The role of Femtosecond Laser in Ophthalmology

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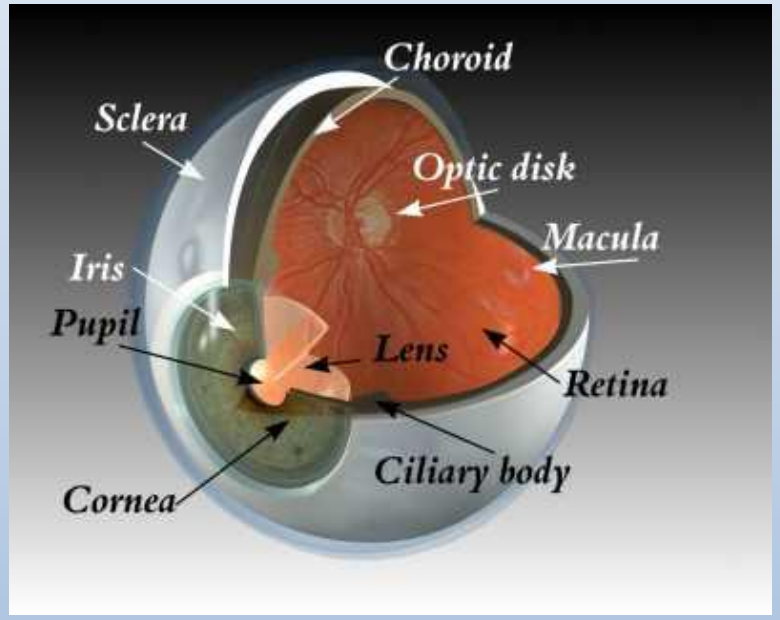
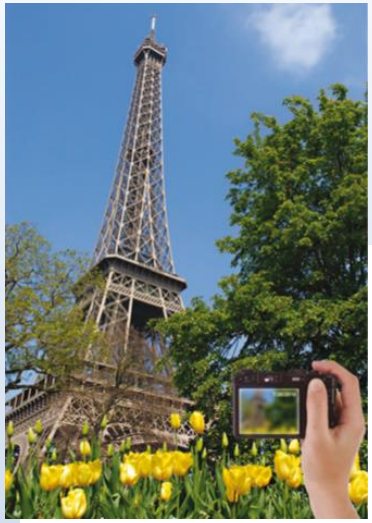
4. Vízió-Med Ophthalmology Budapest, Hungary

Femtosecond Lasers in Ophthalmology

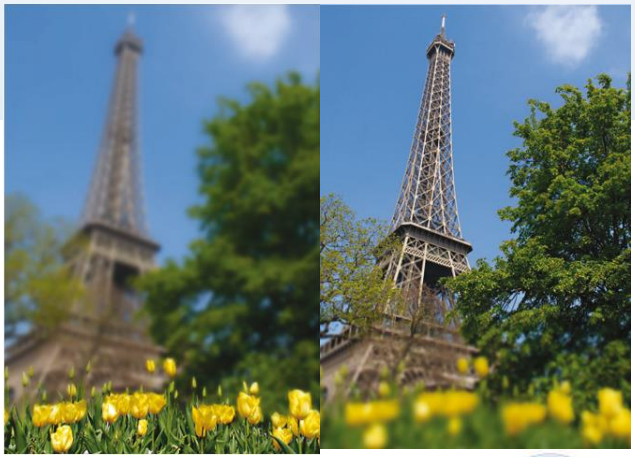
- **Cornea**
  - ***LASIK flap*** *– Refractive Surgery*
  - ***Stand alone*** *intrastromal & lenticular refraktive treatments* ***Smile & SmartSight***
  - *Cornea transplantation -* ***Keratoplastic***
- **Lens**
  - ***Cataract***
  - *Presbyopia*
- **Sclera**
  - ***Glaucoma***
  - *Presbyopia*
- **Vitreous/Retina**
  - *Vitreous surgery*
  - *Retinal imaging*

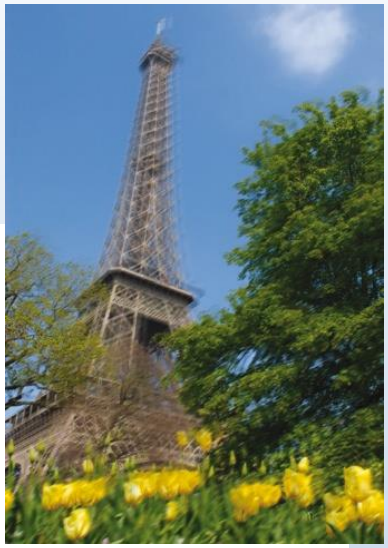


Refractive errors



Presbyopia





Emmetropia

Ametropia

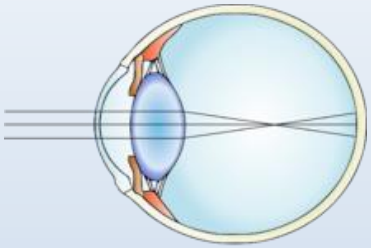
EMMETROPIA

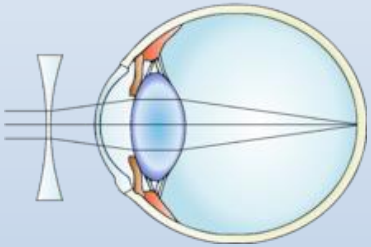
is the refractive state of an eye in which parallel rays of light entering the eye are focused on the retina, creating an image that is perceived as crisp and in focus.

AMETROPIA = REFRACTIVE ERROR

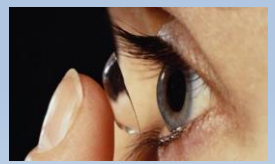
means the deviation from emmetropia measured in dioptres.

Myopia correction



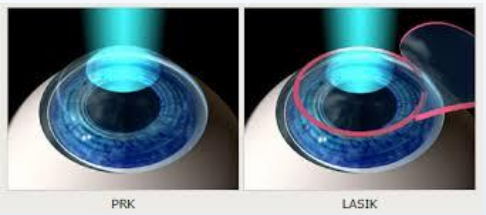


Glasses

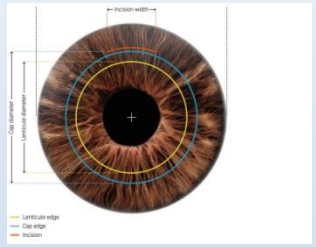


Contact lenses

Laser treatments

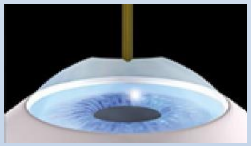


By myopic eye we have to reduce the curvature of the cornea

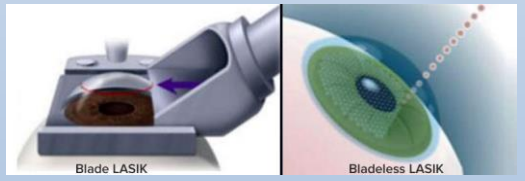


Refractive Surgeries:

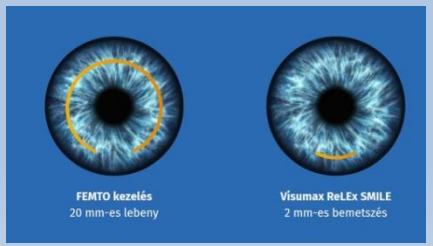
1.) Superficial excimer laser treatments: PRK, no touch PRK



2.) LASIK treatments with flap creations: LASIK, LASER-LASIK

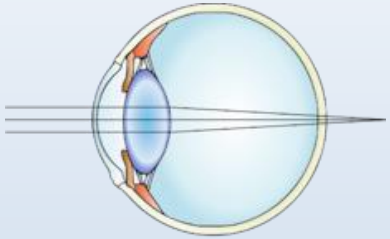


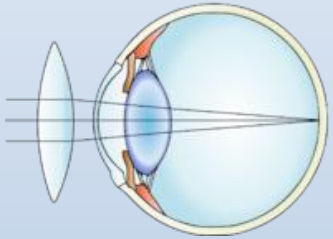
3.) Stand alone Femtosecond Laser procedures:
Smile & Smartsight



The WHO predicted the Myopia a leading reason of blindness statistics for 2050.

