Gerd.auffarth@med.uni-heidelberg.de www.ivcrc.com www.djapplelab.com

CAIRS in CAIRO

G.U.Auffarth

International Vision Correction Research Centre (IVCRC)
The David J. Apple International Laboratory for Ocular Pathology
Department of Ophthalmology
Ruprecht-Karls-University of Heidelberg
Chairman: G. U. Auffarth, MD, PhD, FEBO,FWCRS

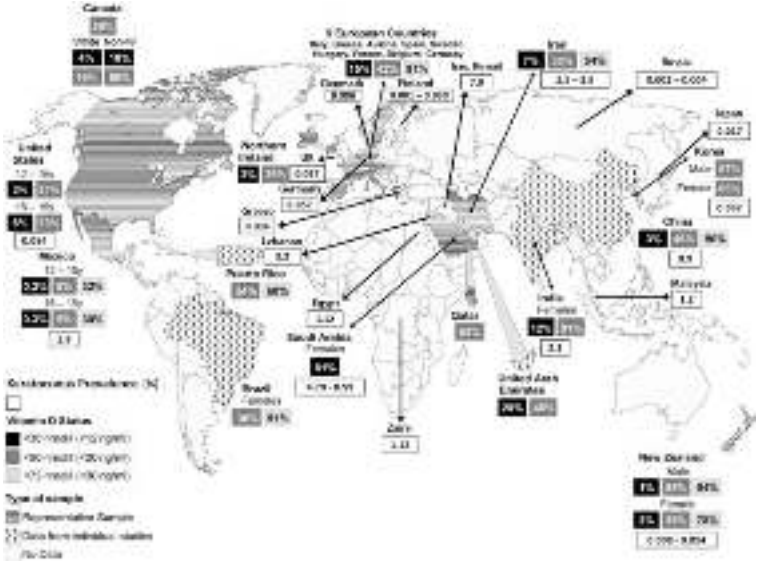
IVCRC / DJ Apple Laboratory: Financial Disclosure 2025/2026

Afidera[3]
Alcon[1,2,3,4]
AMO/Johnson&Johnson[1,2,3,4]
Carl Zeiss Meditec[1,2,3,4]
Contamac[1]
Cristalens[1,2,3,4]
Elios[1,3,4]
Eyebright[3]
EyeD[1]
Eyedeal[1]
EyeYon[1,2,4]
Fluoron[1]
Hanita[1,2,3,4]
Hoya[1,2,3]
Kowa[1,2,3]
Oculus[1,3]
Presbia[1]
Rayner[1,2,3,4]
Teleon[1,2,3]
1stQ[1]

1 = Research Grants; 2 = Travel Expenses; 3 = Lecture Fees; 4 = Consulting

Keratoconus

- Bilateral Corneal Ectasia
- Progressive thinning and asymmetrical protrusion of the cornea
  - → Myopic shift and irregular astigmatism
- Male = Female
- Estimated prevalence up to 4,790 per 100,000



Romero-Jiménez M et al. Keratoconus: a review. *Cont Lens Anterior Eye*. 2010 Aug;33(4):157-66; quiz 205.
Crawford AZ et al. The enigma of environmental factors in keratoconus. *Asia-Pacific J Ophthalmol*. 2020;9:549–556.
Barr JT et al. Factors associated with corneal scarring in the CLEK Study. *Cornea*. 2000 Jul;19(4):501-7.

Treatment Options

Conservative:

Glasses or Contact Lenses (CL)

→ CL-Intolerance

Surgical:

Corneal Crosslinking (CXL)

Keratoplasty (penetrating/lamellar)

→ Transplant insufficiency/rejection

→ Chronic topical corticosteroids (secondary glaucoma)

→ Suture-associated complications

Intracorneal Ring Segments (ICRS)

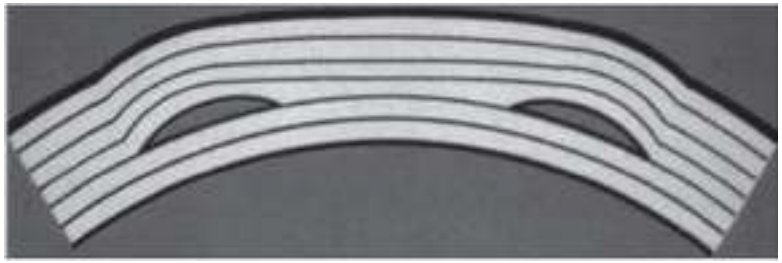
Barraquer's Law of Thickness:

- Corneal power can not only be altered via tissue ablation, but also via tissue addition
- Adding tissue to the corneal periphery flattens the center

→ Re-distribution of the corneal tension forces

→ Regularization of the topography

José Ignacio Barraquer
MD, FACS, FRCOphth



Barraquer JI. Queratoplatica refractiva. *Estudios e informaciones Oftalmologicas*. 1949;2:10.

Synthetic Intracorneal Ring Segments

Introduced in the 90’s

<u>Effective strategy to improve vision</u>:

→ Reduction of refractive error via change in central corneal topography

→ Improvement of the higher-order aberrations (HOA)

Schanzlin DJ et al. The intrastromal corneal ring segments. Phase II results for the correction of myopia. *Ophthalmology*. 1997 Jul;104(7):1067-78.
Colin J et al. Correcting keratoconus with intracorneal rings. *J Cataract Refract Surg*. 2000 Aug;26(8):1117-22.
Benoist d'Azy C, et al. Efficacy of Different Procedures of Intra-Corneal Ring Segment Implantation in Keratoconus: a Systematic Review and Meta-Analysis. *Transl Vis Sci Technol*. 2019 Jun 11;8(3):38.

Synthetic Intracorneal Ring Segments

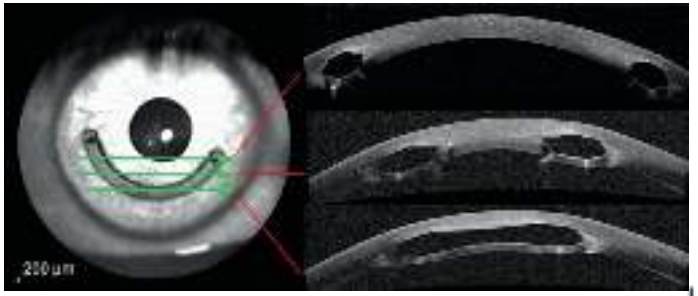
KeraRing

Intacs

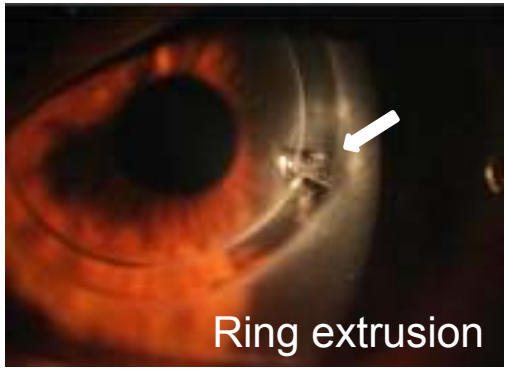
Ferrara Ring

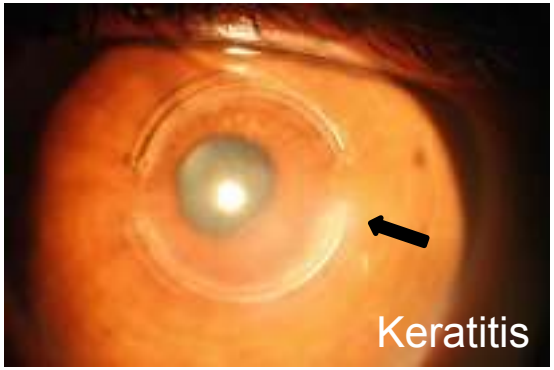
Myoring

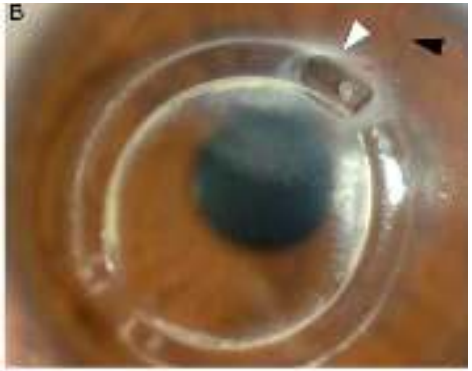
- PMMA Material
- Implantation in 75-80% stromal depth

