Femtosecond Lasers and Corneal Transplantation

Each installment of the "Peer Review" column examines an important issue in ophthalmology through key studies from the peer-reviewed literature selected by Section Editor Mitchell C. Shultz, MD.

OVERVIEW

According to a review by Mian and Shtein,[1] surgeons exclusively relied on mechanical, bladed microkeratomes to prepare corneal tissue for use in penetrating keratoplasty until the introduction of femtosecond technology approximately 8 years ago. Femtosecond lasers such as the IntraLase FS (Advanced Medical Optics, Inc., Santa Ana, CA), the Femtec (20/10 Perfect Vision, Heidelberg, Germany), and the Femto LDV (Ziemer Ophthalmic Systems AG, Port, Switzerland) use photodisruptive energy to vaporize small volumes of corneal tissue. These lasers not only allow surgeons to create corneal flaps for LASIK, but they also enable ophthalmologists to customize the edges of grafts removed from donor and recipient corneas for transplantation. In addition, surgeons have used femtosecond lasers to divide donated corneal tissue into anterior and posterior lamellar segments for use in partial-thickness and Descemet's stripping endothelial keratoplasty (DSEK).

Stephen G. Slade, MD, provided a general overview of the IntraLase FS laser and summarized the results of early clinical trials in which surgeons performed IntraLase-enabled keratoplasty (IEK).[2] The laser's specialized software allows surgeons to vary the angle of the flap's side cuts (range, 30° to 150°) and to create cuts resembling a top hat, an inverted mushroom, a zigzag, or a Christmas tree. All of these cuts, Dr. Slade wrote, are designed to provide a larger area of contact at the interface of donor/recipient tissue and to increase the wound's stability. The goals are to reduce the number of sutures needed to hold the graft in place and minimize the amount of astigmatism induced by the sutures.

THE WOUND'S CONFIGURATIONS

An experimental laboratory evaluation of cadaveric corneas showed that incisions shaped like a top hat (n = 5) created with the IntraLase FS laser were more stable and less likely to leak than those with edges that were vertical (n = 5) or shaped like a mushroom (n = 5), a zigzag (n = 4), or a Christmas tree (n = 4).[3] When the corneal buttons were secured to an artificial anterior chamber with 16 sutures, the top-hat configuration withstood a mean simulated IOP of 102 ±16.8 mm Hg before bursting, more than twice as much pressure as was required to rupture tissue prepared with a straight vertical cut (49 ±6.6 mm Hg). Under similar conditions, the buttons shaped like a zigzag, Christmas tree, and mushroom began to leak at simulated IOPs of 48 ±5.3, 52.3 ±5.6, and 65.8 ±5.3 mm Hg, respectively.

A laboratory study suggested that leaving uncut gaps in recipient corneas during dissection with a femtosecond laser reduced the risk that the wound would rupture as patients were transported between surgical centers.[4] The investigators determined that flaps shaped like top hats with 100-µm gaps in their side cuts (n = 4) could withstand higher mean pressures without bursting (1,564.8 mm Hg) than those that were (1) completely dissected (n = 4; 110.8 mm Hg), (2) had 50-µm gaps in their side cuts (n = 4; 746.8 mm Hg), (3) had 100-µm gaps in their lamellar cuts (n = 4; 550.3 mm Hg), or (4) had 50-µm gaps in their lamellar cuts (n = 4; 392.3 mm Hg). Leaving a 100-µm gap between the lamellar and the posterior side cuts, however, reportedly helped achieve an optimal balance between patients' safety and the ease with which the investigators could remove the dissected tissue from the recipient corneas.

The use of a top-hat configuration appeared to quicken healing and the removal of corneal sutures (mean, 7.0 ±1.9 months) in a prospective, nonrandomized clinical study of six patients treated with IEK.[5] By 1 year postoperatively, the mean density of endothelial cells measured 2,030 ±600 cells/mm^2, and the patients' postoperative BSCVAs ranged from 20/400 to 20/25. The investigators also noted that the presence of corneal scars did not affect the ability of the IntraLase FS laser to create consistently sized buttons of tissue shaped like top hats, and they reported that "near-same sizing of both anterior and posterior dimensions in the donor and host results in the best long-term wound apposition."[5]

In a prospective, interventional case series, surgeons selectively removed sutures 3 months postoperatively from the eyes of five of seven patients who underwent IEK with grafts shaped like a top hat or a mushroom to address astigmatism.[6] The shapes of the grafts were chosen based on the disease they were intended to treat. Therefore, eyes with endothelial disease (ie, bullous keratopathy and Fuchs' dystrophy) received buttons shaped like top hats (anterior diameter = 7 mm; posterior diameter = 9 mm), and keratoconic eyes received buttons shaped like a mushroom (anterior diameter = 9 mm; posterior diameter = 7 mm).[6,7] At 3 months postoperatively, all of the patients' central corneal pachymetry measurements and endothelial cell counts were within the normal range (496 µm and 2,314 cells/mm^2). The observed degree of mean refractive astigmatism in these patients (2.90 D at 3 months) was similar to that reported in larger case series, according to this study's investigators.