Hyperopia correction





Glasses

Contact lenses

Laser treatments

By hyperopic eye we have to decrease the curvature of the cornea

Refractive Surgeries:

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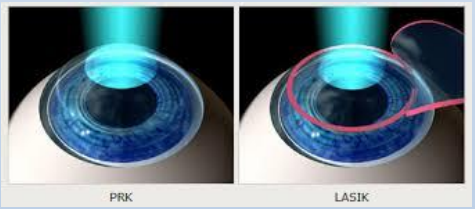
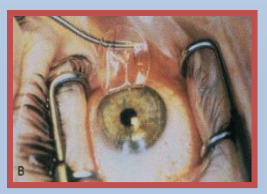
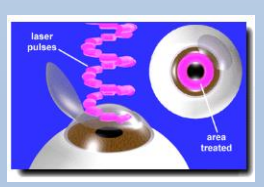
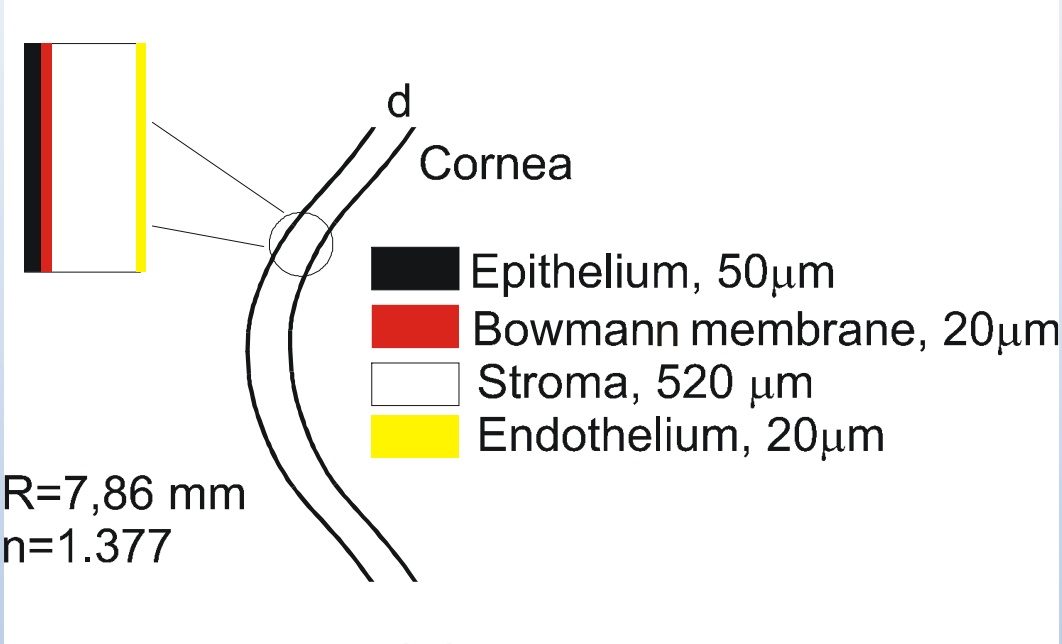


2.) LASIK treatments with flap creations: LASIK, LASER-LASIK



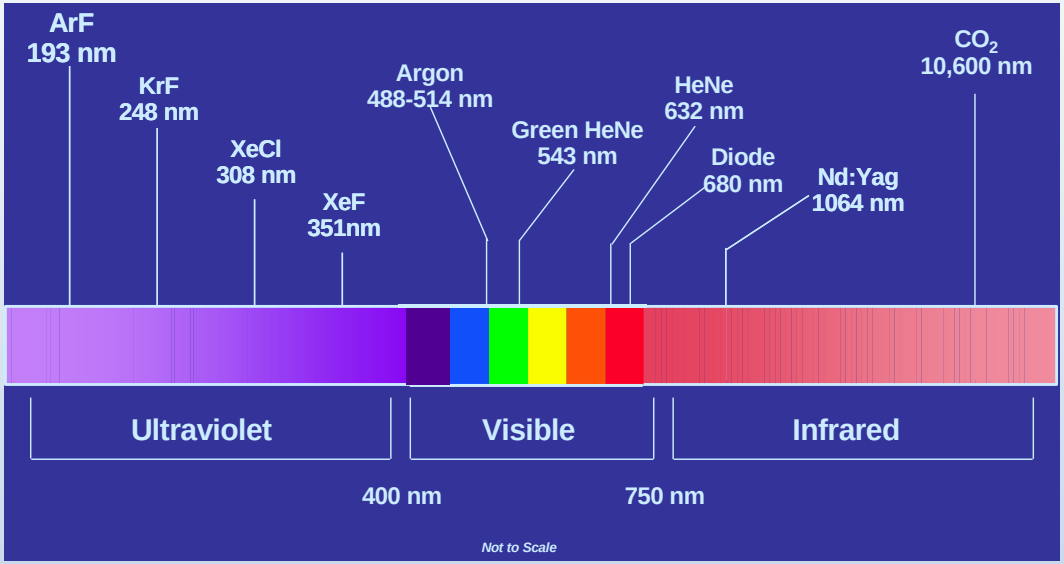


The structure of the human cornea

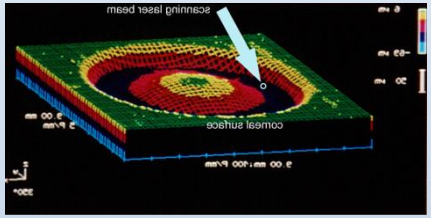


- The power of the cornea ~ 44 D.
- The greater part of the corneal stroma consist of collagen fibers. All changes in the stroma are permanent, while it is no regeneration on it.

Laser-Cornea Interactions

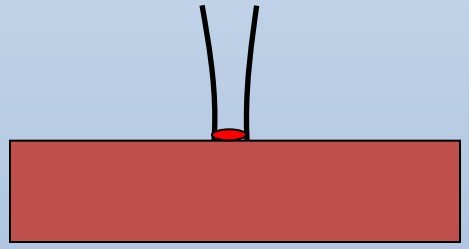


Excimer Laser ablation

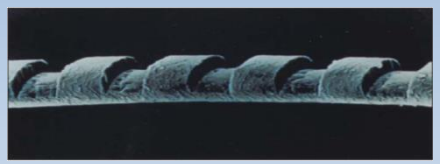


Excimer Laser

193 nm Argon-Fluorid UV-Laser

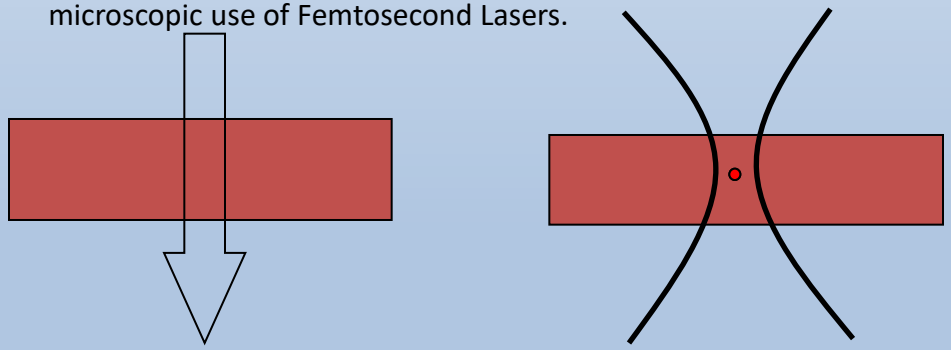


Precise surface effects



Femtosecond Laser

Ultrashort impulse near infrared (λ= 1053 nm) Laser beam is focused in the corneal stroma where it causes photodisruption enabling microscopic use of Femtosecond Lasers.



