

# **Cataract: past, present & future**

**Dr Simone Freundlich**

**Dr Bia Kim**

**Dr Jina V Han**

**Dr Andrew Riley**

**Professor Charles NJ McGhee**

**Maurice Paykel Professor & Chair of Ophthalmology**



# Case Scenario Links

## Cataract Surgery Past Present Future

- Infant with an altered light reflex (Oph12)
- Gradual deterioration in visual acuity over time (Oph07)  
Type 2 diabetes mellitus (Endo11)
- 6 week check (Paed26)
- Family with a genetic disorder (MG02)



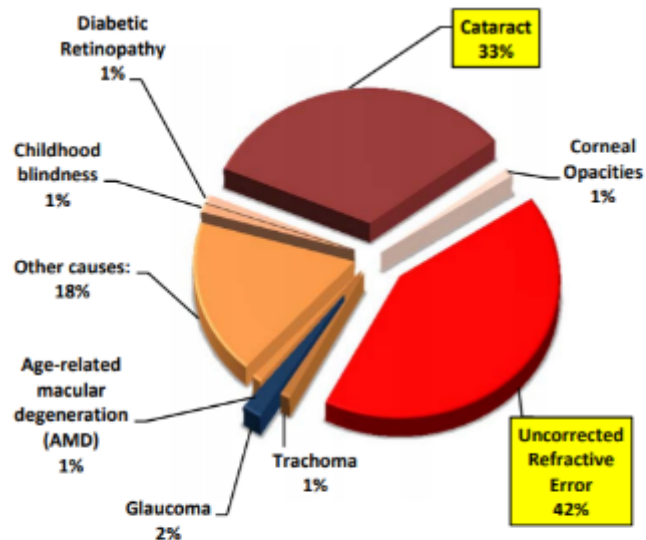
CATARACT



# Cataract: blindness & visual impairment

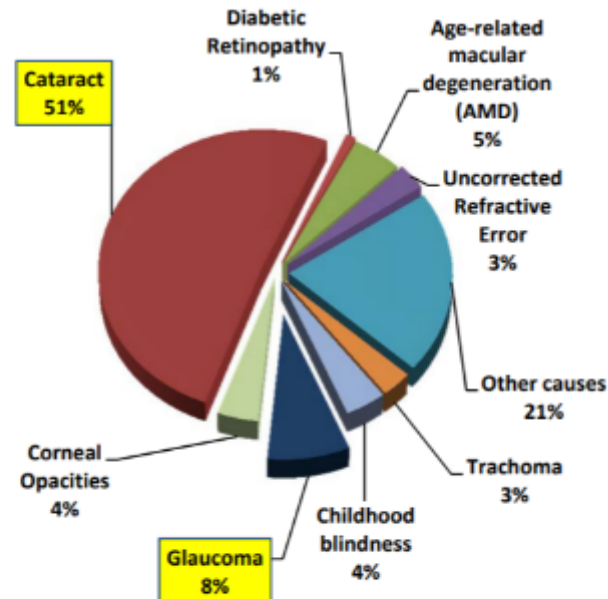
- **Cataract**
  - **Uncorrected Refractive errors**
- are the leading causes of  
Avoidable Visual Impairment.

## Visual Impairment

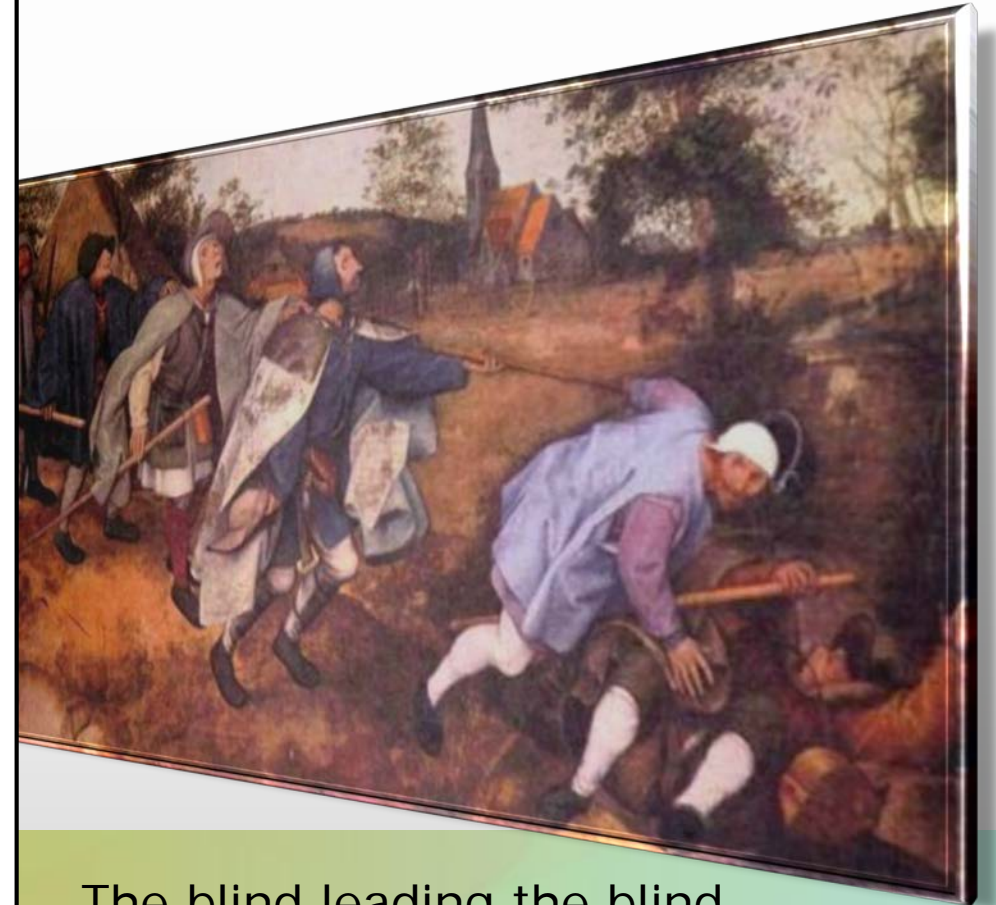


- **Unoperated Cataract and**
  - **Glaucoma**
- are the leading causes of  
Avoidable Blindness.

## Blindness

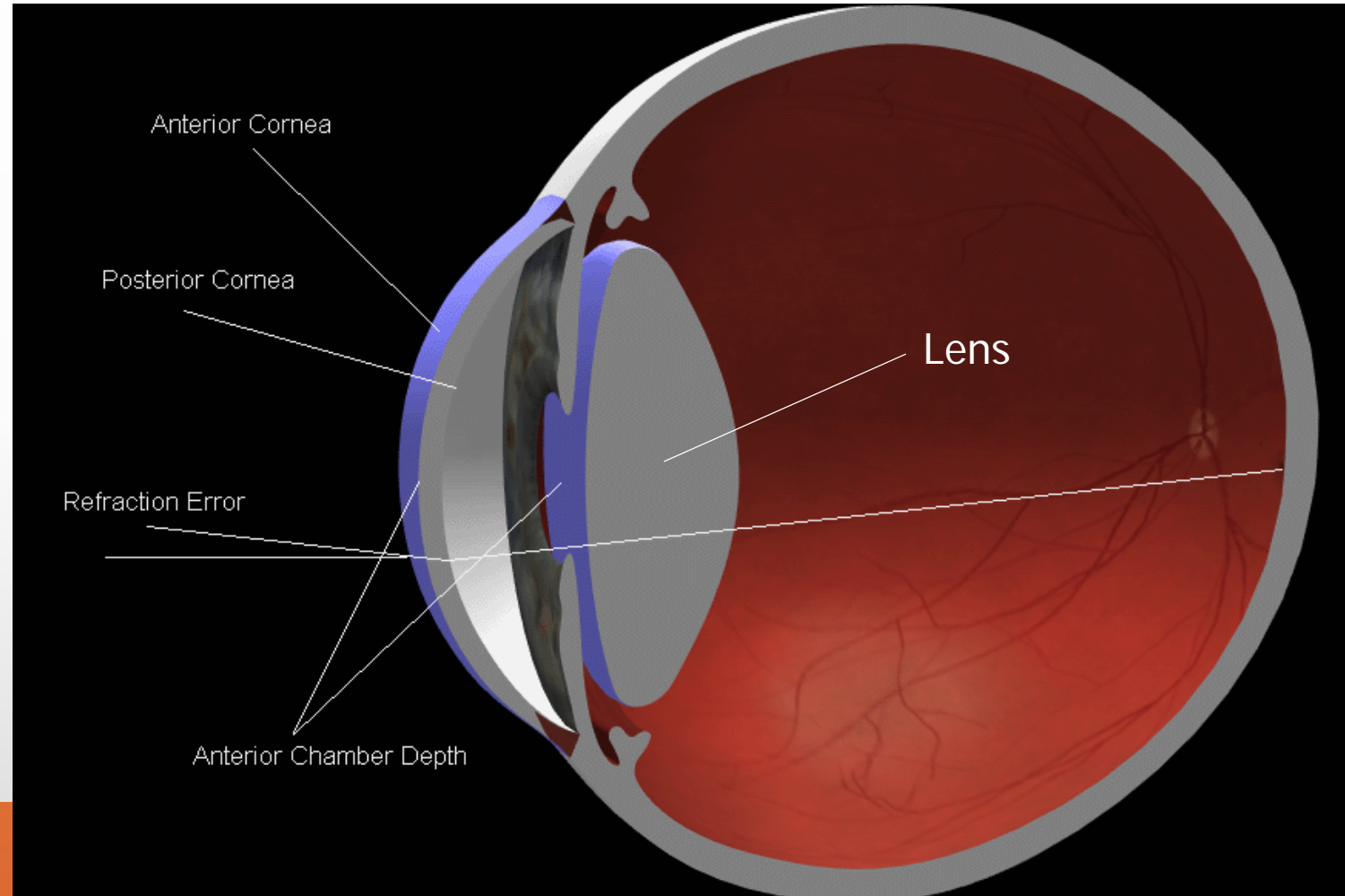


Global estimates of visual impairment: 2010, S.P.Mariotti, D. Pascolini, Br J Ophthalmol. 2012 May;96(5):614-8.

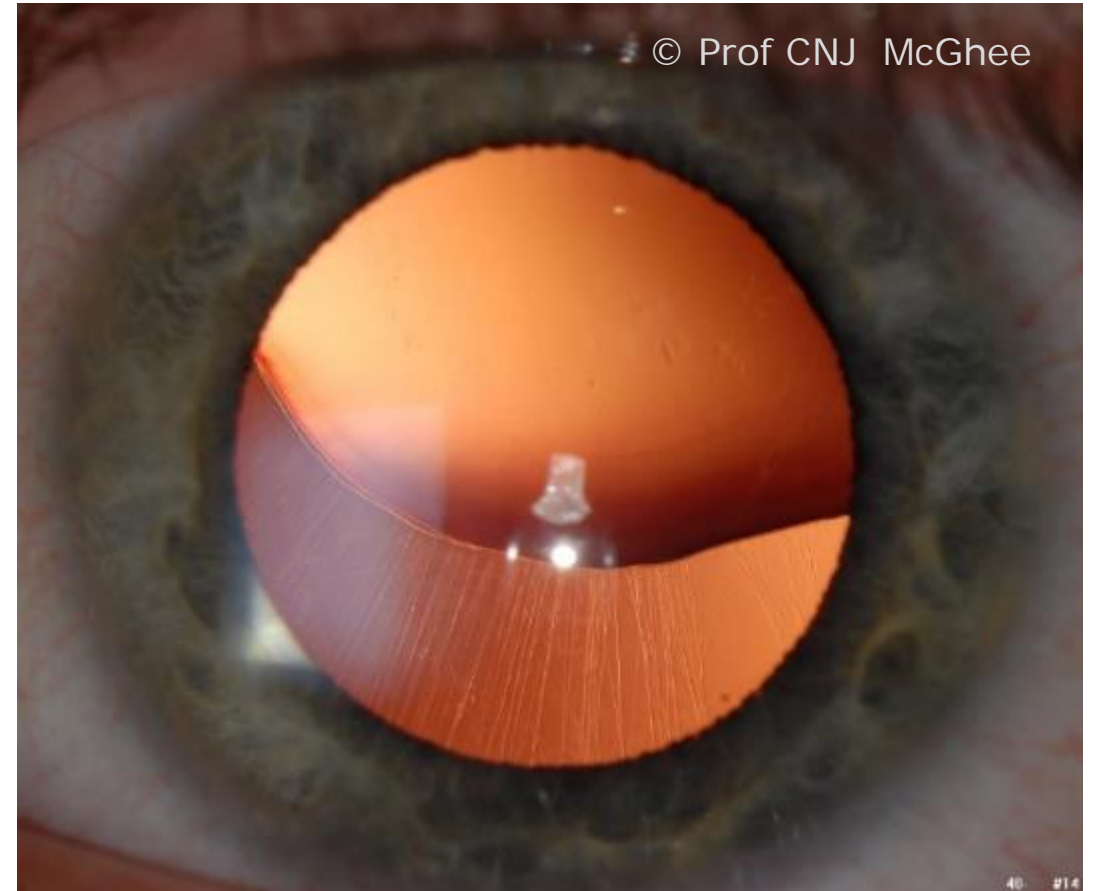
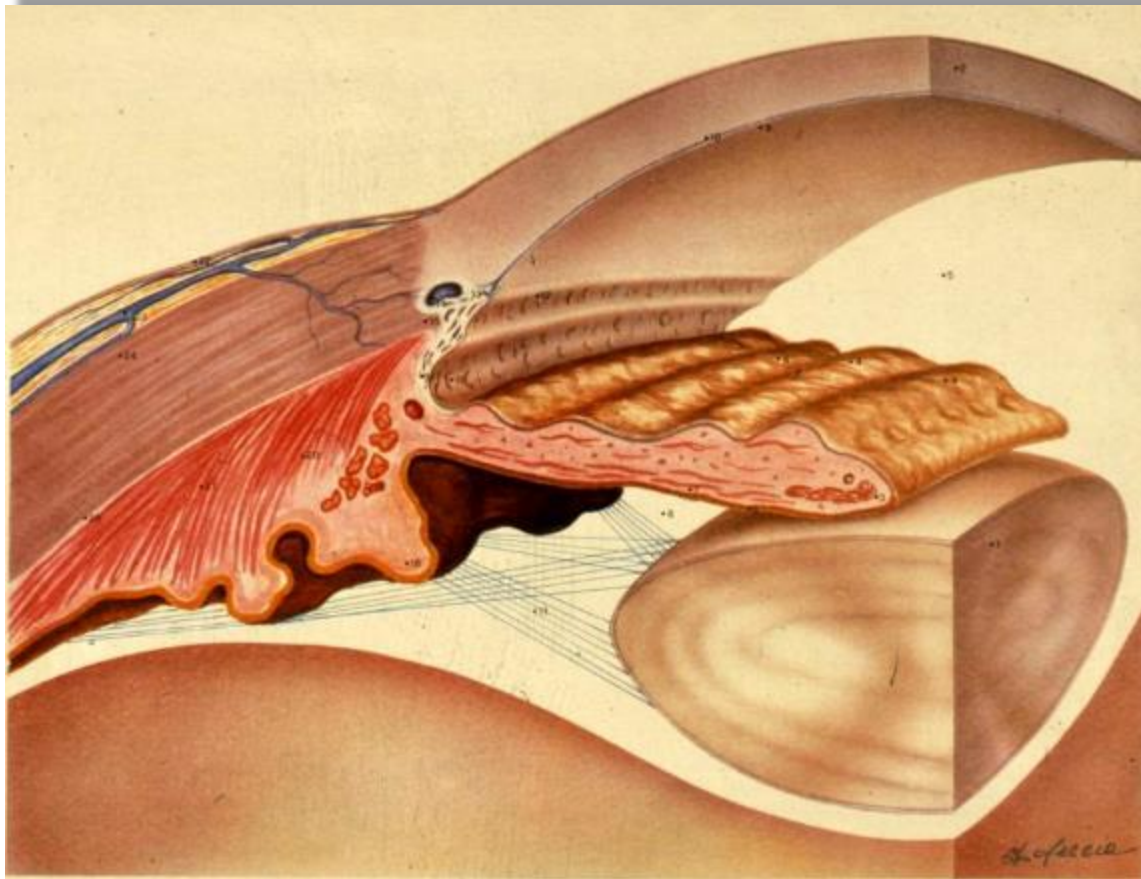