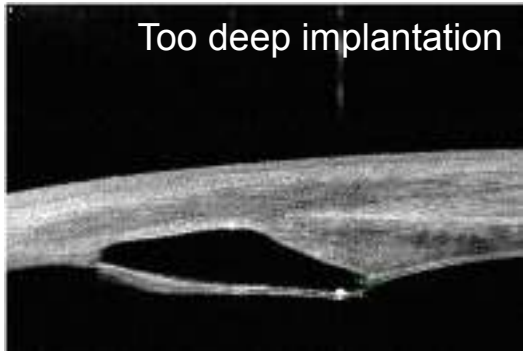


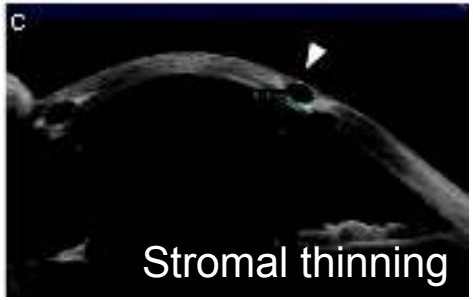
Complication rate of up to 30%











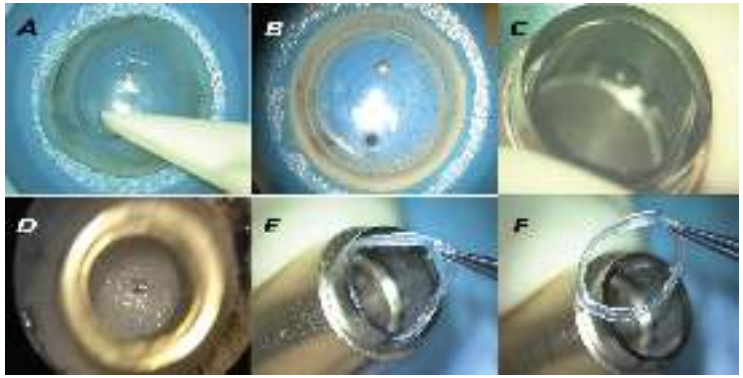
Kanellopoulos AJ et al. *Cornea*. 2006 Jan;25(1):29-33.

Corneal allogeneic intrastromal Ring Segments (CAIRS)


ORIGINAL ARTICLE

Corneal Allogenic Intrastromal Ring Segments (CAIRS) Combined With Corneal Cross-linking for Keratoconus

Sascha Jacob, MS, FRCS, DNB, Sheila R. Patel, DNB, Amar Agarwal, MS, FRCS, FRCO,



Human corneal tissue: allogeneic

→ Eliminates the PMMA-associated complications of ICRS

Transplantation in stromal tunnels (femtosecond laser-assisted or manual tunnel creation)

→ Flattening of the central cornea and reduction in irregular astigmatism

Higher biocompatibility

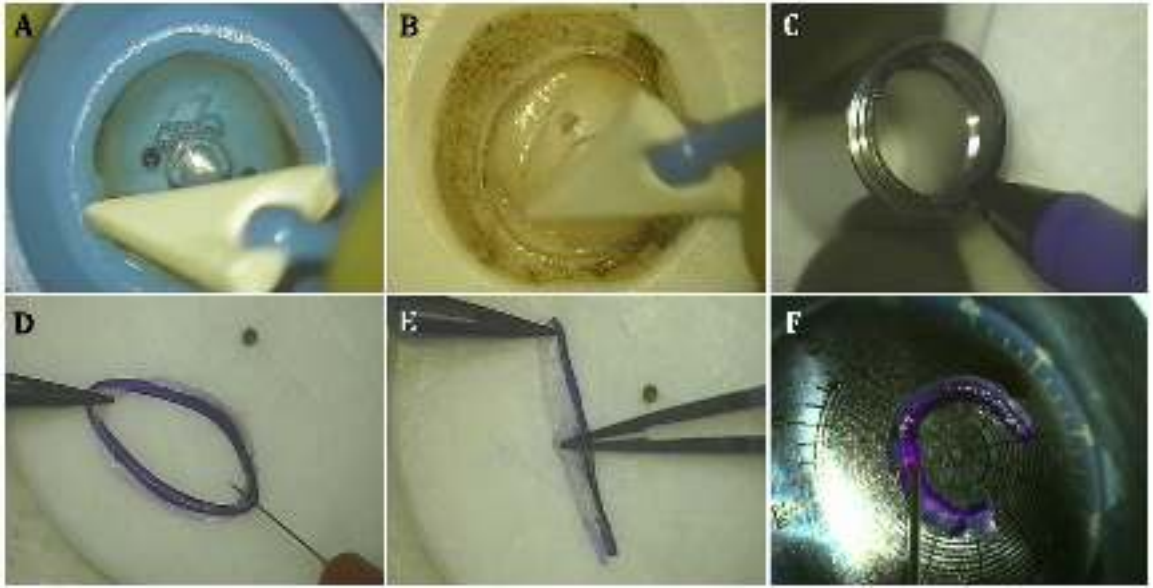
Same refractive index as the recipient cornea

Jacob S et al. Corneal Allogenic Intrastromal Ring Segments (CAIRS) Combined With Corneal Cross-linking for Keratoconus. *J Refract Surg*. 2018 May 1;34(5):296-303.

Numerous clinical studies demonstrate the efficacy

Acquisition of CAIRS-Transplants

1. Manual graft preparation

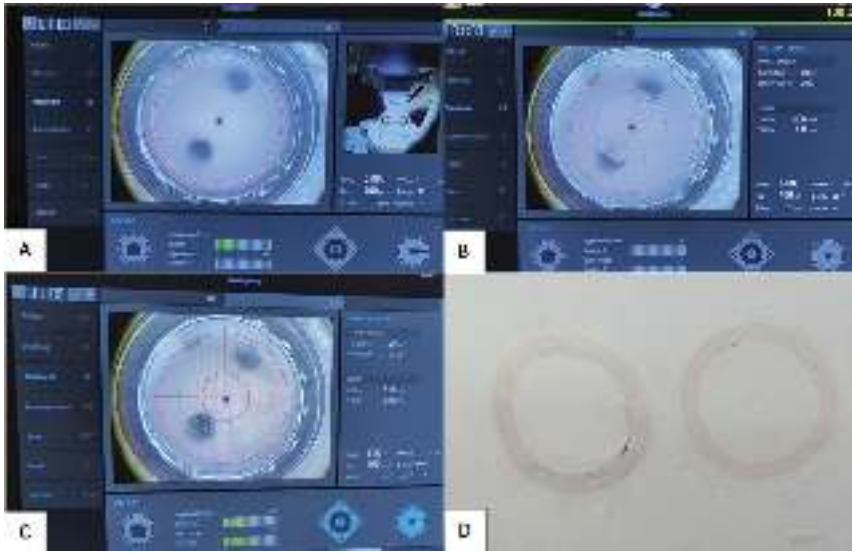


Son HS, Augustin VA, Khoramnia R, Jacob S, Friedrich M, Auffarth GU. Transplantation of a corneal allogeneic intrastromal ring segment (CAIRS) for treatment of keratectasia. *Ophthalmologie*. 2025;122(8):646-651. doi:10.1007/s00347-025-02254-2

Acquisition of CAIRS-Transplants

2. Femtosecond laser-assisted graft preparation


Technique of corneal allogenic ring segment preparation using femtosecond laser: preclinical study on human corneal grafts



Mechleb N, Flamant R, Panthier C, Ghazal W, Dubois M, Gatinel D, Saad A. Technique of corneal allogenic ring segment preparation using femtosecond laser: preclinical study on human corneal grafts. *J Cataract Refract Surg*. 2024 May 1;50(5):518-522.

