The IACLE Contact Lens Course

MODULE 9

Special Topics

First Edition

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The International Association of Contact Lens Educators
IACLE Secretariat,
PO Box 328 RANDWICK
SYDNEY NSW 2031
Australia

Tel: (612) 9385 7466
Fax: (612) 9385 7467
Email: iacle@iacle.org

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Acknowledgements

The IACLE Curriculum Project is the result of a desire to raise the standard of eyecare education, to make contact lens wear safer and more successful, and to develop the contact lens business by creating the educational infrastructure that will produce the teachers, students and practitioners of the future.

The concept of the world's best educators making available their most creative educational contributions for the common good without any recompense, other than a sense of satisfaction, was born out of IACLE's idealism.

The Curriculum Project could not be successful without the assistance and generosity of a large number of talented and dedicated people. To all those contributors of lectures, laboratory notes, videos, slides, etc., we say thank you. Your generosity of spirit will benefit many educators, hundreds of thousands of students and millions of patients throughout the world.

The Vice President of IACLE, Professor Desmond Fonn, has made a tremendous contribution since the inception of IACLE, and has provided his considerable expertise in the final editing stage of the Curriculum. This project was commenced under Professor Brien Holden's leadership. The original plan and layout for the Curriculum was prepared by Sylvie Sulaiman, IACLE's Director of Education. Sylvie's dedication and excellent understanding of practitioner and community requirements have given the Project focus and depth.

More recently, the IACLE Curriculum Project has benefited from the work of Dr Lewis Williams as Manager, Educational Development. Dr Williams has done an amazing amount of work to achieve an impressive collation of diverse material, and has created what I believe to be an invaluable collection of contact lens knowledge. Dr Williams has also been assisted by Rob Terry's considerable experience and understanding of the contact lens field.

Kylie Knox has done an excellent job as Project Editor. To complement the efforts of the editors, layout coordinators Barry Brown and Shane Parker have done an admirable job, as have the rest of the graphics team. The Cornea and Contact Lens Research Unit (CCLRU) at the University of New South Wales has contributed substantially to this project through the donation of time, resources and editorial support.

The IACLE global staff including Director of Administration Yvette Waddell, Global Coordinator Pamela O'Brien and Executive Secretary Gail van Heerden, have expertly managed the considerable tasks of production and distribution.

No acknowledgments page in an IACLE document would be complete without a reference to its sponsors. Bausch & Lomb have been a major corporate sponsor since 1990, providing the original stimulus for IACLE's growth by contributing financial support and the involvement of individuals from their International Division. It was Dr Juan Carlos Aragon (when he was at Bausch & Lomb) who first suggested that if IACLE was to be taken seriously by industry, it needed a global plan to address the educational requirements for the safe, effective growth of the contact lens business. Johnson & Johnson Vision Products is our other major corporate sponsor. They have provided excellent assistance through their provision of industry coordinators for Europe, Africa, and the Middle East. CIBA Vision has been a corporate contributor and also provided excellent industry coordination in Latin America. Allergan and Wesley Jessen/PBH have contributed generously as corporate donors, with Alcon Laboratories, contributing as IACLE donor.

IACLE is a cooperative effort, and none of its activities are more collective than the Curriculum Project. The IACLE Contact Lens Course which resulted from this project is provided to assist educators in accredited institutions to impart eyecare and contact lens knowledge. All the contributors deserve recognition for their selflessness and talent.

Debbie Sweeney

President of IACLE

Contributors

Desmond Fonn, Dip Optom, MOptom
Associate Professor
School of Optometry
University of Waterloo
Waterloo Ontario Canada N2L 3G1

Editor-In-Chief

Fred Edmunds, OD
Bausch & Lomb
1400 N Goodman St
Rochester NY 14692 USA

- **Contact Lenses for Sporting Activities**

Anthony P. Cullen,
Dip Opt, MSc, OD, PhD, DSc, DCLP
Professor
School of Optometry
University of Waterloo
Waterloo Ontario Canada N2L 3G1

- **The Working Environment and Contact Lenses**

Christopher Snyder, OD, MS
Professor
Department of Optometry
The University of Alabama at Birmingham
Birmingham AL 35294-0010 USA

- **Contact Lenses for Sporting Activities**
- **The Working Environment and Contact Lenses**
- **Fitting Scleral Lenses**
- **Fitting an Ocular Prosthesis**

Ma. Meredith Reyes, OD, MA (College Teaching)
Cornea and Contact Lens Research Unit
The University of New South Wales
Sydney NSW 2052 Australia

- **The Working Environment and Contact Lenses**
- **Fitting Scleral Lenses**
- **Fitting an Ocular Prosthesis**

Robert Terry, BOptom, MSc
Cornea and Contact Lens Research Unit
School of Optometry
The University of New South Wales
Sydney NSW 2052 Australia

- **Fitting Scleral Lenses**
- **Fitting an Ocular Prosthesis**

Lewis Williams, AQIT (Optom), MOptom, PhD
IACLE Secretariat
PO Box 328
Randwick NSW 2031 Australia

- **Advanced Techniques and Instrumentation**

Educators Guide to the IACLE Contact Lens Course

Overview

The IACLE Contact Lens Course is a comprehensive package of educational materials and other resources for teaching the subject of contact lenses. This package was designed to encompass *The IACLE Contact Lens Course Syllabus* and covers 360 hours of lectures, practicals and tutorials in ten modules, containing material at basic, intermediate and advanced levels.

The teaching resources have been designed for flexibility, allowing the educator to select the materials appropriate to the students' knowledge and the educational requirements of the class, school, institution or country. The separate document, *The IACLE Contact Lens Course Syllabus,* summarizes the course and includes outlines of Modules 1 to 10.

The English language reference used for the IACLE Contact Lens Course is: Brown L (Ed.), *The New Shorter Oxford English Dictionary,* 1993 ed. Clarendon Press, Oxford (UK). The only spelling exception is *mold* and *mould.* The Oxford dictionary suggests *mould* in all contexts. We chose to use *mold* for manufacturing-related matters and *mould* for fungi since both meanings and spellings appear regularly in contact lens literature. This differentiation is based on common usage. Where words are 'borrowed' from a language other than English they are reproduced in their native form where possible.

Where standards have been ratified by the International Organization for Standardization (ISO), or where draft ISO standards are at an advanced stage, their relevant terminology and symbology are used. Système International (SI) units of measure are used wherever possible.

Many major contact lens textbooks from around the world, and some important journal articles, are referenced in the Course, and copyright illustrations are reproduced with permission of the original publishers and/or copyright owners. The reference section at the end of each unit details the information sources used throughout.

Teaching Resources - Module 9

Module 9 of the IACLE Contact Lens Course has the following materials:

1. **Contact lens manual**

   The contact lens manual consists of:

   - Course overviews
   - Lecture outlines and notes
   - Practical outlines, exercises and notes*
   - Tutorial exercises and notes*

     * Not all units have these sections.

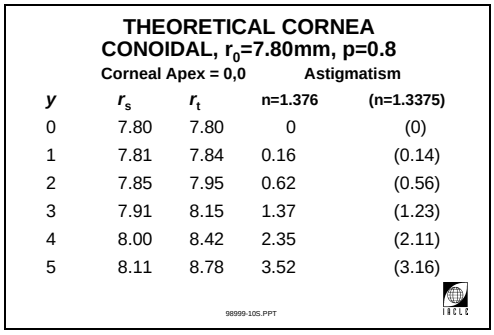
   The suggested lecture, practical and tutorial hours of the module are outlined in the Summary of Module 9 on page *xi*. The manual provides recommended activities, references, textbooks and evaluation techniques in the interests of their standardization. Ultimately however, the design and methodology of the course is left to the discretion of the contact lens educator.

2. **Slides for lectures, practicals and tutorials**

   The slides have been numbered according to the sequence in which they appear in each lecture, practical and tutorial. Single or dual slide projection can be accommodated. Each slide has an identification code which is based on a cataloguing system in use at the IACLE Secretariat and which should be used in any communication with IACLE regarding the slides.

For example:

To re-order this slide please quote this identification code



THEORETICAL CORNEA
CONOIDAL, r_0=7.80mm, p=0.8

Corneal Apex = 0,0 **Astigmatism**

y	r_s	r_t	n=1.376	(n=1.3375)
0	7.80	7.80	0	(0)
1	7.81	7.84	0.16	(0.14)
2	7.85	7.95	0.62	(0.56)
3	7.91	8.15	1.37	(1.23)
4	8.00	8.42	2.35	(2.11)
5	8.11	8.78	3.52	(3.16)

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Symbols, Abbreviations and Acronyms Used in the IACLE Contact Lens Course

SYMBOLS			
↑	increase, high	{	collectively produced by
↓	decrease, low	}	collectively produces
→	produces, towards	↗	sum of
←	produced by, from	±	plus or minus the value of
↔	no change, not obvious	+	plus, add, include, and
↑↑	significant/great increase	–	minus, reduce
↓↓	significant/great decrease	≈	approximately
%	percentage	=	equal to, the same as
<	less than	&	and, as well as
>	greater than	*x*°	degrees: e.g. 45°
≥	equal to or greater than	@	in the meridian of
≤	equal to or less than	D	dioptres
?	unknown, questionable	X	axis: e.g. –1.00 X 175. – 1.00D cylinder, axis in 175° meridian
n, n_{sub}, n_{sub}'	refractive indices	Δ	prism dioptres or difference
∝	proportional		

ABBREVIATIONS			
μg	micrograms (.001 mg)	min	minute, minutes
μL	microlitres (.001 mL)	mL	millilitres (.001L)
μm	microns (.001 mm)	mm	millimetres
μmol	micromoles, micromolar	mmol	millimole, millimolar
cm	centimetres (.01m)	mOsm	milliosmole
d	day, days	nm	nanometres (10^{-9} m)
Endo.	endothelium	Px	patient
Epi.	epithelium	Rx	prescription
h	hour, hours	s	second, seconds
Inf.	inferior	Sup.	superior
kg	kilograms	*t*	thickness
L	litre		

ACRONYMS			
ADP	adenosine diphosphate	LPS	levator palpebrae superioris
ATP	adenosine triphosphate	NADPH	nicotinamide adenine dinucleotide phosphate
ATR	against-the-rule	NIBUT	non-invasive break-up time
BS	best sphere	OD	right eye (Latin: *oculus dexter*)
BUT	break-up time	OO	orbicularis oculi muscle
CCC	central corneal clouding	OS	left eye (Latin: *oculus sinister)*
CCD	charge-coupled device	OU	both eyes (Latin: *oculus uterque* - each eye, or *oculi uterque* - both eyes)
cf.	compared to/with	PD	interpupillary distance
CL	contact lens	PMMA	poly(methyl methacrylate)
Dk	oxygen permeability	R	right
DW	daily wear	R&L	right and left
e.g.	for example (Latin: *exempli gratia*)	RE	right eye
EW	extended wear	RGP	rigid gas permeable
GAG	glycosaminoglycan	SCL	soft contact lens
GPC	giant papillary conjunctivitis	SL	spectacle lens
HCL	hard contact lens	TBUT	tear break-up time
HVID	horizontal visible iris diameter	TCA	tricarboxylic acid
i.e.	that is (Latin: *id est*)	UV	ultraviolet
K	keratometry result	VVID	vertical visible iris diameter
L	left	WTR	with-the-rule
LE	left eye		

Summary of Module 9: Special Topics

Course Program

Lecture			Practical Session			Tutorial (Small Group Teaching)		
Title	***Hrs***	***Level****	***Title***	***Hrs***	***Level****	***Title***	***Hrs***	***Level****
L9.1 Advanced Techniques and Instrumentation	1	3	P9.1.1 Pachometry	2	3	T9.1 Industry Presentation of Contact Lens-Related Products	2	1
			P9.1.2 Tear Film Analysis	2	3			
			P9.1.3 Aesthesiometry	2	3			
L9.2 Contact Lenses for Sporting Activities	1	3						
L9.3 The Working Environment and Contact Lenses	1	2						
L9.4 Fitting Scleral Lenses	1	3						
L9.5 Fitting an Ocular Prosthesis	1	3						

* Level 1 = Basic: essential knowledge

Level 2 = Intermediate: desirable knowledge

Level 3 = Advanced: useful knowledge

Course Time Allocation

Level	Lecture	Practical	Tutorial	Total Hours
Basic	0	0	2	**2**
Intermediate	1	0	0	**1**
Advanced	4	6	0	**10**
TOTAL	**5**	**6**	**2**	**13**

Request for Feedback

As this is the first edition it is our intention to revise and update it periodically. To ensure each revision is an improvement on its predecessor we request your help. We invite you to provide feedback in the form of comments, corrections or suggestions for improvement which you feel will enhance the accuracy or quality of the Course. Such feedback may then be incorporated in subsequent revisions of the Course. We are particularly interested in receiving corrections to, and suggestions for improvements in, the text and slides of the lectures.

