Refractive Outcome of Keratoconus Treated by Combined Femtosecond Laser and Big-bubble Deep Anterior Lamellar Keratoplasty

Luca Buzzonetti, MD; Antonio Laborante, MD; Gianni Petrocelli, MD

ABSTRACT

PURPOSE: To report 1-year follow-up in 11 of 13 eyes with keratoconus treated by deep anterior lamellar keratoplasty with a combined femtosecond laser lamellar resection followed by a big-bubble dissection.

METHODS: Thirteen eyes with keratoconus were treated. Recipient and donor were prepared with the 60-kHz IntraLase femtosecond laser (Abbott Medical Optics). In the recipient, the femtosecond laser, after performing a lamellar cut 100 µm above the thinnest corneal point (measured by Pentacam [Oculus Optikgeräte GmbH]), was used to make a mushroom-shaped resection (anterior diameter, 9 mm; posterior diameter, 8 mm) from the same depth. In the donor, the mushroom lamellar thickness was calculated according to an original model based on the recipient preoperative corneal thickness. Upon removal of the recipient lamella, air was injected into the residual stroma to achieve a big bubble. The keratectomy was continued up to Descemet membrane. The donor was fit into place and sutured using interrupted sutures, which were removed by 8 months postoperative. Corrected distance visual acuity (CDVA) and refractive astigmatism were calculated by manifest refraction, whereas topographic astigmatism and corneal thickness were measured by Pentacam.

RESULTS: A big bubble was successfully achieved in 11 eyes. Twelve months after surgery, mean CDVA was 0.52 ± 0.11 (decimal), and refractive sphere and cylinder were −1.50 ± 1.70 diopters (D) and 2.00 ± 2.60 D, respectively. Three (27%) of 11 eyes at 1 year had a manifest refraction spherical equivalent within 1.00 D of emmetropia. Topographic astigmatism was 2.90 ± 1.60 D. The thinnest corneal point was 519 ± 27 µm.

CONCLUSIONS: This combination of a femtosecond laser lamellar dissection with a big-bubble technique can improve the standardization of deep anterior lamellar keratoplasty for keratoconus. [J Refract Surg. 2010;xx(xx):xxx-xxx.] doi:10.3928/1081597X

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APA


Each step of the technique is presented:

1. A recipient lamellar cut 8.2 mm in diameter with a 90° side-cut is created by the IntraLase femtosecond laser using a target thickness of 100 µm above the thinnest corneal point as measured by the Pentacam.

2. A mushroom lamella (anterior diameter, 9.0 mm; posterior diameter, 8.0 mm) is created by the IntraLase using the same target thickness of the lamellar cut (100 µm above the thinnest corneal point as measured by the Pentacam) because the lamellar cut depth must correspond to the bottom side depth of the mushroom lamella; its diameter (8.2 mm) is greater than the posterior diameter of the mushroom lamella (8.0 mm) to make removal of the lamella easier.

3. The recipient lamella is removed (Fig 1A) and a 30-gauge disposable needle, attached to a 5-mL syringe filled with air and bent at 60° with the bevel facing down, is inserted into the residual stroma, within the inner limit of the plane created from the IntraLase, and slightly advanced toward the center of the cornea.

4. Air is forcefully injected into the stroma to achieve formation of a big bubble (Fig 1B). A peripheral paracentesis is performed, allowing some aqueous to escape to lower the intraocular pressure.

5. The keratectomy is completed with a crescent knife (Fig 1C) up to Descemet membrane (Fig 2).

6. The donor lamella is fit into place and sutured using 14 or 16 interrupted 10-0 monofilament nylon sutures (Fig 1D).

Sutures were selectively removed by 8 months postoperatively, depending on the stitch loosening and postoperative astigmatism. In some patients, single stitches were removed 1 month after surgery. Mean spherical equivalent refraction and refractive and topographic astigmatism progressively changed according to suture removal, but in our cases, the timing of removal was too different in each patient to evaluate its possible effects on the 1-year results.

