The femtosecond laser in everyday clinical use

A first-hand account of the many treatment options available

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The use of femtosecond lasers has significantly increased in recent years, with many surgeons preferring this newer tool to traditional surgical methods.

Here, Mark Tomalla, MD tells us of his experience with the femtosecond laser, Femtec (20/10 Perfect Vision, Heidelberg, Germany) (Figure 1), and reveals a whole host of potential applications for the laser in clinical practice. Dr Tomalla presents a number of cases that he has encountered, each requiring different procedures, and he outlines the outcomes of those procedures having favoured the femtosecond laser over the traditional approach.

We have been using the Femtec femtosecond laser at the Hospital for Refractive and Ophthalmosurgery in Duisburg, Germany since July 2004 and we can now look back on nearly two years of practical experience. We have not ceased to be fascinated by the broad diversity of possible applications for the device and we continue to see promising results in patients other than those receiving LASIK surgery. Yet, we believe that we have only scraped the surface of the possible uses of this exciting technology.

***Figure 1:** Femtec femtosecond laser.*

***Figure 2:** Preparation of implantation tunnel with newly-designed instruments.*

***Figure 3:** Postsurgery: implanted intracorneal ring segments.*

How does it work?

The femtosecond laser, which has both CE certification and FDA approval, is an infrared laser that works at a wavelength of 1,052 nm. It emits ultrashort laser pulses with a diameter of 0.001 mm at one-billionth of a second (10^{-15} sec). With the laser, tissue can be cut very precisely and with practically no heat development. The laser pulses develop their energy at a depth inside the cornea, which is exactly defined in advance. Each laser pulse creates a mini-gas bubble that separates the tissue (photodisruption). Three-dimensional, high-precision laser cuts can then be made within the cornea by means of thousands of computer-positioned laser pulses. In ophthalmosurgery, the laser is used primarily for cuts in the interior of the cornea, for example, for flap preparation prior to LASIK, or for preparation of corneal tunnels for intracorneal ring segment (ICRS) implantation.

What's your experience in…

Progressive keratoconus?

Implantation of ICRS supported by femtosecond laser technology offers a new option in the treatment of progressive keratoconus with a clear central cornea because the laser can be used for exact preparation of the implantation tunnel. The advantages of the femtosecond laser over mechanical techniques are related to the intrastromal cuts, which can be made from inside to outside, the risk of infection is clearly reduced in every procedure, centric or eccentric fixation of the tunnel can be selected and the curvature of the cornea remains intact throughout the procedure. The patented patient interface ensures minimal flattening of the cornea to about 35 D.

With the femtosecond laser, the cornea is prepared from inside at 70% depth. From there, a precise, previously defined tunnel 1 mm in width is created. Depending on the individual patient findings, the outer diameter is set between

8.0 mm and 8.8 mm and the inner diameter between 7.0 mm and 7.8 mm. The laser energy is 3.0 µJ and the spacing 8/10.

Based on these very precise values, we can prepare a minimal implantation tunnel, which is adapted exactly to the ICRS and leaves no empty space. The intracorneal ring segments can then be easily implanted with new, specially designed instruments (Figures 2 & 3).

Based on 15 months of postoperative experience gained in 30 ICRS patients, we can report that the conus was successfully flattened and shifted in all patients and all patients showed a significant improvement in visual acuity of more than 50% and a clear reduction in astigmatism.

Penetrating and lamellar keratoplasties?

We successfully performed our first penetrating keratoplasty with the femtosecond laser in July 2005 and presented our findings at the ASCRS annual meeting earlier this year.

In preparing the donor cornea, we began the precise incision at a depth of 1,200 µm and brought it up toward the epithelium, in an endothelium-sparing procedure. We selected 90° to the corneal curvature as the cutting angle, the laser energy was 4 µJ and the spacing 8/11. Both the donor and the recipient corneas were cut with such high precision that the two diameters could be selected at the same size (between 7.8 mm and 8.0 mm).

Preparation of the recipient cornea was just as precise, with the mechanical pressure stress on the bulbus during the procedure reaching only ca. 35 mmHg. Here, too, we began the cut with the femtosecond laser at 1,200 µm depth and brought it upwards toward the epithelium. We selected 90° to the corneal curvature as the cutting angle, the laser energy was 4 µJ and the spacing 3/6.