To facilitate this feedback process a *pro forma* is included on the next page. This can be photocopied. Please complete your contact details as the team may wish to discuss your suggestions in greater detail or even ask you to participate in any revision resulting from your input.

The IACLE Contact Lens Course
Feedback / Corrections / Suggestions Form

Name: _____ Date: _____
(yy-mm-dd)

Institution: _____

Address: _____

_____

_____

_____

_____

Module: _____ Unit: _____ Page Number: _____

Slide Code: _____ Section: _____

Comments:

Thank you

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Unit 9.1

(1 Hour)

Lecture 9.1: Advanced Techniques and Instrumentation

Practical 9.1.1: Pachometry

Practical 9.1.2: Tear Film Analysis

Practical 9.1.3: Aesthesiometry

Tutorial 9.1: Industry Presentation of Contact Lens-Related Products

Course Overview

Lecture 9.1: Advanced Techniques and Instrumentation

I. Newer and more advanced clinical procedures and instrumentation
II. Role of computers in routine contact lens practice
III. Future directions

Practical 9.1.1: Pachometry

I. Demonstration of a pachometer
II. Instruction in the use of a pachometer
III. Use of a pachometer on normal and keratoconic corneas

Practical 9.1.2: Tear Film Analysers

I. Demonstration of a tear film analyser
II. Use of a tear film analyser
III. Use of a tear film analyser on normal, contact lens wearing and dry eye patients

Practical 9.1.3: Aesthesiometers

I. Demonstration of an aesthesiometer
II. Use of an aesthesiometer
III. Use of an aesthesiometer on normal, soft lens wearing and RGP wearing corneas

Tutorial 9.1: Industry Presentations

Lecture 9.1

(1 Hour)

Advanced Techniques and Instrumentation

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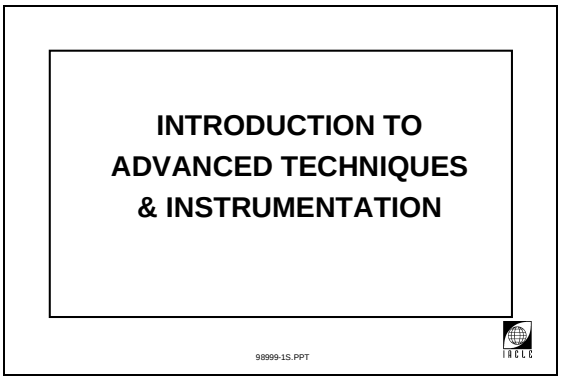
I Introduction

1



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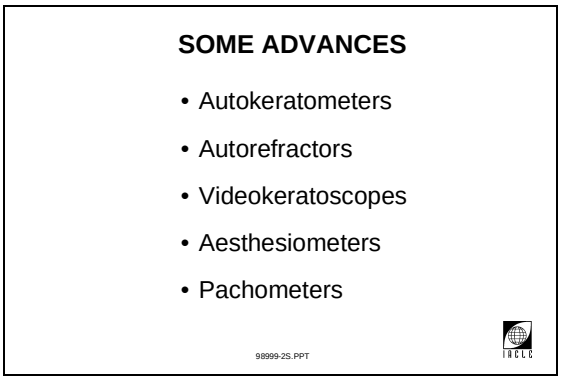

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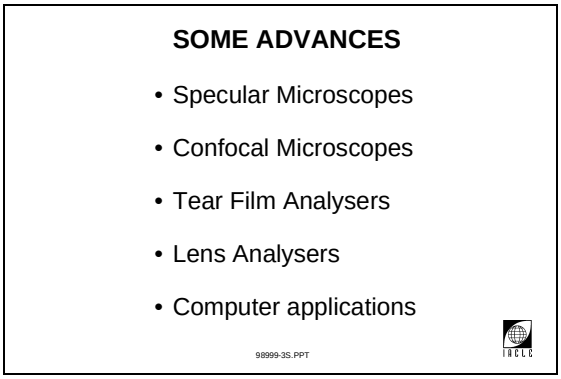

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Introduction to Advanced Techniques and Instrumentation

The progress of technology, particularly that related to computers, has had a major impact on ophthalmic equipment, data collection/storage, and clinical procedures.

Some of the advances relevant to contact lens practice are listed in slides 2 and 3.

While not all advances necessarily result in better or more accurate results, most enable tasks to be performed more easily, rapidly, and with greater repeatability. They also enable tasks to be delegated to other staff.

The introduction of sophisticated electronics and/or microprocessors to instruments has resulted in equipment which is either self-aligning or which include alignment aids, often with interlocked functions to prevent the acquisition of erroneous data. This enables ancillary staff to gather valid information with a reasonable degree of reliability. This increases practice staff satisfaction and frees the practitioner for the more demanding aspects of a consultation. It also makes more time available for patient education and communication.

II Automated Keratometers

4

ROLE OF AUTOMATED KERATOMETERS

- Provide accurate corneal meridional radii of curvature
- Estimate corneal dioptric power
- Prevent the acquisition of invalid data
- Display, print and store data as required

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Role of Automated Keratometers

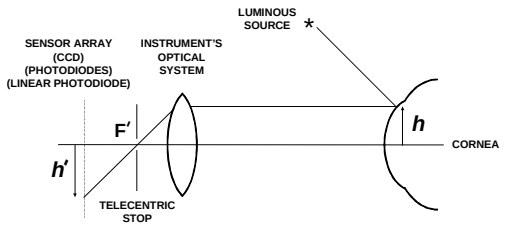
Automated keratometers produce information on the radius of curvature, dioptric power and axis of the cornea being measured. The devices usually incorporate an alignment system (circles, cross-hair cursors or some form of image splitting requiring vernier alignment). Usually, results are not provided unless in-built criteria are satisfied. Criteria include correct alignment and proper focus.

Most instruments display the results on either a digital display or some form of computer monitor. Some also include a printer (internally or in a base station) which provides a written record of the results and, increasingly, a computer-compatible link (RS-232C serial port, Universal Serial Bus (USB), IR link (IrDA) or a proprietary system) that allows the data to be logged by a computer or computer network.

The bases of the optical systems of many of the instruments available differ little from their conventional optical/visual counterparts. However, some instruments utilize three light beams (often infrared) whose reflections are received so selectively as to allow the location of the 'reflecting points' to be determined accurately.

5

SIMPLIFIED AUTOKERATOMETER
(AFTER DOUTHWAITE, 1995)



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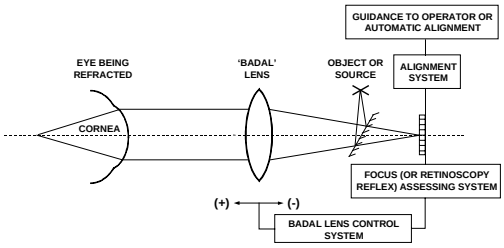
Autokeratometer: Optical Principle

Autokeratometers are based on one of several designs. One possible principle is illustrated opposite.

This autokeratometer is based on the telecentric stop principle. An aperture is placed in the second focal plane of the instrument's objective lens, thereby limiting image forming rays to those of zero incident vergence. This means that a relationship between h' and the radius of the cornea (acting as a convex mirror) can be established, since the position of the luminous source or sources is known. By measuring h', the instrument can determine the radius of curvature of the cornea.

6

AUTOREFRACTOR OVERIEW



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Autorefractor: Optical Principle

The principle of the autorefractor is somewhat more complex. In such instruments optical components (e.g. the Badal lens) need to be moved under the influence of data from a 'receptor' being fed into a control 'loop'. Complexity is increased when extra features, such as automatic alignment, are included. The basic control systems are shown in boxes in the diagram opposite.

Combination Instruments

The combination of autorefraction and keratometry in one instrument represents a significant achievement because of the integration of differing requirements, both optical and mechanical, in a

7

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8

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single device. Some of this integration is possible because of the availability of small integrated computers to provide the instrument's 'intelligence'. However, the optical and mechanical requirements of such a combination instrument still present a challenge to designers.

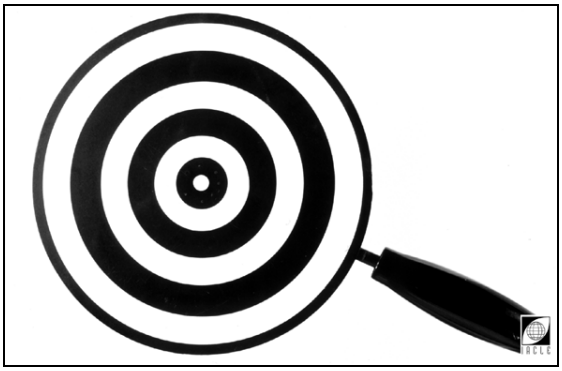
Automated Keratometers or Combination Autokeratometers/Autorefractors: Current Market

- Reichert EyeChek KM.
- Humphrey HARK 597K, 599.
- Nikon Retinomax K plus (hand-held).
- Alcon Hand-Held Autokeratometer.
- Nidek KR-500 (hand-held).
- Topcon KR-7100P (auto-Rx, auto-K and topographer, see slide 7).
- Luneau L60 Keratoref.
- Auto Ref-Keratometer RK-3 by Canon (auto-K and auto-Rx (slide 8).

III Keratoscopes

III.A Photokeratoscopes

9



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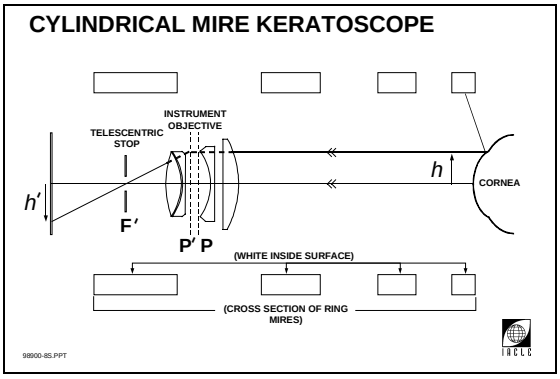
Photokeratoscope: Optical Principles

In its simplest form a keratoscope consists of a Placido Disc (slide 9) and a camera to record the reflection of the rings from the pre-corneal tear film.

The basic principles of a cylindrical-mire, telecentric-stop photokeratoscope appear in slide 10.

10



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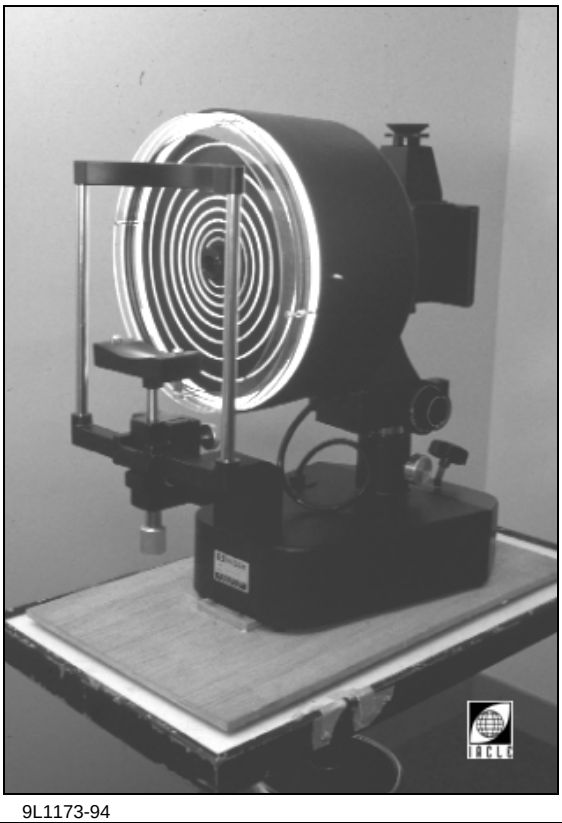
The mire rings are made thicker (wider) and more widely separated, the further they are away from the cornea. A rear telecentric stop is located at F' of the instrument objective.

