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A Brief History of Corneal Refractive Surgery

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Summary: The invention of corneal refractive surgery changed the lives of millions of people worldwide. Its development has undergone a remarkable evolution over more than a century. This review outlines the main milestones in the history of laser refractive procedures, from radial keratotomy to high-quality femtosecond laser procedures. Attention is given to the ophthalmic surgery pioneers, such as Sato, Fyodorov, Barraquer, Trokel, and Pallikaris. This article highlights the historical trajectory and technological breakthroughs that have transformed refractive surgery into a widely accessible and highly effective solution for visual correction.

Key words: femtosecond laser, FLEx, keratoplasty, LASEK, LASIK, radial keratotomy, refractive surgery, SMILE.

The origins of corneal refractive surgery date back to 1894, when W.H. Bates (United States) described the effect of corneal incisions on astigmatism. He published data based on 6 eyes treated with his technique.

At that time, in 1898, Lans (The Netherlands) published his results of performing keratotomy, keratectomy and thermokeratoplasty on the corneas of animals in order to correct astigmatism [1].

In the 20th century, some ophthalmologists focused on refraction correction aimed not only at the cornea, but also the sclera. In 1903 August Müller reported the effect of scleral contact lenses on high myopia in self-experimentation. In 1900, Terrien and Wray independently published results concerning corneal cauterization in order to correct hyperopia (and hyperopic astigmatism). Terrien's study group included cases of corneal degeneration later called Terrien marginal degeneration. In 1933 O'Connor's study presented data from a 10-year observation of eyes that had undergone corneal cauterization in myopic astigmatism correction [1].

It was not until 1953 that T. Sato (Japan) provided findings on the effects of corneal keratotomy in refractive correction. He demonstrated the effectiveness of the surgery in keratoconus, myopia, and astigmatism. Firstly, he performed the incisions on the posterior corneal surface. Later on, the incisions involved both the anterior and the posterior surface. The study was published in the *American Journal of Ophthalmology* and initiated the chain of events that led to the development of what is now modern refractive surgery [2].

The serious adverse effect of keratotomy – endothelial decompensation leading to bullous keratopathy – was the reason why further dissemination of keratotomy was temporarily halted. Bullous keratopathy eventually occurred as a late consequence of the surgery up to 20 years after the procedure.

Corneal incisions were focused on again in the 1960s due to Yenaliev (USSR). Due to the incidence of endothelial decompensation after Sato's procedures, he performed them only on the anterior surface. Yenaliev's incisions were numerous (24–32), radially oriented, and enabled refractive correction up to 4 diopters. The surgery became known as radial keratotomy (RK).

Further spread of RK and studies on its effects are attributed to the contribution of Svyatoslav Fyodorov. He brought this procedure into the mainstream between the 1970s and the 1990s, making it a popular method of correcting refractive error – which was also available in Poland at that time.

At the same time, the procedures were also gaining popularity in India and the United States. Dr. Siva-Reddy performed more than 200 RKs in India in the 1970s. American surgeons developed modifications of the RK technique. They reduced the quantity of incisions, thus reducing the risk of complications.

Adverse effects of radial keratotomy, such as glare and halo effects, were particularly significant. They occurred due to the small central optical zone, 3–4 mm in diameter. Further development of laser techniques led to a decline in the popularity of RK and its replacement by laser refractive surgery.

Lamellar modeling of corneal shape is an alternative (to RK) approach for refractive correction problems. Lamellar refractive keratoplasty procedures include *keratomileusis*, epikeratoplasty, and keratophakia.

In the 1960s José Ignacio Barraquer (Colombia) performed the first *keratomileusis* procedures on human eyes. He removed a corneal flap using a microkeratome. Then the flap was processed at low temperatures and sutured back to the cornea. The modelling of a frozen flap was based on prior computer analysis, which was an innovation at the time. The procedure was successful in both myopia and hyperopia correction [3].

Automated lamellar keratoplasty (ALK) involved the use of an automated microkeratome in order to correct myopia. It gained popularity in the 1980s and 1990s.

Epikeratoplasty and keratophakia are procedures in which a flap derived from donor tissue is sutured to the patient's cornea. It is placed on the anterior corneal surface (epikeratoplasty) or into the stroma (keratophakia). These procedures were performed to correct aphakia, in eyes with keratoconus and myopia.