The blind leading the blind  
By Pieter Bruegel the elder

# The Human Crystalline Lens



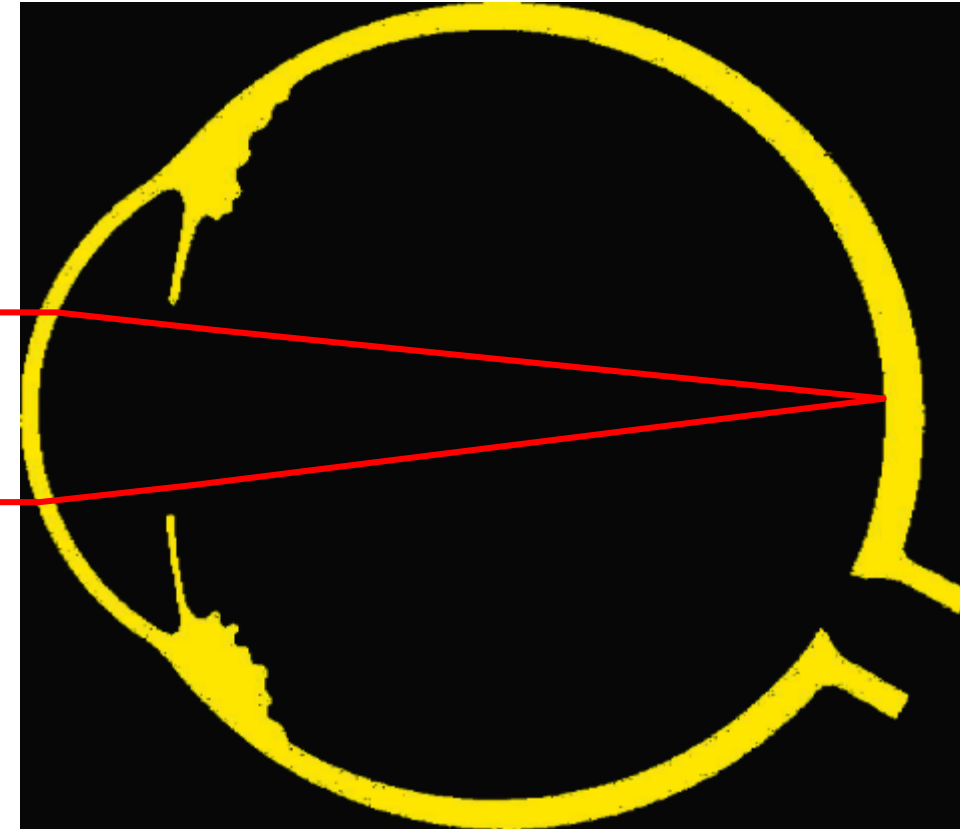
# Basic anatomy: Lens and anterior segment



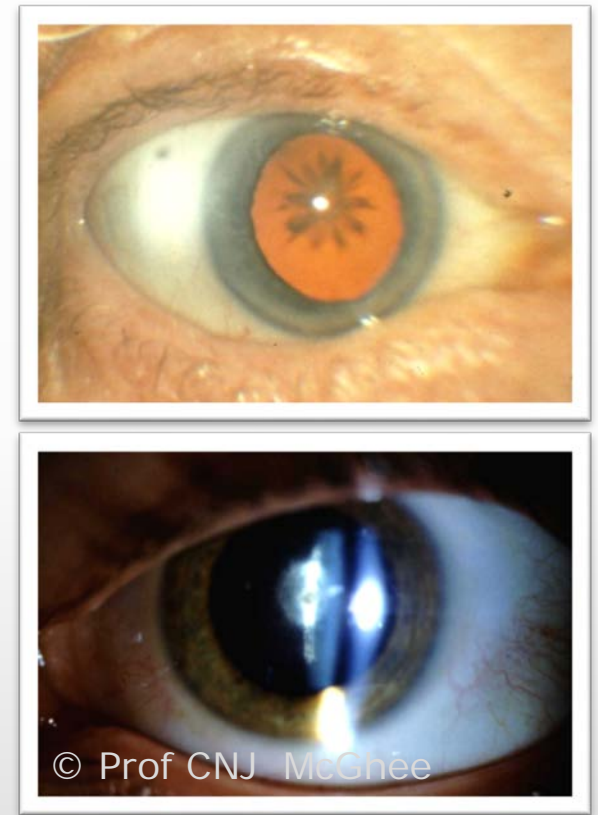
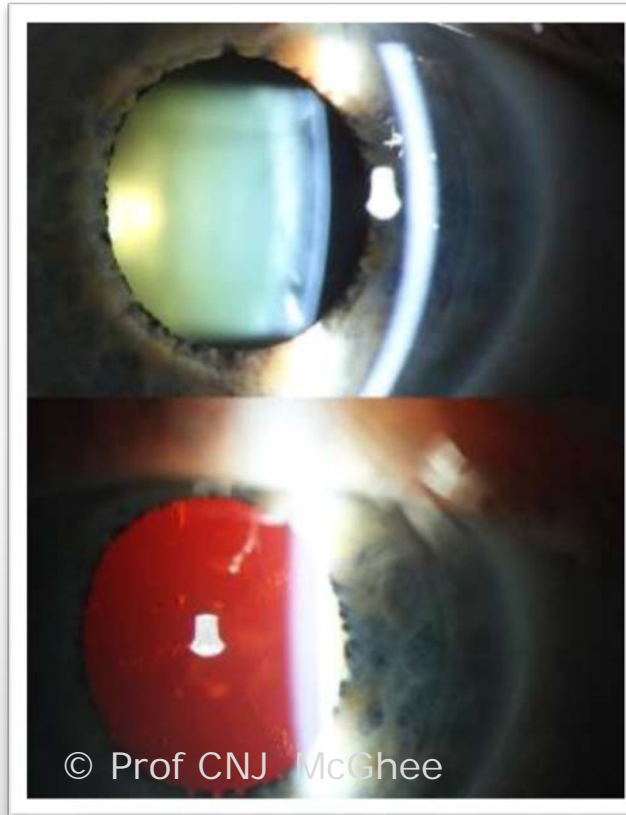
# Simplified diagrammatic eye

## Eye has 2 principal focusing structures

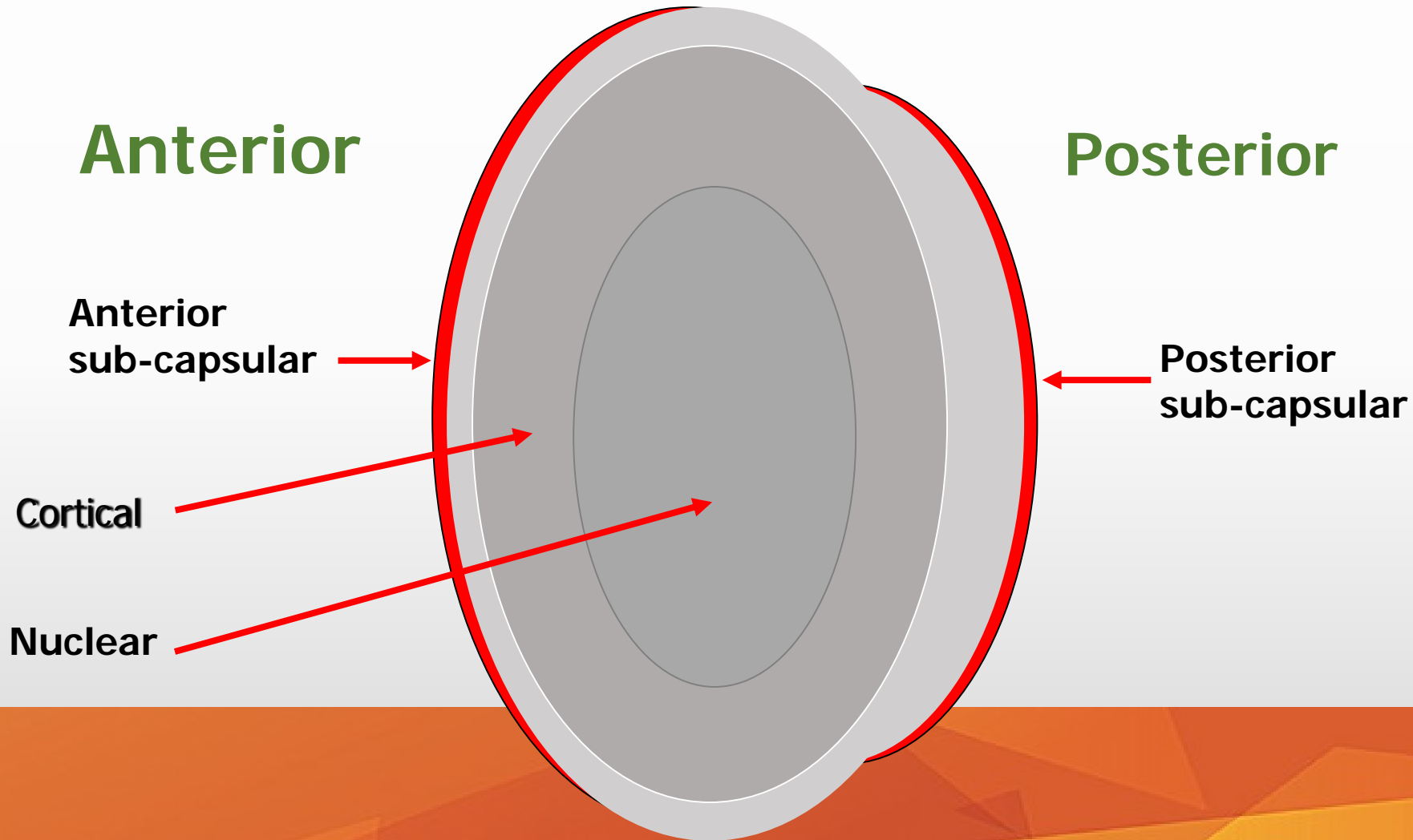
- a) **The cornea**  $2/3^{\text{rd}}$   
approximately 40 dioptres
- b) **The crystalline lens**  $1/3^{\text{rd}}$   
approximately 20 dioptres
- c) **If lens cataract is removed**  
the focussing power (20D)  
needs to be replaced
- d) **Historically lens power** replaced by spectacles,  
in last 40 years mainly by intraocular lenses



# Cataract assessment: acuity, ophthalmoscope and slit lamp



# Describing Cataract Anatomy



# The global burden of cataract

- 20 million blind globally - classified as  $<6/30$  - 2010 (WHO)
- Additional 2 million new cases per annum
- 90% of blindness in developing world - 51% due to cataract
- $>100$  million severe visual impairment
- However only around 12 million cataract procedures per annum

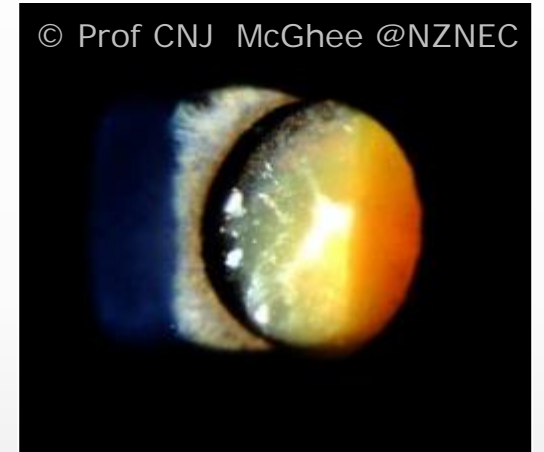


# Cataract- multiple aetiologies

- Congenital
- Inherited
- **Age-related (the majority)**
- Metabolic – e.g. diabetes
- Toxic – e.g. corticosteroids
- Traumatic – e.g. irradiation
- Secondary – e.g. ant. uveitis