To achieve a suitable postoperative corneal thickness, we propose a method to create lamellae of different thicknesses in recipient and donor lamellae using the IntraLase femtosecond laser (Fig 3). We defined two constant values: 80 µm (the approximate amount of stroma dissected to reach the Descemet plane in the recipient) and 20 µm (corresponding to the theoretical residual thickness of the Descemet membrane–endothelium complex). Ring lamellar cut and full lamellar cut depth are reference parameters in laser settings and the ring lamellar cut usually corresponds to half of the full lamellar cut. The length of the donor inner part of the

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**TABLE 1**

<table>
<thead>
<tr>
<th>Laser Energy (µJ)</th>
<th>Spot and Line Separation (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamellar cut</td>
<td>2.0</td>
</tr>
<tr>
<td>Side-cut</td>
<td>2.5</td>
</tr>
</tbody>
</table>

*Big-bubble deep anterior lamellar keratoplasty with IntraLase femtosecond laser.
mushroom resection is calculated by adding the recipient full lamellar cut to 80 µm plus the thickness factor. The thickness factor is the sum of 20 µm plus a variable value. The thickness factor could be defined as a variable value different for each patient, corresponding to the intended increase calculated to achieve a suitable postoperative corneal thickness. We routinely planned a postoperative increase of 120 µm; however, further studies are needed to evaluate whether an individual thickness increase coefficient can be calculated.

The corneal depth of the donor ring lamellar cut is calculated by adding the thickness factor to the recipient ring lamellar cut depth to overlap the ring lamellar cut in the recipient and donor lamella.

The length of the recipient and donor inner and outer part of the mushroom resection changes in each patient, depending on the preoperative corneal thickness.

**RESULTS**

Thirteen eyes of 13 patients with keratoconus were treated with the IntraBubble technique and a big bubble was successfully achieved in 8 eyes. Intraoperative perforation of Descemet membrane occurred in 2 cases, but only in 1 case was the surgical procedure intraoperatively converted to full thickness keratoplasty because of a large tear of the Descemet membrane.

At 1, 3, 6, and 12 months postoperatively, mean decimal CDVA was 0.25±0.1, 0.35±0.1, 0.41±0.1, and 0.52±0.2, respectively; mean spherical equivalent refraction was −1.20±2.90 diopters (D), −0.50±3.40 D, −1.90±3.10 D, and −2.50±2.70 D, respectively (Table 2). Mean refractive and topographic astigmatism values were 1.00±2.30 D and 6.50±2.70 D at 1 month, 0.30±5.50 D and 4.40±1.70 D at 3 months, 1.20±3.00 D and 3.90±1.50 D at 6 months, and 2.00±2.60 D and 2.90±1.60 D at 12 months, respectively. The mean thinnest corneal point was 485±69 µm, 487±66 µm, 502±47 µm, and 519±27 µm at 1, 3, 6, and 12 months postoperatively, respectively (Table 3). At last follow-up, mean topographic keratometry was 46.28±2.60 D.

**DISCUSSION**

Several authors have observed the high precision of the IntraLase femtosecond laser in corneal lamellar surgery. They reported on the quality and precision of the femtosecond laser engine obtained through a
lower pulse energy and spot separation settings, and on the high reproducibility of cuts performed in donor and host tissue.8

Buratto and Bohm6 reported that the IntraLase femtosecond laser improves and simplifies the preparation of the corneal tissue for PK, creating corneal buttons of differing shapes depending on the corneal disease, and increasing the contact area between donor and recipient, thus resulting in faster and better wound healing and reduced suture-induced astigmatism.

Farid and Steinert10 recently described a case report in which deep anterior lamellar keratoplasty was performed with the IntraLase zigzag incision for the treatment of keratoconus. The IntraLase was planned to maintain a 70-μm posterior residual stroma, whereas the donor was ordered as precut tissue (zigzag and anterior corneal diameter specified). A 30-gauge disposable sharp needle attached to a 5-mL syringe filled with air and bent at 60° with the bevel facing down was inserted into the stroma along the lamellar cut 70 μm above the thinnest corneal point.

Price et al11 described a technique for deep anterior lamellar keratoplasty that uses IntraLase zigzag incisions created 70 μm from the thinnest corneal thickness measurement, providing a reference for gauging the dissection depth in case of manual dissection of the residual stroma, and an interlocked configuration that better fit the recipient and donor. Also in this procedure, a needle is inserted into the stromal bed, at the edge of the zigzag incision, to inject air into the posterior stroma to achieve a big bubble.