The Polish ophthalmic surgeon Professor Tadeusz Krwawicz was primarily famous for his innovations in cryotherapy. He was also a pioneer in corneal modelling. Prof. Krwawicz developed a refractive corrective method called *strumectomia corneae centralis*, which used low temperatures to remodel the corneal shape.

Keratectomy is a technique in which the corneal tissue is removed in order to correct astigmatism, post-keratoplasty refractive error, and irregularities secondary to marginal degenerations and ectasia.

The excimer laser ushered in a new era for corneal refractive surgery, fundamentally changing the field. Its invention and de-

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velopment were a breakthrough unmatched by previous technologies.

The invention of the excimer laser and its interaction with corneal tissue is credited to Stephen L. Trokel from Columbia Presbyterian Medical Center in New York City, USA. In 1983, he published an article explaining the mode of action of the excited dimers – known as excimers, from which the laser derived its name – on corneal stroma. According to his calculations, the application of 1 joule per square centimeter results in tissue ablation to a depth of 1 μm. In 1987, Trokel performed the first excimer surgery on a human cornea. The surgery was called photorefractive keratectomy (PRK). The excimer laser was approved in the USA for refractive surgery in 1996 [4].

Before the introduction of the excimer laser, photorefractive keratectomy was also designed and performed with other laser types, such as a solid-state laser (wavelength 213 nm). Margaret McDonald performed the first ablation on a healthy eye in 1988 with a solid-state laser.

Due to subsequent development and evolution of *laser-assisted in situ keratomileusis* (LASIK) technique in the 1990s, surface procedures (such as PRK) are now used less frequently.

The invention of LASIK sparked a revolution that changed public attitudes toward corneal refractive surgery. LASIK is used in myopia, hyperopia, and astigmatism correction, and enables customized treatment based on an individual profile of aberrations. Nowadays, LASIK modification is also used in presbyopia.

LASIK was pioneered by Ioannis Pallikaris (Greece). He published a description of surgery performed on animal eyes in 1990 and then on human eyes in 1991. In LASIK, the 300 μm thick corneal flap was initially created using a microkeratome and could be repositioned with no need for suturing. A bandage contact lens diminished postoperative pain, which was already lower than after PRK [5–7].

Sub-Bowman *keratomileusis* (SBK) is a LASIK modification presented in 2009. It was characterized by a decreased flap thickness to 90–110 μm and leaving more stromal tissue unaffected. It was useful in thin corneas and large refractive errors where deeper ablation is needed. Nowadays, this technique is used under the name of ultra-thin femto-LASIK, where a femtosecond laser creates an 80 μm flap.

Laser subepithelial *keratomileusis* (LASEK) is a technique introduced in 1998 by Massimo Camellin (Italy). LASEK is performed by excimer laser ablation performed on stromal tissue with the epithelial flap previously removed with ethanol. It was initially promoted as a painless technique with quick recovery. Since then, LASEK has been shown to be as effective as PRK in clinical trials.

Epi-LASIK is another procedure invented by Ioannis Pallikaris. It is a LASEK analogue without the use of ethanol – the thin corneal epithelial flap is created with a microkeratome [6].

In 1996, Ito (USA) reported the feasibility of performing LASIK without using a microkeratome. He used a picosecond laser to create a 160 μm-deep corneal flap. It was the precursor of the now-famous femto-LASIK procedure, in which the flap is made with a femtosecond laser [8, 9].

Femtosecond laser use dates back to 2003. Then, the first femto-LASIK procedures took place. At the same time, the femtolaser was also used to create the stromal tunnels prior to implanting the intrastromal implants, e.g. in ectasia [9].

In 1998 Krueger published data on corneal refractive correction without the use of an excimer laser. He created a 200 μm flap, then, using a picosecond laser, he cut out a lenticule, achieving correction of 20 D of myopia in two eyes of a single patient. Later, the femtosecond laser was introduced in place of the picosecond laser, leading to fewer corneal surface irregularities [9–11].

Walter Secundo (Germany) performed the first femtosecond lenticule extraction (FLEx) procedures in 2008. He created the flap and lenticule using a femtosecond laser, then he manually removed the lenticule and repositioned the flap.