Posterior polar cataract



Dense brunescent  
(advanced) cataract

# Cataract aetiology in developing world: repeated dehydrational crises

*British Journal of Ophthalmology*, 1989, 73, 100–105

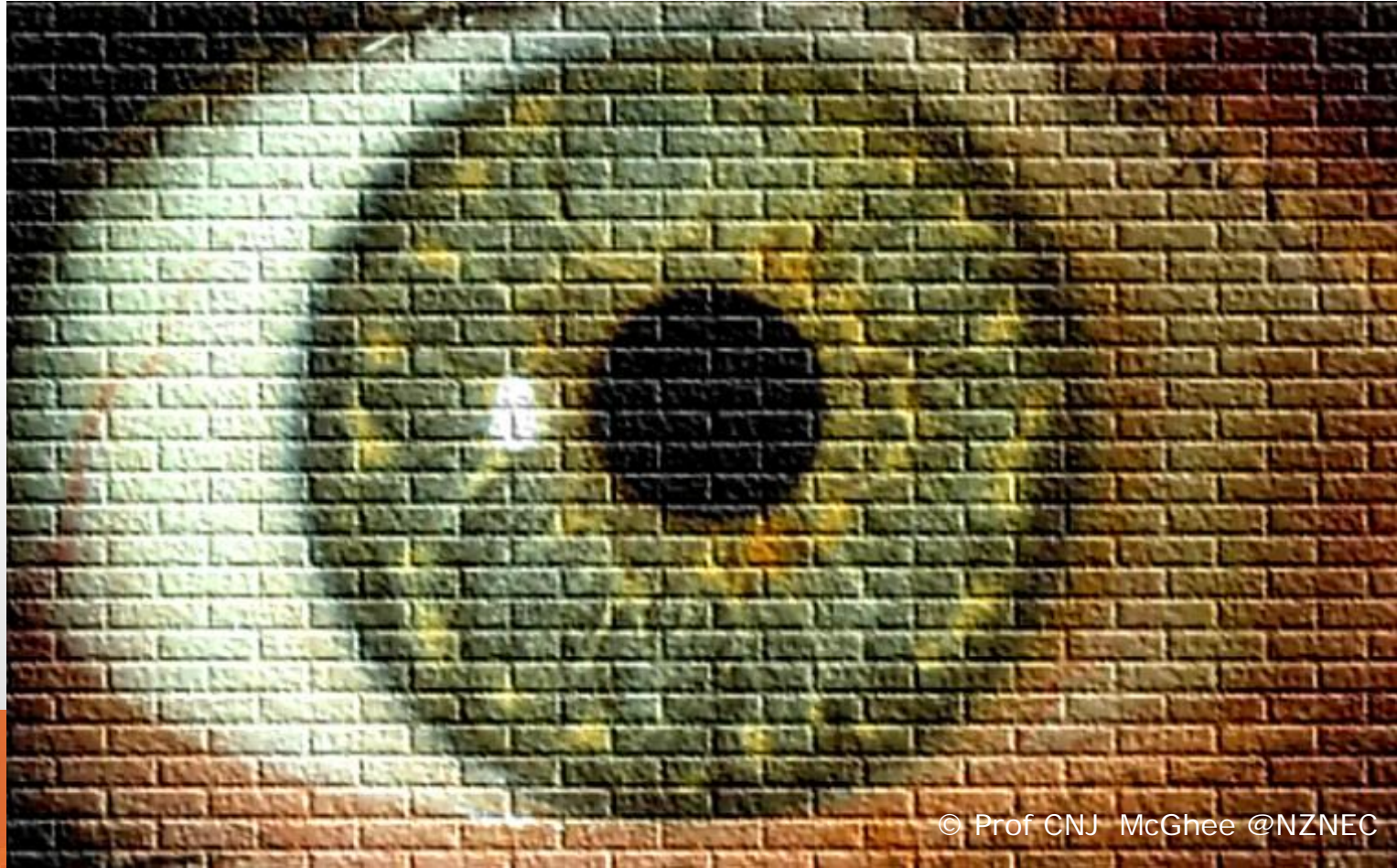
## Dehydrational crises: a major risk factor in blinding cataract

D C MINASSIAN,<sup>1</sup> V MEHRA,<sup>2</sup> AND J-D VERREY<sup>1</sup>

*From the <sup>1</sup>International Centre for Eye Health, Institute of Ophthalmology, 27–29 Cayton Street, London EC1V 9EJ, and the <sup>2</sup>Chattisgarh Eye Hospital, Fafadih, Raipur, MP, India*

**SUMMARY** An earlier case control investigation has indicated a strong relationship between dehydrational crises and risk of presenile cataract. A second methodologically distinct case control study of risk factors in cataract has been carried out in a population very different in terms of environmental and sociocultural characteristics from the population investigated in the earlier study in Central India. The results strongly confirm the findings from the first study and indicate that an estimated 38% of blinding cataract may be attributable to repeated dehydrational crises resulting from severe life threatening diarrhoeal disease and/or heatstroke. The risk of blinding cataract was strongly related to level of exposure to dehydrational crises in a consistent and dose dependent manner, thus indicating a causal association. The findings are discussed in relation to possible sources of bias in the study, confounding in the data, and the steps that were taken to minimise their undesirable effects.

# Breaking down barriers: a (R)evolution in cataract surgery



© Prof CNJ McGhee @NZNEC

# Cataract surgery: ancient to modern

## Ancient Techniques

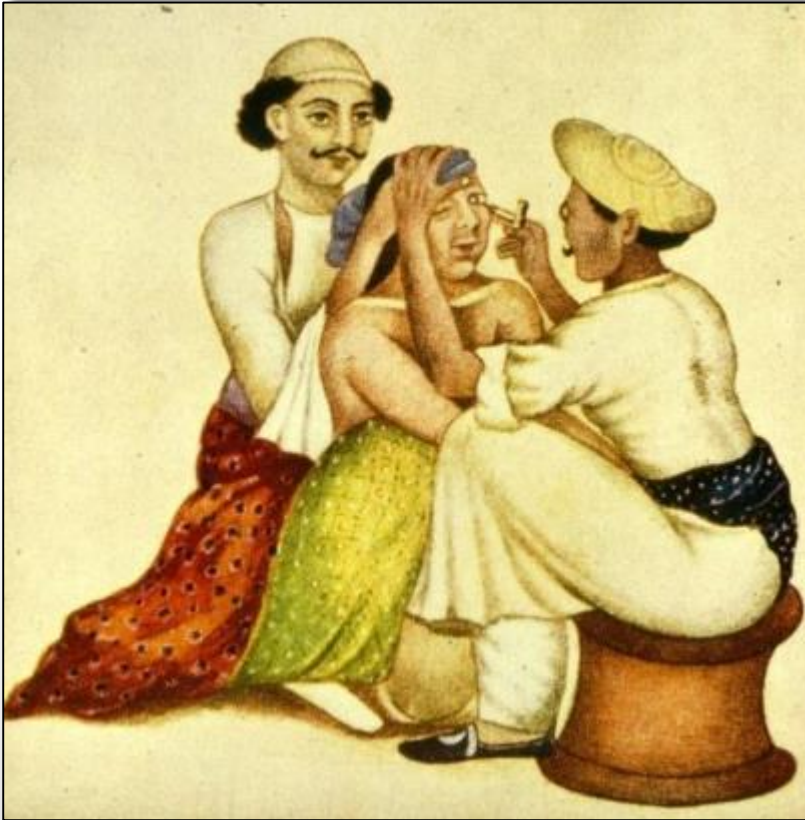
Couching

## Current cataract extraction techniques

1. Intra-capsular – now mainly in developing world
2. Extra-capsular – some use in developed world
3. Phacoemulsification – most popular technique



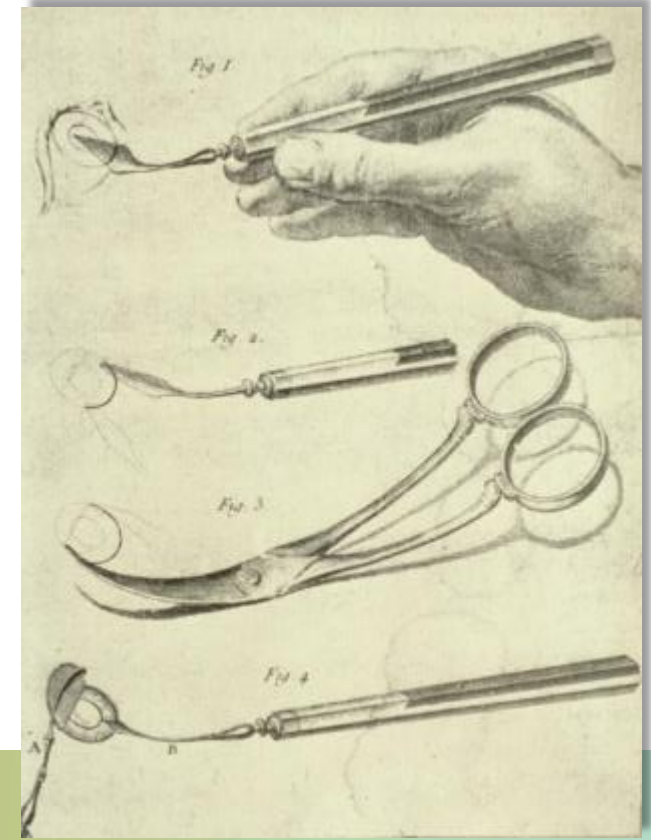
# The ancient art of cataract surgery: India to Europe



# Origin of modern Cataract Surgery:

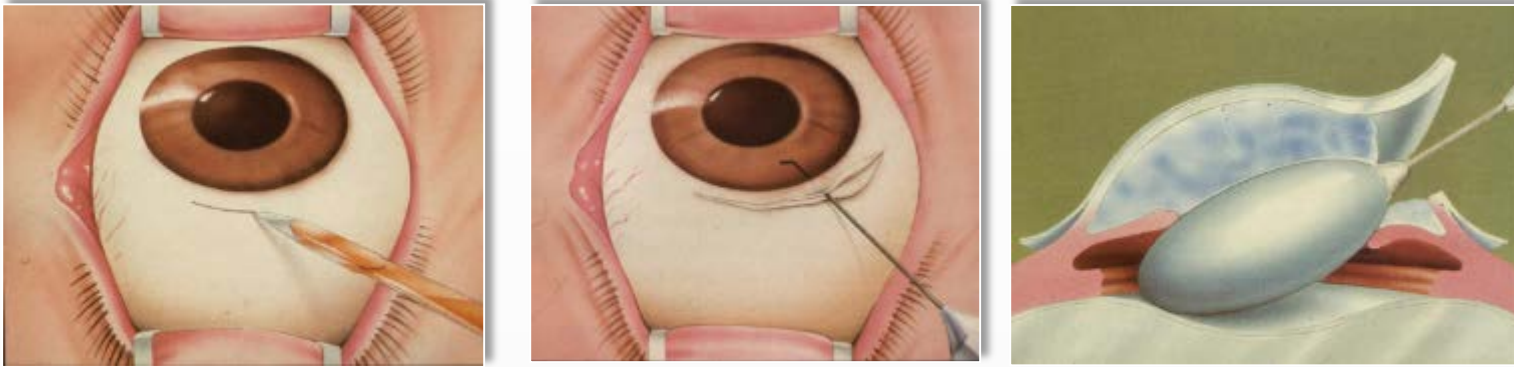
## 1750's Extra-capsular cataract (ECCE) surgery

**Dr Jacques Daviel** a French Ophthalmologist first described the ECCE technique in 1752 – and a variation of this technique was the mainstay of cataract surgery until 1990's

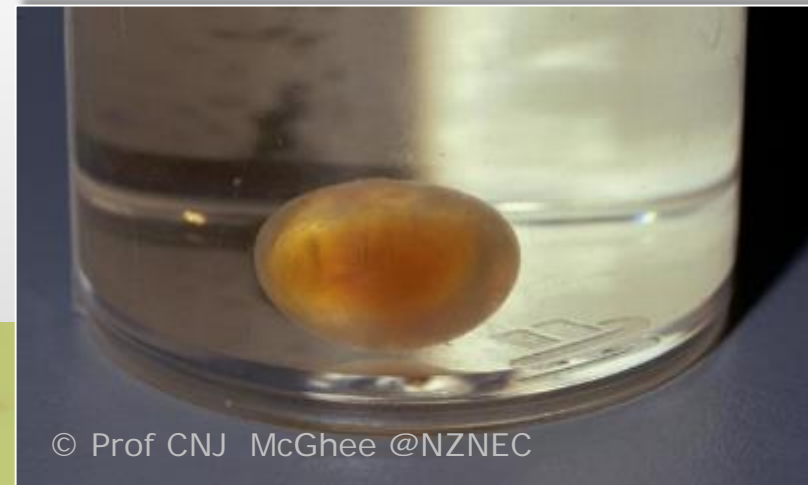


# Intra-capsular cataract extraction (ICCE)

the cataract (lens) is removed with the capsule



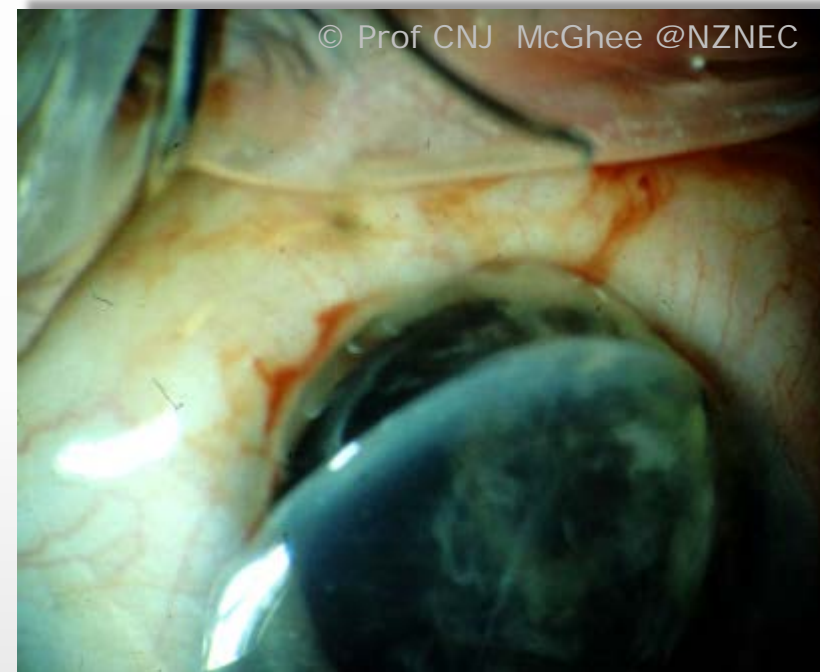
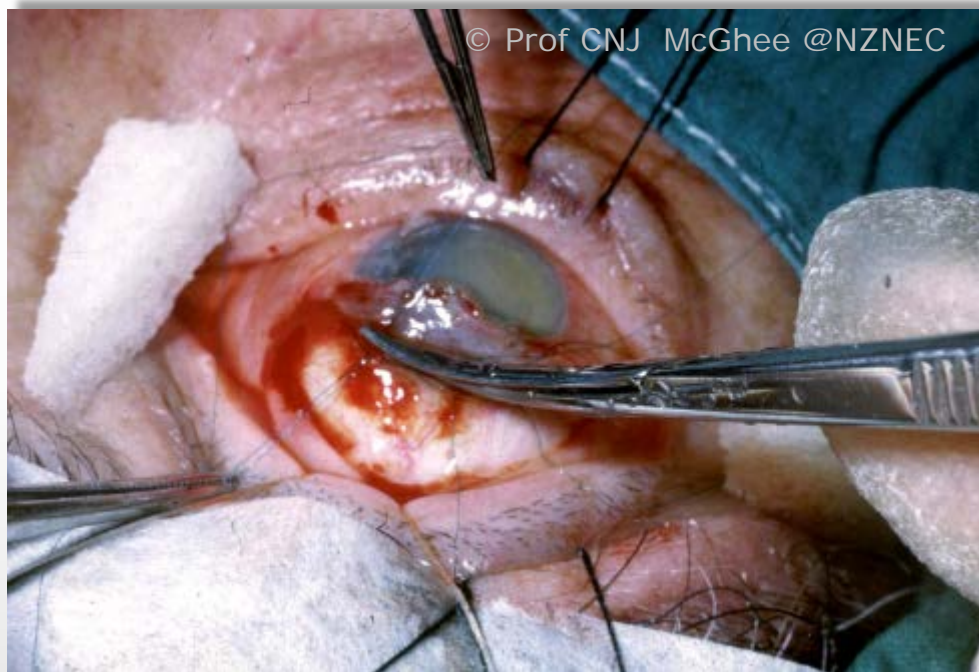
Still successfully performed in parts of developing world in 2020