Precise sub-surface effects

1053 nm Neodynium-glass infrared Laser
Impulse time: 10^{-13} secundum (100 femtosecond)

Technology Timeline to use Femtosecond Laser

- **1998:** First clinical use of Femtosecond Laser **in Cornea**: **Intrastromal ablation (ISPRK)** *Ratkay-Traub I, Hun*

- **1999:** Initial use of Femtosecond Laser Keratome worldwide: **IntraLasik** (flap)**, FLK** (flap+lenticule), **ICR** (pre-cut channel + entry cut), *Ratkay-Traub I, Hun*
- **2001:** Commercial launch of **IntraLase FS – FDA**

- **2005-2006: FS Laser** tested in the lens for **Presbyopia** *(Krueger R USA; Ratkay-Traub I Hun)*

- **2008:** First clinical use of femtosecond laser **in cataract surgery**: Capsulotomy, Fragmentation *(Z. Zs. Nagy, Budapest Hun)*
- **2009:** Commercial launch of **LenSx – FDA**

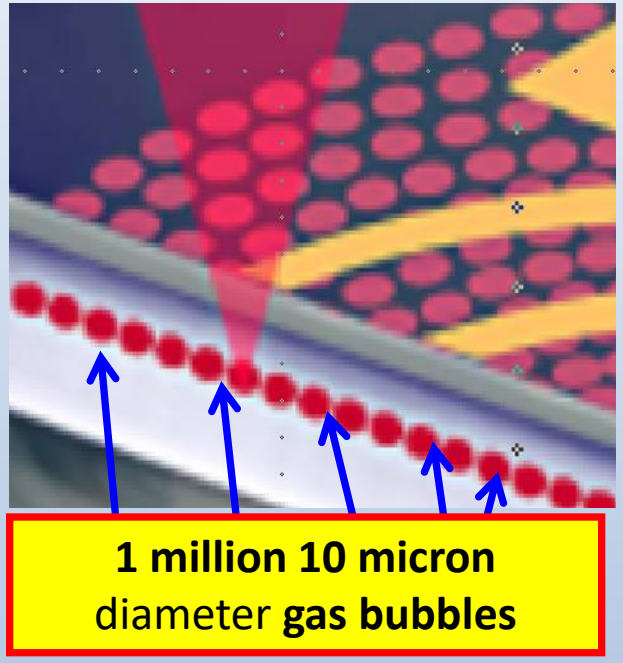
- **2010:** First **Presbylens** implantation in Europe to treat **Presbyopia** *(Ratkay-Traub I, Budapest Hun)*

Tibor Juhasz, PhD, and Christopher Horvath, PhD, installing the prototype laser at the first clinical site in 1998.

Initial Clinical Use

Budapest, Hungary

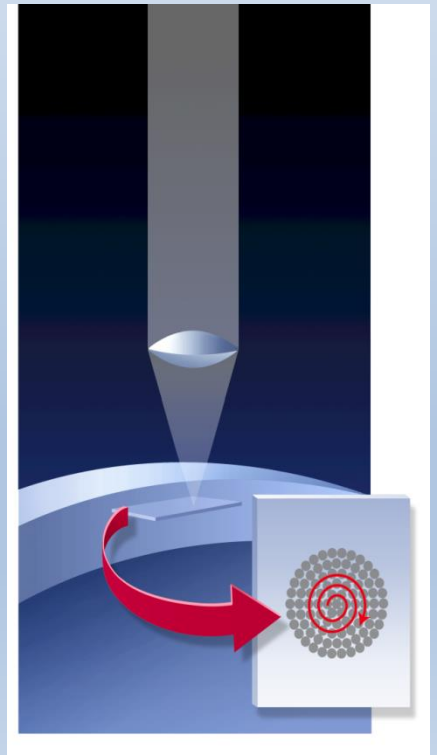
Microcavitation with Femtosecond Laser pulses: Application to the cornea



1 million 10 micron diameter **gas bubbles**

- Laser pulses can be focused to any location in the corneal stroma with micron level accuracy.
- Computer controlled scanning allows creation of any surgical pattern or shape.

- Laser keratome for creation of optimized corneal flap (**Femto-LASIK**)
- Creation of corneal pockets for implants (**Femto-ICR**)
- Creation of flap with lenticule (Hyperopic and Myopic **Femto-ALK**)
- Intrastromal Procedures (**Femto-ISPRK**) Myopia, Hyperopia, Astigmatism
- Corneal pockets
- Stand-alone procedures



Development of the FS Laser

Repetition frequency:
5-10 kHz → 15 kHz → 30 kHz → 60 kHz → 150 kHz → 500 kHz → 4 mHz
Flap's cutting-time:
150-80 s → 30 s → 40 s → 17 s → 12 s → <10 s
Impulse energy of the cutting:
5 µJ → 3,5 µJ→ < 2,0 µJ → < 1,0 µ J → < 0,5 µJ → < 0,3 µJ

600C, a-prototype

FS1

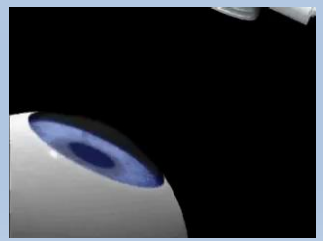
FS2

iFS 150

Schwind Atos

Different cutting procedures

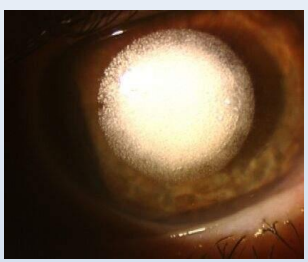
Patterns of cutting:
- spirál (600C, FS1 & FS2)



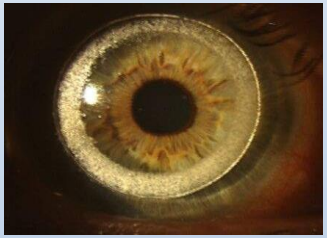
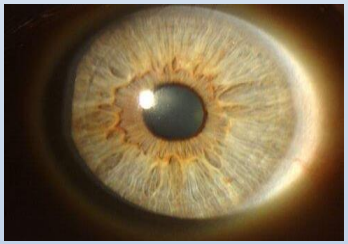
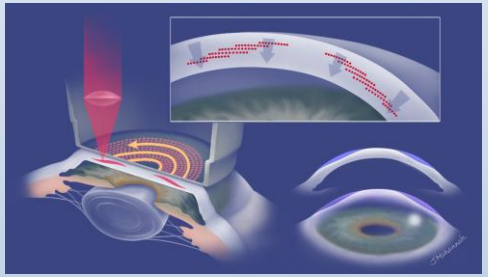
- raster" és „double raster" (FS1 & FS2)

1998-1999 The first Intrastromal procedures (**ISPRK**) performed by Femtosecond Laser

- Myopic **ISPRK**



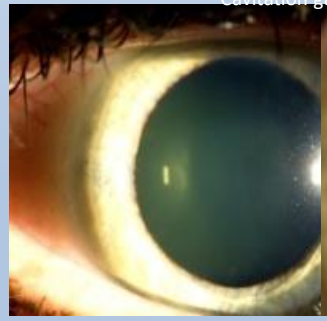
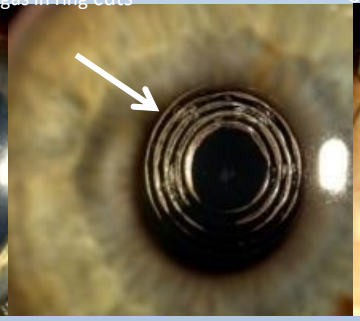
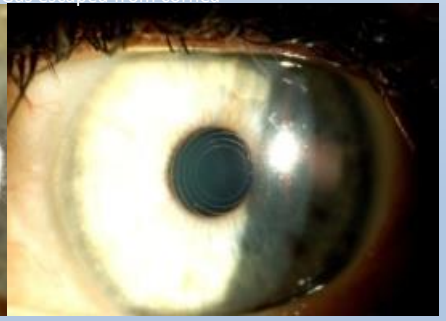
- Hyperopic **ISPRK**

INTRACOR Presbyopia

Cavitation gas in ring cuts

Gas escaped from cornea

4 days preop

1 hour postop

1 day postop

Mike P. Holzer, MD

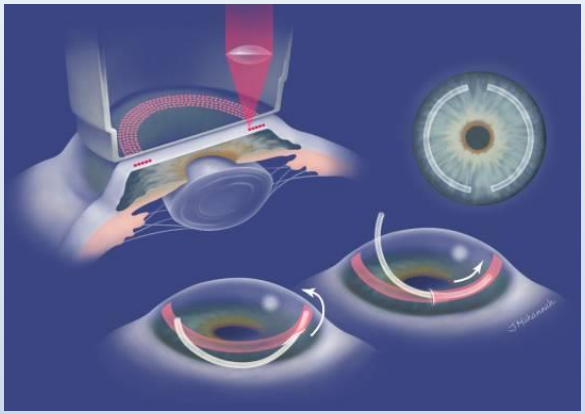
Ron Kurtz & Ratkay I.

