THE FEMTOSECOND LASER: A REVOLUTIONARY INNOVATION IN OPHTHALMOLOGY

Femtosecond laser technology has been a game-changing development in ophthalmology, significantly enhancing the precision and safety of eye surgeries. This groundbreaking invention, awarded the Nobel Prize in 2018, led to numerous breakthroughs in fields such as spectroscopy, microscopy, and optogenetics. Its unique properties enable femtosecond lasers to precisely target tissues without causing collateral damage to surrounding areas. As a result, femtosecond lasers have driven major advances in ophthalmology, starting with refractive surgery. This paper examines the history, applications, and potential benefits of femtosecond lasers in ophthalmic procedures.

FEMTOSECOND LASER PROPERTIES

A femtosecond laser emits optical pulses with durations in the femtosecond range (1 femtosecond = 10^{-15} seconds).[1] The ultra-short pulses of laser energy generate micro-plasmas within the tissue allowing for precise tissue ablation with minimal thermal and mechanical damage to surrounding structures.[2]

EARLY DEVELOPMENT AND ADOPTION

The origins of femtosecond laser technology in ophthalmology trace back to the work of Ron Kurtz, MD, and Tibor Juhasz, PhD, the founders of IntraLase Corp. Between 1995 and 1997, they developed the IntraLase Femtosecond Laser at the University of Michigan. The first clinical application involved creating corneal flaps for LASIK surgery, a procedure now known as femtosecond laser-assisted in situ keratomileusis (FS-LASIK).

POTENTIAL BENEFITS

The ultrashort bursts of the femtosecond laser do not permit the transfer of temperature from photon energy, producing a 'cold ablation' with minimal thermal and mechanical damage to surrounding tissues. This process, known as photodisruption, occurs only at the focal point of the laser. Since the laser's intensity is low as it travels through tissue, it does not generate micro-plasmas beyond the intended target area. This precise targeting is key to femtosecond lasers' ability to achieve accurate and controlled tissue removal.

Femtosecond lasers are frequently used in combination with optical coherence tomography (OCT) for real-time, high-definition imaging. OCT guidance ensures optimal visualization of the ablation location within the tissue and allows for precise positioning. The automated nature of femtosecond lasers reduces the variability associated with manual techniques, ensuring repeatable and precise results with minimal damage to surrounding tissues.

CURRENT APPLICATIONS

Femtosecond Laser Assisted in situ Keratomileusis (FS-LASIK)

The use of femtosecond lasers in LASIK surgery has largely replaced mechanical microkeratomes. Traditional microkeratomes used for flap creation had fixed side-cut angles of 25–30°. In contrast, femtosecond lasers allow for customizable side-cut angles, ranging from 30° to 150°. These adjustable angles enhance the precision of the flap creation process and have been shown to result in fewer high-order aberrations (HOAs) compared to microkeratomes.

Femtosecond Laser Assisted Cataract Surgery (FLACS)

FFLACS enhances the precision of key steps in cataract surgery, such as corneal incisions, anterior capsulotomy, lens fragmentation, and arcuate incisions. Customizable to the surgeon's needs, FLACS reduces variability and enhances reproducibility. Femtosecond laser-created capsulotomies have been shown to be more precise in size, shape, and strength compared to manual techniques, improving the stability and positioning of intraocular lenses (IOLs), particularly in complex designs like toric or multifocal lenses.

Femtosecond laser lens fragmentation also reduces the need for ultrasound energy during phacoemulsification, decreasing the risk of corneal endothelial damage and other complications associated with conventional cataract surgery.

FUTURE APPLICATIONS

Open-Angle Glaucoma

A promising new application of femtosecond lasers is in the treatment of open-angle glaucoma. The Femtosecond Laser Image-Guided High-Precision Trabeculotomy (FLIGHT) procedure uses a femtosecond laser to create a precise aperture through the trabecular meshwork (TM) to Schlemm's Canal, eliminating the need for a corneal incision. FLIGHT combines high-definition gonioscopic imaging for precise, real-time positioning of the drainage channel, allowing for highly accurate tissue removal with no need for external incisions.