We report 1-year follow-up after big-bubble deep anterior lamellar keratoplasty assisted by the IntraLase femtosecond laser (IntraBubble). The IntraBubble combines femtosecond technology to the big-bubble technique for deep anterior lamellar keratoplasty in an attempt to improve the reproducibility of the latter. Deep anterior lamellar keratoplasty, an alternative to PK in cases with a healthy endothelium, is the first choice for many surgeons who appreciate the advantages of extraocular surgery and the associated good visual outcome. However, because technical difficulties, protracted operating times, and the risk of corneal intraoperative perforation limit the success of deep anterior lamellar keratoplasty, many deep corneal cleavage methods have been proposed. The use of pneumatic pressure to detach Descemet membrane by injecting air into the deep stroma1 showed several advantages, but also some limitations. In fact, experimental models for learning about and practicing big-bubble deep anterior lamellar keratplasty,12 as well as variants of this technique,13 were proposed to reduce intraoperative variables.

Use of the femtosecond laser allows a partial standardization of the big-bubble technique. The femtosecond laser is more accurate in achieving the desired corneal depth than the manual technique, making the big-bubble technique relatively fast and reproducible. Also, because air injection can be performed close to

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**Figure 3. Left** The recipient is shown with a hypothetical preoperative corneal thickness of 400 μm. The full lamellar cut depth is 300 μm, whereas the ring lamellar cut depth is 150 μm. **Right** The donor full lamellar cut depth is calculated by adding the recipient full lamellar cut, 300 μm, to 80 μm (the constant corresponding to the amount of stroma dissected to reach the Descemet membrane plane in the recipient) plus the thickness factor (T factor) of 120 μm (the T factor is the sum of 20, a constant value corresponding to the theoretical residual thickness of the Descemet membrane-endothelium complex, plus a variable value—in this case 100 μm; it is different for each patient and corresponds to the intended increase calculated to achieve a suitable postoperative corneal thickness). The corneal depth of the donor ring lamellar cut is calculated by adding the T factor (120 μm) to the recipient ring lamellar cut depth (150 μm) to overlap the ring lamellar cut in recipient and donor. The length of the inner part of the mushroom cut is similar in the recipient and donor (230 μm) to overlap the ring lamellar cut and to achieve the postoperative intended corneal thickness.
the endothelium, the surgeon can easily find the reference plane for performing manual dissection. We propose a model to calculate the lamellar depth for recipient and donor lamella that provides a suitable postoperative corneal thickness (see Fig 3).

If intraoperative perforation were to occur, conversion to PK using the mushroom configuration produces a more favorable environment for surgery, resulting in a better fit of the donor lamella and faster visual recovery for the patient.\(^6\) In our opinion, the IntraBubble technique could also reduce the learning curve of the big-bubble technique.

One limitation of our technique is that, in contrast to normal use, the recipient has to undergo laser treatment before the donor, whose lamellar thickness depends on the final surgical procedure (deep anterior lamellar keratoplasty or PK). In this study, we used the mushroom configuration because of our satisfactory experience with this shape in PK assisted by IntraLase performed previously; however, we realize that the need to spare the recipient endothelium is not an issue in deep anterior lamellar keratoplasty, eliminating the main rationale for the mushroom shape. The zigzag profile may provide better outcomes.

Fontana et al\(^{14}\) reported clinical outcomes after 78 big-bubble deep anterior lamellar keratoplasties with 24-month follow-up. Twelve months postoperatively, CDVA was 0.736±0.182, spherical equivalent refraction was −1.56±3.22 D, topographic astigmatism was 3.35±1.76 D, and central corneal thickness was 503.58±41.53 μm. In our cases, topographic astigmatism was probably lower because the mushroom configuration provides a more regular contact area between the donor and recipient, whereas CDVA, which was worse than that reported by Fontana et al,\(^{14}\) could have been affected by the interface between the donor lamella and the recipient Descemet membrane. We did not observe double anterior chamber; however, in subsequent studies, an imaging evaluation would be useful to document the interface. Little is currently known about the quality of the interface created with the various lamellar dissection techniques. Brown et al,\(^{15}\) using optical coherence tomography to perform a noninvasive in situ characterization of eye bank corneal tissue processed for lamellar keratoplasty, observed the presence of debris at the interface after the IntraLase femtosecond laser cut, probably due to the nature of the tissue separation. However, presently, the IntraBubble technique does not provide better refractive results than the standard big-bubble technique.