Acquisition of CAIRS-Transplants

3. Commercially available grafts

Son HS, Augustin VA, Khoramnia R, Jacob S, Friedrich M, Auffarth GU. Transplantation of a corneal allogeneic intrastromal ring segment (CAIRS) for treatment of keratectasia. *Ophthalmologie*. 2025;122(8):646-651. doi:10.1007/s00347-025-02254-2

Commercially Available CAIRS Grafts

- 2-year shelf life at room temperature
- Guaranteed sterility via patented sterilization process
- 6 mm / 8 mm length
- Various transplant thickness

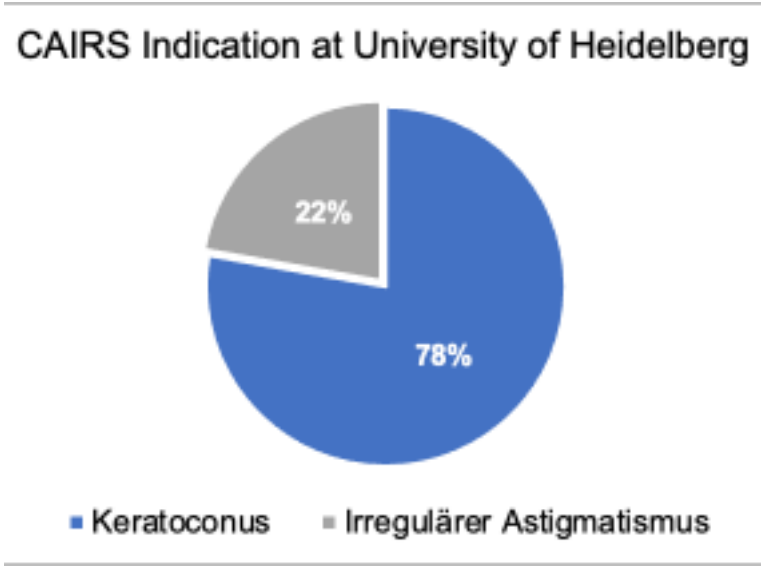
KeraNatural Ring

KeraNatural Arc

CAIRS Transplantation Indications

Corneal Ectasia:

- Keratoconus
- Irregular Astigmatism
- Pellucid marginal degeneration
- Post-LASIK Ectasia

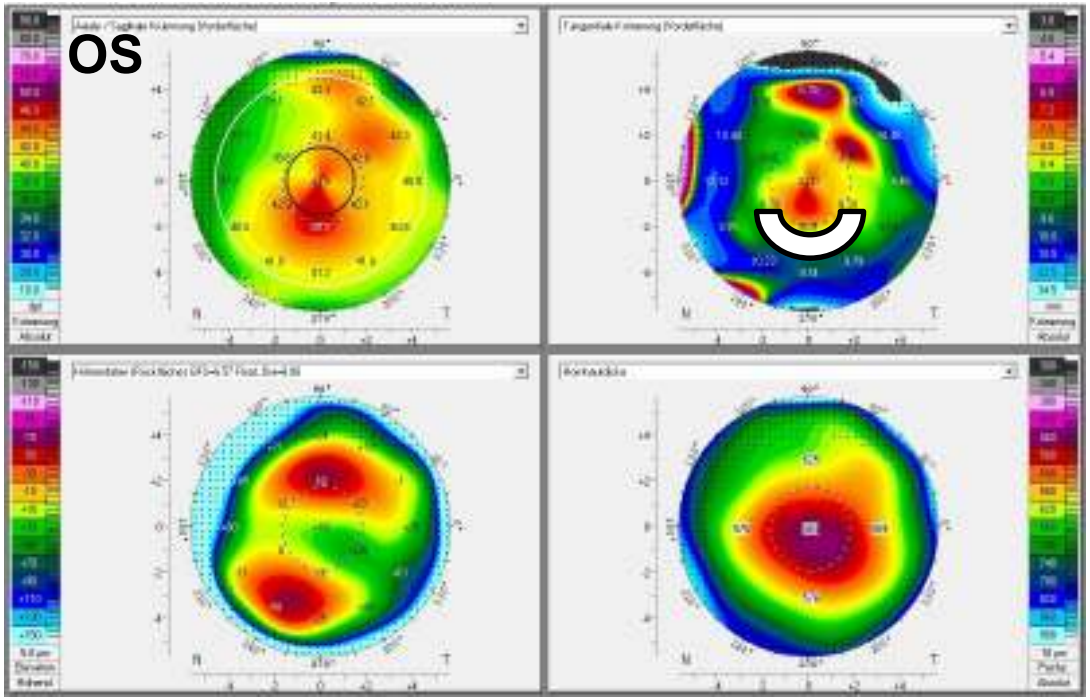


Patient Selection:

- Keratoconus: mild to moderate cases (Kmax <70 D)
- No central scar or edema
- Vision potential, i.e., no vision-limiting ocular comorbidities

CAIRS - Case 1: 26-year-old male

- L>R Corneal ectasia
- RGP lens intolerance
- Good vision with spectacles
- Alternatives for better UDVA?



KeraNatural Arc, 6 mm, 447 µm

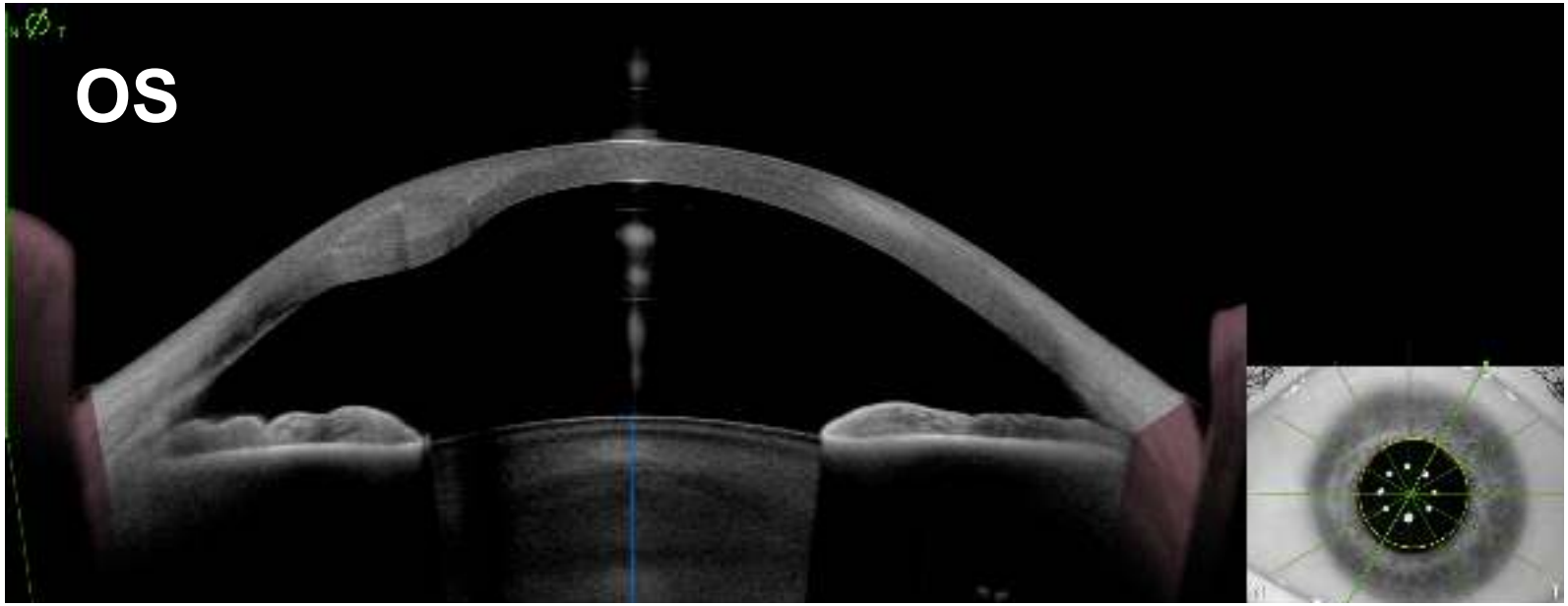
UDVA: OD =0.5
CDVA: OD 0.0 -1.0 23° = 1.0

