-assisted lamellar keratoplasty: early results. *Cornea* 2008;27:668–72.
11 Price FW Jr, Price MO, Grandin JC, *et al*. Deep anterior lamellar keratoplasty with femtosecond-laser zigzag incisions. *J Cataract Refract Surg* 2009;35:804–8.
12 Angunawela RI, Riau A, Chaurasia SS, *et al*. Manual suction versus femtosecond laser trephination for penetrating keratoplasty: intraocular pressure, endothelial cell damage, incision geometry, and wound healing responses. *Invest Ophthalmol Vis Sci* 2012;53:2571–9.
13 Bahar I, Kaiserman I, McAllum P, *et al*. Femtosecond laser-assisted penetrating keratoplasty: stability evaluation of different wound configurations. *Cornea* 2008;27:209–11.
14 Proust H, Baeteman C, Matonti F, *et al*. Femtosecond laser-assisted decagonal penetrating keratoplasty. *Am J Ophthalmol* 2011;151:29–34.
15 Wiffen SJ, Maguire LJ, Bourne WM. Keratometric results of penetrating keratoplasty with the Hessburg-Barron and Hanna trephine systems using a standard double-running suture technique. *Cornea* 1997;16:306–13.
16 Farid M, Steinert RF, Gaster RN, *et al*. Comparison of penetrating keratoplasty performed with a femtosecond laser zig-zag incision versus conventional blade trephination. *Ophthalmology* 2009;116:1638–43.
17 Chamberlain WD, Rush SW, Mathers WD, *et al*. Comparison of femtosecond laser-assisted keratoplasty versus conventional penetrating keratoplasty. *Ophthalmology* 2011;118:486–91.
18 Cheng YY, Pels E, Nuijts RM. Femtosecond-laser-assisted Descemet's stripping endothelial keratoplasty. *J Cataract Refract Surg* 2007;33:152–5.
19 Cheng YY, van den Berg TJ, Schouten JS, *et al*. Quality of vision after femtosecond laser-assisted descemet stripping endothelial keratoplasty and penetrating keratoplasty: a randomized, multicenter clinical trial. *Am J Ophthalmol* 2011;152:556–66.
20 Yoo SH, Hurmeric V. Femtosecond laser-assisted keratoplasty. *Am J Ophthalmol* 2011;151:189–91.
21 Rousseau A, Bensalem A, Garnier V, *et al*. Interface quality of endothelial keratoplasty buttons obtained with optimised femtosecond laser settings. *Br J Ophthalmol* 2012;96:122–7.
22 Bahar I, Kaiserman I, McAllum P, *et al*. Comparison of posterior lamellar keratoplasty techniques to penetrating keratoplasty. *Ophthalmology* 2008;115:1525–33.

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