Seitz et al\(^{16}\) reported that different from laser trephination where donor and recipient are cut with the

### TABLE 2

**Mean Corrected Distance Visual Acuity and Spherical Equivalent Refraction After Big-bubble Deep Anterior Lamellar Keratoplasty Assisted by IntraLase Femtosecond Laser**

<table>
<thead>
<tr>
<th></th>
<th>1 Month</th>
<th>3 Months</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDVA (decimal)</td>
<td>0.25±2.10 (0.1 to 0.7)</td>
<td>0.35±1.0 (0.2 to 0.7)</td>
<td>0.41±1.8 (0.4 to 0.7)</td>
<td>0.52±1.2 (0.4 to 0.8)</td>
</tr>
<tr>
<td>SE (D)</td>
<td>−1.20±2.90 (0 to −8.25)</td>
<td>−0.50±3.40 (0 to −4.50)</td>
<td>−1.90±3.10 (0 to −6.00)</td>
<td>−2.50±2.70 (0 to −6.00)</td>
</tr>
</tbody>
</table>

\(CDVA = \) corrected distance visual acuity, \(SE = \) spherical equivalent refraction.

### TABLE 3

**Astigmatism and Thinnest Corneal Point Recorded in 11 Eyes That Underwent Big-bubble Deep Anterior Lamellar Keratoplasty With IntraLase Femtosecond Laser**

<table>
<thead>
<tr>
<th></th>
<th>1 Month</th>
<th>3 Months</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refractive astigmatism (D)</td>
<td>1.00±2.30 (0 to 5.00)</td>
<td>0.30±5.50 (0 to 11.00)</td>
<td>1.20±3.00 (0 to 6.00)</td>
<td>2.00±2.60 (0 to 4.50)</td>
</tr>
<tr>
<td>Topographic astigmatism (D)</td>
<td>6.50±2.70 (4.30 to 23.50)</td>
<td>4.40±1.70 (3.80 to 11.00)</td>
<td>3.90±1.50 (0.70 to 4.60)</td>
<td>2.90±1.60 (1.90 to 8.10)</td>
</tr>
<tr>
<td>Thinnest corneal point (μm)</td>
<td>485±69 (363 to 518)</td>
<td>487±66 (364 to 503)</td>
<td>502±47 (429 to 518)</td>
<td>519±27 (481 to 542)</td>
</tr>
</tbody>
</table>

\(\text{CDVA} = \) corrected distance visual acuity, \(\text{SE} = \) spherical equivalent refraction.
endothelium down, in mechanical trephination, where the donor is cut with the endothelium up and the recipient with the endothelium down, and the diameter of the recipient bed tends to be larger while the diameter of the donor button tends to be smaller than the trephine diameter, donor oversizing becomes necessary because the recipient hole generally is larger than intended with divergent cut angles. These authors observed that after PK a smaller graft diameter results in a flatter curvature and a higher degree of topographic irregularity, but not in a higher amount of total astigmatism.

Ignacio et al reported the quality and precision of the femtosecond laser obtained through a lower pulse energy and spot separation settings and the high reproducibility of cuts performed in donor and host tissue, resulting in edges that are congruent in the donor and recipient.

In our experience, the refractive outcome after deep anterior lamellar keratoplasty assisted by IntraLase femtosecond laser with an oversized donor button results in myopia. A larger sample of patients is needed to confirm these early data; however, we believe each surgeon, according to individual outcome, could approach toward oversizing the grafts in femtosecond laser trephination to influence the postoperative spherical equivalent refraction, according to additional parameters such as the graft diameter, suture type and tension, and preoperative corneal curvature.

AUTHOR CONTRIBUTIONS

Study concept and design (L.B.); data collection (L.B., G.P.); analysis and interpretation of data (L.B., A.L.); drafting of the manuscript (L.B.); critical revision of the manuscript (A.L., G.P.)

REFERENCES


AUTHOR QUERY

Page 6, left column: The following statement needs further clarification. What is meant by the bolded phrase?

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