© Prof CNJ McGhee @NZNEC

# Extra-capsular Cataract Surgery (ECCE)

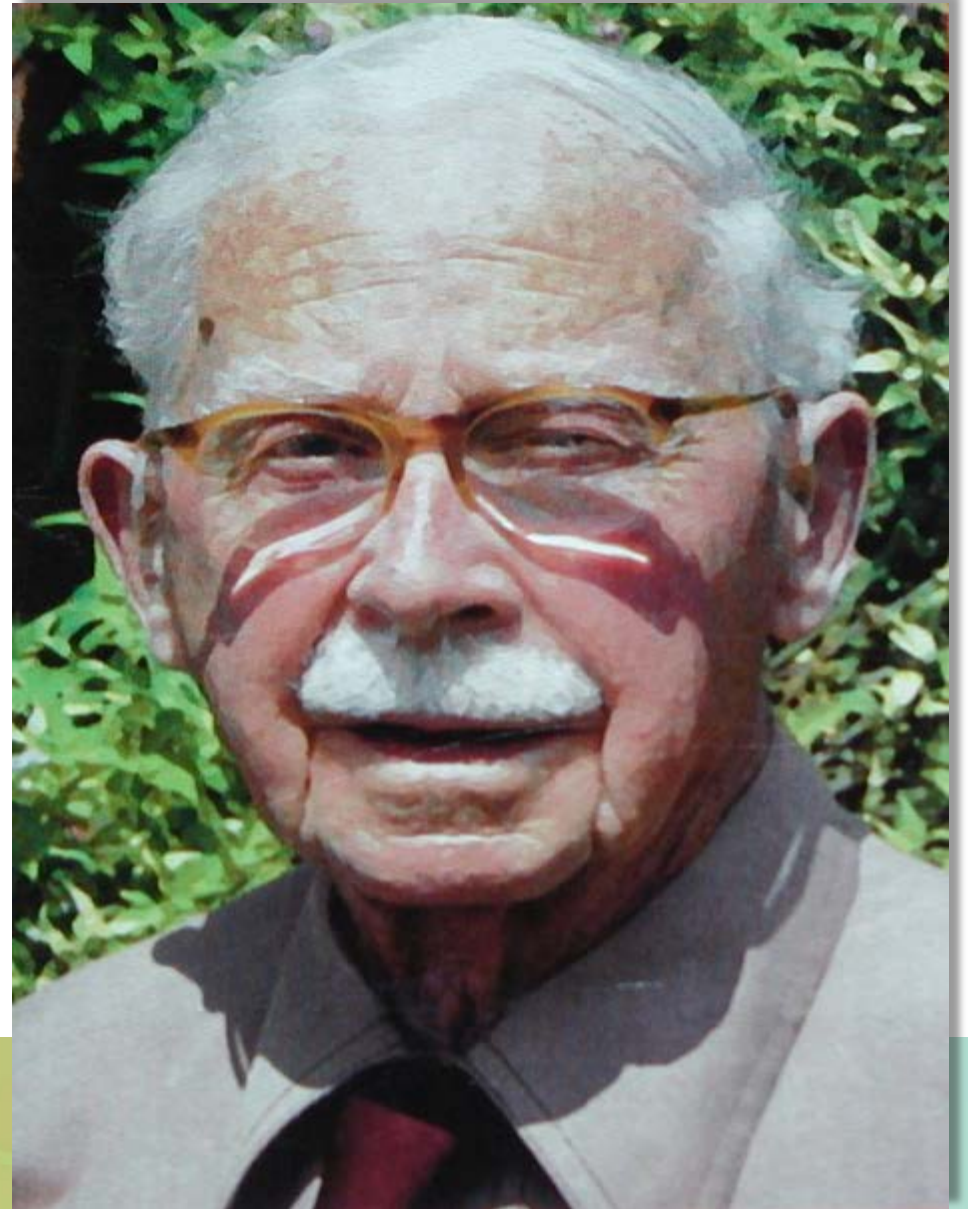
the cataract is removed leaving the lens capsule



# Intra-ocular lenses 1949

## Sir Harold Ridley

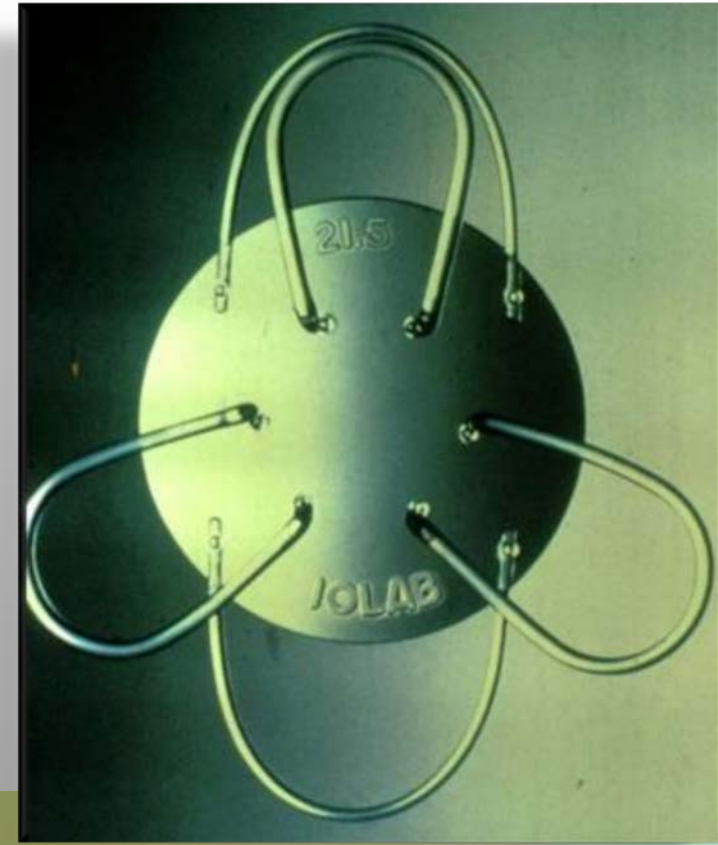
Invented intra-ocular lenses (IOLs) and performed the first successful Surgery in Moorfields Eye Hospital, London, 1949



# 1970's Iris-clip intra-ocular lenses



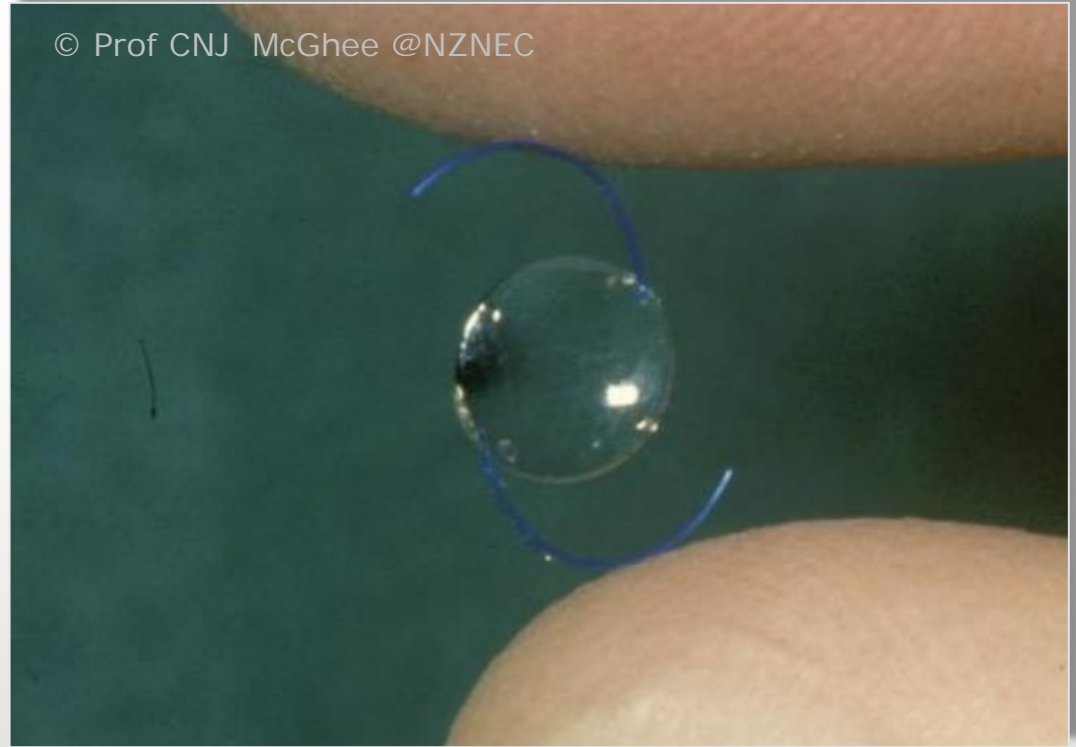
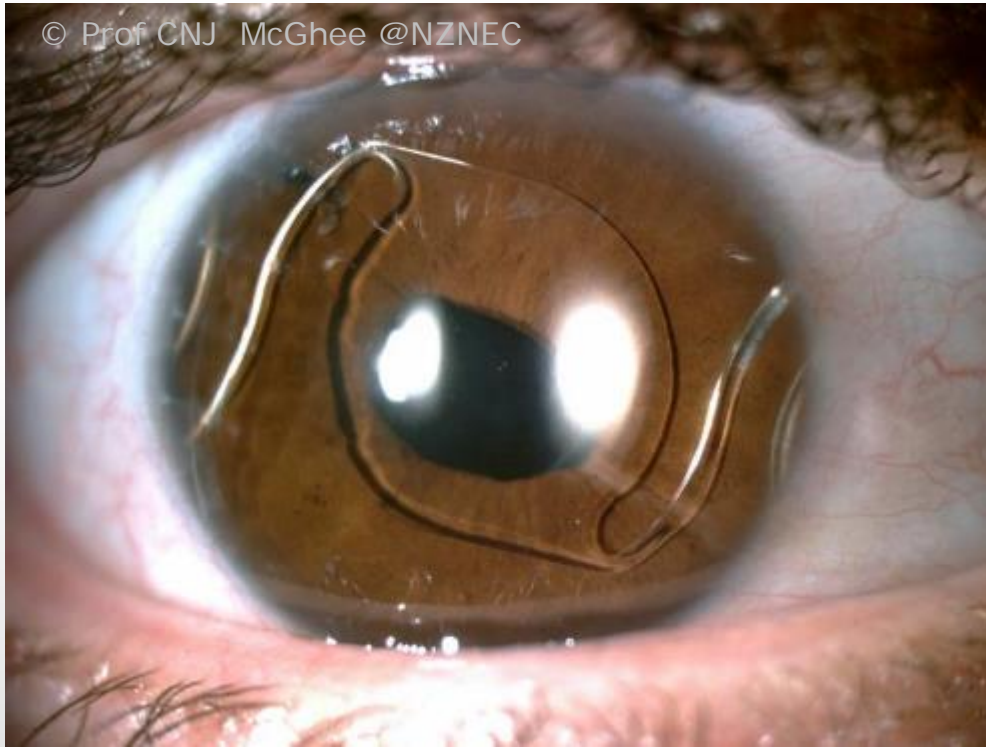
© Prof CNJ McGhee @NZNEC