UDVA: OS =0.16
CDVA: OS -0.5 -3.25 155° = 1.0

University Eye Clinic Heidelberg: Data on file

CAIRS – Case 1: 1. Postoperative Day

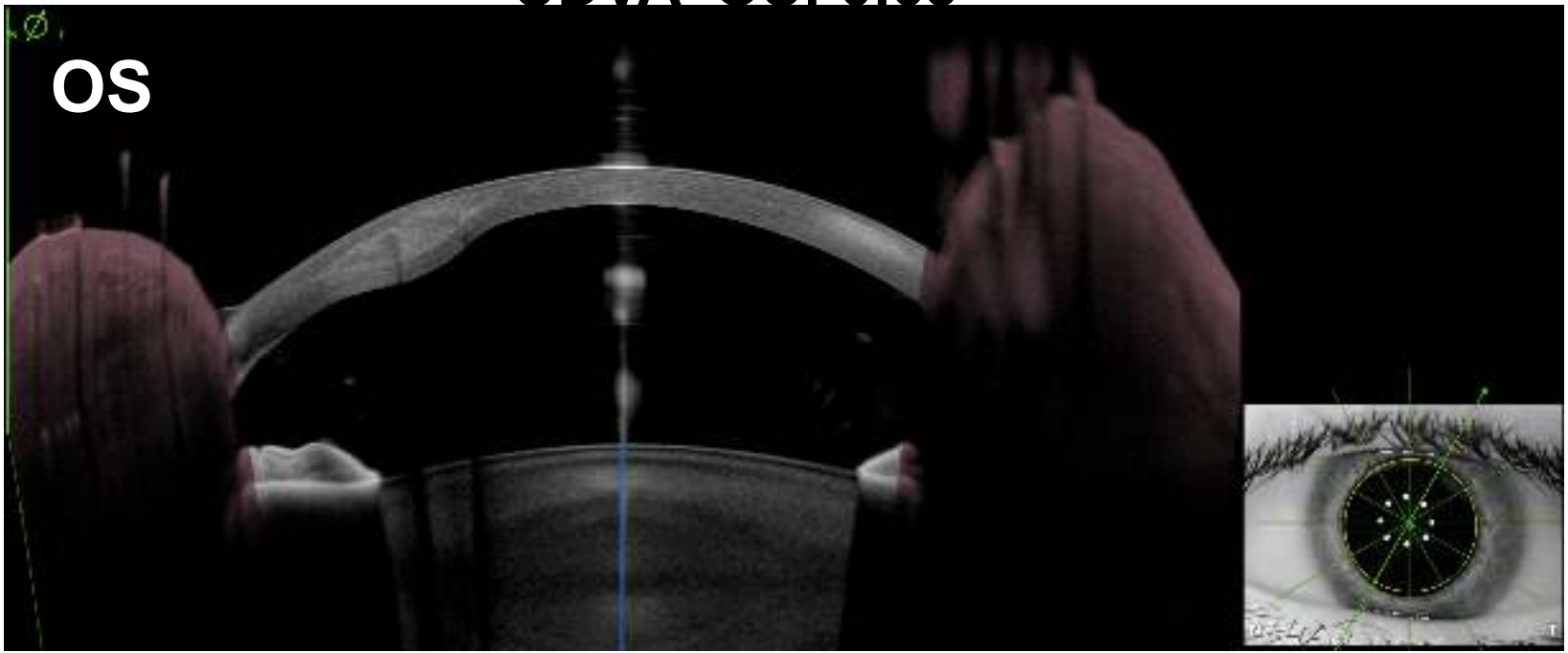
UDVA OS: 0.5



University Eye Clinic Heidelberg: Data on file

CAIRS – Case 1: 1. Postoperative Week

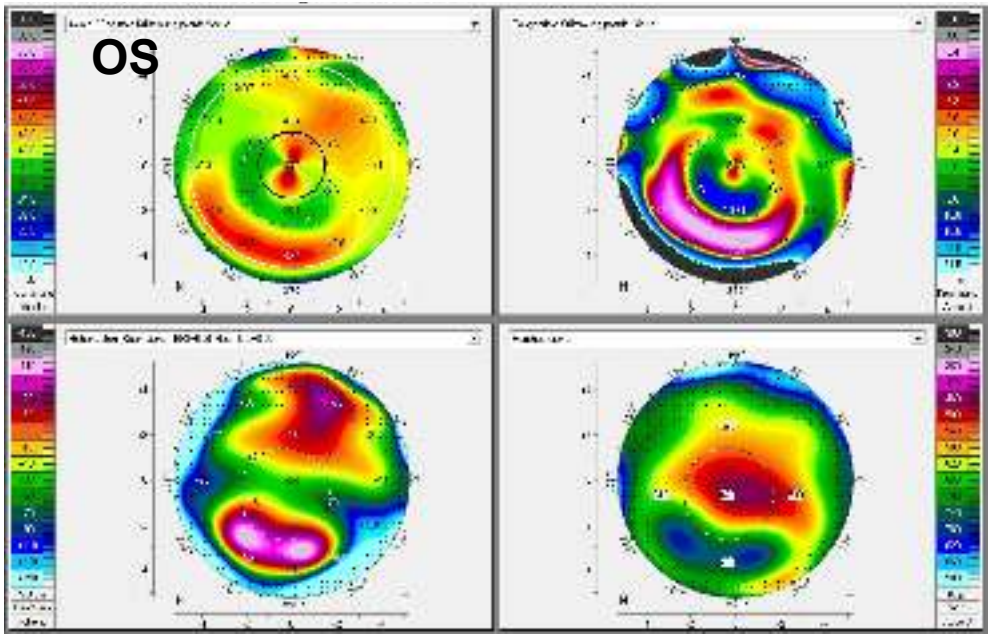
UDVA OS: 0.63



University Eye Clinic Heidelberg: Data on file

CAIRS – Case 1: 6. Postoperative Month

UDVA OS: 1.0

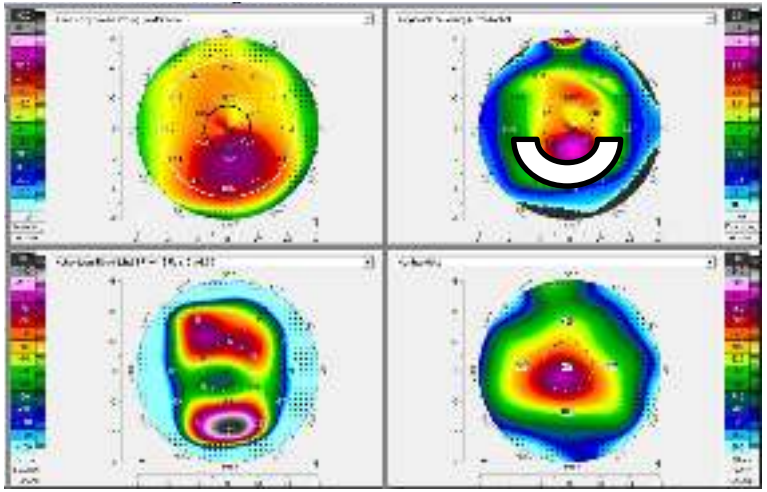


University Eye Clinic Heidelberg: Data on file

CAIRS - Case 2: 34-year-old female

- R/L Keratoconus with irregular astigmatism
- Suboptimal vision with spectacles
- RGP lens intolerance
- Alternatives?

OD



KeraNatural Arc, 6 mm, 478 µm

CDVA

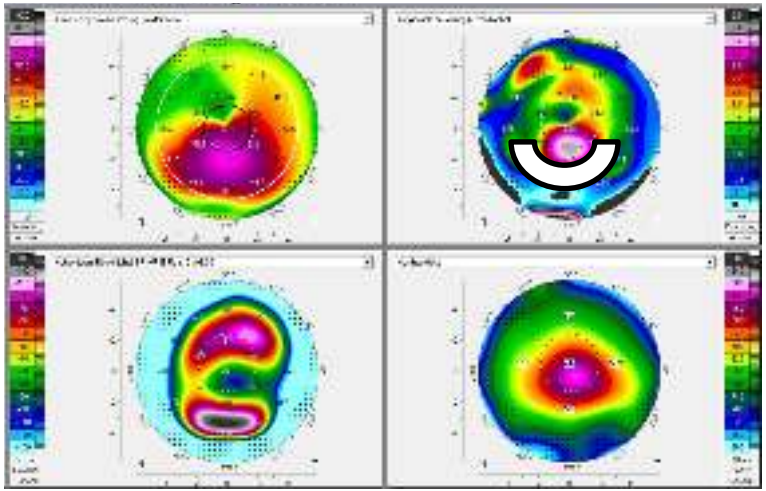
OD -0.5 -3.75 23° = 0.5

OS -1.75 -5.50 126° = 0.63

CAIRS - Case 2: 34-year-old female

- R/L Keratoconus with irregular astigmatism
- Suboptimal vision with spectacles
- RGP lens intolerance
- Alternatives?