Femtosecond Laser Keratome

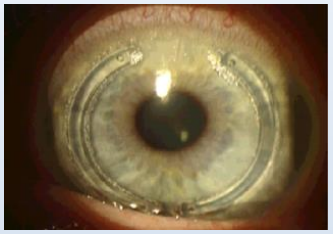
1999. Channels for corneal implants

IntraCorneal Ring (ICR)

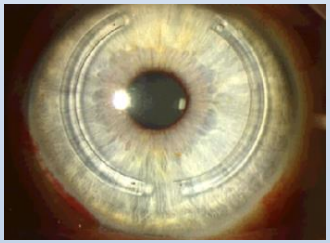
Same device used to create pre-cut channels and entry cuts for IntraCorneal Ring segments (ICR)



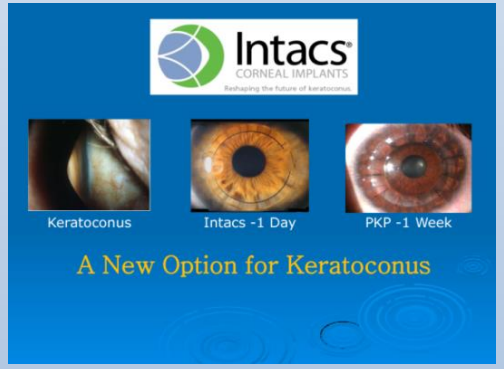
After the operation



1 day follow-up



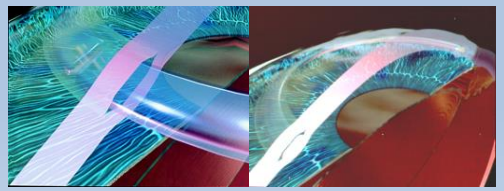
Pulses are scanned in circular pattern below the surface to create a channel, after which a cut is made on the surface to allow insertion of the implants

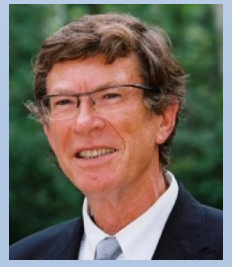


Indication to treat:
- low Myopia: -1,0D- - 3,0D
  or
- Keratoconus

R Alexander, **Ratkay I**, D Schanzlin, Ferincz I, Nádas K, Chr Horvath, **Juhász T** & T Silvestrini

Ferrara Rings



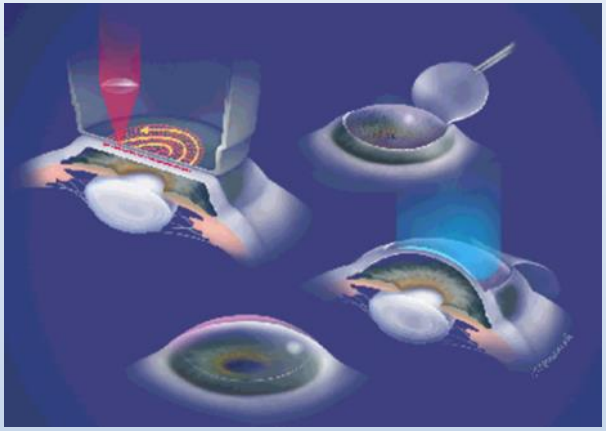


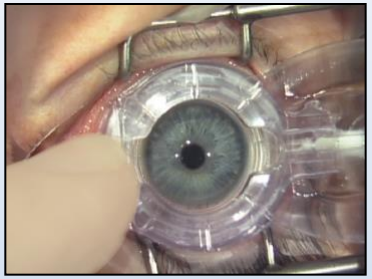
Prof. Joseph Colin MD

Ratkay-Traub, I. Ferincz, T. Juhasz, R. Kurtz, R. Krueger: ***The Initial Clinical Studies with the Intralase Femtosecond Laser***. *Journal of Refractive Surgery 19*, 94-103, (**2003**)

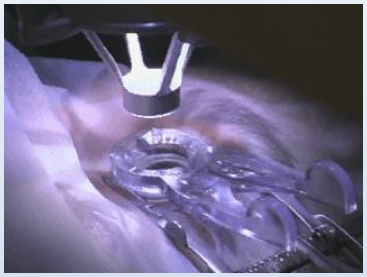
1999. Inicial Use of Femtosecond Laser Keratome

LaserLASIK = FemtoLasik





Suction ring fixates eye

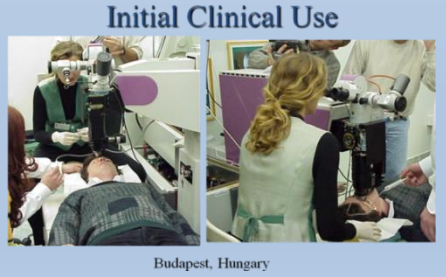


Glass lens applanates cornea to maintain precise distance from laser head to focal point

- Laser is set to desired depth
- Pulses delivered in a preset pattern to create precise incisions in 3 Dimensions

Refractive indications: (≤ 100µm flap)

- Myopia: -1,0 D - -10,0 D
- Hyperopia: +1,0 D - +5,0 D
- Astigmatism: ±1,0 D - ±6,0 D



Ratkay-Traub I, Juhasz T, Horvath C, Suarez C, Kiss K, Ferincz I, Kurtz R: Ultra-short Pulse (Femtosecond) Laser Surgery: ***Initial Use in LASIK Flap Creation***. *Ophthalmology Clinics of North America* 14, 347-355 (**2001**.)