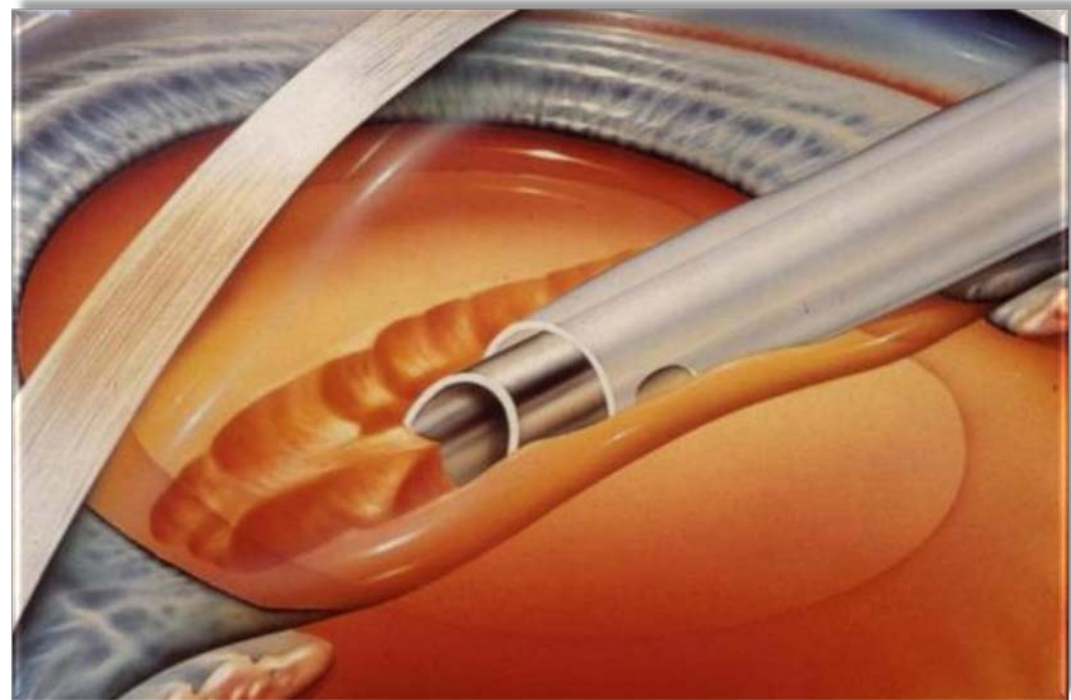
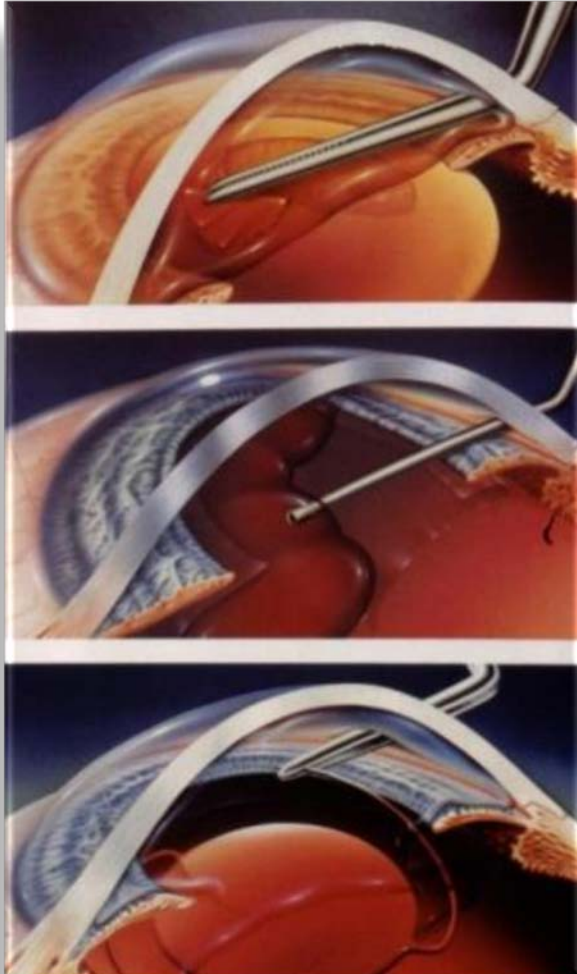
Iris clip lenses used when no capsular support e.g. after ICCE

# 1980's Intra-ocular lenses:

single piece anterior chamber IOLs & three piece posterior chamber IOL



# 1990's: widespread acceptance of small incision phacoemulsification surgery

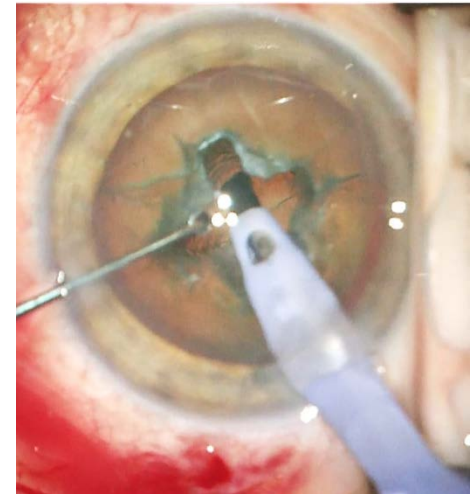
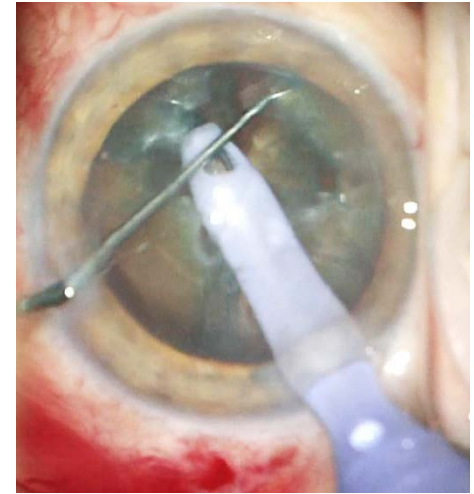


Use of high frequency ultrasound to emulsify cataract performed through a smaller incision (6mm verses traditional 10mm incision of ECCE procedures)

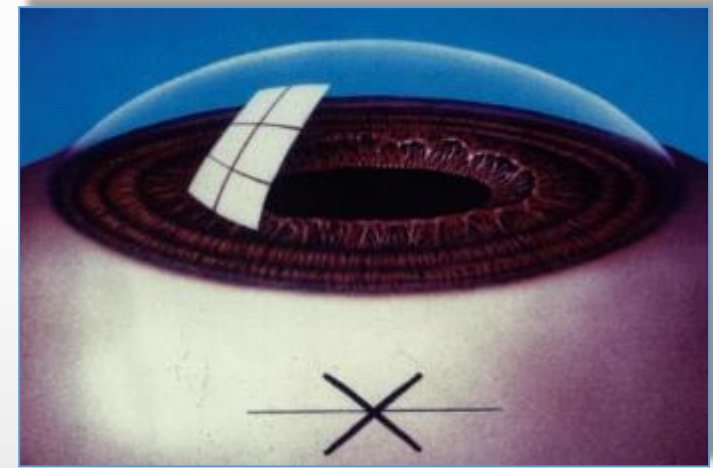
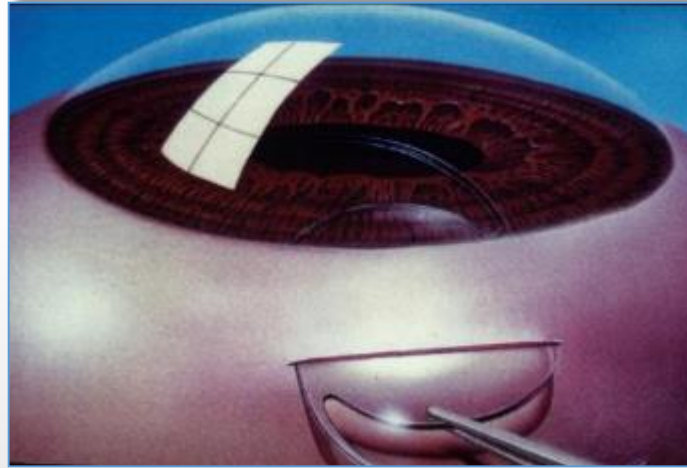
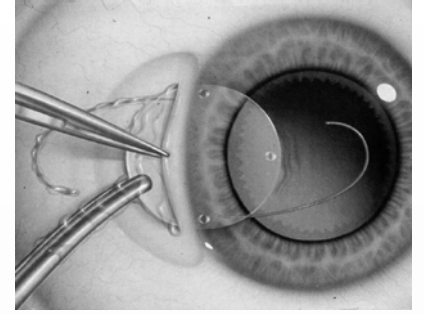
# Phacoemulsification basics

## Phacoemulsification (ultrasound) hand piece

- Driven electrically Piezoelectric crystal vibrates **ultrasonically**
- Frequency 25,000 – 60,000 Hz
- Phaco “needle” is hollow (0.9mm) with central aspiration port
- Needle surrounded by soft irrigation sleeve with two ports which maintains fluid in anterior chamber
- Phacoemulsification tip has both a “jack-hammer” mechanical effect and a cavitation (acoustic) effect.



# Superior scleral tunnel approach to phacoemulsification in 1990's

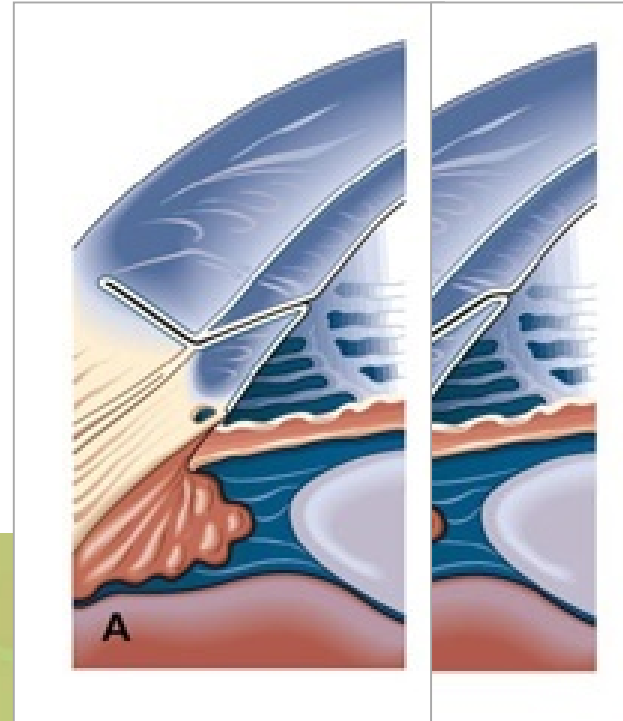
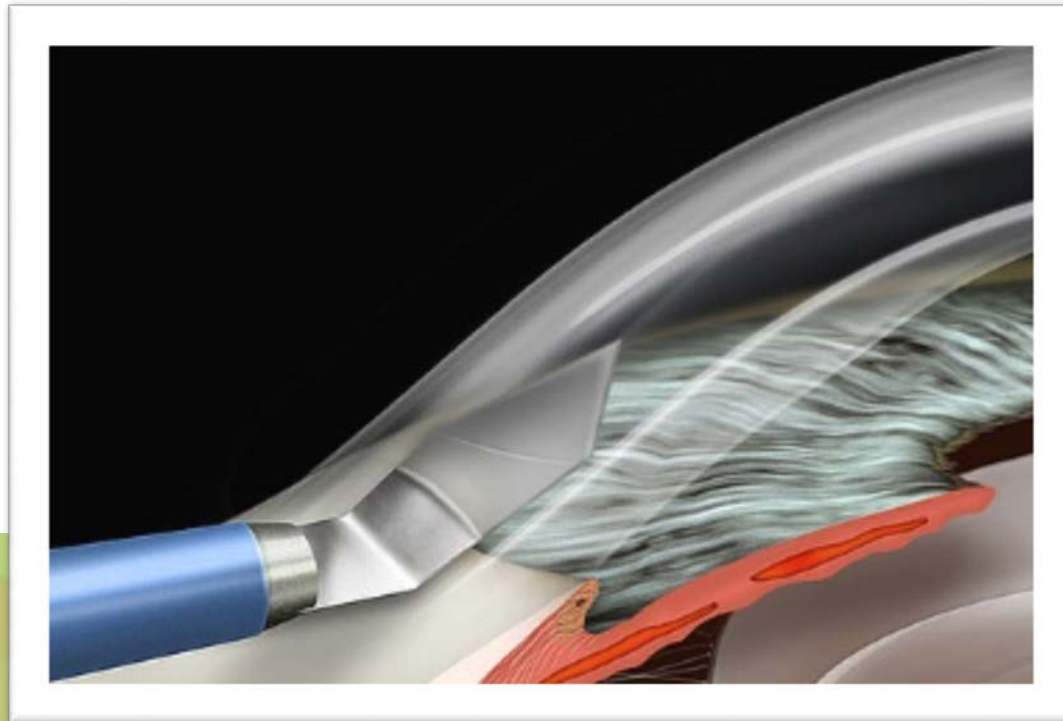


In early 1990's IOLs were typically **rigid** and therefore needed a larger (5-6mm) incision, further back on the sclera than contemporary incisions, and sutures

# Contemporary corneal Incision structure

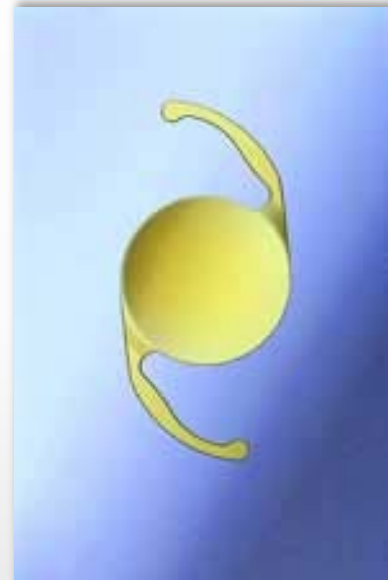
## 1, 2 or 3 step corneal incisions

- Quick, no bleeding, single instrument, typically no suture
- Enables topical anaesthetic, popular – now 90% procedures



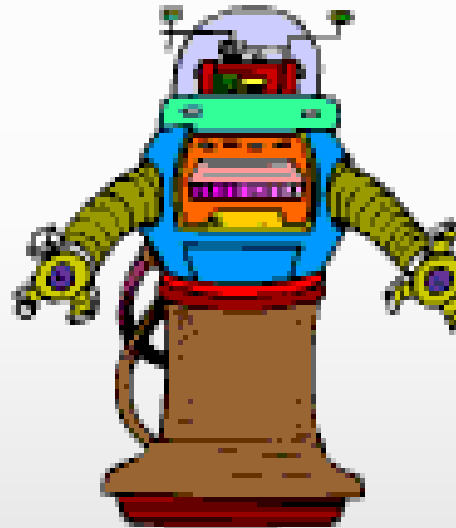
# Late 1990's Intra-ocular lenses:

small incision phacoemulsification and the evolution of foldable or injectable Intraocular lenses