The chief image forming rays are those incident rays of zero vergence. This reduces the image height errors caused by imperfect focus due to incorrect instrument location along the instrument's optical axis (i.e. anterior – posterior mislocation).

The use of a telecentric system also simplifies the calculations of the corneal characteristics, since the point of reflection (ray height) can be found directly from the image height in the photokeratograph.

11



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Photokeratoscopes

With the advent of videokeratoscopes the popularity of the photokeratoscope has declined significantly. Few are still available commercially. However, special-purpose custom-built devices are still constructed by researchers as needed. The level of sophistication and automation applied to the *analysis* of the photokeratographs produced has changed over the years. Automated analysis of photokeratographs was available more than 20 years ago (e.g. the Wesley Jessen PEK System 2000 photokeratoscope). The advent of powerful computers has enabled the analysis to be done in real time without the intermediate photographic step. Essentially, videokeratoscopes are automated keratoscopes which do not require film.

The continued use in photokeratoscopes (and videokeratoscopes) of mire loci which were shown to be less than optimum up to 60 years ago is difficult to justify. The least desirable locus is flat, i.e. a Placido disc-like set of rings. Not all rings are in focus simultaneously and it requires a large array to provide peripheral corneal coverage. While the edge-detection optoelectronics used in many instruments overcome some of the limitations of out-of-focus mire image edges, particularly in the periphery, it would seem that better results could be

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9L10126-98

achieved with more appropriate mire loci. Shallow conical arrays perform little better, yet such shapes are common in many current videokeratoscopes.

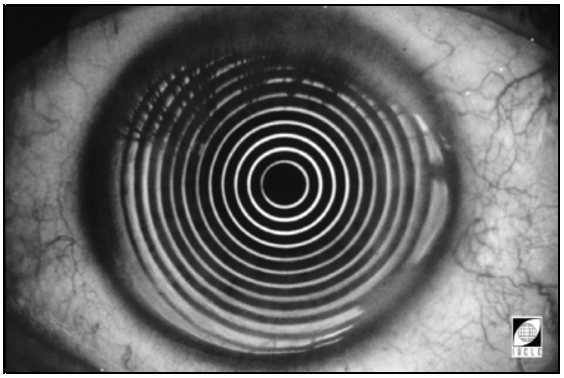
Loci suggested as being better include cylindrical mires (a series of rings, each of the same diameter), cardioid and ellipsoidal mires (solid or multiple point sources). Projected targets have also been used (see summary in Guillon and Ho, 1994). On the 'average' cornea, these shapes provide better focus across the range of cornea covered and, if mire size is chosen judiciously, provide approximately equal-sized mire images from all corneal positions.

Regardless of the mire locus used, photokeratoscopes make excellent qualitative instruments. Slide 12 shows a Sun (Japan) photokeratoscope which uses Polaroid™ 'instant' film.

Disadvantages of photokeratoscopes:

- Usually provide photographic records only.
- Most lack computerized image analysis of any description.
- Curvature, height or power analysis is difficult.

13



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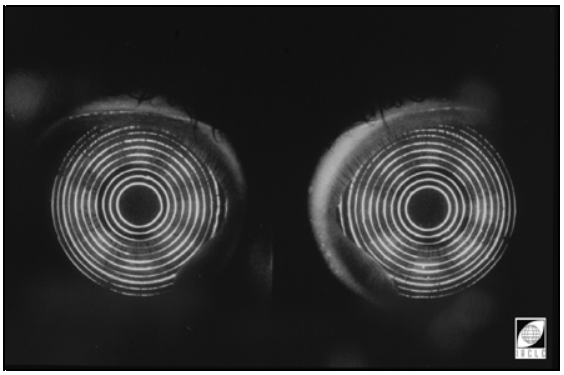
Photokeratographs

In slide 13, the extent of corneal coverage and the limitations caused by nose, eyelid and eyebrow anatomy are apparent. The uneven width of the mire rings is also apparent as is the non-uniformity of the illumination of the mires and the decreased quality of focus in the periphery.

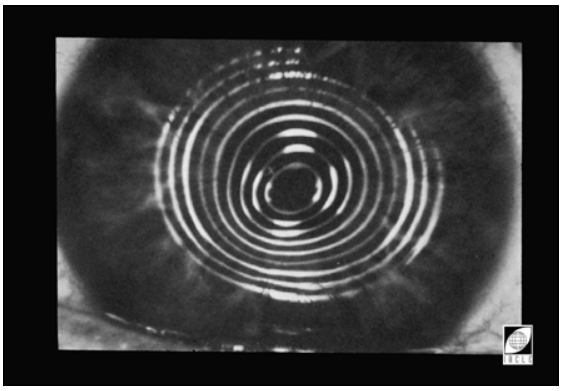
14



9L11130-91

Slide 14 shows a pair of normal photokeratographs. The 'spoke' pattern is an instrument artefact due to the configuration of the illumination system.

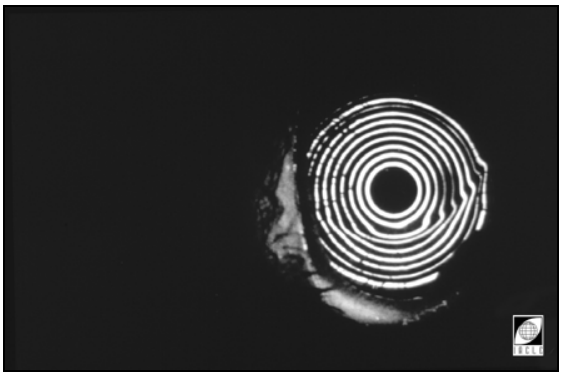
15



9L13037-93

Slide 15 shows a keratoconic cornea. The typical irregularity and distortion of the surface shape is apparent.

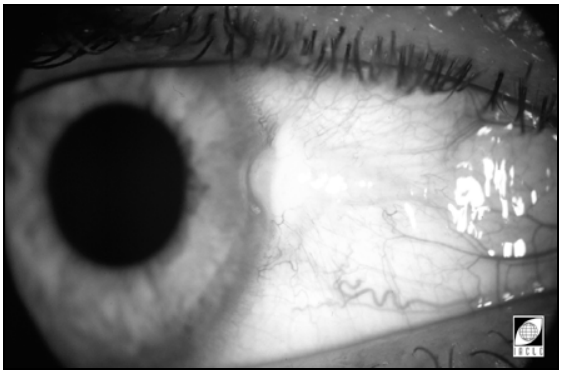
16



9L10044-92

Slide 16 shows a cornea *after* a high-riding adherent RGP lens has been removed. The epithelial indentation (and possibly some effects of lens adherence on the tear film) can be seen clearly.

17

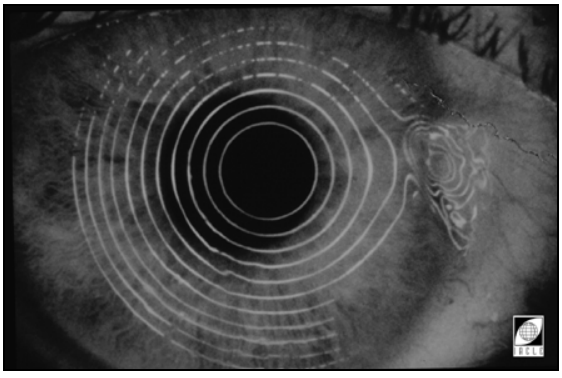


9L10443-92

Corneal Irregularities

Slide 17 shows a white light photograph of an early pterygium. Slide 18 shows a photokeratograph of the same eye. The extent of the corneal distortion resulting from the head of the pterygium confirms the textbook claims that the visible extent of the pterygium underestimates the true extent of the condition and certainly indicates little of the optical effects (all deleterious).

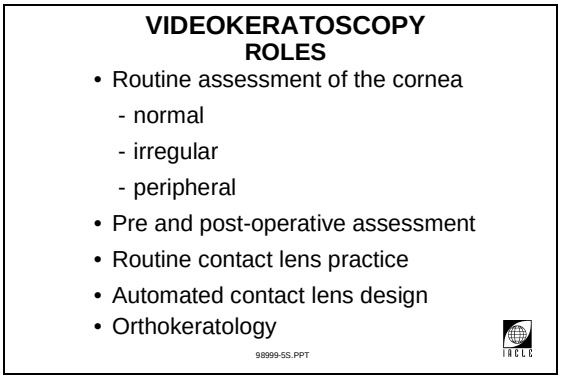
18



9L10173-92

III.B Videokeratoscopes

19



L198999-5

Roles of Videokeratoscopes

Videokeratoscopes have evolved from the photokeratoscope. They were introduced briefly under the heading Topography Analysers in Module 1.

Their roles include:

- Routine assessment of the normal cornea.
- Investigation of eyes demonstrating unexplained reduced visual acuities.
- Assessment of irregular corneas, providing a starting point for contact lens selection.
- Pre and post-operative examinations
  - Refractive surgery (post-surgical shape, disclosure of central islands, level of irregularity, etc.)
  - Cataracts
  - Screening out incipient keratoconics, keratoconics and other irregular cornea patients from prospective refractive surgery waiting lists.
- Routine contact lens care.
- Automated and/or objective contact lens design and parameter selection.
- Fluorescein pattern simulation.
- Bitoric lens calculation aid.
- Assessment of the peripheral cornea.
- Tracking corneal changes over extended time periods.
- Baseline data determination and recording.
- Orthokeratology, where they are used in both initial and on-going patient management.
- As a teaching aid for the study of simulated fluorescein patterns and corneal topography.

20

9L10008-98

Mire Loci

- Placido disc (flat, concentric ring targets, slide 20. Note the internally-lit rings are not visible in this illustration).
- Modified Placido disc (including shallow cones, slide 21).
- Conical (slide 22).
- A conic section.
- Cylindrical (slide 23).
- Cardioid.
- Grid projection or pattern projection usually with the aid of fluorescein-stained tears (slide 25). This technique allows the measurement of the topography of the anterior eye, not just the cornea (i.e. beyond the limbus, e.g. Euclid ET-800). This method is also used in the PAR CTS in which a 0.2 mm grid pattern is projected onto the anterior eye and the data points extracted by a stereo-triangulation technique (Belin *et al.,* 1995).
- Interference patterns and Moiré fringes.

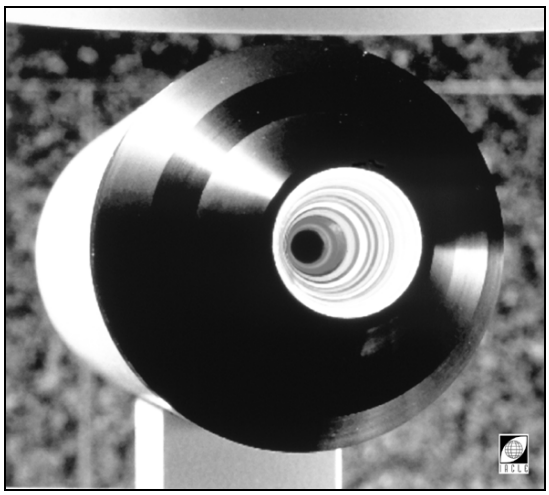
21

9L10328-95

Slide 21 shows the patient side of an EyeSys videokeratoscope. This instrument uses a shallow conical mire locus.

Comments about mire loci made previously, apply equally to videokeratoscopes. Franket *et al.* (1995) found that Placido disc-based videokeratoscopes were better suited to normal corneal topography. Abnormal topography resulted in greater inter-map variability which was exacerbated by corneal steepness. A similar finding has also been presented by Chan *et al.* (1995A).