Reports on a further modification – small incision lenticule extraction (SMILE) – were published at the same time by Sekundo and Shah (India). In this pioneering procedure, an incision of only 3–5 mm is sufficient to remove the stromal lenticule manually. Aside from lenticule removal, both the incision and creation of the lenticule are performed entirely by a femtosecond laser. Modifications of the SMILE procedure are called kerato-lenticule extraction (KLeX). KLeX is one of the leading choices for laser refractive procedures, especially in myopia, and soon possibly also in hyperopia and presbyopia [12–13].

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References:

1. Reinstein DZ, Archer TJ, Gobbe M: *The history of LASIK*. J Refract Surg. 2012 Apr; 28(4): 291–298. doi: 10.3928/1081597X-20120229-01. PMID: 22496438.
2. Sato T, Akiyama K, Shibata H: *A new surgical approach to myopia*. Am J Ophthalmol. 1953 Jun; 36(61): 823–829. doi: 10.1016/0002-9394(53)90183-4. PMID: 13050675.
3. Kaufman HE, Werblin TP: *Epikeratophakia for the treatment of keratoconus*. Am J Ophthalmol. 1982 Mar; 93(3): 342–347. doi: 10.1016/0002-9394(82)90537-2. PMID: 7041655.
4. Trokel SL, Srinivasan R, Braren B: *Excimer laser surgery of the cornea.* Am J Ophthalmol. 1983 Dec; 96(6): 710–715. doi: 10.1016/s0002-9394(14)71911-7. PMID: 6660257.
5. Pallikaris IG, Papatzanaki ME, Stathi EZ, et al.: *Laser in situ keratomileusis*. Lasers Surg Med. 1990; 10(5): 463–468. doi: 10.1002/lsm.1900100511. PMID: 2233101.
6. Moshirfar M, Bennett P, Ronquillo Y: *Laser In Situ Keratomileusis (LASIK)* [Updated 2023 Jul 24]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK555970/
7. Pallikaris IG, Papatzanaki ME, Siganos DS, et al.: *A corneal flap technique for laser in situ keratomileusis. Human studies.* Arch Ophthalmol. 1991 Dec; 109(12): 1699–702. doi: 10.1001/archopht.1991.01080120083031. PMID: 1841579.
8. Ito M, Quantock AJ, Malhan S, et al.: *Picosecond laser in situ keratomileusis with a 1053-nm Nd: YLF laser*. J Refract Surg. 1996 Sep-Oct; 12(6): 721–728. doi: 10.3928/1081-597X-19960901-16. PMID: 8895129.
9. Reinstein DZ, Archer TJ, Gobbe M: *Small incision lenticule extraction (SMILE) history, fundamentals of a new refractive surgery technique and clinical outcomes.* Eye Vis (Lond). 2014 Oct 16; 1: 3. doi: 10.1186/s40662-014-0003-1. PMID: 26605350; PMCID: PMC4604118.
10. Krueger RR, Juhasz T, Gualano A, et al.: *The picosecond laser for nonmechanical laser in situ keratomileusis*. J Refract Surg. 1998 Jul-Aug; 14(4): 467–469. doi: 10.3928/1081-597X-19980701-15. PMID: 9699173.
11. Ratkay-Traub I, Ferincz IE, Juhasz T, et al.: *First clinical results with the femtosecond neodynium-glass laser in refractive surgery.* J Refract Surg. 2003 Mar-Apr; 19(2): 94–103. doi: 10.3928/1081-597X-20030301-03. PMID: 12701713.
12. Shah R, Shah S, Sengupta S: *Results of small incision lenticule extraction: All-in-one femtosecond laser refractive surgery.* J Cataract Refract Surg. 2011 Jan; 37(1): 127–137. doi: 10.1016/j.jcrs.2010.07.033. PMID: 21183108.
13. Sekundo W, Kunert KS, Blum M: *Small incision corneal refractive surgery using the small incision lenticule extraction (SMILE) procedure for the correction of myopia and myopic astigmatism: results of a 6 month prospective study.* Br J Ophthalmol. 2011 Mar; 95(3): 335–339. doi: 10.1136/bjo.2009.174284. Epub 2010 Jul 3. PMID: 20601657.

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