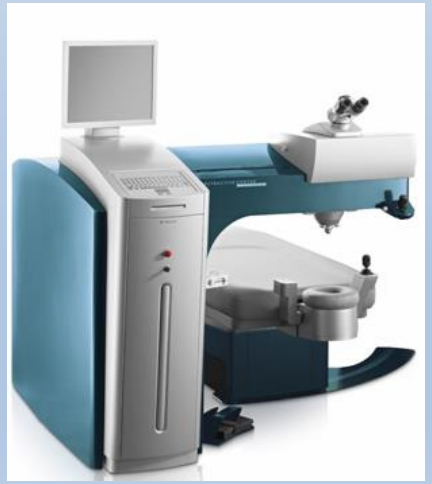
FEMTOSECOND LASERS FOR LASIK

INTRALASE; ABBOTT

TECHNOLAS; B&L

VISUMAX; ZEISS

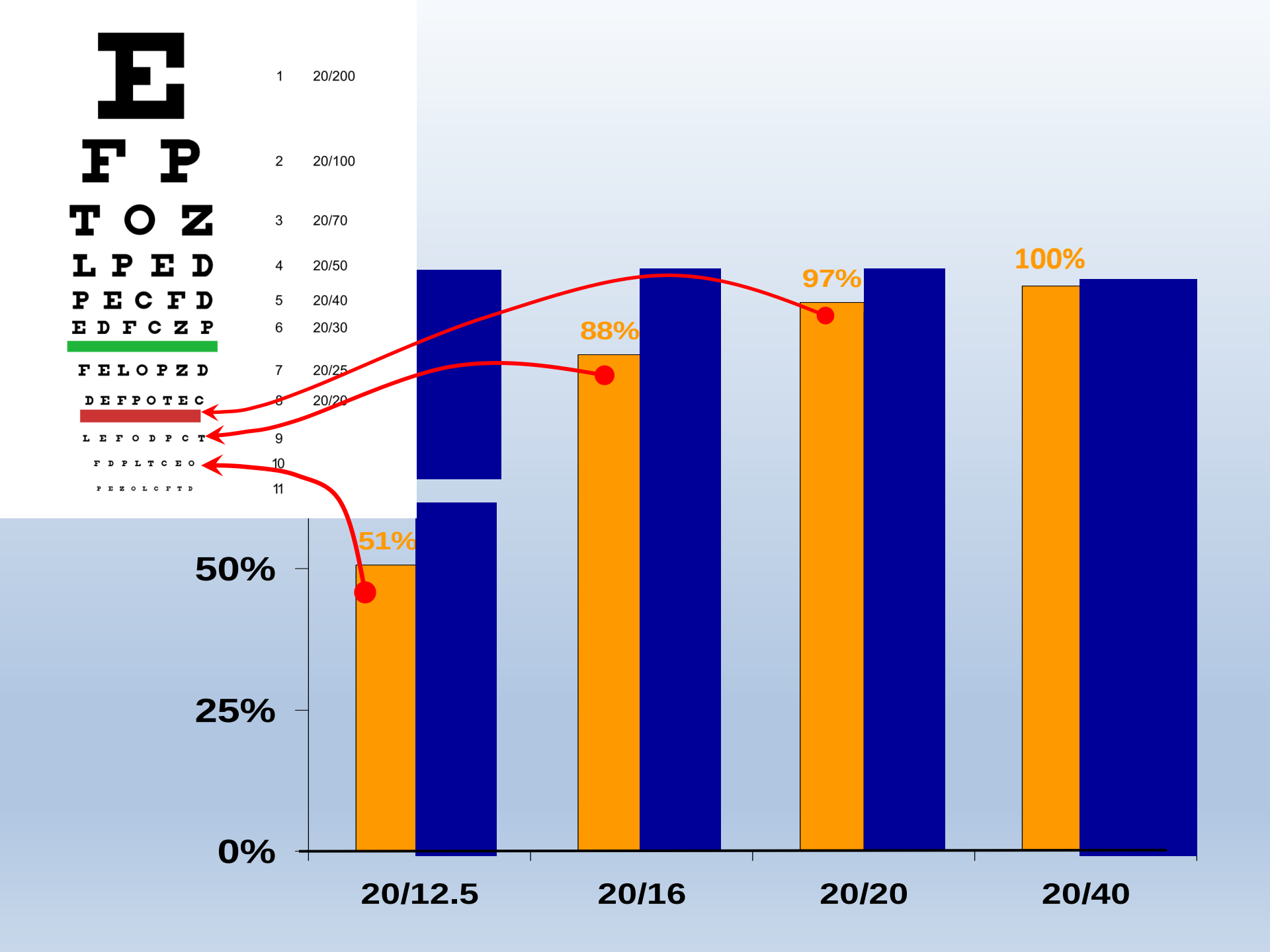
LDV Z6; ZIEMER



WAVELIGHT; ALCON

LensX; ALCON

ATOS; SCHWIND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F P
T O Z
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P E C F D
E D F C Z P
F E L O P Z D
D E F P O T E C
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F D P L T C E O
P E Z O L C F T D
1 20/200
2 20/100
3 20/70
4 20/50
5 20/40
6 20/30
7 20/25
8 20/20
9
10
11
51%
88%
97%
100%
50%
25%
0%
20/12.5
20/16
20/20
20/40

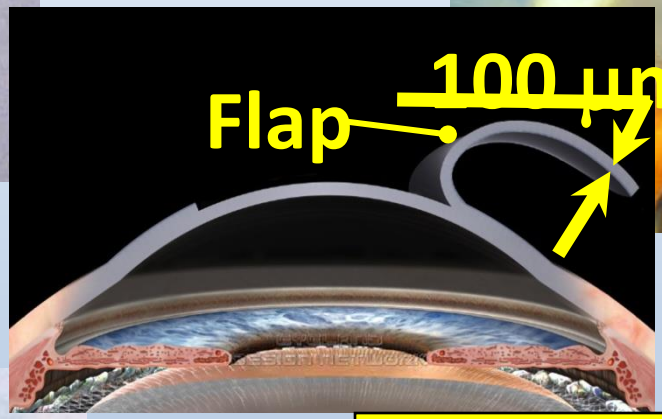
20/20 Vision

20/5 Vision

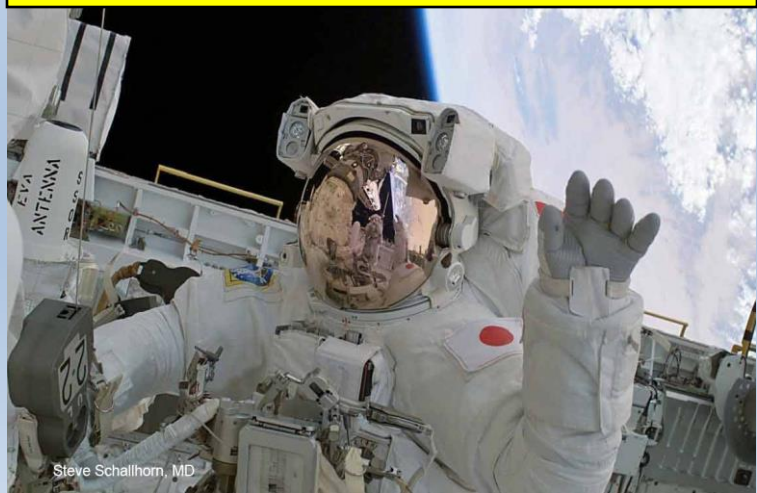
Photoreceptors

20/5 vision is the limite

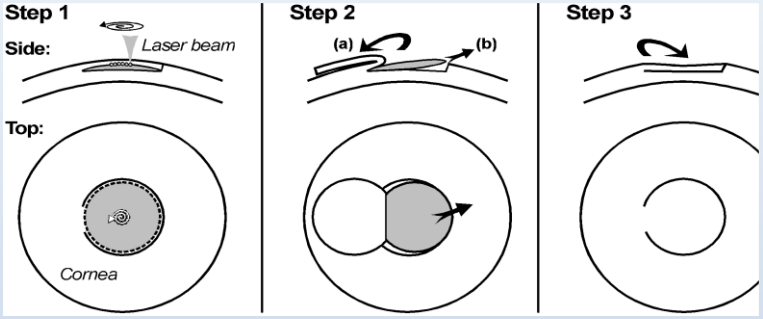
YES



Approved for astronauts as well



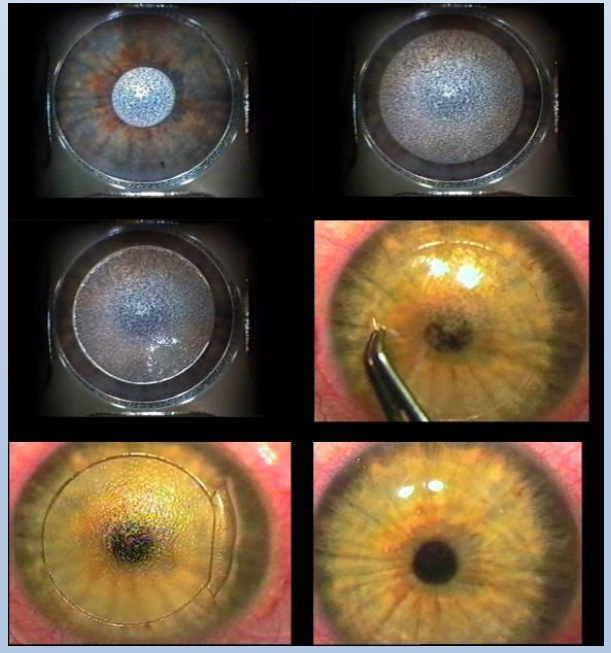
Femtosecond Laser Keratome

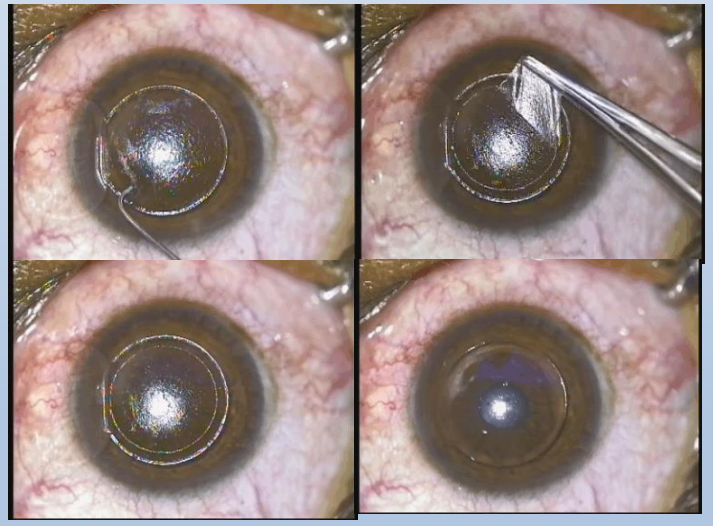


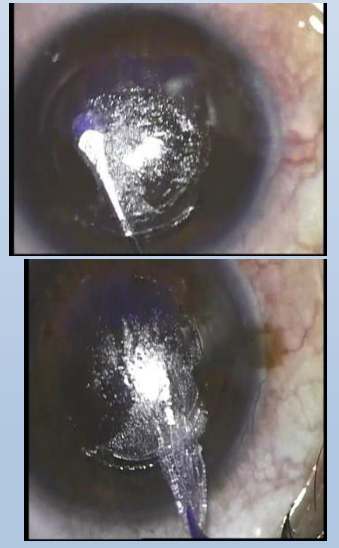
Femtosecond Laser Keratomileusis (FLK)

1999 Flap and intrastromal lens cutting by Femtosecond Laser

The FLEX & ***ReLEX „smile"*** procedure by ***Zeiss SmartSight*** procedure by ***Schwind*** based on our FLK idea