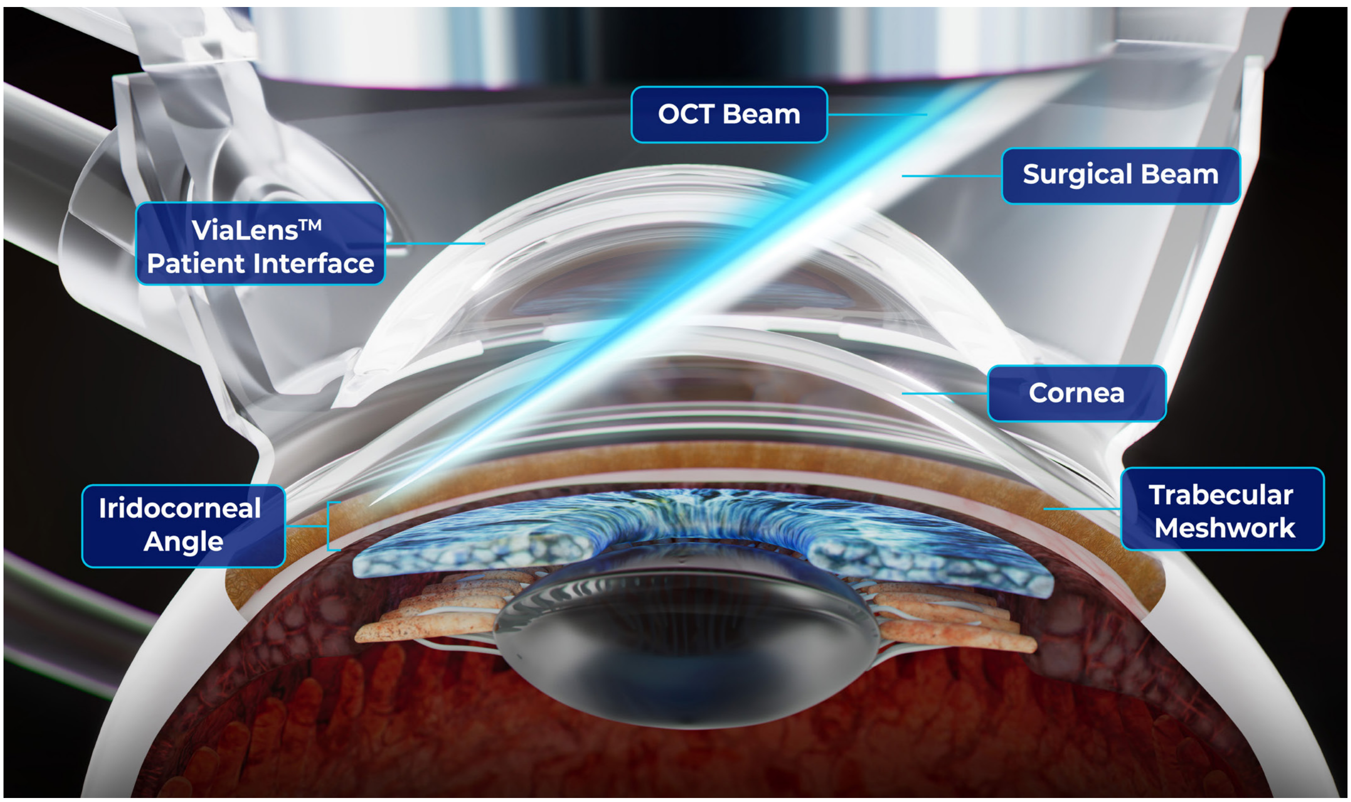

FIGURE 1 Principle of the FLIGHT treatment

Principle of the FLIGHT procedure: Using proprietary, high definition OCT and gonioscopic image guidance, the ViaLuxe Laser System (tm) creates a precise aperture through the trabecular meshwork into Schlemm's canal, enabling direct aqueous outflow without opening up the eye.

CONCLUSION

The introduction of femtosecond lasers has revolutionized anterior segment surgery by offering improved precision and safety. As technology continues to evolve, femtosecond lasers are poised to play an increasingly integral role in the future of eye care. Continued research and clinical studies will refine these techniques and expand their applications, improving outcomes for a broader range of ophthalmic conditions.

REFERENCES

1 Paschotta DR. femtosecond lasers. https:// www.rp-photonics.com/femtosecond_lasers.html (accessed 18 June 2024)

2 Lubatschowski H, Maatz G, Heisterkamp A, et al. Application of ultrashort laser pulses for intrastromal refractive surgery. Graefes Arch Clin Exp Ophthalmol. 2000;238:33–9. doi: 10.1007/s004170050006

3 Juhasz T, Loesel FH, Kurtz RM, et al. Corneal refractive surgery with femtosecond lasers. IEEE J Select Topics Quantum Electron. 1999;5:902–10. doi: 10.1109/2944.796309

4 Palanker DV, Blumenkranz MS, Andersen D, et al. Femtosecond laser-assisted cataract surgery with integrated optical coherence tomography. Sci Transl Med. 2010;2:58ra85. doi: 10.1126/scitranslmed.
3001305

5 Zhang D, Guan L. 4.06 - Laser Ablation. In: Hashmi S, Batalha GF, Van Tyne CJ, et al., eds. Comprehensive Materials Processing. Oxford: Elsevier 2014:125–69.

6 Binder PS, Moore M, Lambert RW, et al. Comparison of two microkeratome systems. J Refract Surg. 1997;13:142–53. doi: 10.3928/1081-597X-19970301-10

7 Hosny M, Medhat M, Sobhi R, et al. A morphological comparison between sub-bowman keratomileusis flap and femtosecond laser-assisted flap in LASIK surgery for myopia. Journal of Cornea and Ocular Surface. 2023;1.

8 Tran DB, Sarayba MA, Bor Z, et al. Randomized prospective clinical study comparing induced aberrations with IntraLase and Hansatome flap creation in fellow eyes: potential impact on wavefront-guided laser in situ keratomileusis. J Cataract Refract Surg. 2005;31:97–105. doi: 10.1016/j.
jcrs.2004.10.037

9 Durrie DS, Kezirian GM. Femtosecond laser versus mechanical keratome flaps in wavefront-guided laser in situ keratomileusis: prospective contralateral eye study. J Cataract Refract Surg. 2005;31:120–6. doi: 10.1016/j.
jcrs.2004.09.046

SEEING IS BELIEVING

FOR MORE INFORMATION,
VISIT OUR WEBSITE
WWW.VIALASE.COM

2460

ViaLase, Inc. 95 Enterprise, Suite 100, Aliso Viejo, CA 92656

QR
CODE