OS



KeraNatural Arc, 6 mm, 560 µm

CDVA

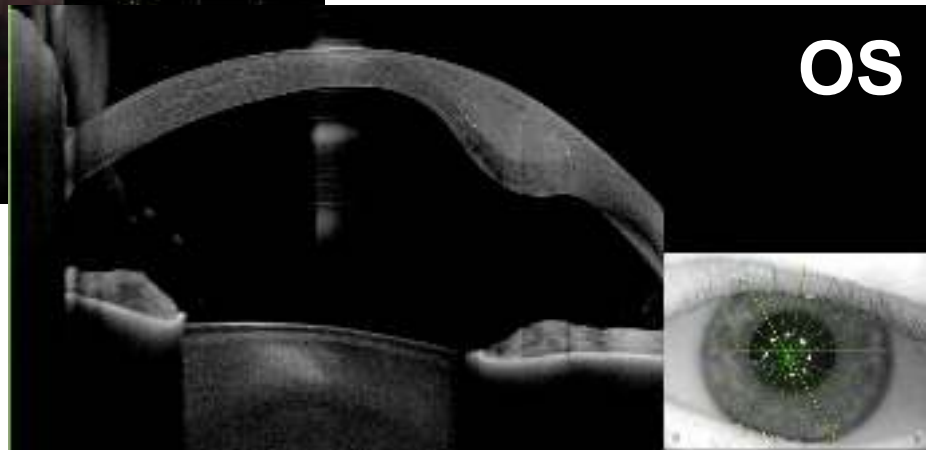
OD -0.5 -3.75 23° = 0.5

OS -1.75 -5.50 126° = 0.63

CAIRS – Case 2: 1. Postoperative Day

UDVA OS: 0.32

UDVA OS: 0.63



University Eye Clinic Heidelberg: Data on file

CAIRS – Case 2: 1. Postoperative Week

UDVA OS: 0.5

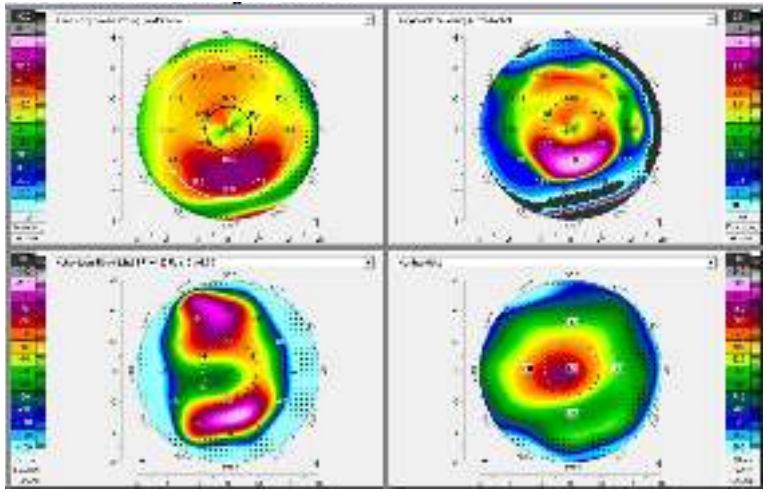
UDVA OS: 0.63

University Eye Clinic Heidelberg: Data on file

CAIRS – Case 2: 3. Postoperative Month

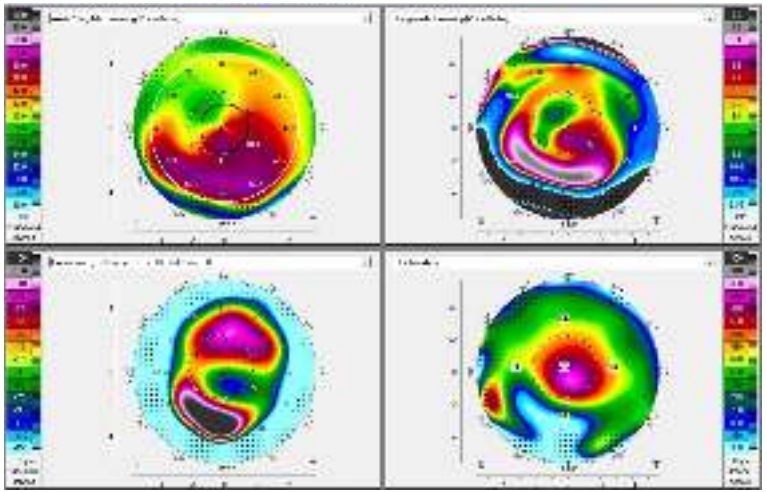
UDVA: OD = 0.63

CDVA OD = -0.5 -2.0 175° = 0.8



UDVA: OS = 0.63

CDVA : OS = +0.25 -2.0 125° = 0.8



University Eye Clinic Heidelberg: Data on file

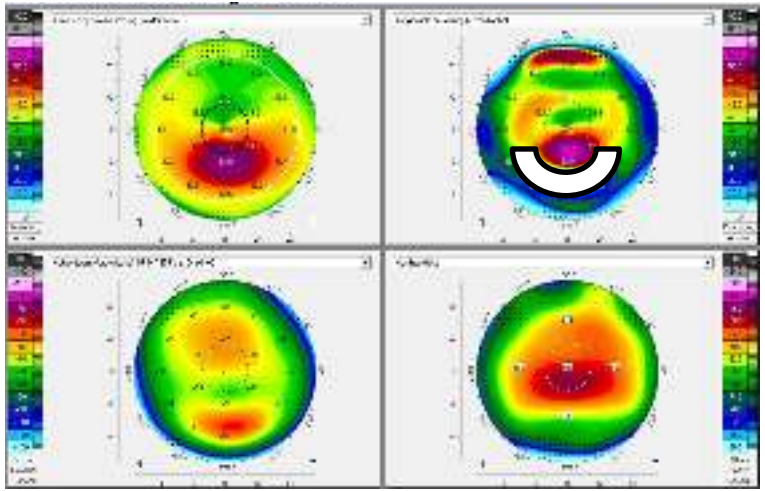
CAIRS - Case 3: 27-year-old male

- L>R Keratoconus
- R/L h/o CXL 2 years ago
- CL intolerance
- “I heard about CAIRS – would I be a candidate?”