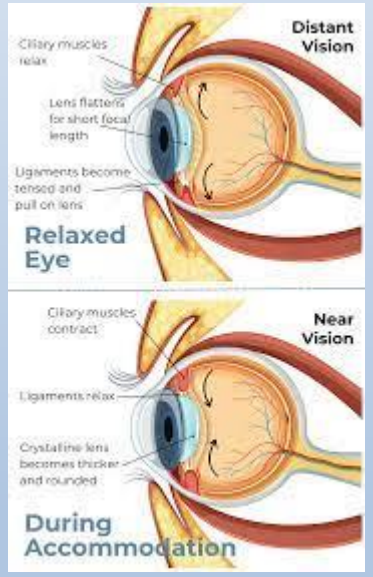


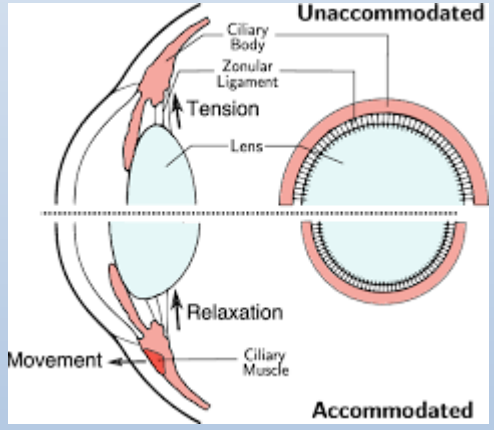
The Smile & SmartSight Procedures

PRESBYOPIA

Accommodation occurs when the eye automatically adjusts its focus for short vision. During accommodation, the ciliary muscles contract, the supporting ligaments relax, and crystalline lens of the eye becomes thicker — focusing the vision for nearby objects.

Between ages 12 and 50 the cristallin lens becomes a thousand time more rigid.



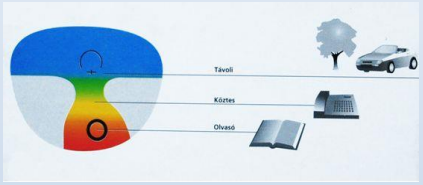


Accomodation loss is normal with ageing

In 2020 lived about 2,6 milliard presbyopic people in the world and this number growing every year.

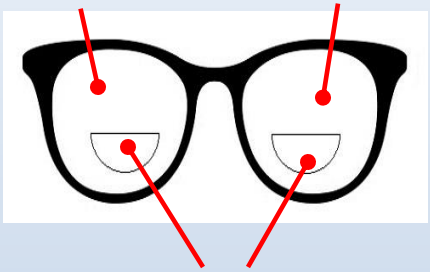
Presbyopia corrections

Multifocal glasses



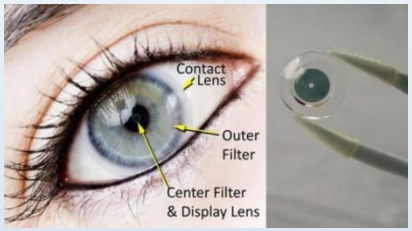
Bifocal glasses

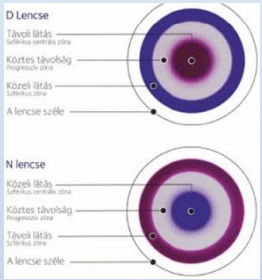
Far vision correction



Near vision correction +3 D

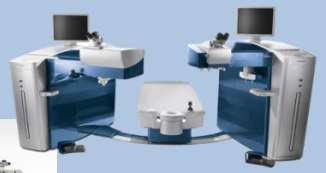
Multifocal contacs





Corneal Refractive Surgery

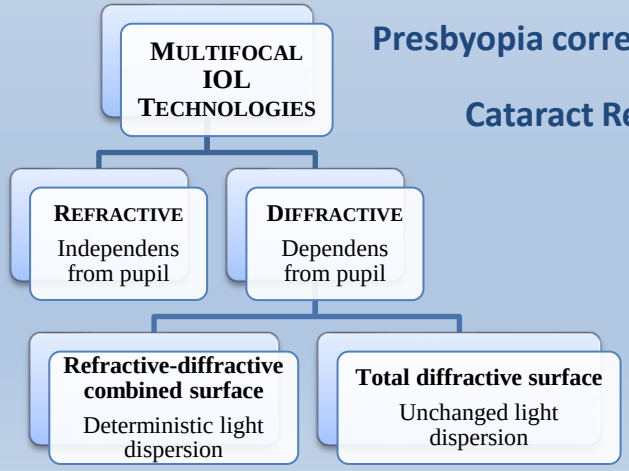
- **Corneal inlays**
(Camra, Presbylens)



- **Presby-Lasik**

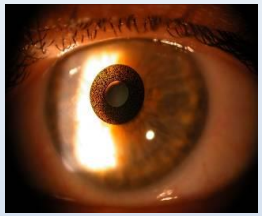
Presbyopia correction with IOL

Cataract Refractive Surgery



2009-2013 Testing the efficacy of different Corneal Inlays implant to Presbyopia correction

„Camra Inlay”

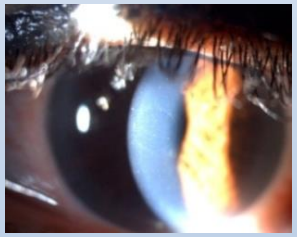


AcuFocus™ ACI 7000 ***How it Works***

Intrastromal implants:
- Camra inlay
  - Pinhole
  - Increase depth of focus
  - Presbyopia correction

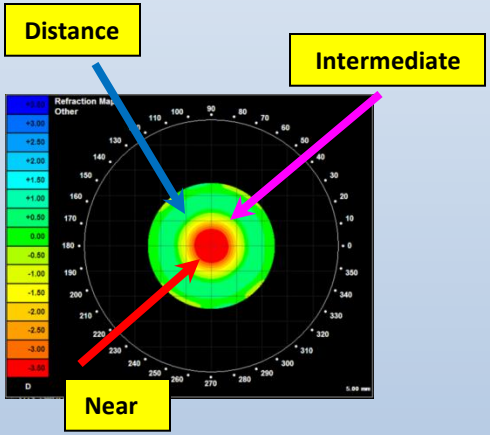
Bor Zs, Kiss K, Ratkay I, R. Palmisano, Ferincz I, Ch Gauhier

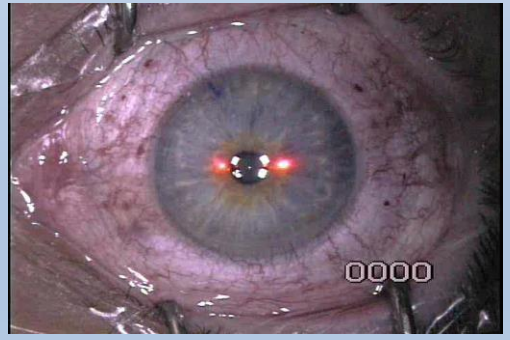
„Presby-microlens”

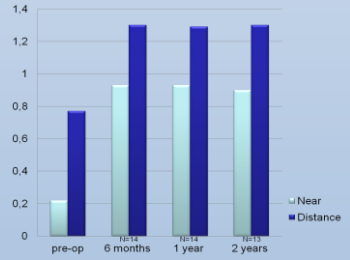


The first Presby-microlens was implanted in **2010** in Europe by us

- Presby-microlens
  - Reshape the corneal surface
  - Correction of ammetropia/ presbyopia







Advantages:

- Improve near & intermedia vision
- Easy to implant
- Minimal changing in far vision
- Reversible

Disadvantages:

- Foreign body in the cornea
- After longer follow-up can cause autoimmun inflammation
- Price

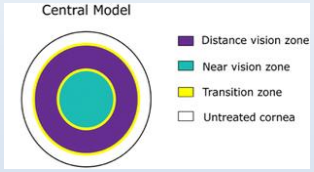
Intracorneal implant types (inlays)

	Raindrop™ (revision optics)	Flexivue™ microlens (Presbya)	Icolens (Neoptics)	Kamra™ (Acufocus)
Diameter	2.0 mm	3.2 mm total 1.mm central	3.0 mm	3.8 mm total 1.6 mm central
				
Thickness	30 µm	15 µm Grosor de borde	15 A 20 µm	5 µm
Potency	None	External ring for near	External ring +1.25A + 3.00 D	None
Corneal depth	130-150 µm	280 µm		220 µm

Ratkay-Traub I.: Long term follow-up of presbyopia treatment. *Ophthalmology Times Europe*. V10 N2 26-29 (**2014**.)