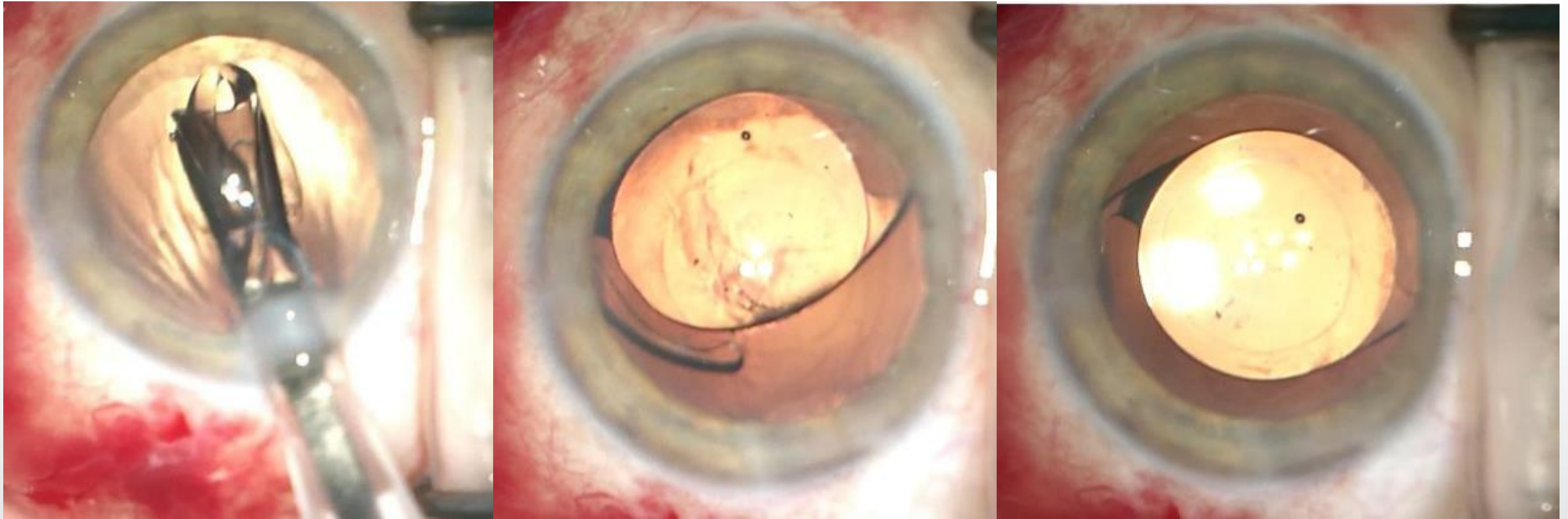


Folding or injecting the 6mm diameter IOL enables the incision size to be reduced to 3mm width for no-suture phacoemulsification with incisions moving from largely scleral to corneal based

# Complexity of phacoemulsification technology



# Injecting a single piece IOL via corneal incision



Images © Prof CNJ McGhee @NZNEC

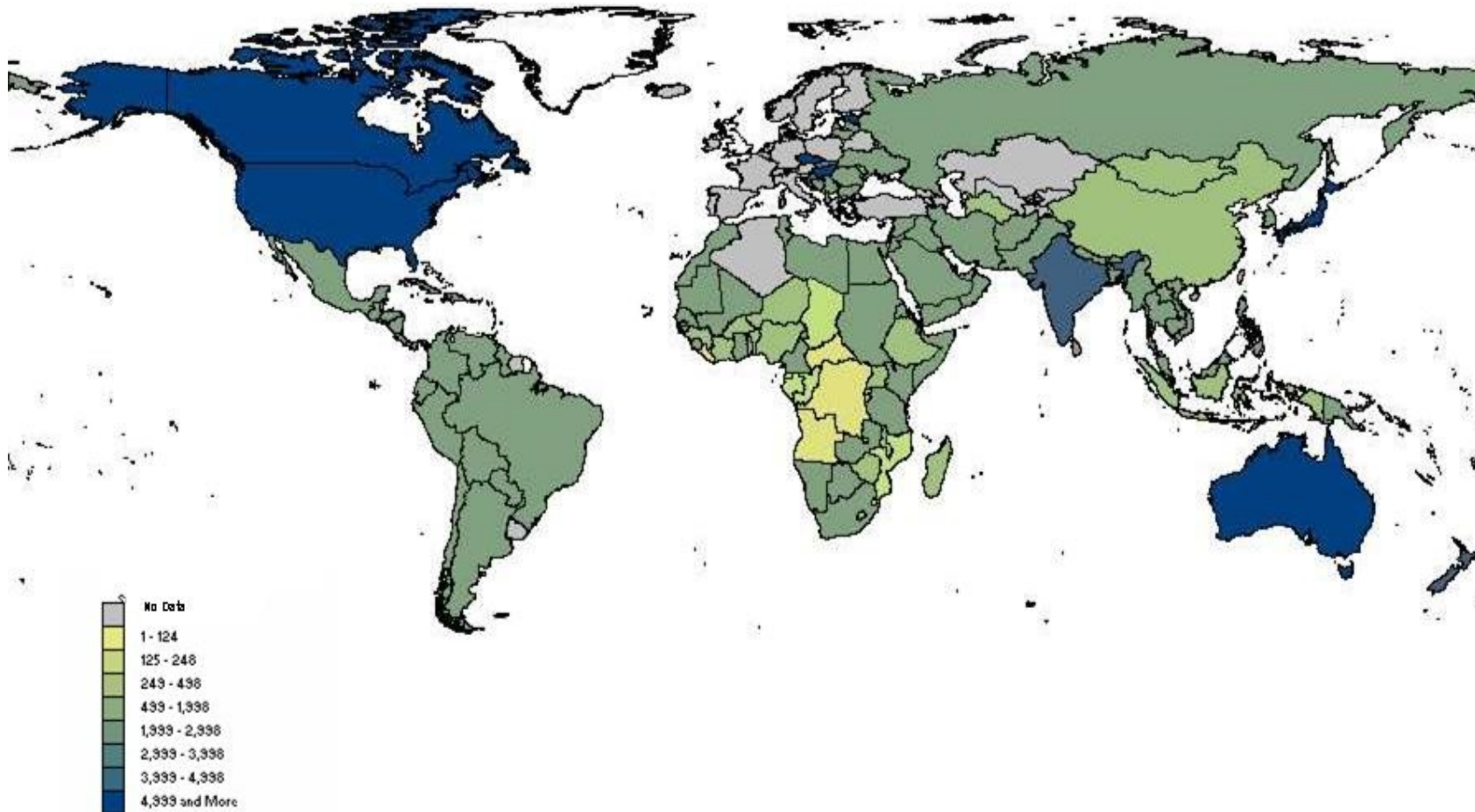


# Complexity of phacoemulsification technology

## Phacoemulsification video

# Cataract Surgery: varied global rates

Cataract Surgery Rate 2006



# Cataract presentation in a New Zealand perspective: Auckland Cataract Studies 2000 - 2020



© Prof CNJ McGhee @NZNEC

# The Auckland Cataract Studies

- The first ACS provided a prospective snapshot of 500 patients with cataract, cataract services, and state of the art surgical techniques in a public hospital service in the year 2000
- Also highlighted public cataract waiting list issues and access to appropriate government funded care in a major metropolitan area (now resolved)
- Results published in a series of scientific publications in the British Journal of Ophthalmology and Clinical and Experimental Ophthalmology



# Evolution of NZ Cataract Prioritization Questionnaire

A F F E C T E D  E Y E	Contralateral Eye							
		6/9	6/12	6/18	6/24	6/36	6/60	CF/HM
	6/9	0	1	2	3	4	5	6
	6/12	1	7	8	9	10	11	13
	6/18	2	8	14	15	16	17	18
	6/24	9	9	15	21	22	23	24
	6/36	10	10	16	22	29	29	30
	6/60	11	11	17	23	35	35	36
	CF/HM	12	12	18	24	36	36	40

Clinical modifiers eg. ARMD, Diabetic retinopathy  
 Work and independence  
 Non-vision physical disability  
 Activities of Daily Life questionnaire  
 Driving



-10 to +20  
 0 to 10  
 0 to 10  
 0 to 13  
 0 to 7

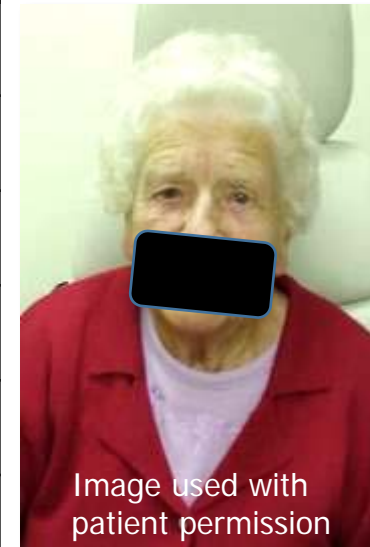


Image used with patient permission

Mrs JW

11  
 1  
 5  
 0  
 0  
 0  
 7

24pts

# The Auckland Cataract Study 1 :

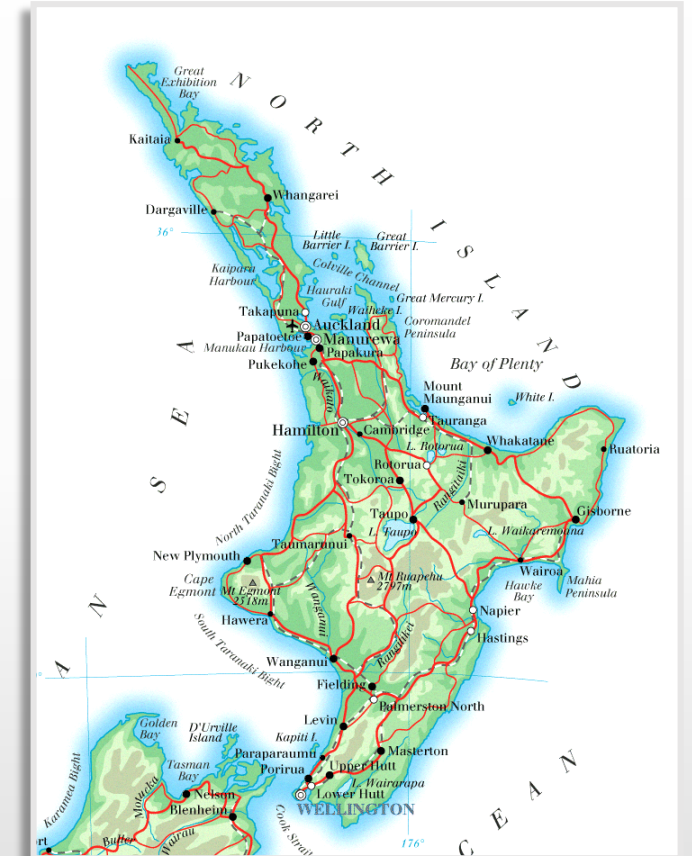
waiting for surgery in a developed country

## Harbour Bridge Study (N=193)

Mean age	77.2 years
Mean wait	18.2+/-11.6
Mean BSCVA	6/36

## Outcome

Still waiting	49%
Expedited Rx	4%
Private Surgery	21%
Deceased	12%
Declined Surgery	12%



**The Waiting Game:** The natural history of a cataract waiting list in New Zealand  
*AF Riley, C Grupcheva, TY Malik, JP Craig, CN McGhee. Clin Expt Ophthalmol 2001*

# Auckland Cataract Project: Associated Systemic Disease

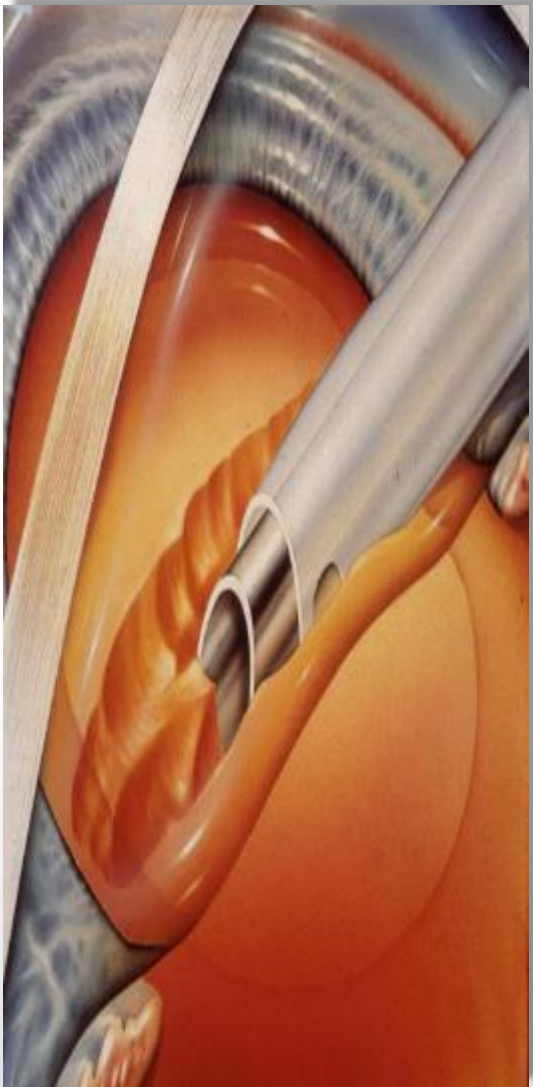
The majority of those with significant cataract have General Health issues

Hypertension	25%
Cerebral vascular disease	12%
Diabetes Melitus	11%
Ischaemic Heart disease	10%
<b>Rx</b>	
Aspirin	42%
Warfarin	6%



© Prof CNJ McGhee @NZNEC

Pre-proliferative diabetic retinopathy



# Auckland Cataract Study 1

488 consecutive cataract operations

Moderately advanced cataracts with mean BSCVA of 6/48 (20/160)

Mean pre-op refraction  $-0.49 \pm 1.03D$

99.8% local anaesthesia (95% subtenons)

97.5% small incision phacoemulsification

Typically less than 30 minute procedure

# Phacoemulsification outcomes (N=488)

Unselected, consecutive, moderately advanced cataracts treated in a tertiary public hospital by residents / consultants

## Outcome :

Mean BSCVA = 6 / 7.5 (20/25)

Majority (88%)  $\geq$  6/12 (20/40)

Mean SphEq  $-0.46 \pm 0.89D$

## Complications :

4.9% capsular tears

3.7% cystoid macular oedema

0.2% endophthalmitis

1.5% of eyes red'n in potential BSCVA due to surgery



# The Initial Auckland Study: Summary 1

Predominantly elderly, majority female population

Significant systemic illness and co-existing ocular diseases,

Relatively advanced cataracts and poor visual acuity

Majority (97.5%) phacoemulsification, local anaesthetic (mainly sub-Tenons anaesthesia) , day-case surgery in 2000

Remaining 2.5% underwent extra-capsular cataract surgery

# The Initial Auckland Study: Summary 2

Almost 90% achieved BSCVA of 6/12 (20/40) or better which meets the NZ & UK driver's licence standard.