After we had successfully removed the recipient cornea, the prepared donor cornea nestled perfectly in the opened eye. The exact cutting edges of both the patient's cornea and the precisely-prepared donor cornea showed their worth: they fitted together almost exactly. Four placement sutures were then made for fixation before the continuous sutures were made (Figures 4-8).

During the entire preparation, there was uninterrupted visual control. The eye remained a closed and thus stable system as long as possible and the preparation took considerably less time when compared with the traditional methods.

We found the femtosecond laser to be precise and safe, even in cases where the cornea was completely cloudy or in a cornea with inhomogeneous tissue thickness, with variously-heavily scarred zones.

We have now performed this procedure with the femtosecond laser in 15 patients and have observed rapid wound healing and a marked increase in vision in all patients. The corneas adapted well and the transplants were clear and wrinkle-free six months after the surgery.

Meanwhile, November 2005 bore witness to our first anterior lamellar keratoplasty with the laser and we can now report the three-month postoperative results.

The case was a 72-year-old man who presented with paracentral corneal scars with indentations in the central edge area and with corneal vascularizations. His preoperative visual acuity was +8.0 –3.75/35° = 0.05. Corneal pachymetry showed a value of 384 µm in the thinnest area. We began with the preparation of the donor cornea, selecting a diameter of 9.1 mm, a thickness of 230 µm and a cutting edge with 90° angle. The preparation was intrastromal from the epithelial side.

For the preparation of the recipient cornea, we also selected a diameter of 9.1 mm and a cutting angle of exactly 90°. For the thickness of the trepanation of the recipient cornea, we selected a slightly smaller value than for the donor cornea, 200 µm specifically. The preparation was again made intrastromal from the epithelial side. The corneal bed showed a completely homogeneous structure, despite the scars. During the procedure, the laser energy was 3 µJ and the spacing 8/10.

The procedure was considerably less traumatic than a mechanical procedure, this was largely because of the femtosecond laser's patented, curved patient interface. The entire surgery was performed under visual control.

The donor cornea was successfully sutured into the recipient tissue with a continuous suture and a therapeutic contact lens was positioned, which was worn for four weeks with weekly changes.

Postoperatively, the patient showed excellent and rapid wound healing. The cornea was well-adapted, clear and wrinkle-free. Only five days postoperatively, the BCVA was +0.75 -2.25/70° = 0.4, while three months after the surgery, the recorded BCVA value was +2.00 –3.75/85° = 0.4 and remained unchanged thereafter.

***Figure 4:** Recipient cornea after preparation with femtosecond laser.*

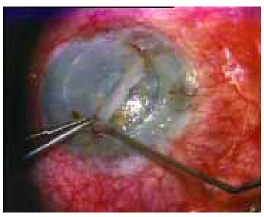

***Figure 5:** Partial removal of recipient cornea.*

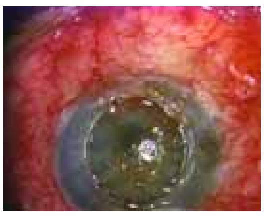

***Figure 6:** Completed partial removal of clouded cornea.*

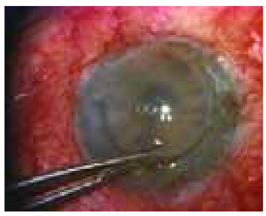

***Figure 7:** Prepared donor cornea fits perfectly into recipient cornea.*

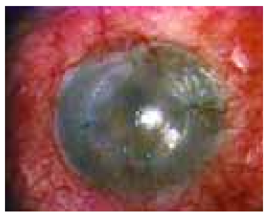

***Figure 8:** Sutured recipient cornea.*

We have now very successfully performed a further lamellar keratoplasty in Duisburg and, because of our success so far, we will apply the same procedure in further patients.

Flap preparation prior to LASIK?

Thus far, the femtosecond laser technology has been used in the majority of cases for the preparation of the corneal flap prior to LASIK (Figure 9). In my experience, much more precise flaps can be created compared with mechanical microkeratomes and the incidence of complications, such as button holes or free caps, is clearly reduced.