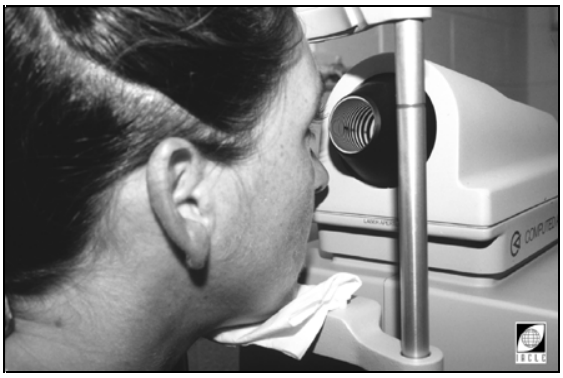
22



9L10002-98

Slide 22 shows the steeply conical, coloured-ring mire of the C-Scan instrument.

23

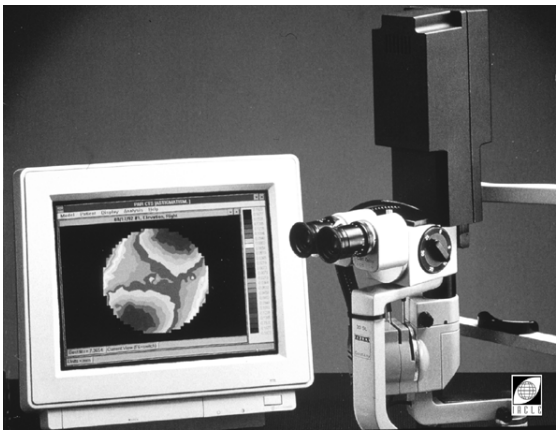


9L10723-93

Slide 23 shows a Topographic Modeling System TMS-1 videokeratoscope by Computed Anatomy, Inc. (now marketed by Tomey). This instrument uses a combination of mire loci:

- A small cylindrical mire for the corneal periphery.
- A flat Placido disc for the central cornea.

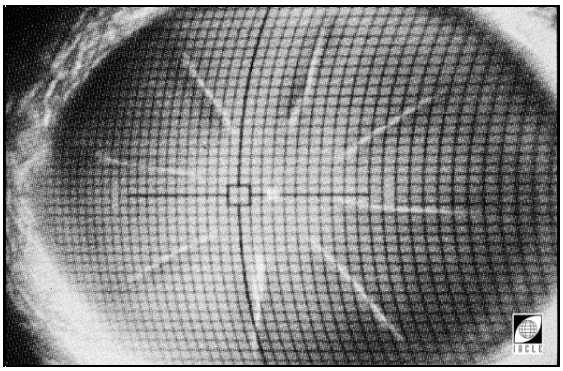
24



9L10060-98

Slide 24 shows the PAR Vision System's PAR CTS instrument which projects a fine grid pattern onto the fluorescein-stained anterior eye (slide 25). The compact PAR CTS projector, shown here attached to a Zeiss slit-lamp, can also be mounted on operating microscopes and other ophthalmic equipment.

25



9L10072-98

III.C Corneal Topography

26

CORNEAL COVERAGE
7 - <11mm

- 7 mm +, C-Scan
- 8 mm, Topcon KR-7100P
- 9.6 mm, EyeSys
- 10 mm, EyeMap
- 10.7 mm Keratron (Optikon 2000)

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9L19899-6

27

CORNEAL COVERAGE
> 11mm

- 11 mm, Medmont E300
- 11+ mm, CLAS-1000
- 11.5 mm, Tomey Auto Topographer
- 12 mm, PAR CTS
- 12.5 mm, Humphrey Atlas Eclipse
- 'Anterior Eye', Euclid ET-800

98999-7S.PPT

9L198999-7

Corneal Coverage

The corneal coverage of each instrument is limited by physical (size), anatomical (nose, orbital margins, lashes) and optical (mire locus shape) considerations. Some claimed coverage characteristics are shown in slides 26 and 27.

28

CORNEAL TOPOGRAPHY
PRESENTATION

Three basic types:

- Curvature
- Height
- Power

98999-8S.PPT

9L198999-8

Presentation of Corneal Topography

There are three basic types of corneal topography presentation:

- Curvature.
- Height.
- Power.

When refractive power maps are presented, the results indicate the optical function of the anterior corneal surface and not the corneal shape.

29

MEASURES AVAILABLE

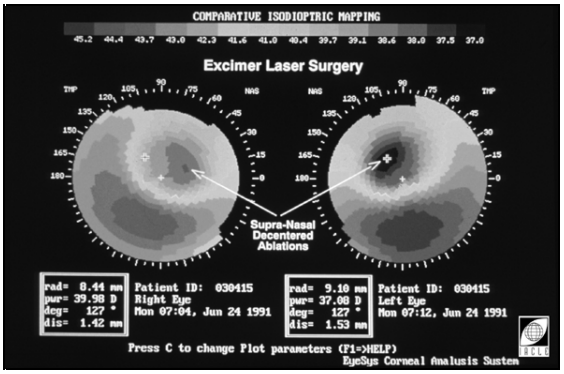
- Sagittal (Axial), Tangential radii
- Refractive Power
- Differences / Comparisons
- Meridonal profile
- Heights
- Eccentricity (of a conic)
- Irregularity index
- Numeric data

98999-9S.PPT

9L198999-9

Measures Available

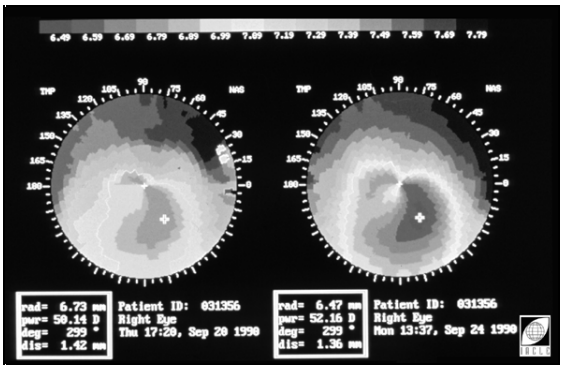
30



9L11055-92

Slide 30 shows a typical type of keratograph. The right and left eyes are shown side by side and the key to the colours employed is included in the image. This particular example is of the cornea of a post-refractive surgery patient.

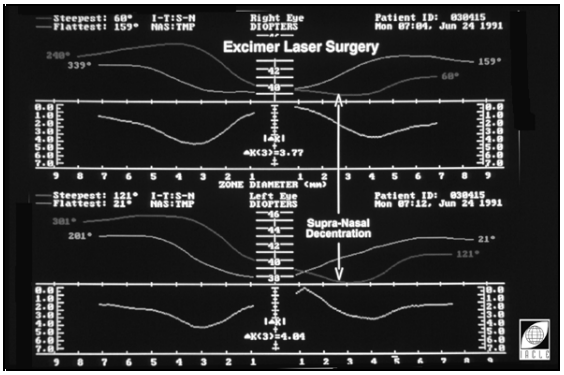
31



9L11059-92

Slide 31 is a comparative visualization showing the same eye on two different dates.

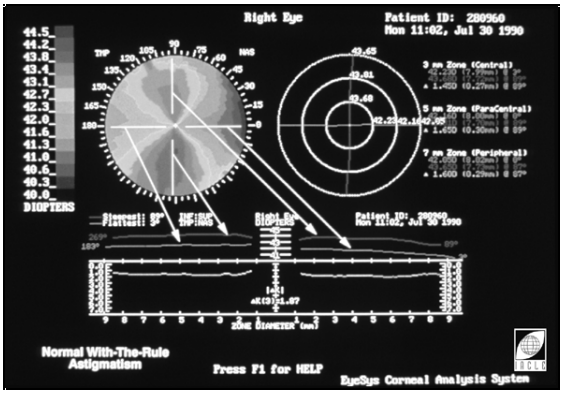
32



9L11055-92

Slide 32 shows a graphical plot of the corneal profile of an excimer laser patient with on-screen annotation of findings.

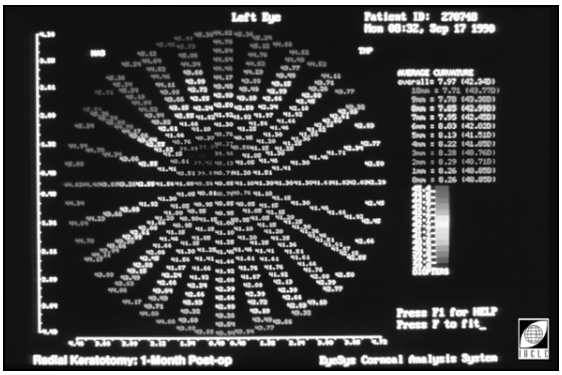
33



9L11031-92

Slide 33 shows a composite image demonstrating several of the previous types of displays.

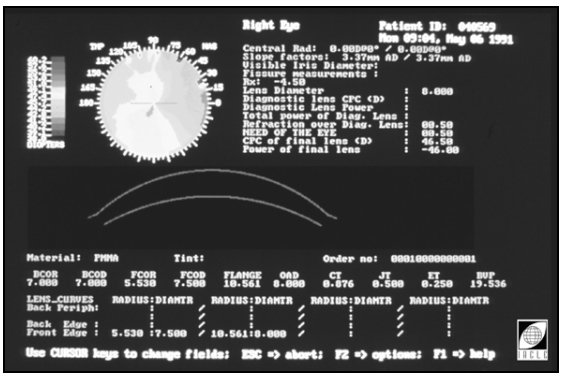
34



9L11048-92

Slide 34 shows a less common presentation in which dioptric power is presented as colour-coded numerical data in locations analogous to the corneal positions from which the data was derived.

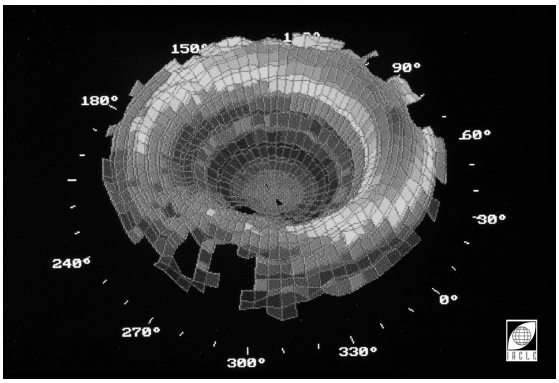
35



9L11057-92

Slide 35 shows a contact lens-fitting software module's output in which contact lens parameters are presented along with a profile of the lens suggested. Front surface information is based on the BVP required.

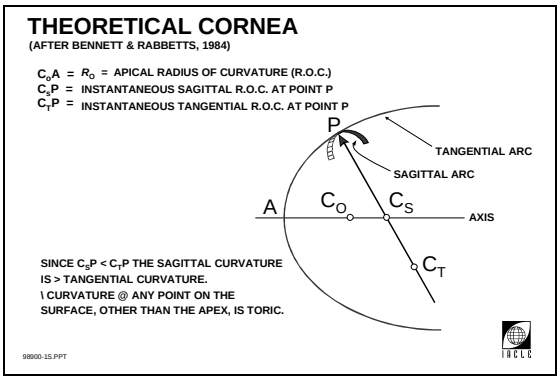
36



9L10059-98

Slide 36 shows a difference plot between corneal topography before and after surgery, using a C-Scan instrument. This is a dramatic representation of the corneal tissue 'removed' during surgery.

37



9L198900-1

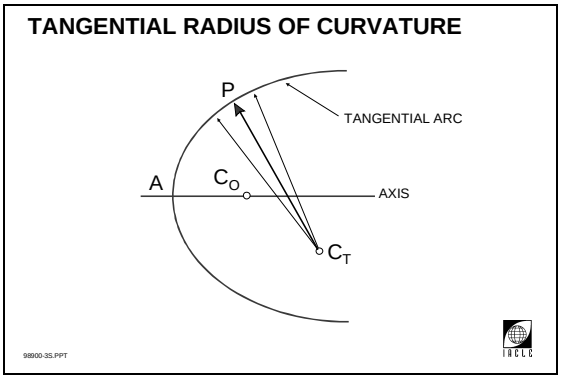
Corneal Topography: Terminology

Competition between manufacturers has resulted in differences in terminology. In some cases, differences between rigorous scientific terminology and that used conversationally also exist. This leads to inconsistencies and confusion.