~5% of eyes had an adverse intra-operative event

However, only 1.5% of eyes exhibited poorer post-operative BSCVA than predicted based on overall eye health in 2000



# ACS 2000: Complications Summary

## CLINICAL SCIENCE

The Auckland Cataract Study: co-morbidity, surgical techniques, and clinical outcomes in a public hospital service

Andrew F Riley, Tahira Y Malik, Christina N Grupcheva, Michael J Fisk,  
Jennifer P Craig, Charles N McGhee

N=500 Intraoperative complications	n	%
Posterior capsule tear	24	4.9%
Iris prolapse / Iris trauma	21	4.3%
Wounds retraction/minor phaco burn	19	3.9%
Incomplete capsulorrhexis	11	2.2%
Dropped lens fragment	4	0.8%

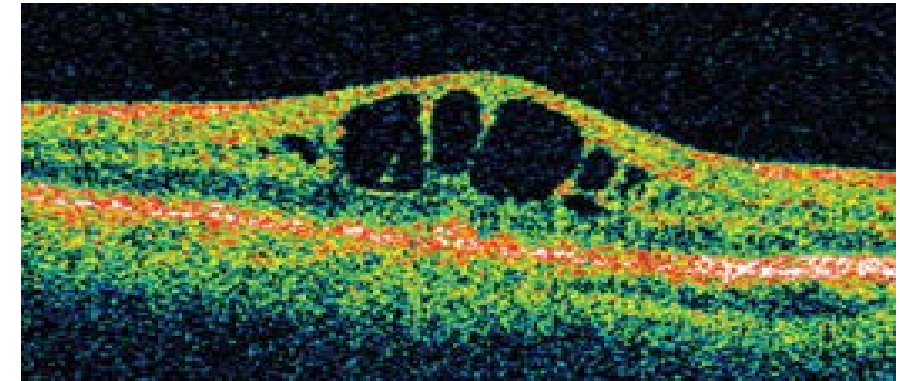
Consultants 320 phacoemulsifications - 4.7% capsule tear

Registrars 168 phacoemulsifications - 5.4% capsule tear

# Always consider knowledge in context of contemporary international evidence base



- Posterior capsule rupture **1.9 - 5.2%**
- Cystoid macular oedema **1.0 - 5.7%**



Riley A, Malik T, Grupcheva C, et al. The Auckland Cataract Study: co-morbidity, surgical techniques and clinical outcomes in a public hospital service. *Br J Ophthalmol*. **2002**;86:185-90.

Narendran N, Jaycock P, Johnston RL, et al. The cataract national dataset electronic multicenter audit of 55 567 operations: risk stratification for posterior capsule rupture and vitreous loss. *Eye*. **2009**;23:31-37

Ti SE, Yang YN, Lang SS, et al. A 5-Year audit of cataract surgery outcomes after posterior capsule rupture and risk factors affecting visual acuity. *Am J Ophthalmol* **2014**;157:180-185

Kothari M, Thomas R, Parikh R, et al. The incidence of vitreous loss and visual outcome in patients undergoing cataract surgery in a teaching hospital. *Indian J Ophthalmol* **2003**; 51:45-52.

Wegener M, Alsbirk PH, Højgaard-Olsen K. Outcome of 1000 consecutive clinic- and hospital-based cataract surgeries in a Danish county. *J Cataract Refract Surg* **1998**; 24:1152-1160

# Auckland cataract Studies 2000 to 2020

## Considering

Contemporary trends and outcomes

Registrar training and patient safety

Risk stratification for cataract surgery

Decreasing intra-operative complications



# What's new in IOL design?

## Developments since ACS 2000

Posterior capsule opacity & square edge

Multifocal / accommodative IOLs

Coloured IOLs & macular protection

Correction of astigmatism

Correction of spherical aberration

Specialised IOLs for reconstruction



# *An Evidence based approach*

**Can we do better in assessing surgical risk for a patient?**

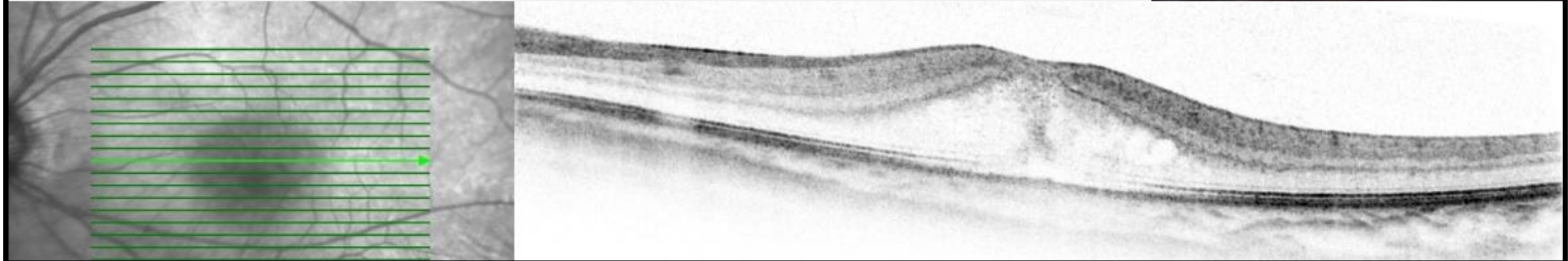

**Can we improve complication rates in a teaching hospital?**



# Audit: Cataract Surgery in Auckland 2002 to 2015

Can we make further improvements in a teaching hospital?

2002		2015
4.9%	Posterior capsule tear*	2.6%
3.8%	Cystoid macular oedema	3.5%
67.7%	UAVA 6/12 or better	73.9%



\*May reflect better technology, less advanced cases, and improved training

## PART 2:

### Auckland Cataract Studies: Improving outcomes Routine procedure & standard of care 2020



- Almost all cases ambulatory same-day surgery
- Anaesthesia typically sub-Tenons L.A. in DHBs
- Routine cases approx. 30 minutes theatre time
- Pad or shield overnight with day 1 and 28 review
- Post-op. Rx topical antibiotic (Chloramphenicol) for two weeks and topical steroid (Prednisolone or Dexamethasone) for four weeks

# Auckland Cataract Study II

## Risk stratification: Non-intervention phase (NIP)

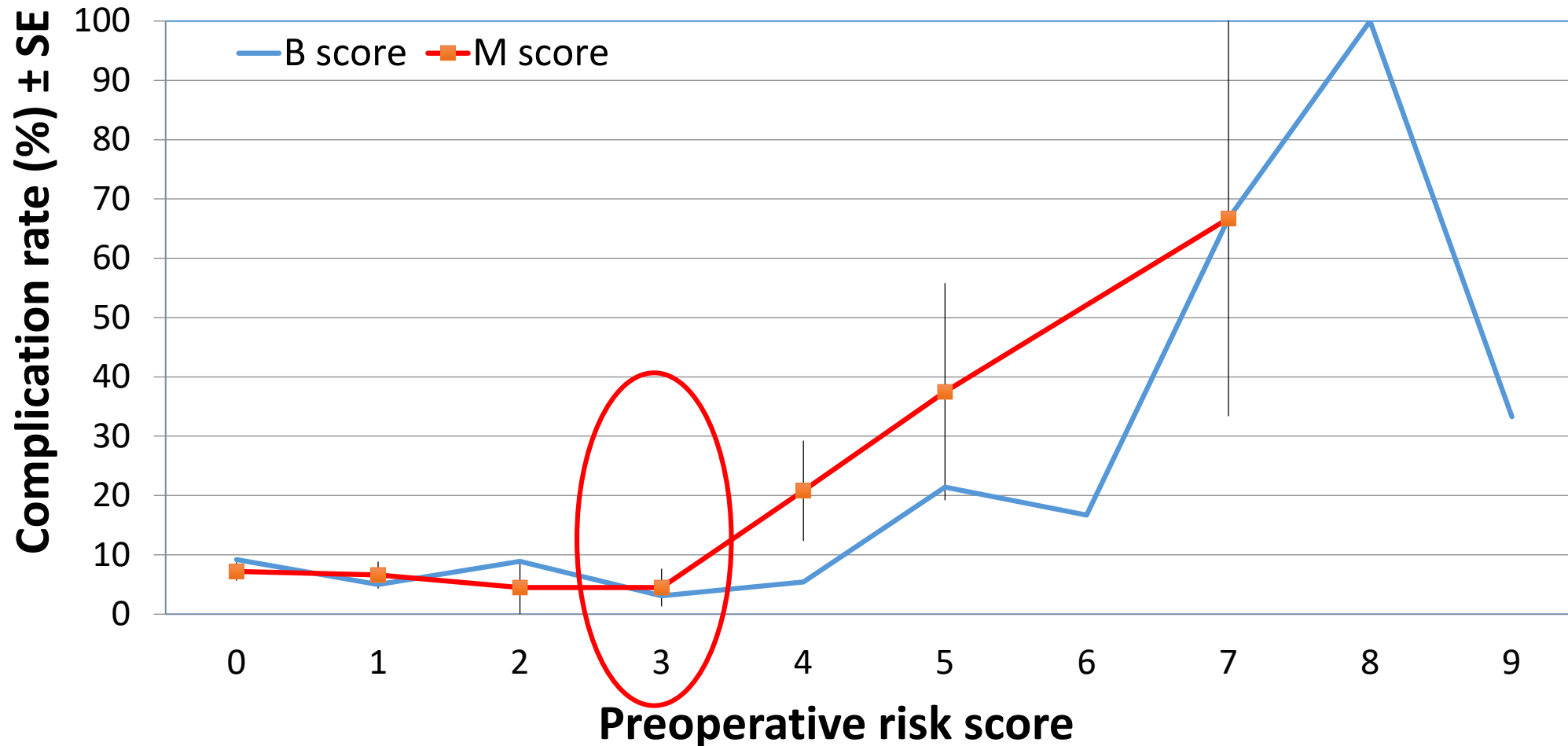


- Preoperative data used to calculate individual **risk scores (N=500 )** surgeon unaware of score
- Muhtaseb et al. and Butler T.K. risk scoring systems utilized
- **Certain patient factors** associated increased risk of intraoperative complications



- Muhtaseb M, Kalhor A, Ionides A. A system for preoperative stratification of cataract patients according to risk of intraoperative complications a prospective analysis of 1441 cases. Br J Ophthalmol 2004;88:1242–1246
- Butler TK. Risk stratification and assessment in cataract surgery. J Cataract Refr Surg. 2012; 38(1):184

# Intraoperative complication rate per risk score in Auckland cataract Study IIA. Observational / NIP Phase



M-Score of  
>3 associated  
with an  
increasing  
risk of intra-  
operative  
complication

- Muhtaseb M, Kalhoro A, Ionides A. A system for preoperative stratification of cataract patients according to risk of intraoperative complications a prospective analysis of 1441 cases. Br J Ophthalmol 2004;88:1242–1246
- Butler TK. Risk stratification and assessment in cataract surgery. J Cataract Refr Surg. 2012; 38(1):184

# Auckland Cataract Study IIB

## Mutasheb intervention phase (MIP) 2016



- Preoperatively scored a **further 500 cases**
- Suggested cases scoring **>3** be performed by **fellows/consultants**



Kim BZ, Patel DV, Sherwin T, McGhee CN. The Auckland Cataract Study: Assessing Preoperative Risk Stratification Systems for Phacoemulsification Surgery in a Teaching Hospital. Am J Ophthalmol. **2016** Nov;171:145-150.

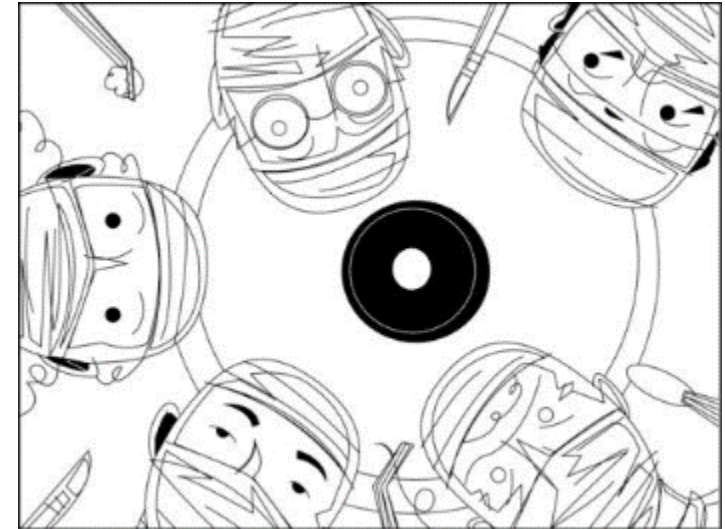
Kim BZ, Patel DV, McGhee CN. Auckland cataract study 2: clinical outcomes of phacoemulsification cataract surgery in a public teaching hospital. Clin Exp Ophthalmol. **2017** Feb 7. [Epub ahead of print]

# Complication rates per surgeon group

## Auckland Cataract Study IIA (NIP) vs IIB (MIP)



	2015	2016	P-value
Registrars	10.8%	7.0%	0.449
Fellows	6.4%	3.9%	0.554
Consultants	8.4%	4.8%	0.094



- Note: complications ascribed to primary surgeon
- **Case-adjusted odds ratios** between groups **not significantly different** – registrars/ fellows/ consultants had similar complication rates, allowing for appropriate allocation

# Auckland Study II (MIP): Conclusions



1. **Risk scores** correlate with **complication rates**
2. **Fewer intraoperative complications** with stratification
3. Higher risk cases **appropriately allocated** senior surgeons
4. Lower risk cases also benefit from **increased awareness?**
5. ? **“Hawthorne effect”** altered behavior when studied



The Auckland Cataract Study II: reducing intraoperative complications by preoperative risk stratification and case allocation in a teaching hospital. Kim BZ, Patel DV, McKelvie J, McGhee C. Am J Ophthalmol 2017

# Auckland Cataract Study III: (NZCRS 1) 2017

## Employing the evidence base in practice



To assess **New Zealand Cataract Risk Stratification system (NZCRS-1)** on intraoperative **complications** of cataract surgery

### Prospective cohort study

- **500** cases of phacoemulsification cataract surgery
- Public **teaching hospital**, Auckland, NZ
- **43 surgeons**, 24 consultants 19 trainees\*