Comparison of the pre-programmed cutting depth with the created cut shows a deviation of only <10 μm, while the optical and mechanical quality of the cut is also clearly improved when the femtosecond laser is used. Furthermore, the flap thickness remains exactly the same over the entire diameter of the cornea. This is a result of the patented spherical patient interface employed by the Femtec laser, which fits perfectly to the curvature of the cornea making it possible to cut the cornea along the lamellar level. Thanks to the concave form of the patient interface, the pressure stress on the bulbus is moderate during the procedure. As with all of the application possibilities described thus far, there is visual control during the entire procedure.

We performed our first flap preparation in July 2004 and, in our opinion, an essential advantage of the femtosecond laser is that cuts can be made more precisely, even with higher grades of astigmatism, because the cornea is only flattened to ca. 35 D. In addition, the cut — unlike with mechanical keratomes — is made under complete visual control. The advantage of this is that we can interrupt the procedure immediately if we have any doubts along the way, thereby minimizing any damage.

The case that we will now describe relates to surgery that was performed more recently, in January 2006. After a cataract surgery, a 68-year-old patient presented with a refraction of +1.0 -4.0/35 = 0.63 and astigmatism of 4 D. The

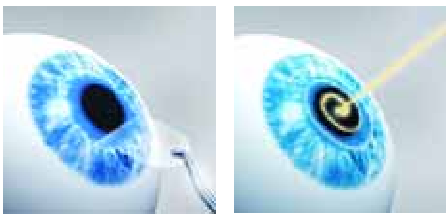

Figure 9: *Flap preparation (beam of femtosecond laser).*

pachymetry measurement showed a value of 569 µm at the thinnest point. As a result, we selected the following parameters for flap preparation with the femtosecond laser: diameter 8.5 mm with superior hinge position, a flap thickness of 140 µm and a cutting edge of 90°. During the procedure, the laser energy was 3 µJ, the spacing 8/10.

The entire procedure lasted only 45 seconds and the repositioning of the flap, in particular, was greatly facilitated by the exact cutting edges. One day postoperatively, after flap preparation, we measured a visual value identical to the preoperative value, but with a reduction of astigmatism to 3.5 D. The measurement four weeks postoperatively showed astigmatism reduction to 3.25 D.

> ***As a result of our excellent postoperative patient data in a variety of applications, we will continue to use the femtosecond laser technology in our practice. It supports our procedures with great precision and safety, it is easy to use and enables us to set new standards in our surgeries***

We performed LASIK in a second surgery and we observed that, especially in patients with greater astigmatism, less tissue needs to be removed during the dual procedure, since the flap cut itself alleviates tension from the cornea, thus resulting in a reduced astigmatism. As soon as the value is stable, we can perform tissue removal in a second session, using the excimer laser.

After LASIK was performed, four weeks after flap preparation, the patient showed refraction of -0.25 = 0.80 immediately postoperatively. Our four-month postoperative measurement showed the same refraction value.

Sum it all up for me

Femto-LASIK has now become routine in Duisburg. Like other femtosecond laser users, we often observe a somewhat longer healing time in our patients, but the advantages clearly exceed the disadvantages. For us, the main advantage is the possibility of individualizing every procedure, in which there is a choice between hinge positions, flap diameter and flap thickness. This is especially important in the case of thin corneas, where thinner flaps can be cut with the femtosecond laser. Postoperative complications, like corneal ectasias, are also minimised. The greater precision in flap preparation and the possibility of offering an individualized procedure means, in our opinion, the femtosecond laser has clear advantages over mechanical microkeratomes (where you only have a choice of two flap thicknesses).

As a result of our excellent postoperative patient data in a variety of applications, we will continue to use the femtosecond laser technology in our clinic. It supports our procedures with great precision and safety, it is easy to use and enables us to set new standards in our surgeries.

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Dr Tomalla together with Mike Holzer, MD, Omid Kermani, MD and Gerd Auffarth, MD will host an instructional course on the clinical applications and performance of femtosecond lasers on Sunday 10 September, 2006 at the ESCRS annual meeting in London.