In an attempt to resolve the issues surrounding terminology, a committee comprising the interested parties and the American National Standards Institute (ANSI) has been formed to standardize the language and issues involved in corneal topography. As yet no recommendations have been issued.

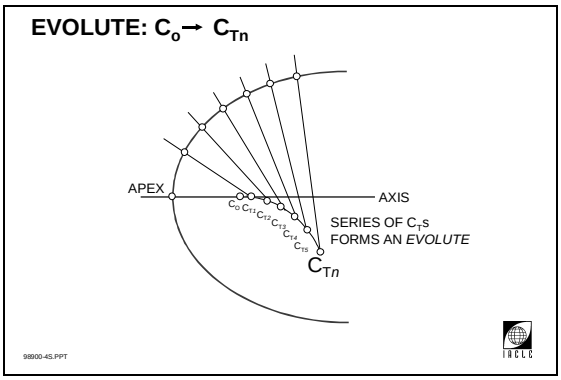
The most widely accepted definitions of tangential and sagittal radii are presented in slides 38 and 40.

38



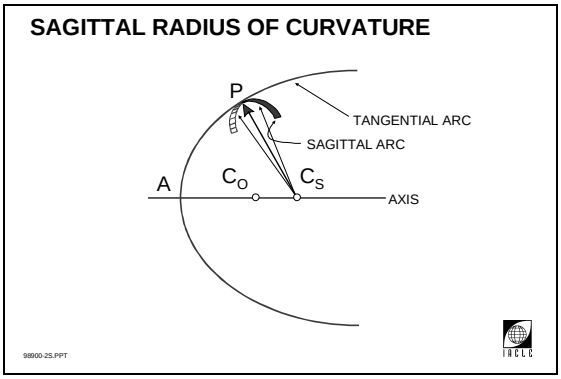
9L198900-3

39



9L198900-4

40



9L198900-2

41

THEORETICAL CORNEA
CONOIDAL, r_0=7.80mm, p=0.8

	Corneal Apex = 0,0		Astigmatism	
y	r_s	r_t	**n=1.376**	**(n=1.3375)**
0	7.80	7.80	0	(0)
1	7.81	7.84	0.16	(0.14)
2	7.85	7.95	0.62	(0.56)
3	7.91	8.15	1.37	(1.23)
4	8.00	8.42	2.35	(2.11)
5	8.11	8.78	3.52	(3.16)

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9L198999-10

The tangential radius is further complicated by having a series of centres (see slide 39) which depends on the location referred to. The locus of all centres ($C_{T0\ to\ n}$) is an evolute.

However, there is some confusion in the literature, even among mainstream workers in the field of corneal topography. Guillon and Ho (1994) point out that some texts use *local* and *sagittal* interchangeably whereas Roberts (1998) and others use *local* and *tangential* interchangeably. Some are inconsistent in usage e.g. Klein and Mandell (1995, 1995b) agree with the terminology for *instantaneous power* generally used (i.e. a tangential radius basis) whereas Klein and Mandell (1994) used an axial radius-based definition. Klein (1997) explains the various definitions of *instantaneous power* including instantaneous sagittal and instantaneous tangential powers and the confusion that can arise when shape and power are used in similar contexts.

The sagittal (axial) radius of curvature is the corneal parameter measured by the keratometer (Chan *et al.,* 1995) and the videokeratoscope (Klein and Mandell, 1994). However, axial measures fail to show subtle abnormalities of corneal shape (early keratoconus, degenerations, contact lens induced warpage, effects of refractive surgery, etc.) (Mattioli *et al.,* 1995). Instantaneous (tangential) radii were found to resolve this failing.

The following provides more details of these issues.

Terminology of Measures of Corneal Shape (after Roberts, 1998):

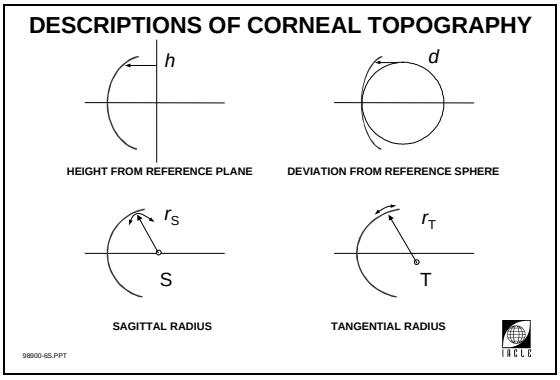
- Curvature
  - tangential, also instantaneous, local or true
  - sagittal, also axial, colour map or default.
- Height
  - elevation or height
    - height relative to a reference plane or 'absolute height'.
    - height relative to a reference sphere or 'elevation'.

Slide 41 shows the data calculated for a theoretical cornea based on the average figures appearing in the literature (e.g. Kiely *et al.,* 1984, Guillon *et al.,* 1986). Figures for n = 1.3375 are included because of industry's persistent use of this value to represent the cornea as a single refracting surface. However, in 'abnormal' corneas there is little justification for this approach. Nothing is usually known or can be assumed about the posterior corneal surface, and the 'optics' resulting from the cornea's shape are not necessarily regular or normal.

Dioptres

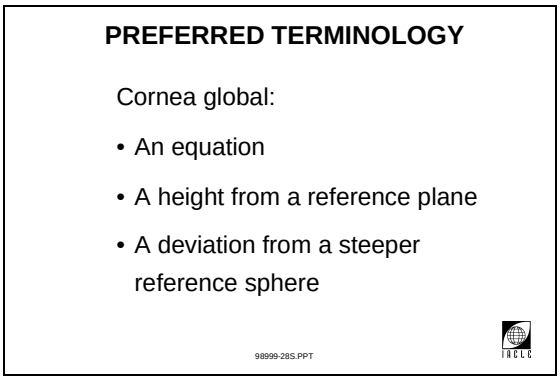
The use of the unit *dioptre* is very confusing. In many cases it seems not to be used as an optical term. Rather it is used as an alternative unit of

42



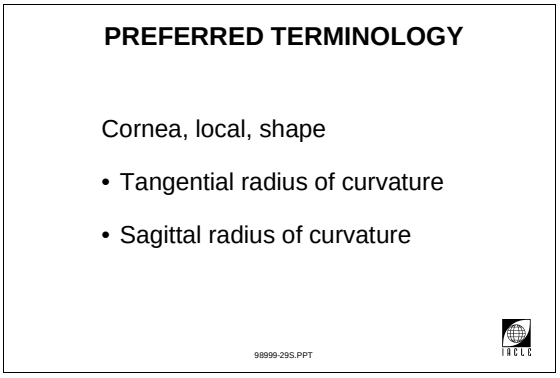
9L198900-6

43



9L198999-28

44



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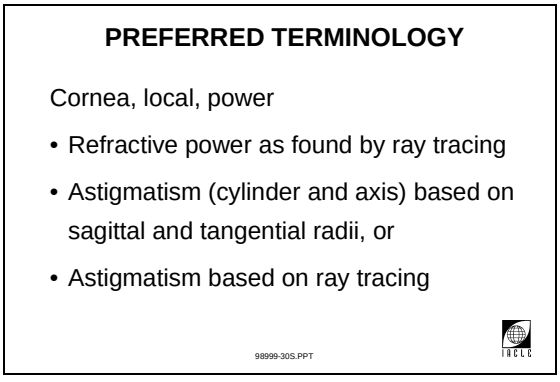
45



9L198999-30

curvature, a conclusion also presented by Salmon and Horner (1995). In some cases the distance from the axis to the point of interest (along the normal to the axis) is used, while in others the true sagittal or tangential radius is used. The 'refractive index' used may be the keratometer index, 1.3375, the anatomical index, 1.376 or some other value chosen by the manufacturer. The effect the refractive index value has on calculated astigmatism can be seen in slide 41.

Further, the use of radii (any one) to estimate power assumes nearly normal angles of incidence for light rays. In the periphery this is not the case and any estimates are erroneous. Ray tracing is suggested as a more accurate method (Salmon and Horner, 1995).

Since curvature is a physical parameter it seems prudent to use radii for physical descriptions and leave the term dioptre to optical usage (see next section: Preferred Terminology). This approach is supported by Roberts (1994), especially in relation to peripheral areas where the error is significant and of a pattern 'opposite' to that of corneal refractive power, i.e. (mis)calculation shows decreasing power in the corneal periphery, whereas the opposite is true.

Preferred Terminology

In the topography industry at large there is a proliferation of terms describing various aspects of corneal topography. There appears to be little justification for this approach. Optics already has a series of terms which appear to describe corneal topography, both globally and locally, more than adequately.

Global descriptions refer to the cornea as a whole, or to a particular meridian taken as a continuous curve across a given diameter. Local descriptions refer to a small area on the surface of the cornea or a small arc (partial section) along a particular meridian.

Suggested terminology:

Cornea, global:

- An equation with the origin (0,0) located at the corneal apex or perhaps the sighting centre.
- A height from a reference plane.
- A deviation from a steeper reference sphere (i.e. the peripheral flattening will be apparent).

Cornea, local: shape:

- Tangential radius of curvature.
- Sagittal radius of curvature.

Cornea, local: power:

- Refractive power as found by ray tracing and using $n_{cornea} = 1.376$

- Astigmatism (cylinder and axis) based on sagittal and tangential radii and n_{cornea} = 1.376 or astigmatism based on surface refractive power as found by ray tracing.

If the mean of the local maximum and minimum curvatures is required (as suggested by Barsky, 1996), it can be derived within the schema above.

46

TYPES OF MAPS

- Curvature Measures
  - tangential
  - axial (sagittal)
- Height Measures
  - evaluation
  - ablation profiles

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9L198999-11

Types of Maps

Curvature Measures

- Tangential. Tangential maps are used whenever local details and accurate curvature representations are required. They have also been shown to be more accurate in keratoconus (Valdez *et al.,* 1995). Applicable to:
  - post-refractive surgery evaluation
  - keratoconus
  - axial (sagittal)
  - contact lens fitting

Height Measures.

- Elevation. Applicable to:
  - contact lens fitting and fluorescein
  - patterns
  - post-penetrating keratoplasty
  - Irregular astigmatism
  - ablation profiles. Ablation profiles provide height data for use in laser refractive surgery.

47

ALIGNMENT

- Commonly, a fixation target is located along the instrument's optical axis
- Fixation and working distances vary from instrument to instrument

Preferred:

- The 'sighting centre' for power maps
- The corneal apex for shape maps

Few instruments use the preferred reference points

98999-12S.PPT

9L198999-12

Alignment

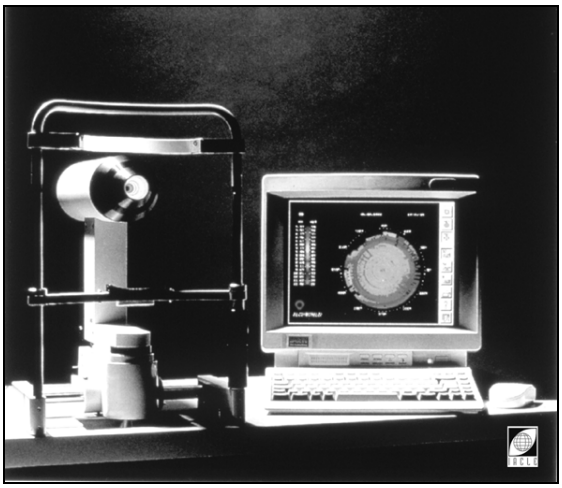
As the two principle applications of videokeratoscopes are determining corneal shape and corneal power, the data generated is related to either the corneal apex (for shape) or the corneal sighting centre (for power) (Mandell *et al.,* 1995).

Mandell *et al.* showed that only small errors existed (e.g. <0.50D) for central corneal power, toricity and axis when a comparison was made between standard instrument alignment and alignment at the corneal 'sighting centre'. However, in comparing standard alignment with apical alignment, significant differences were disclosed (i.e. >0.50D and >10° in several eyes).

The alignment of instruments with either the corneal apex or the corneal sighting centre was found to be laborious and was not recommended as a clinical technique. The authors expressed a wish for the manufacturers to transpose the instrument data to either of two reference points, the sighting centre (power) or the corneal apex (shape).