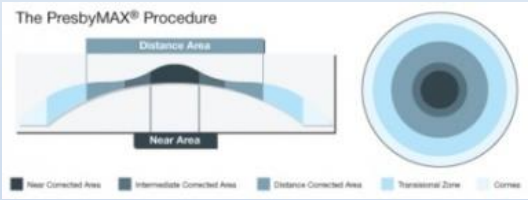
Presbyopic laser correction

PresbyLasik



• **Central:** ***a) multifocality on both eyes***

Custom Vue (VISX), *PresbyMAX* Symmetric (Schwind), *Supracor* (Technolas),

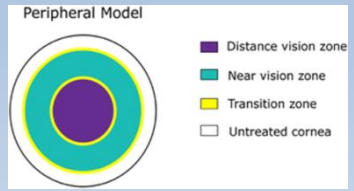


b) little multifocality, *D eye far, non D eye more near*

•*PresbyMAX* -mikro-monovision, Hybrid (Schwind)

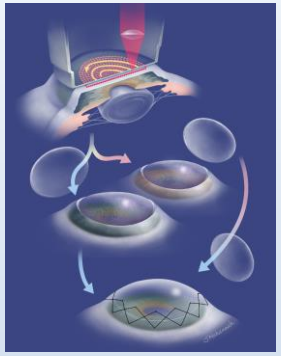
c) little multifocality with encrease depth of focus, *D eye far, non D eye near*

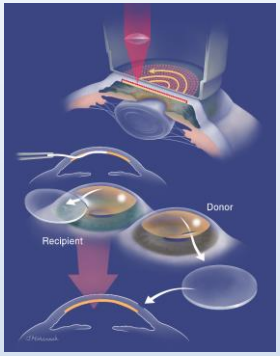
•Laser Blended Vision *LBV - Presbyond* (Zeiss) – also for Myop-presbyops



•**Peripheral**: Nidek

The Femtosecond Laser revolutionized therapeutic corneal surgery





Lamellar Keratoplasty

- Anterior Lamellar Keratoplasty (ALK, FALK)
- Posterior Lamellar Keratoplasty (DSEK, DMEK, DALK)

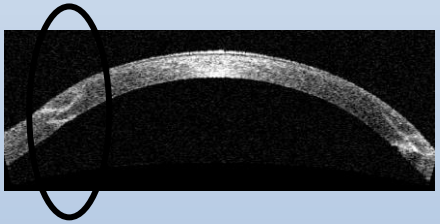
Penetrating Keratoplasty

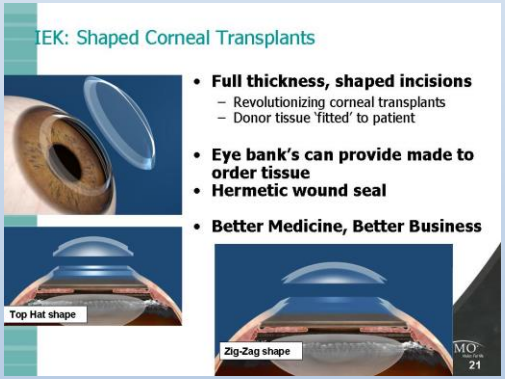
Advantages

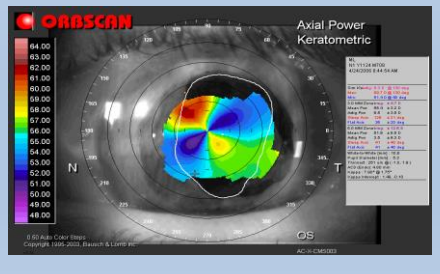
- Complete suture removal by three months
- With the larger posterior diameter, more endothelial cells are transplanted
- Anterior graft margins are at a safe distance from the limbus

Disadvantages

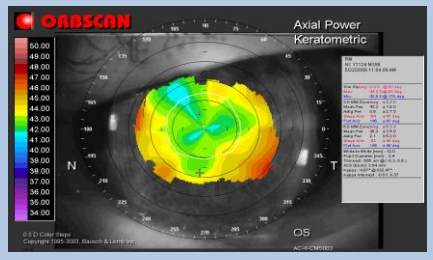
• Manual stromal dissection takes time to prepare the host and the graft
• Learning curve







Typical 1 year post-op result with standard trephine cut PKP = [8 diopters of astigmatism]



IntraLase Advanced Keratoplasty at 3 months post-op = [1-2 diopter of astigmatism]

FEMTOSECOND LASERS FOR CATARACT

TECHNOLAS, B&L

Crystalline Lens Surgery

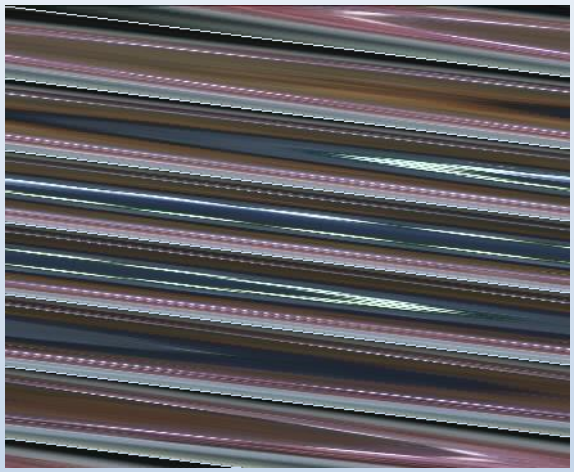
- Direct ablation of the crystalline lens: increase flexibility for Presbyopia or
- Capsulorhexis=>Lens ablation for Cataract
- Theory: By controlling corneal incisions, capsulorhexis dimensions, and lens removal, one is improving outcomes with less energy

LENSX, ALCON

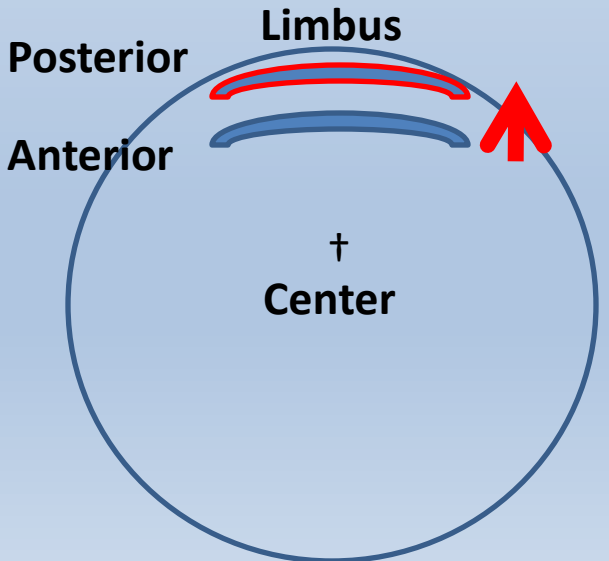
LensAR

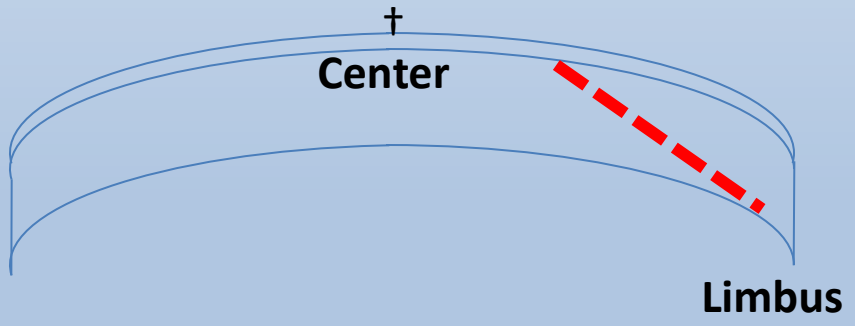
OPTIMEDICA; ABBOTT

Keratotomy Procedures



- Astigmatic Keratotomy
- Relaxing corneal incisions
- Intrastromal incisions
  - Through Epithelium
  - Intrastromal: Perpendicular; slanted and spare Bowman's and Descemet's





Femtosecond Laser Applications

- **Glaucoma** Budapest & Szeged Univ. trials

Tibor Juhász

See this image and copyright information in PMC
Figure 1 ViaLase Laser System. 1, System chassis. 2, Touchscreen. 3, Optical delivery head. 4, Proprietary coupling lens.