Using the IntraLase FS laser to create matching zigzag-shaped incisions in donor and recipient corneas also produced structurally stable wounds that induced less than 3.00 D of postoperative astigmatism in a small series of patients (n = 13).[8] By 3 months postoperatively, seven of the eight eyes (87.5%) that had the potential to achieve normal vision after corneal transplantation had BSCVAs of 20/30 or better. The postoperative outcomes of the remaining five eyes were affected by visually significant macular or optic nerve disease. As observed with other graft configurations created with the IntraLase FS, the large area of apposition created by the zigzag-shaped cut appeared to facilitate healing (indicated by an increased signal on anterior segment OCT [Visante; Carl Zeiss Meditec, Inc., Dublin CA] by 1 month postoperatively), and it allowed the surgeon to remove sutures from at least one eye by 3 months postoperatively.

PARTIAL-THICKNESS CORNEAL GRAFTS

In a retrospective, noncomparative case series, investigators used the 30-kHz IntraLase FS laser to perform anterior lamellar keratoplasty on 12 patients whose vision was partially obscured by corneal scars.[9] After removing similarly sized lenticular grafts from the donor and recipient eyes (n = 12; thickness = 160 to 170 µm), the investigator placed the donated tissue onto the patients' eyes under a corneal flap and applied a bandage contact lens. At last follow-up (mean, 12.7 months), the patients' mean UCVA and BSCVA improved by 2.5 and 3.8 lines, respectively. Based on the lack of intraoperative complications and the ability of the femtosecond laser to dissect partial-thickness grafts from scarred corneas, the investigators concluded that femtosecond-assisted anterior lamellar keratoplasty "seems to be an alternative to conventional [anterior lamellar keratoplasty] and [penetrating keratoplasty] without significant short-term complications."[9]

Four months after receiving a posterior corneal disc dissected from a donor eye with the IntraLase FS laser, an 82-year-old man's BCVA improved from count fingers at 1 meter to 20/50.[10] According to the study's authors, the case is remarkable because they used the femtosecond laser to create a deep horizontal lamellar interface in the donor cornea approximately 3 weeks before the patient underwent DSEK. Immediately prior to the transplant procedure, the surgeons trephined an 8.0-mm corneal button from the donor eye and separated it into anterior and posterior portions. They then replaced the diseased tissue stripped from the patient's eye (a 7.0-mm circle of Descemet's membrane and endothelium) by inserting the posterior button into its anterior chamber through a 5.5-mm corneoscleral incision. Because the graft was not secured with sutures, the procedure reportedly prevented the patient from developing the irregular astigmatism that is frequently induced by penetrating keratoplasty.

The DSEK technique described by Cheng et al[10] did not adversely affect the density of endothelial cells in 14 posterior lamellar discs dissected from cadaveric corneas that were not suitable for transplantation.[11] Each of the discs was composed of posterior stroma, Descemet's membrane, and endothelium. Although scanning electron microscopy showed that posterior lamellar discs stored in organ culture for a mean of 7.3 ±5.3 days lost more endothelial cells from baseline when the corneas were prepared with the IntraLase FS laser set at 15 kHz (n = 8; 7.7 ±6.9%) versus 30 kHz (n = 6; 4.3 ±4.0%), the difference was not statistically significant. Dissecting the posterior discs from the corneoscleral button with forceps, however, was associated with a greater loss of endothelial cells than the use of blunt dissection (13.0% vs 6.5%, respectively).

OTHER FEMTOSECOND LASERS

To date, most femtosecond-assisted full- and partial-thickness corneal transplantations have been performed with the IntraLase FS laser. In a prospective interventional case series of penetrating keratoplasties performed with the Femtec femtosecond laser, this technology also produced good visual outcomes in patients with corneal pathology (n = 8).[12] Preoperatively, the patients had BCVAs of hand motion only (n = 1), count fingers (n = 6), or 20/400 (n = 1). The investigators used the Femtec laser to remove straight-edged, circular corneal buttons from the donor and recipient eyes. The donated tissue, which had a slightly larger diameter than that removed from the recipient eyes (range, 0.25 to 0.50 mm), was secured to the corneal surface with 16 10–0 nylon sutures. By 3 months postoperatively, all but two of the patients saw 20/80 or better (range, 20/80 to 20/20), and the mean cylindrical refractive error measured 2.53 D (range, 0.50 to 5.50 D).

The addition of full-thickness orientation teeth and notches to the edges of corneal buttons created with the Femtec femtosecond laser appeared to facilitate the grafts' precise placement and improve their rotational stability on four recipient corneas, according to a prospective interventional case series.[13] High-powered slit-lamp photography obtained at 3 months postoperatively showed strong apposition between the customized grafts' orientation teeth and the corresponding notches on the patients' corneas. The investigators also observed a significant improvement in the patients' BSCVAs from baseline at 6 months postoperatively (20/400 to 20/32; 20/100 to 20/40; 20/160 to 20/25; and count fingers to 20/50). ■

In their published studies, Francis W. Price, MD, and Sonia H. Yoo, MD, disclosed that they are consultants to Advanced Medical Optics, Inc.

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