Neither of these reference points are used by most instruments. Rather, they use a fixation target located along the instrument's optical axis. The actual fixation distance varies from instrument to

48



9L10001-98

instrument. This introduces inter-instrument variations (Mandell, 1992). Mandell (and Klein and Mandell, 1994) suggested aligning the instrument's axis with the centre of the pupil as viewed by the instrument operator. This would necessitate re-writing the algorithms used.

The importance of alignment and fixation have been demonstrated by Owens and Watters (1994), who showed that in keratoconus, gaze position varied the topography results.

To address these issues a more recent instrument, the Technomed C-Scan Color-Ellipsoid-Topometer, (slide 48) uses line-of-sight (sighting centre) geometric centring. To achieve this, a fixation target and a laser for instrument alignment and focus are used (in the manufacturer's words, captive-field focusing with integrated Z-axis correlation) (see Oltrup *et al.,* 1997 for details).

49

ADDITIONAL CAPABILITIES

- Pachometry (few)
- Incision 'overlay'
- Surface angles
- Tear film & fluorescein profile stimulation
- Contact lens parameter suggestion
- Computer generated order form/fax and/or date/e-mail protocols

98999-13S.PPT

9L198999-13

Additional Capabilities

Because of the technology used in their design, some videokeratoscopes offer additional features of clinical interest. Features which may be included are listed in slide 49.

50

VIDEOKERATOSCOPES
CONTACT LENS FITTING SOFTWARE

- C-Scan
- Euclid
- EyeMap
- EyeSys Pro-Fit
- Humphrey's MasterFit™
- PAR
- Tomey

98999-14S.PPT

9L198999-14

Videokeratoscopes: Contact Lens Fitting Software

- C-Scan. This module selects contact lenses using a sagittal-radius method.
- Euclid. The use of fluorescein is required with this device and it is prudent to use high molecular weight fluorescein if soft lens fitting is envisaged.
- EyeMap.
- EyeSys Pro-Fit™ software.
- Humphrey's MasterFit™ module.
- PAR CTS.
- Tomey.

Fasce *et al.* (1995) and Schnider *et al.* (1995) found that rigid contact lens fitting was more accurate and faster with videokeratoscopy.

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INSTRUMENT FEATURES

Some instruments feature:

- Auto ID of R and L eyes
- Auto-focus
- Auto-align
- Auto-capture (of data)
- A graphical user interface (GUI)
- In-office calibration
- Portability

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Instrument Features

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DATA MAPPING & VISUALIZATION

- Iso curvature maps
- Iso heights
  - Iso deviations
- Iso power maps
- Other
  - lines delineating points of equal height, curvature, power etc
  - line drawings or graphs of profiles

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Data Mapping & Visualization

Most conventional videokeratoscopes offer a series of data mapping methods. Most allocate a spectrum of colours to a range of radii, heights, deviations or powers. Using such encoding it is possible to establish visually, points or regions of the same or similar radii, heights, etc. There is no agreement on the allocation of colours but there is a similarity between instruments. Numerical data (often also colour coded) can be overlaid in fixed increments if absolute data is required.

Reference surfaces such as spheres or ellipses must be used to reveal elevation differences at the micron level (Salmon and Horner, 1995). Technically, there is no reason why a plane could not be used as a reference surface. However, the magnitude of the resultant data would probably disguise the detailed information on corneal shape being sought.

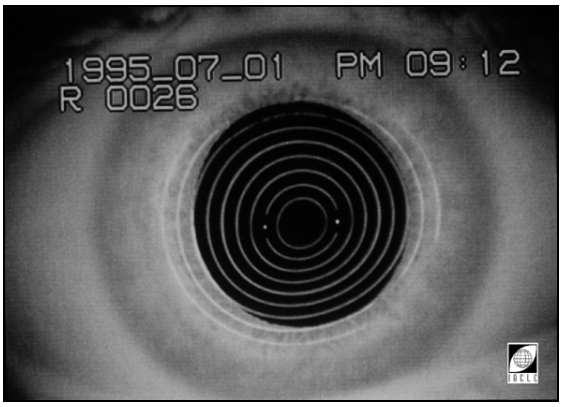
Curvature maps are an oversimplification of the optics of a surface which may be exposed to obliquely incident light. Power maps are more informative, albeit incompletely, than curvature maps and may have a role in predicting visual outcomes. However the tangential (instantaneous radius of curvature) best depicts the physical corneal shape and is more sensitive to surface irregularities such as those seen in keratoconus (Salmon and Horner,1995). The sagittal plot is sensitive to the position of the optic axis.

Barsky (1996) suggested two methods of visualization:

- Gaussian power, the geometric mean of the minimum and maximum curvatures at each data point.
- Cylindrical power, the difference between minimum and maximum curvature at each data point. To represent such data correctly, the orientation of the cylinder would also have to be provided. The latter issue was raised in a later paper (Barsky *et al.,* 1997).

Mathematically, all maps are related and each can be derived from one or more of the others (after Roberts, 1998).

53



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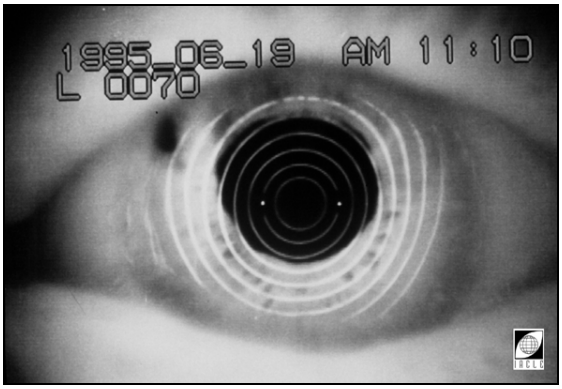

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55

ANALYSIS OF DATA

- Extrapolation - prediction
- Interpolation - smoothes data
  - most systems have difficulty imaging objects with sudden transitions
- Assumptions:
  - single centre of curvature
  - each area on or part of a spherical surface
  - astigmatism due to obliquity of light does not exist
- Apparent accuracy of digital data deceptive

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Analysis of Data

Algorithms & Analysis: Relative Merits

For largely competitive reasons, little information about computational algorithms is usually supplied or published by manufacturers. The information that is supplied is often general and may state the principle(s) followed without detailing them. Where data relevant to specific tasks is generated, the manufacturer may attribute the algorithm to its authors.

Publications by such authors may reveal details of the methods used (e.g. Rabinowitz-Klyce-Maeda Keratoconus Screening algorithms used in the Tomey Corneal Topographer, see Maeda *et al.,* 1994).

Several devices use an arc-step algorithm in which output data is based on a recreation of the surface shape, meridian by meridian. This is done with a series of arcs joining adjacent measured points along a meridian. This was found to be more accurate than axial algorithms. However, the accuracy decreases when measuring corneal heights for rotationally asymmetrical corneas (Ellis *et al.,* 1995).

Non-proprietary algorithms have also been presented in the literature, e.g. Klein, 1992, Halstead *et al.,* 1995.

- Extrapolation.
  Once a mathematical description of a meridian or a surface is generated, it is possible to produce data relating to corneal areas beyond that already measured. Unfortunately, the cornea, being a biological 'system', may not conform to the mathematics derived from the measured area. As a result extrapolations should be treated with caution.
- Interpolation.

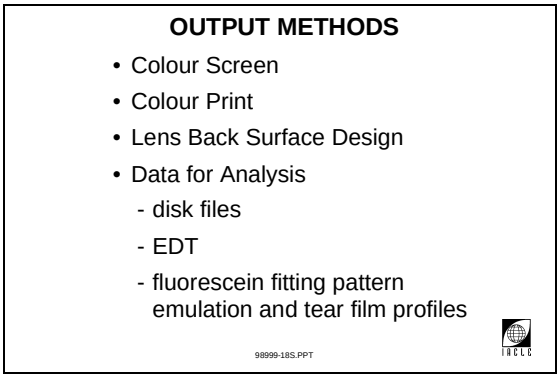
  Interpolation of corneal curvature is probably more reliable than extrapolation. However, given that most data is derived from points, meridians or rings, a conservative approach should still be applied to data generated for a location which is not actually measured, i.e. when local data is interpolated from regional data.
  Because interpolation has an 'averaging' or 'smoothing' aspect to its character, data derived from eyes measured post-surgically should be treated with great caution since the discrete area altered is likely to fall between measuring points and the real anatomy of the cornea will not be presented precisely. This is because most systems have difficulty imaging objects with sudden transitions (Applegate *et al.,* 1995, Belin and Ratliff, 1996).
- Assumptions:
  - cornea has a single centre of curvature (the sagittal display)
  - each area is assumed to be on or part of a spherical surface
  - the astigmatism arising from obliquely incident light on a spherical surface is usually ignored.

As a result of incorrect assumptions made, or apparently made (few algorithms for commercial instruments are made public) instruments produce erroneous data when presenting the slope of distorted corneas, e.g. in keratoconus (Halstead *et al.,* 1995).

- Apparent accuracy.
  The application of digital technology to corneal topography results in the generation of numerical data. While such data is unambiguous, it is still subject to system errors (including calibration issues) similar to non-computerized instruments. Other errors might include random error and operator error.
  It is important not to take digital data as being absolutely accurate. Only the interpretation of the display is accurate and even this can be transcribed to clinical records inaccurately (human error).
  Applegate *et al.* (1995) show accuracy of 5 µm (root mean squared error – RMSE) for spherical and elliptical surfaces without abrupt transitions.

If such transitions are present, the use of elevation data rather than surface profile data was advised.
Zadnik *et al.* (1995) concluded that the repeatability of corneal topography measures by videokeratoscopy decreased as the area of interest became more peripheral. They also found differences between instruments which they attributed to different working distances, algorithms, alignment, right *versus* left and focus issues. The working distance and focus issues are covered in detail by Keller and van Saarloos (1997).

56



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Output Methods

- Colour Screen & Print.

  Videokeratoscopy produces brightly coloured maps, on-screen or printed, to characterize the cornea. These maps are based on the established technique of false-colour representation in which some physical attribute is quantified and each value subsequently assigned a colour. In this way numerical data is visualized as an array of colours. Unfortunately, there is no agreement between interested parties as to what the assigned colours should be.

- Lens Back Surface Design.
  With the detailed knowledge of corneal topography provided by a videokeratoscope, a contact lens practitioner is well equipped to custom design the back surface shape of a lens. While this is true for both rigid and soft lenses, the flexibility of the latter means that such finesse is usually not required. Instrument-based techniques are especially useful for irregular corneas for which little useful information is provided by keratometry.

- Data for Analysis
  - disc files. Data generated can be stored on discs or tapes. Data can be stored for comparison purposes or used later for numerical or qualitative analysis. Such analysis may include novel algorithms, experimental procedures and database creation.
  - EDT. Technology which permits the transfer of data to remote locations has existed for some time. Therefore, it is feasible to send topographical data to a contact lens laboratory (especially an RGP laboratory) for the purpose of having a contact lens designed. Subject to laboratory or designer philosophy, there is no barrier to this process being automated. Data can also be sent to remote consultants for their opinions.

- Fluorescein fitting-pattern emulation and tear film profiles.

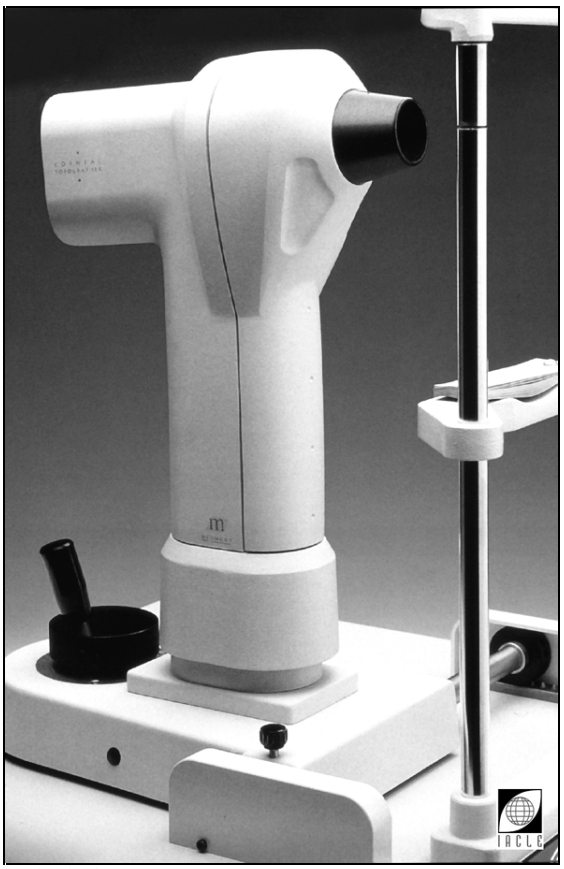
  When topographical data is combined with the parameters of a suitable lens, a logical outcome is an emulation, and subsequent visualization on-screen or in print, of the fitting pattern or post-lens tear film that would be observed by the fitter.