UDVA OD =0.4
CDVA OD = -1.25 -0.75 74° = 0.8

UDVA OS = 0.32
CDVA OS = -1.75 -1.0 90° = 0.8

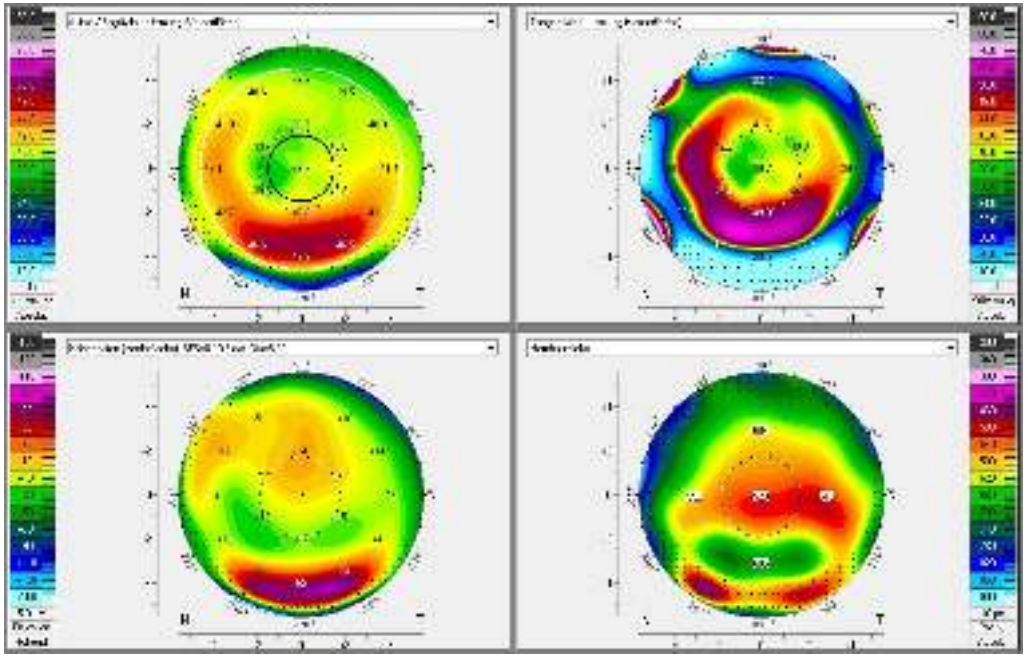
OS



KeraNatural Arc, 6 mm, 468 µm

CAIRS – Case 3: 1. Postoperative Week

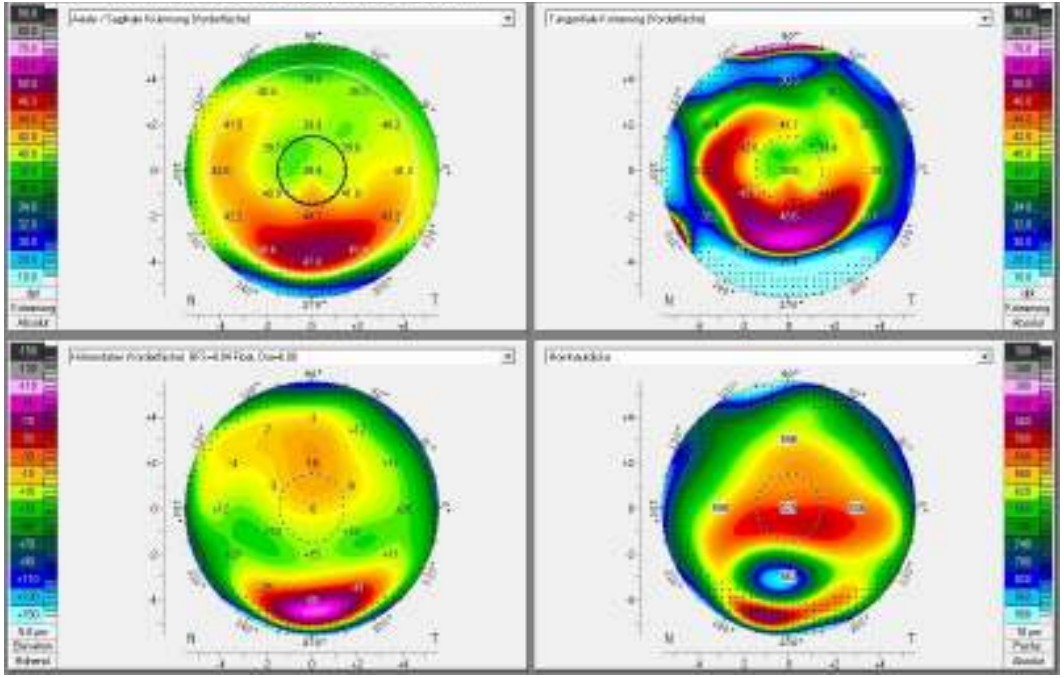
UDVA OS = 0.8



University Eye Clinic Heidelberg: Data on file

CAIRS – Case 3: 4. Postoperative Month

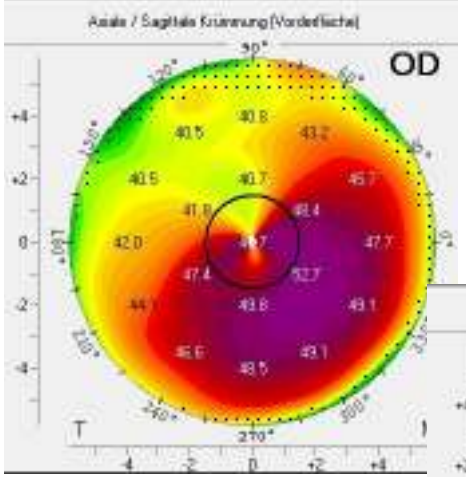
UDVA OS = 1.0

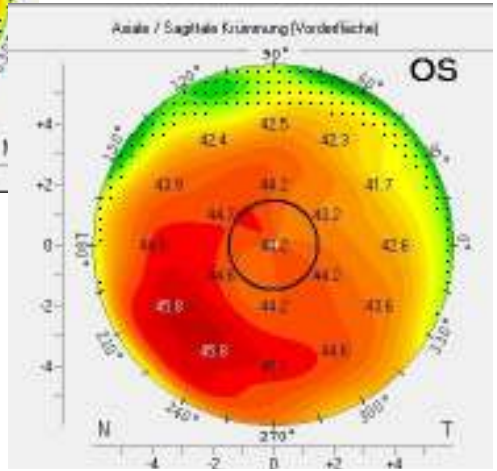


University Eye Clinic Heidelberg: Data on file

CAIRS - Case 4: 70-year-old male

- R>L Corticonuclear cataract
- Myopia magna
- FECD
- Irregulärer astigmatism





UDVA	**CDVA**
R FC @ 1 m	**-18.0 -2.0 99° = 0.16**
L FC @ 1 m	**-14.25 -1.75 29° = 0.32**

University Eye Clinic Heidelberg: Data on file

Treatment Options for the Right Eye

1. Cataract surgery

   + postoperative correction of residual refractive error

2. CAIRS

   + cataract surgery in 6 Months

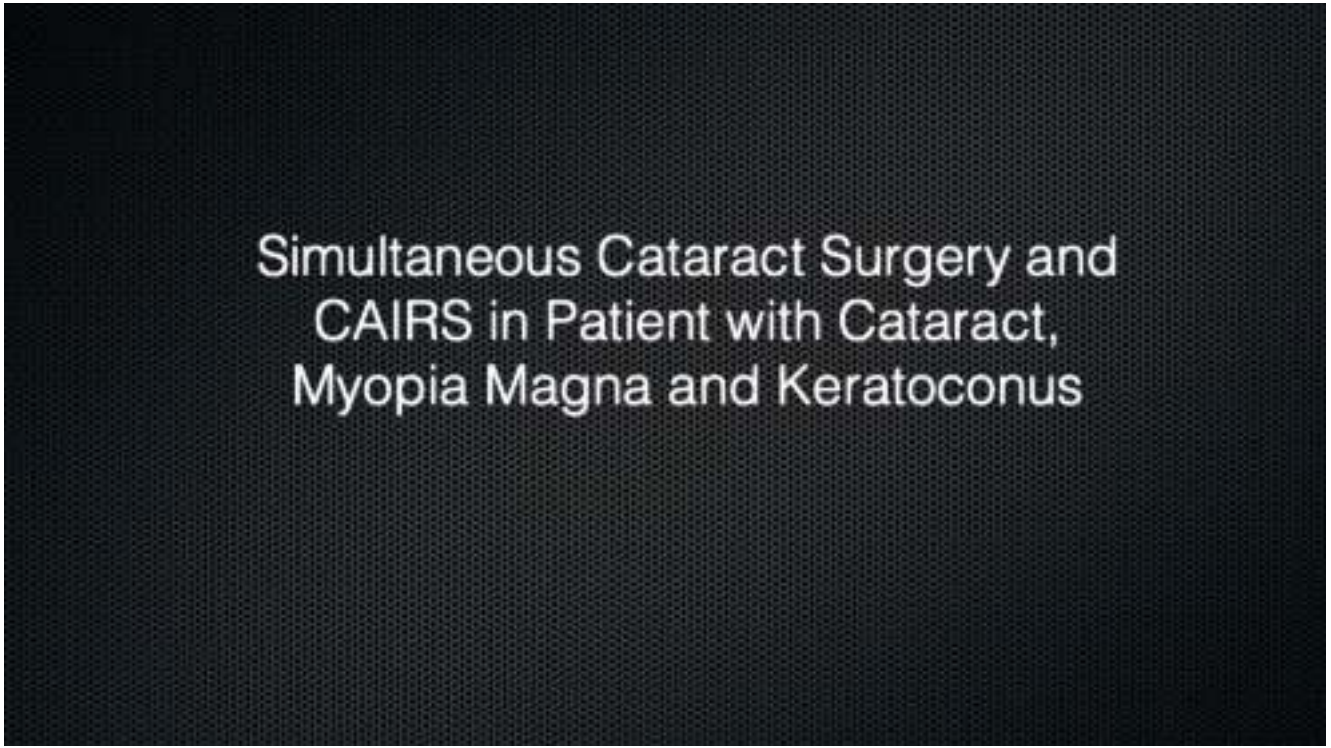
   +/- postoperative correction of residual refractive error

3. Simultaneous CAIRS/cataract surgery

   +/- postoperative correction of residual refractive error (Target refraction -3.0 D)

University Eye Clinic Heidelberg: Data on file

Surgery: Sim.Cat./CAIRS



University Eye Clinic Heidelberg: Data on file

Sim.Cat./CAIRS: Postoperative Exams

Complaints

No pain, significant visual improvement, very satisfied

UDVA
R 0.2
(pre-OP FC, CDVA 0.16)