## NZ Cataract Risk Stratification (NZCRS)

Please tick **ALL** that apply:

<i>Risk factor</i>	<i>Points</i>	<i>Risk factor</i>	<i>Points</i>
Dense/total/white/ brunescent cataract /no fundus view	3 <input type="checkbox"/>	High ametropia (>6D myopia/ hyperopia)	1 <input type="checkbox"/>
Pseudoexfoliation	3 <input type="checkbox"/>	Posterior capsule plaque (1)	1 <input type="checkbox"/>
Phacodonesis	3 <input type="checkbox"/>	Posterior polar cataract (1)	1 <input type="checkbox"/>
Oral alpha-receptor antagonist	2 <input type="checkbox"/>	Shallow AC (<2.5mm) (1)	1 <input type="checkbox"/>
Age >88 years	1 <input type="checkbox"/>	Small pupil (<3mm dilated) (1)	1 <input type="checkbox"/>
Corneal scarring	1 <input type="checkbox"/>	Miscellaneous risks assessed by surgeon (e.g. poor position/ cooperation) (1)	1 <input type="checkbox"/>
<b>Total points:</b>			

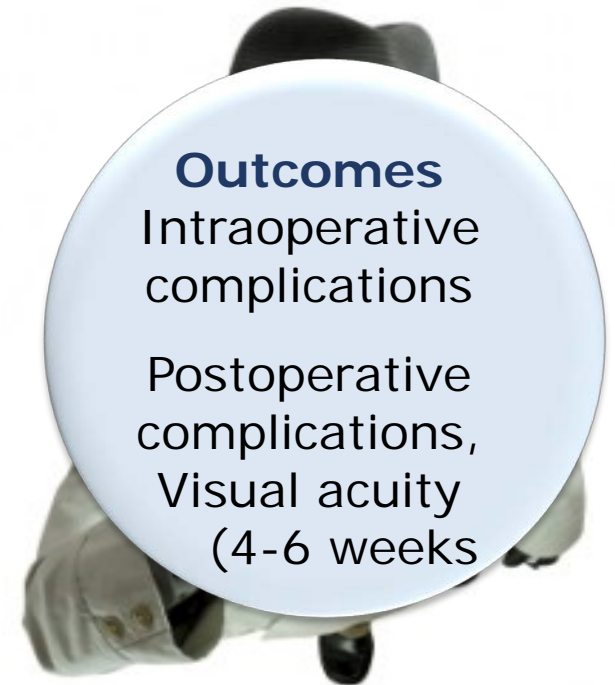
Please tick:

**Previous vitrectomy?** Yes ☐ No ☐

**Only eye?** Yes ☐ No ☐

If **total points >3** OR **prev vity** OR **only eye**, then fellow or SMO only case (tick below)

**Fellow or SMO ONLY case** ☐



### Outcomes

Intraoperative complications

Postoperative complications,  
Visual acuity  
(4-6 weeks)

Pre-op all patient clinical notes reviewed by **single investigator**, risk score calculated using **NZCRS**

# NZCRS-1: Intraoperative complications

	NZCRS (N=500)
<b>Intraoperative complications (Total)</b>	<b>5.0%</b>
<b>Iris prolapse</b>	<b>1.4%</b>
<b>Iris trauma</b>	<b>1.2%</b>
<b>Anterior capsule tear</b>	<b>1.4%</b>
<b>Dropped nucleus</b>	<b>0.2%</b>
<b>Post. capsule tear ± vitreous loss</b>	<b>0.6%</b>
<b>Zonule dehiscence</b>	<b>0.6%</b>
<b>Vitreous loss</b>	<b>0.0%</b>



NZCRS adherence  
(N=448)

**4.5%**



Non-adherence  
(N=52)

**9.6%**

# Visual outcome NZCRS : 1 month

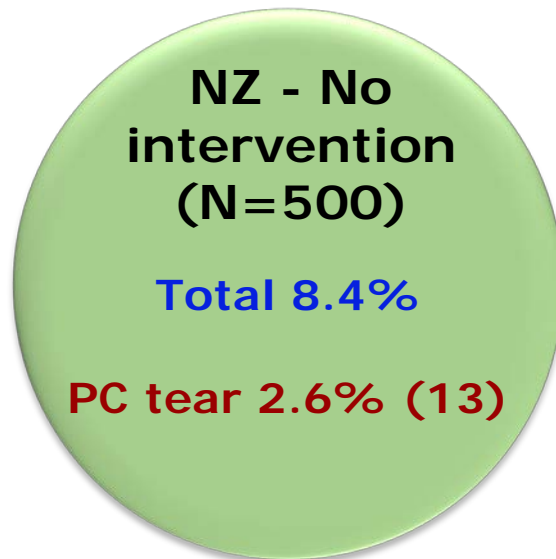


NZCRS	Preoperative	Postoperative (4-6 weeks)	P-values
Unaided visual acuity	6/38	6/12	<0.05
Best corrected visual acuity	6/20	6/10	<0.05

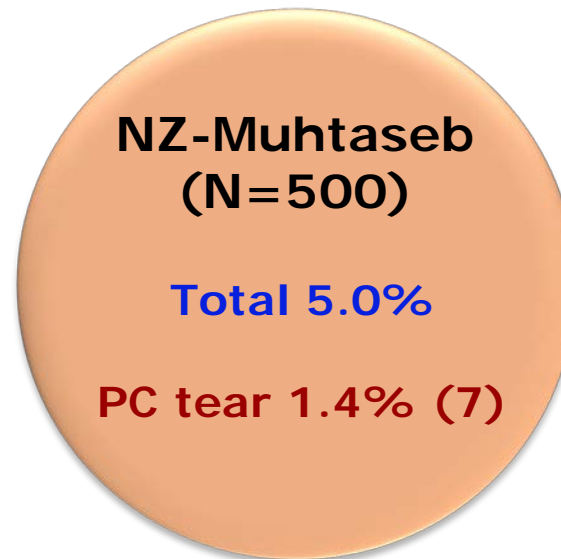
No patients excluded on basis of co-morbidity e.g. glaucoma, AMD, diabetic retinopathy

**Preceding NIP and MIP phases postoperative BCVA: 6/9 (20/30)**

# Intraoperative complications: 3-phase prospective Auckland Cataract Study (N=1500)



Phase 1: (NIP) risk  
score calculated but  
no intervention



Phase 2: (MIP) risk  
score calculated  
with intervention

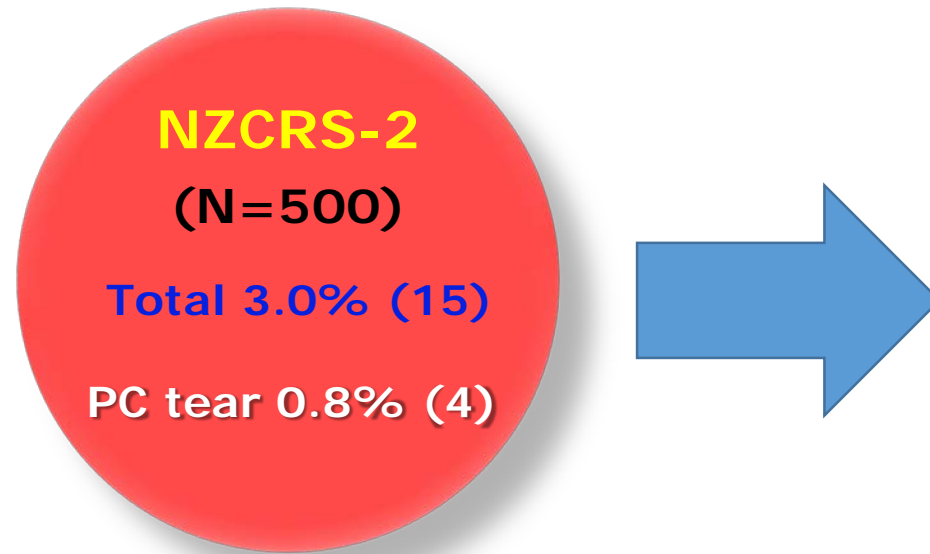


**(p= .035)**

Phase 3: NZCRS-1  
risk score calculated  
with intervention



# Auckland Cataract Study IV: NZCRS-2 standard of care phase



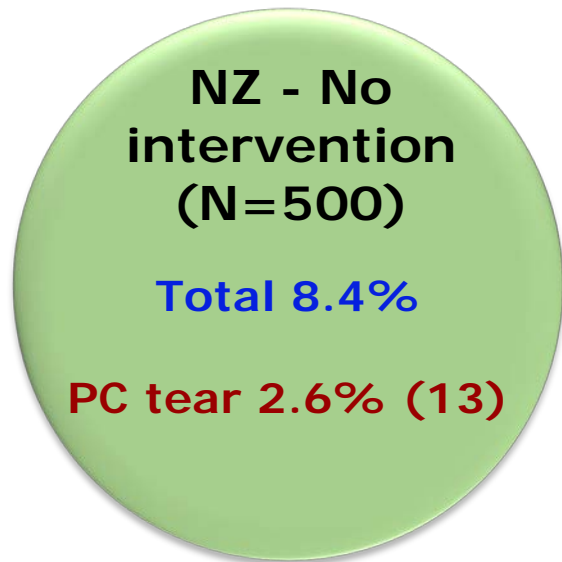
## Intraoperative complication rate

- Registrar 5% (5/100 cases)
- Fellows 5.7% (2/35 cases)
- Consultants 2.2% (8/365 cases)

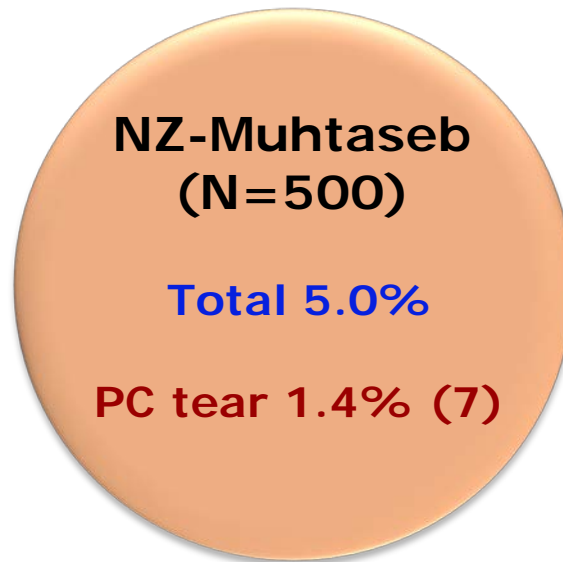
## Mean NZCRS-2 risk score per group

- Registrar 0.81
- Fellows 1.6
- Consultants 1.6

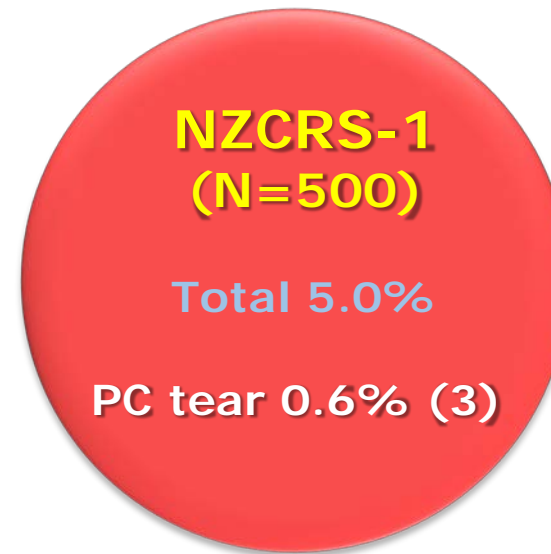
# Comparing Auckland Cataract Studies II-IV: intraoperative complications (N=2000)



Phase 1: (NIP) risk  
score calculated but  
no intervention



Phase 2: (MIP) risk  
score calculated  
with intervention



**(p= .035)**

Phase 3: NZCRS-1  
risk score calculated  
with intervention



**(p<0.05)**

Phase 4: NZCRS-2  
risk score calculated  
with intervention but  
no oversight

# Risk stratification with NZCRS



- **Does stratification work?**
  - 64% reduction of intraoperative complications (8.4% to 3.0%  $p < 0.05$ )
  - Reduced severity of complications (PCR 2.6% to  $< 1.0\%$ )
- **Practical in day-to-day clinical setting?**
  - Good utilisation initial setup phase (80.5%)
  - Excellent adherence to stratification (99%)

Han JV, Patel DV, Wallace HB, Kim BZ, Sherwin T, McGhee CNJ. **Auckland Cataract Study III:** Refining Preoperative Assessment With Cataract Risk Stratification to Reduce Intraoperative Complications. Am J Ophthalmol. 2019 Apr;200:253-254.

Han JV, Patel DV, Liu K, Kim BZ, Sherwin T, McGhee CNJ. **Auckland Cataract Study IV:** Practical application of NZCRS cataract risk stratification to reduce phacoemulsification complications. Clin Exp Ophthalmol. 2019 Dec 5. [Epub ahead of print]

# NZCRS Risk Stratification Summary



- **Reduction of intraoperative complications** with **NZCRS**
  - Despite **higher proportion** of **high risk cases/ trainees**
- **Preoperative risk stratification**
  - **identification** of high risk cases
  - **appropriate allocation** of case
  - **Increased awareness** of risk factors
  - *Enables comparison of case complexity in training assessments*



# Summary: Auckland Studies 2000-2020

- Prospective study of more than 3000 patients
- Almost all patients undergo phacoemulsification cataract surgery with local anesthesia.
- Despite co-existing eye disease majority achieved 6/12 meeting the NZ driving standard.
- 5% of eyes experienced adverse intra-operative event however only 1.0% visually significant
- 3% will develop cystoid macular oedema (most common post-operative complication)
- Only 1.0 - 1.5% of eyes exhibit poorer post-operative BSCVA than anticipated.
- Severe post-operative complications endophthalmitis and retinal detachment were uncommon
- Cataract stratification enables best allocation of patient to surgeons and decreases complications



Namkung S, Han JV, McGhee CNJ. Harmonizing cataract surgery training and patient-centred care in 2020: Disclosure, consent, supervision and patient altruism. Clin Exp Ophthalmol. 2019;47(8):975-977.

# Translational Vision Research



Department of Ophthalmology

## The End

Material contained in this lecture presentation is copyright of The Department of Ophthalmology, New Zealand National Eye Centre, University of Auckland, and should not be reproduced without first obtaining written permission