  While such a pattern is based on the clearance depths (or heights) calculated, it cannot account for the absorption of fluorescence by the fluorescein-stained tears themselves and the vagaries in shape of real corneas and contact lenses.

  While the former can be offset to some extent in calculations it is probable that the latter can not.

  It is conceivable that the recent announcement of a holographic-based instrument may be able to address the vagaries of corneal and contact lens shapes separately and combine the data in a single representation (visualization).

57



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Current Market
(in alphabetical order by model identification)

- CLAS-1000 by KeraMetrics Corp.
- C-Scan (Keratech) by Technomed Technology.
- Dicon CT-200 by Dicon.
- Euclid ET-800 by Euclid Systems Corp.
- EyeMap EH Series (Visioptic EH-270 & 290) by Alcon International Inc.
- EyeSys System 2000, EyeSys Vista Hand-Held by EyeSys Technologies Inc.
- Humphrey Atlas 990 and Humphrey Eclipse 992 by Humphrey Instruments.
- Medmont E300 by Medmont (the prototype is shown in slide 57, the production model will differ slightly in appearance.
- Keratron (Optikon 2000) Corneal Analyser by Alliance Medical Marketing Inc.
- Orbscan, Orbscan II, Orbshot by Orbtek.
- PAR CTS by PAR Vision Systems.
- Tomey TMS-3, AutoTopographer by Tomey Corp.
- Topcon CM-1000, KR-7100P by Topcon Corp.

IV Aesthesiometers

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ROLE OF AESTHESIOMETERS

Assessing:

- Corneal sensitivity in various conditions
  - normal (baseline) conditions
  - keratoconus
  - pregnancy
  - diabetes and other diseases
- Loss of corneal sensitivity following various modes of contact lens wear
- The effects of topical anaesthetics

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Aesthesiometry: History and Role

Corneal aesthesiometry has been practised for just over 100 years. von Frey (1894 , 1897 cited in Vega, 1997) used horse hairs of different lengths mounted on, and perpendicularly to, wooden handles. Aesthesiometry was carried out by applying the horse hair tip to the corneal surface and ascertaining whether or not the subject could detect (feel) the impingement. A longer hair constituted a smaller stimulus (load), a shorter hair a greater stimulus. The effects of gravity, which results in a slight downward curving of the hair, were ignored. A spring balance was used to calibrate the forces delivered. Subsequently, alternative stimuli were tried. These included cotton wisps and metal probes (Vega, 1997).

The development of Nylon™ (nylon-6,6) by Carothers at Du Pont in 1935 (Cook and Guise, 1989) ultimately led to its incorporation into hair aesthesiometers. While Nylon filaments first appeared in toothbrushes (1937) and clothing (1940) it was the mid-1950s before Boberg-Ans (1955) used nylon filaments in a corneal aesthesiometer. A commercial variation (Luneau, France), which held sway for many years, was originally developed by Cochet and Bonnet (1960) (slide 60). Alternative forms of aesthesiometers, including non-contact models, have since been developed (see later).

Aesthesiometers are used for assessing (after Millodot, 1994):

- Corneal sensitivity in various conditions
  - normal (baseline) conditions
  - low ambient temperatures
  - keratoconus
  - pregnancy
  - variations during the menstrual cycle
  - diabetes and other diseases.
- The effects of contact lens wear on corneal sensitivity.
- The effects of topical anaesthetics.
- The effects of refractive surgery (only non-invasive techniques are applicable immediately after surgery).

Ishikawa *et al.*(1994) found an increase in corneal sensitivity following manual debridement and Excimer laser ablation of the rabbit cornea. They found a rapid return (5 days) to normal sensitivity followed by an increase which peaked much later (42 days). Values remained elevated until very much later (126 days) and returned to normal by 210 days. Sensitivity increase was correlated with increasing nerve density.

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AESTHESIOMETERS

- Cochet-Bonnet
- Beuerman & Tanelian
- Carbon dioxide laser (Brennan & Maurice)
- Non-contact aesthesiometers (Zaidman *et al*)
- Chemical (Dupuy *et al*)

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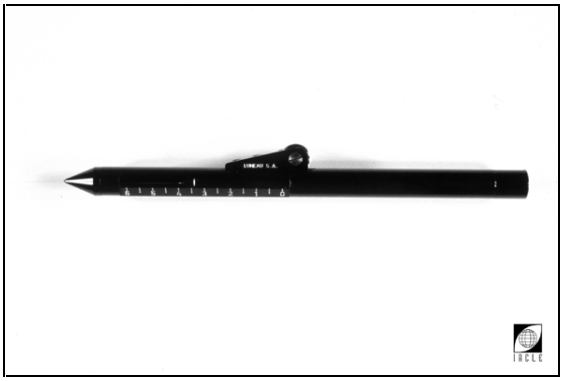
Aesthesiometers

- Cochet-Bonnet Aesthesiometer(1960). This aesthesiometer used a Nylon filament (0.12 mm OD) as the stimulus.
- Beuerman & Tanelian (1979) research aesthesiometer. This late 1970s development used a jet of water at variable temperatures to test the sensitivity of the cornea.
- Carbon dioxide laser (Brennan & Maurice, 1989) This late 1980s development used a low-power carbon dioxide laser as a test stimulus.
- Non-contact aesthesiometer (Murphy & Patel, 1994, U Waterloo/Vega, 1997). Having some similarity to a non-contact 'puff' tonometer, this device uses temperature-controlled air at variable pressures to test corneal sensitivity.

60



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Cochet-Bonnet Aesthesiometer

The Cochet-Bonnet aesthesiometer uses a Nylon monofilament 0.12 mm in diameter as the stimulus. Pressures applied range from 11 to 200 mg over an area of 0.013 mm^2 (Millodot, 1984). This device is something of a standard because it is simple, affordable, reasonably reliable (repeatability ±5%, Millodot, 1994) and quite common in contact lens research clinics. However, the device has some inherent limitations.

A disadvantage of all filament-based devices, variations of which are still used, is their invasive nature and the need for proper hygiene of the filament tip. Such devices cannot be used in surgical cases in the immediate post-operative period.

A more subtle disadvantage is the difficulty in quantifying the load actually applied. Since the hair/thread is applied 'end-on', the initial impact is probably a maximum. Once the filament flexes, the load decreases. This cyclic application of load detracts from the validity and repeatability of all tests using this generic principle. To overcome this problem at least partially, it is recommended that the stimulus be applied until the initial bending is first observed.

Other problems are the effect of relative humidity on the physical properties of the filament (water absorption at high humidities results in increased weight and greater unloaded filament curvature) and ageing effects (e.g. the filament becomes more rigid over time). The former overrates (apparent stimulus load higher than actual) corneal sensitivity, the latter underrates it (apparent load lower than actual).

Millodot (1984 and 1994) recommends that the Cochet-Bonnet aesthesiometer be mounted in an x,y,z manipulator and applied to the cornea perpendicularly. Hand-held use of the device is not

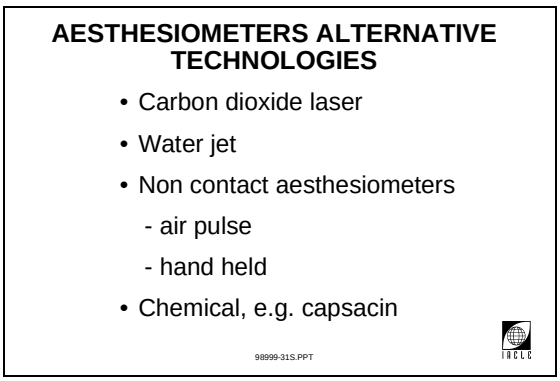
recommended. The applied force should begin at a low level (sub-threshold or undetectable) and be increased. The relative humidity should be noted. A series of four to eight measurements should be made and a buzzer or some other finger-operated indicator should be used to obviate the need for any facial/eye movement. A few trial runs are suggested as training for the test series. The filament length is converted to pressure using tables that accompany the instrument. An alternative to the buzzer or indicator approach is to watch the eye closely and interpret its reaction, e.g. a rapid blink indicating a sensation.

The Corneal Touch Threshold (CTT) is defined as the filament length at which the subject responds to 50% of the applications.

There is no general agreement on the corneal locations which should be tested, unless of course the differential performance of all areas of the cornea is being ascertained.

Instruments should not be stored with the filament extended.

61



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Aesthesiometers: Alternative Technologies

- Carbon dioxide laser (Brennan and Maurice, 1989).

  This technique tests the thermal sensitivity of the cornea using a low-power CO_2 laser (infra red) as the test stimulus.

  Laser advantages relate largely to the precision with which the stimulus can be controlled. Excellent duration, intensity, position and size control make a laser an almost ideal stimulus.

  Safety is dependent largely on the absorption characteristics of the tear film. It is believed that the deeper corneal layers are exposed to minimal risk because of the tear film's absorption of the incident energy. It was claimed that the brevity of the stimulus prevented the thermal nature of the test being detected. Instead, a 'prickling' sensation was reported. Significant temporal effects were measured whereby repeated exposure of corneal areas required a doubling of the stimulus intensity. No slit-lamp evidence of corneal damage was observed.

  An unexplained phenomenon has been reported in which a reduction in sensitivity following overnight contact lens wear does not register using this method (Brennan and Bruce, 1991). This is contrary to other findings using 'conventional' techniques such as the Cochet-Bonnet aesthesiometer.

- Water jet (Bauerman and Tanelian, 1979, Beuerman and Thompson, 1990).
  Sterile saline at 33° C is directed steadily and continuously as a stream at the test eye (face horizontal, looking down). This saline acts as a conditioning stream. Injected into this stream is a saline test stimulus at a different temperature. While temperature control is 'tight' (±0.1°C) over a range of 15°C, the stimulus is not perceived as a thermal one.
  It is believed that corneal sensations are along the pain continuum and the perceptions arising are of discomfort or pain only. To investigate this further, equal temperature intervals above and below the adapting temperature were applied. The subjects could not distinguish temperature changes in either direction as being equal. The normal cornea was found to require a temperature increase of 4.5°C to elicit a response (Beuerman and Thompson, 1990).
  Recent research efforts have been directed towards eliciting true thermal and other responses from human corneas. The cat has already demonstrated responses to thermal, mechanical, and chemical stimuli (Belmonte *et al.,* 1997).
- Non-contact aesthesiometers.
  - Air pulse (Zaidman *et al.,* 1988)

    Air pulses of varying intensity are applied to the eye as a 'mechanical' stimulus which is non-invasive. Intensity is measured in standard mL of air/min. Flow rates are altered in 10 mL/min increments.
    Zaidman *et al.* found that they could not determine the sensitivity of most post-penetrating keratoplasty corneas (beyond the upper limit of the instrument), suggesting a large decrease in sensitivity which was not related to the time after surgery. Relative humidity and patient apprehension were not found to be problems, in contrast with the Cochet-Bonnet instrument.
  - Air pulse (Murphy and Patel, 1994 and Vega *et al.*, 1996).

    These instruments are based on the same design. The U Waterloo instrument had design input from Murphy and Patel. As with the Zaidman instrument, controlled pulses of air are used as the test stimuli. These devices preset the air pressure before application by compressing air into a reservoir. The air flow (air escaping from the reservoir) is controlled manually by a valve. Air pressure is transduced electronically and displayed. The data is ultimately recorded as mm Hg pressure.
    While most instruments are one-jet designs, the U Waterloo instrument is a two-jet design giving the user the option of

stimulating one or both eyes. The duration of the pulse is adjustable over the range 300 ms to 2.6 s.