4th Postoperative Day
UDVA 0.4
CDVA +2.25 -0.5 170° = 0.8

University Eye Clinic Heidelberg: Data on file

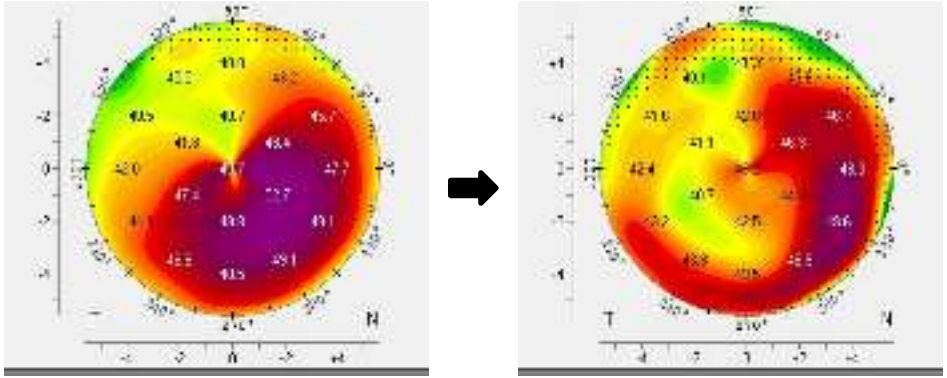
Sim.Cat./CAIRS: Postoperative Exams

Complaints

No pain, significant visual improvement, very satisfied

UDVA
R 0.2
(pre-OP FC, CDVA 0.16)

4th Postoperative Day
UDVA 0.4
CDVA +2.25 -0.5 170° = 0.8



Pre **4. POD**

University Eye Clinic Heidelberg: Data on file

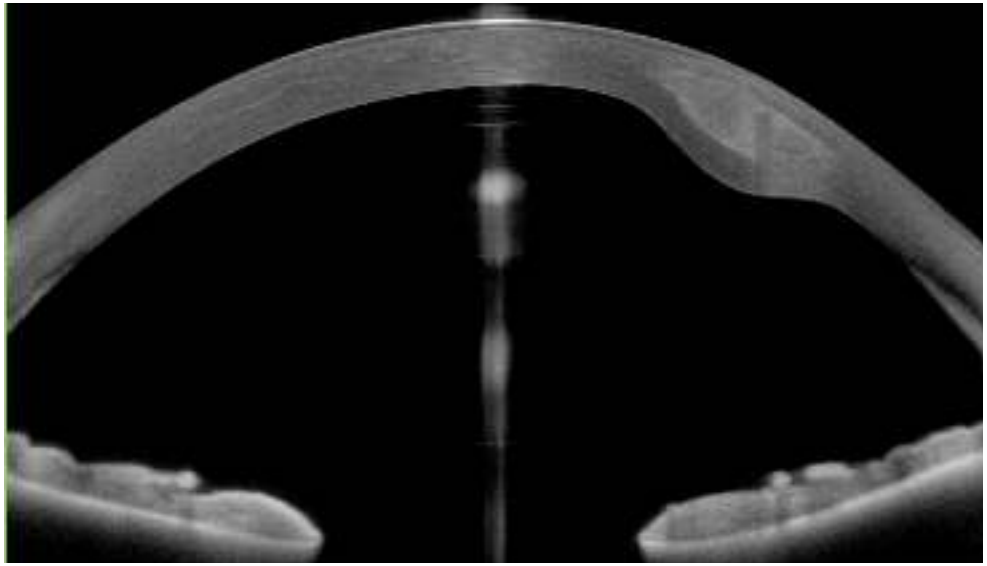
Sim.Cat./CAIRS: Postoperative Exam: 1. Month

OD: UDVA = 0.2

OD: CDVA +1.5 -0.75 105°= 0.5

OS: UDVA = 0.05

OS: CDVA -2.0 -1.75 73° = 0.63



TPL in loco

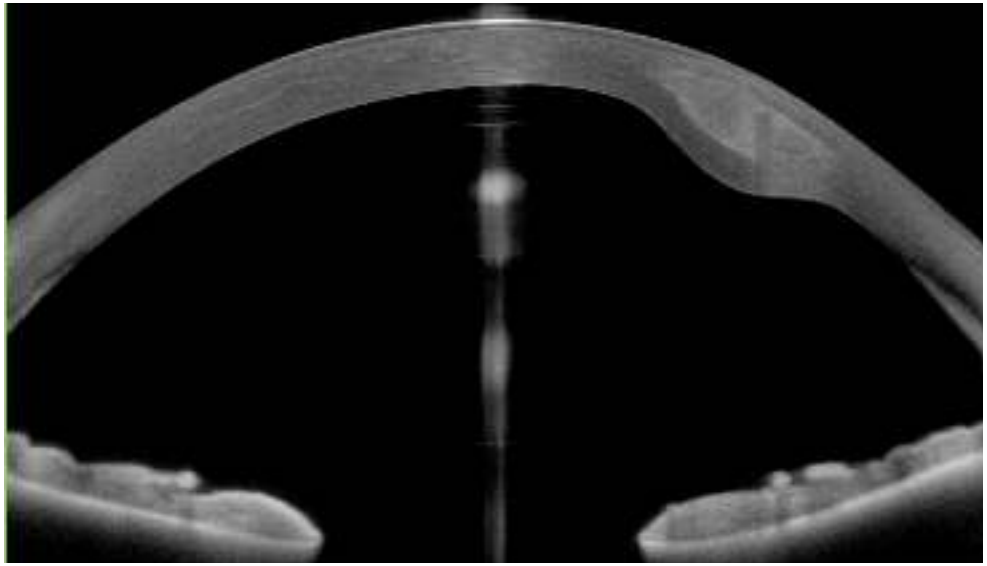
Sim.Cat./CAIRS: Postoperative Exam: 2. Month

OD: UDVA = 0.4

OD: CDVA +1.5 -0.75 105°= 0.63

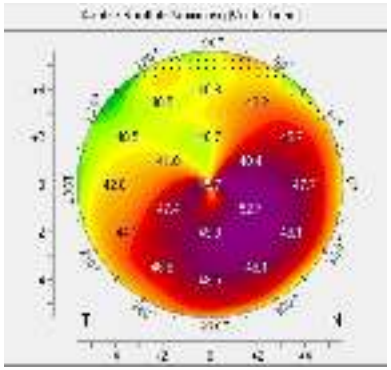
OS: UDVA = 0.1

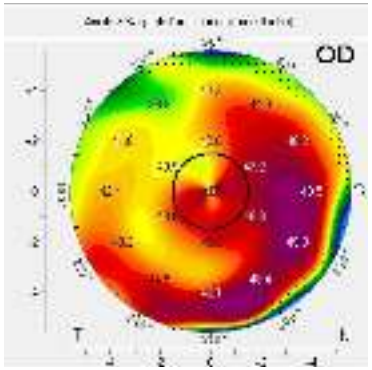
OS: CDVA -2.0 -1.75 73° = 0.63



TPL in loco

Immediate Sequential CAIRS with Cataract Surgery





- Combined surgery is generally not our first-line strategy; however, in select patients the immediate sequential approach may be effective
- Further studies with a larger sample size and long-term follow-up are necessary to better predict the change in topographic outcomes after CAIRS and assist in more accurate IOL power calculation in cases of a combined approach

CAIRS: Meta-Analysis

14 Studies – 442 Eyes with Keratoconus

Primary Endpoint:

Best-corrected distance vision (CDVA)

Secondary Endpoints:

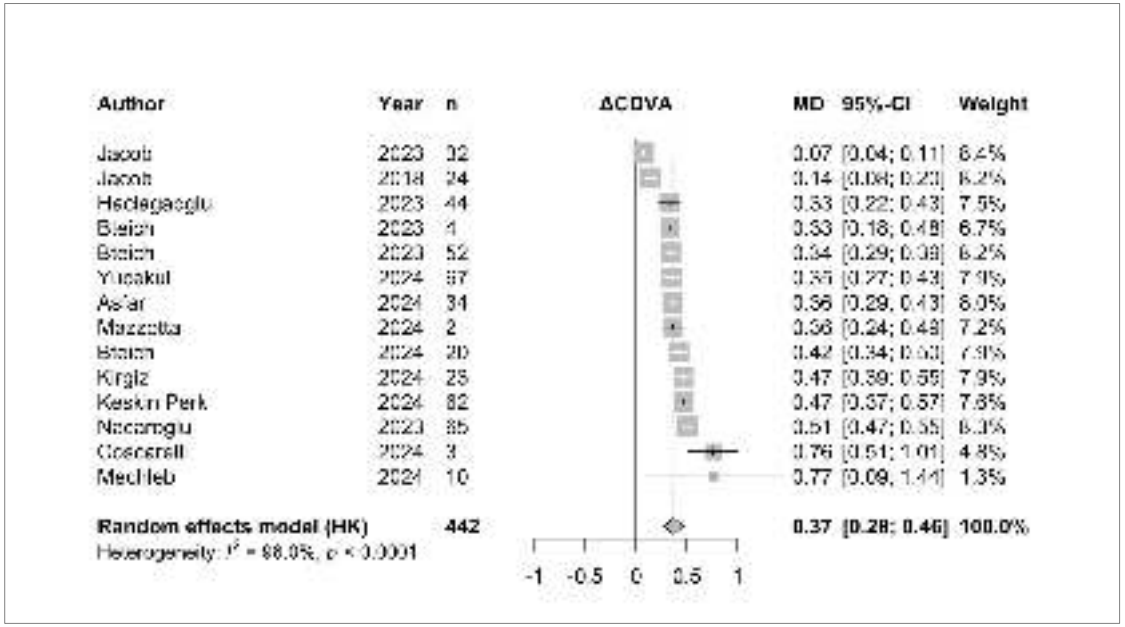
Uncorrected distance vision (UDVA), spherical equivalent (SE), Kmax, HOA