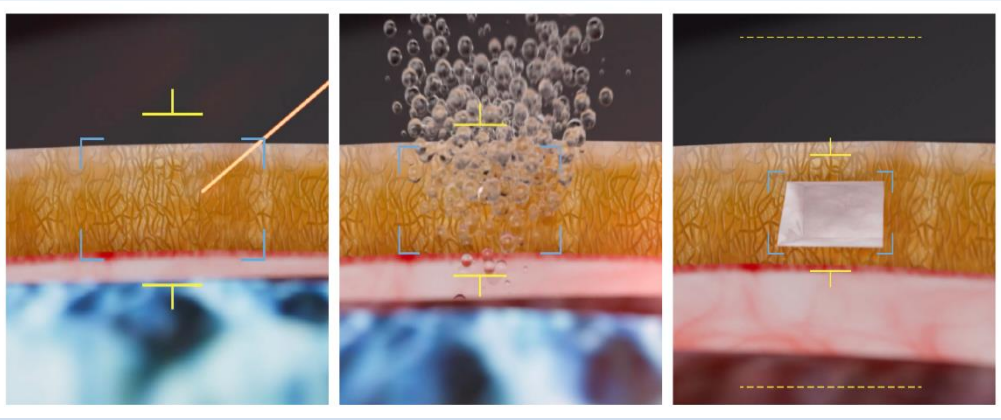
1.0 – ViaLase Laser System

2.0 – ViaLux

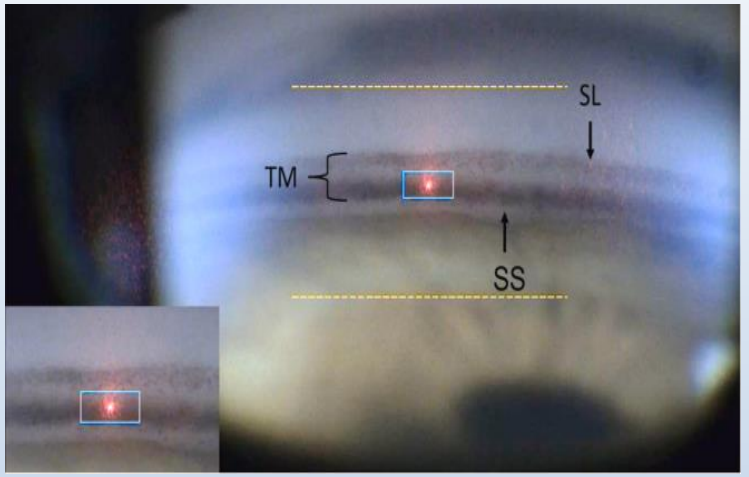
Áron Szabó

Glaucoma Femtolaser Research Group in Szeged Med. Univ.

Femtosecond laser image-guided high-precision trabeculotomy (FLigHT)



https://www.reviewofoptometry.com/news/article/new-femto-laser-trabeculotomy-method-safe-at-24-months



Outpatient procedure – VIA 002 phase III clinical trial at site 2004 Szeged, Hungary

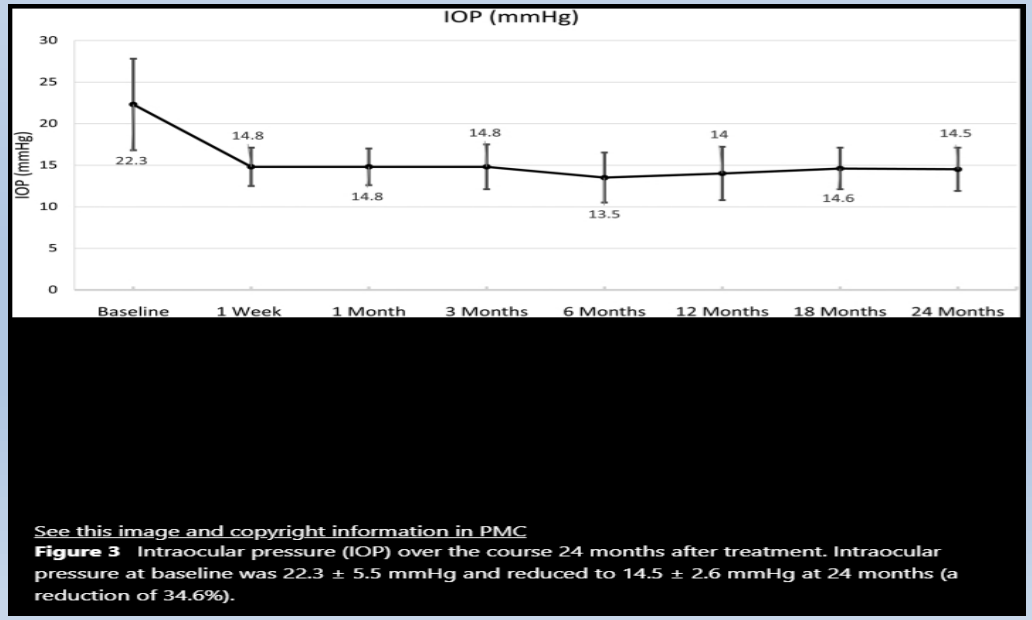
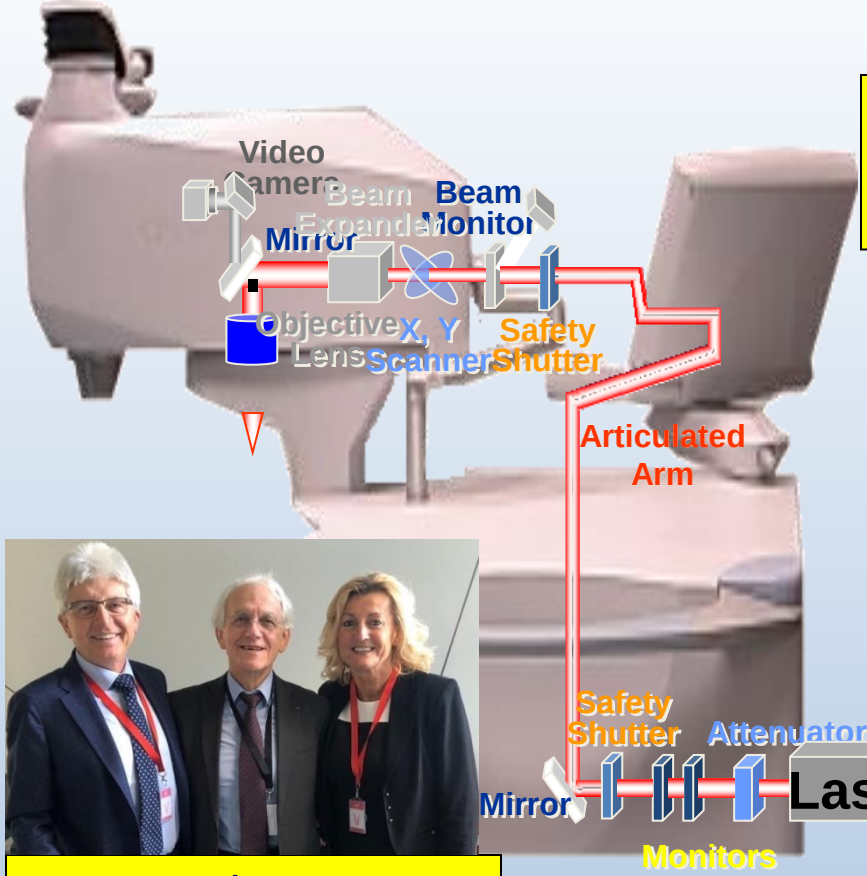


Figure 3 Intraocular pressure (IOP) over the course 24 months after treatment. Intraocular pressure at baseline was 22.3 ± 5.5 mmHg and reduced to 14.5 ± 2.6 mmHg at 24 months (a reduction of 34.6%).

The first Corneal Femtosecond Laser Research Group (1998)



Gerard Mourou,
Nobel-Prize in Physics 2018

RATKAY-TRAUB IMOLA

KISS KRISZTINA

JUHÁSZ TIBOR

RÁKSI FERENC

BOR ZSOLT

GOLDSTEIN PÉTER

FERINCZ ISTVÁN

RON KURTZ

Refractive treatments worldwide

2004. Szentendre
G & M Mourou & I. Ratkay

LASIK procedures

- USA ***20 million***
- Europe since 1996 more than
  10 million

- Currently, more than 50% of LASIK operations are performed with Femtosecond Lasers

- *Over **40 million** procedures were performed in the USA and Europe now*

This means that over the past 20 years Femtosecond Lasers were used in more than
20 million *Refractive treatments* on the cornea

&

*about **5 million** treatments in the lens during Cataract surgery.*

Bp MTA 2019: Bor Zs, Ratkay I, Mourou G,
Nagy Z Zs, Juhász T

Paris, 2020.02.14.

Donna Strickland & Gérard Mourou

Karikó Katalin

Krausz Ferenc

Thank you for your attention!