Exclusion Criteria:

- CAIRS as secondary procedure, i.e., after removal of an ICRS
- Presence of vision-limiting ocular comorbidities

Friedrich M, Auffarth GU, Soiberman U, Augustin VA, Khoramnia R, Son HS. Visual and Topographic Outcomes After Corneal Allogeneic Intrastromal Ring Segments for Keratoconus: A Systematic Review and Meta-Analysis. *Am J Ophthalmol*. 2025 Mar 27;276:81-91.

Significant Improvement in CDVA

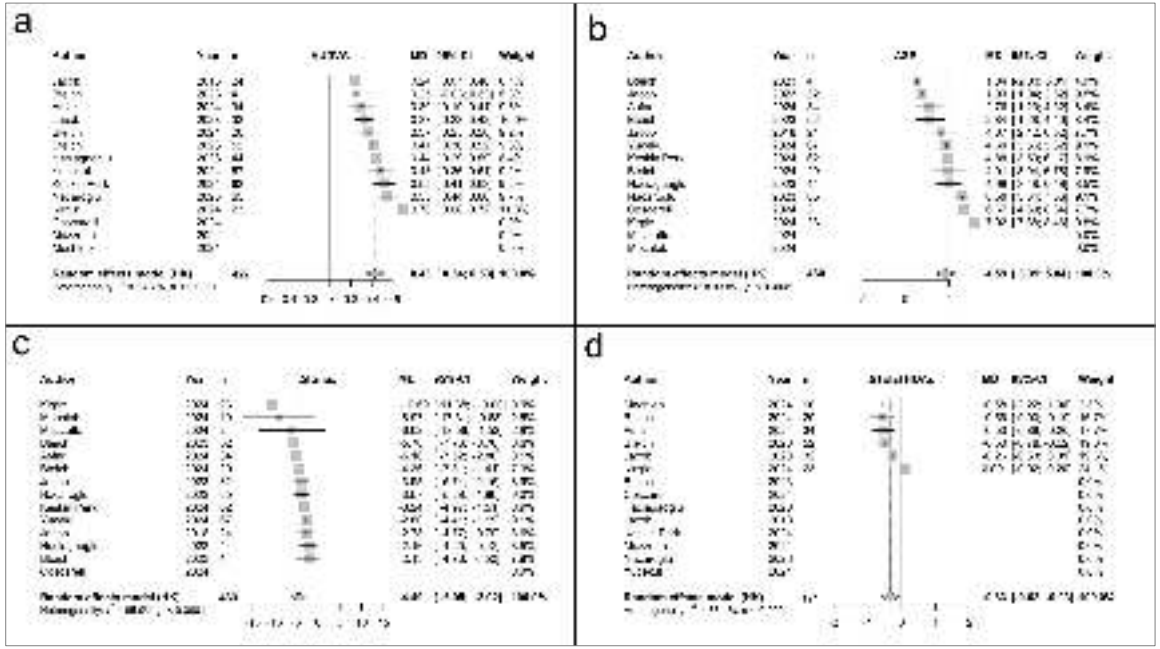


Mean Improvement in CDVA:

0.37 logMAR

Friedrich M, Auffarth GU, Soiberman U, Augustin VA, Khoramnia R, Son HS. Visual and Topographic Outcomes After Corneal Allogeneic Intrastromal Ring Segments for Keratoconus: A Systematic Review and Meta-Analysis. *Am J Ophthalmol*. 2025 Mar 27;276:81-91.

Significant Improvement of Refractive and Topographic Parameters



Mean Improvements:

UDVA: 0.43 logMAR

SE: 4.59 D

Kmax: 4.49 D

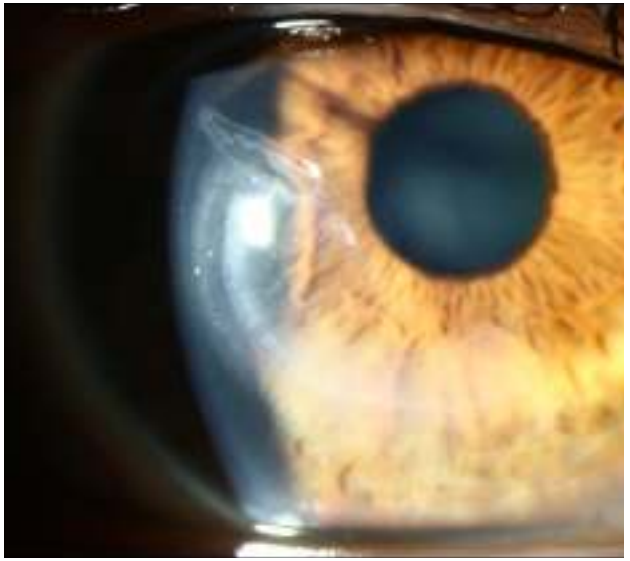
Total HOA: -0.33 µm

Friedrich M, Auffarth GU, Soiberman U, Augustin VA, Khoramnia R, Son HS. Visual and Topographic Outcomes After Corneal Allogeneic Intrastromal Ring Segments for Keratoconus: A Systematic Review and Meta-Analysis. *Am J Ophthalmol*. 2025 Mar 27;276:81-91.

Favourable Safety Profile

Low Complication Rates:

- No neovascularisation, corneal melt or DM perforation
- Explantation due to acute rejection (n=1, 0.2%)
- Halo Perception (n=1, 0.2%)
- Yellowish-white deposits in the tunnel (n=18, 4.1%)
- CAIRS migration to tunnel entry (n=3, 0.7%)



Friedrich M, Auffarth GU, Soiberman U, Augustin VA, Khoramnia R, Son HS. Visual and Topographic Outcomes After Corneal Allogeneic Intrastromal Ring Segments for Keratoconus: A Systematic Review and Meta-Analysis. *Am J Ophthalmol*. 2025 Mar 27;276:81-91.

Various Nomograms for Surgical Planning

Critical Factors for Optimal Outcomes:

- Number of segments
- Optical zone
- Depth of implantation

Soosan Jacob
Jacob Nomogram

Shady Awwad
Awwad Nomogram

Aylin Kilic
Istanbul Nomogram

David Gunn
Brisbane Nomogram

CAIRS

- CAIRS is an effective and safe treatment option for keratoconus, offering clear advantages over conventional ICRS due to its high degree of customization
- Tailored segment adjustment enables targeted treatment of different types of keratoconus and leads to stable improvements in visual acuity and corneal topography
- Complications are rare, which underscores the good biocompatibility of the allogeneic tissue

CAIRS

- However, long-term analyses are needed to compare its complication profile with that of ICRS, which has been in use for more than two decades
- Careful patient selection remains crucial for treatment success. In the future, artificial intelligence (AI)-supported algorithms could help analyze individual risk factors and topographical patterns even more precisely and generate personalized nomograms. This would further improve the predictability and efficacy of CAIRS and standardize the indication

HEIDELBERG UNIVERSITY HOSPITAL

UNIVERSITY EYE CLINIC 158 Years

DAVID J APPLE LABORATORY

IVCRC

Certified for DIN EN ISO 9001:2015

EVICR.net
EUROPEAN VISION CLINICAL RESEARCH

Steinbeis-Forschungszentrum
The David J Apple Center
for Vision Research

IVCRC.net
International Vision Correction Research Center Network