The jets are located 10 mm from the cornea and this distance is repeatable with the aid of a visible laser/beam splitter/mirror alignment system acting as a coincidence rangefinder (two red dots seen when out of focus, a single dot is seen by superimposition when focused). Thus far, this system can only be used on the conjunctiva (most details from Vega, 1997).

Other instruments have been constructed (e.g. Belmonte, Spain).

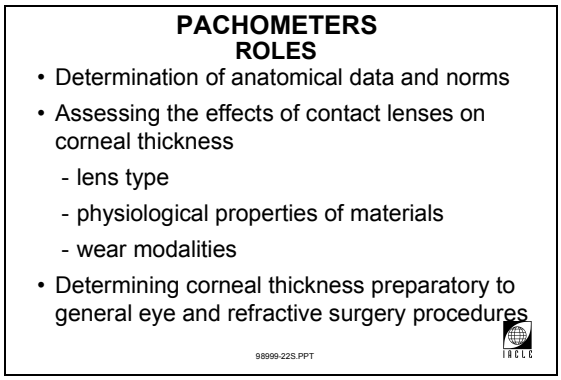
- Chemical, capsaicin drops (chilli) (Dupuy *et al.,* 1988).

  Chemical stimulants were employed by Dupuy *et al.* Refined 80-90% pure capsaicin was used to make dilute saline solutions which were then applied to the eye as small (5µL) drops. The solutions were warmed to eye temperature to avoid the drops behaving as a thermal stimulus.

  Slit-lamp inspection of the corneas revealed no apparent damage and the authors saw a potential role for the technique in testing topical anaesthetics.

V Pachometers

62



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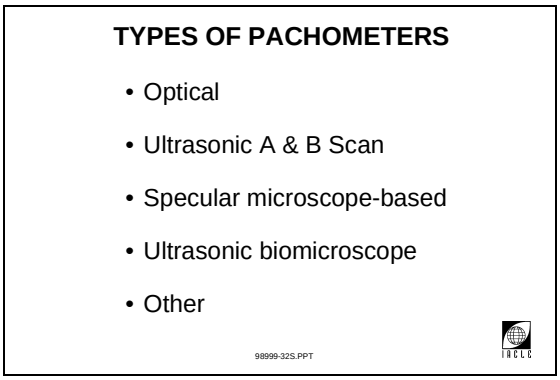
Pachometers: Roles

Pachometers measure corneal thickness. The uses for corneal thickness measurement have varied over the years.

These uses include:

- Determination of anatomical data.
  Early instruments were intended to establish anatomical norms for corneal thickness in human and other eyes.
  Later uses included:
  - corneal thickness data for calculating the optical properties of the eye
  - specular microscope magnification data (contact and non-contact modes)
  - endothelial cell density and morphology estimation
  - data on thickness variation as a result of diurnal or menstrual influences.
- Assessing the effects of tears and tear film on corneal thickness.
- Assessing the effects of various corneal/eye diseases (e.g. keratoconus) on corneal thickness.
- Assessing the effect of contact lenses on corneal thickness.
  This later role includes the effects of lens types, physiological properties of contact lens materials, especially Dk/*t,* and wear modalities on corneal thickness. Data on central and other areas of the cornea (sometimes referred to as central and topographical thicknesses) is recorded.
- Determining corneal thickness in preparation for general eye and refractive surgery procedures.
  Surgical procedures ranging from Radial Keratotomy (RK) to LASIK (Laser-ASsisted *in situ* Keratomileusis) require a knowledge of the corneal thickness if unintentional perforation or excessive tissue removal with a keratome is to be avoided.
- Assessing corneal thickness in toxicity studies including animal models.
- Determining corneal thickness before and during courses of orthokeratology.

63



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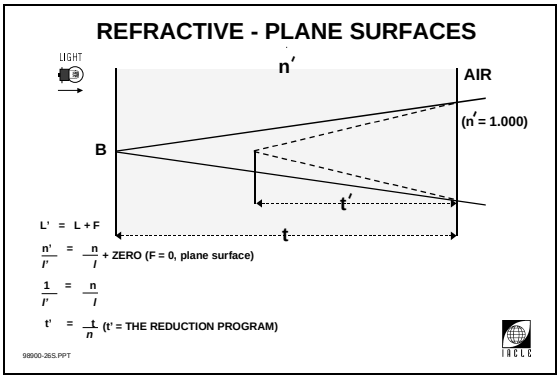
Pachometers: Types

The main types of pachometers in current use are listed in slide 63.

In practice, a significant difference between types is the issue of fixation control. Because the cornea has a minus meniscus profile, a key to reliable pachometry is the accurate location and relocation of a particular corneal point. Not all instrument technologies lend themselves to the incorporation of suitable fixation or aiming systems. For example, ultrasonic pachometers, being essentially non-optical, must employ other methods to locate/relocate a particular corneal area.

In many laboratory animals, the thickness variation across the cornea is small and the need to precisely locate an area is reduced.

64



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Pachometry: Specular Microscopes

The reason some contacting specular microscopes can be used to estimate corneal thickness is made apparent in slide 64. The applanation of the cornea by the instrument's objective simplifies the optics of the cornea (makes it into a parallel-surfaced 'plate'). By measuring the apparent depth (the difference in focus, epithelium to endothelium), the actual thickness can be estimated, since the cornea's refractive index is the only other variable.

The Koester (slides 65 and 84) and Konan (slide 86) specular microscopes include such pachometer functions.

65

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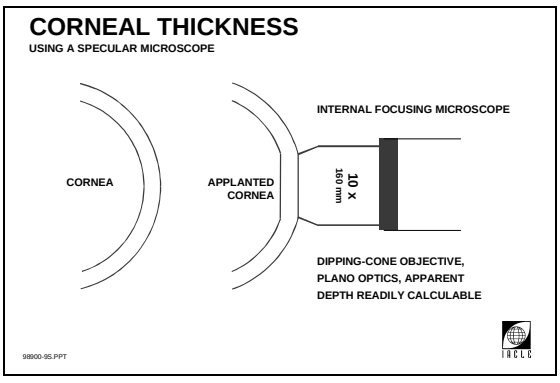

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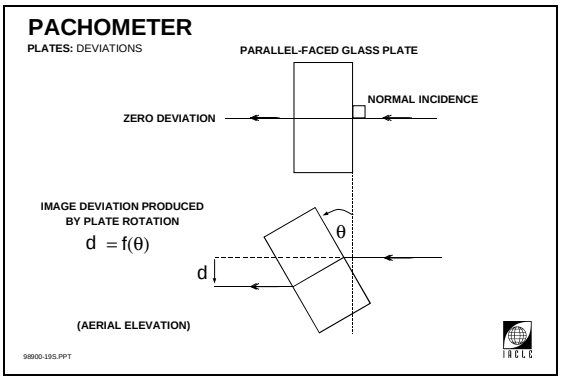

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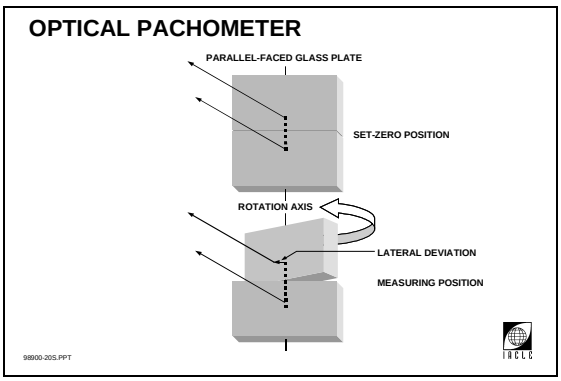

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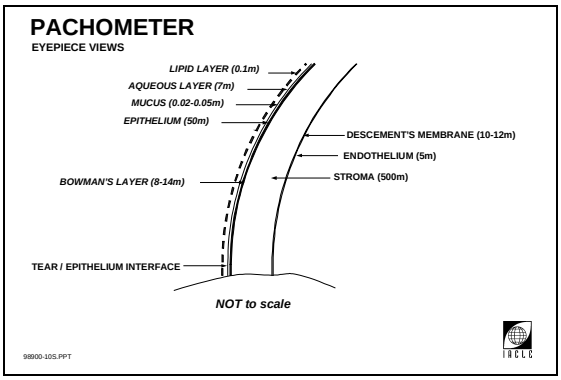

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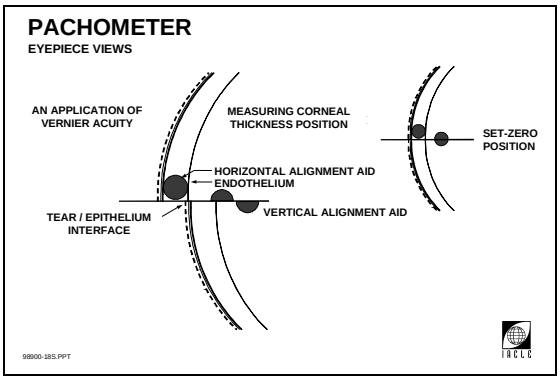
Optical Pachometers: Optical Principles

All optical pachometers use the principle of image splitting or doubling. Using a selective alignment technique similar to that of a split-image rangefinder, the eye's precise ability to align the linear components of an image, i.e. its vernier acuity, is utilized. If light rays are incident normally to a glass plate with parallel surfaces, they pass through the plate undeviated. Should the plate be rotated about its centre, the incident light will be deviated by an amount related to the rotation and the plate thickness (slide 67).

In an optical pachometer, two coaxial, identical, thick, parallel-surfaced glass plates, one above the other (slide 68), are used to split the image of the cornea in optic section into two images, one above the other (slides 69 and 70).

This image-doubling plate system is mounted in front of a slit-lamp. Also aligned with the horizontally split image so created, is a horizontally divided special biprism eyepiece mounted in the slit-lamp.

70



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Slide 70 also illustrates a type of alignment aid used in optical pachometers. In this variation (the Payor-Holden Micropachometer) two bright light emitting diodes (LEDs) are included. Firstly, the corneal sections are focused by the operator to obtain a correct z-axis alignment. When the upper LED appears complete and centred in the focused upper cross section of the cornea, the instrument is correctly aligned in the horizontal (x-axis) plane. The y-axis is positioned correctly by adjusting the vertical position of the slit-lamp (pachometer) until the two halves of the vertical alignment LED are of equal size.

Frequently, the positioning of one axis mislocates another and some experience is required before harmonious alignment becomes routine.

71

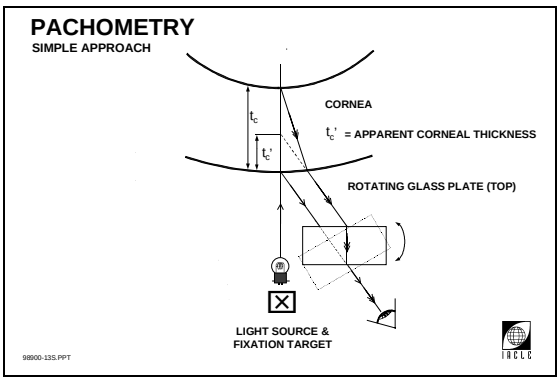

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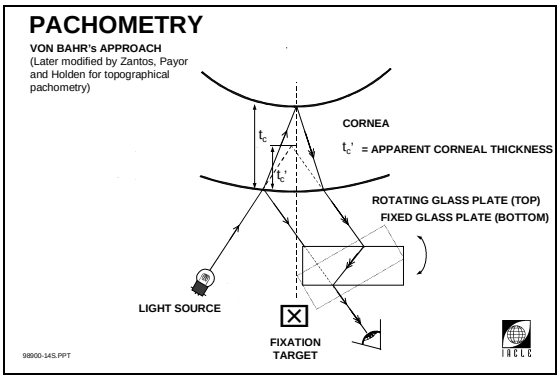
Figure 71 shows a very simplistic approach to optical pachometry which has the disadvantage of presenting a relatively narrow apparent width of the sectioned cornea. Using the von Bahr approach (slide 72), a broader corneal section is realized.

This enhances the accuracy and ease of measuring corneal thickness optically. Unfortunately, it also makes the optics of the measurement more complicated because the incident and reflected light rays are now oblique.

72



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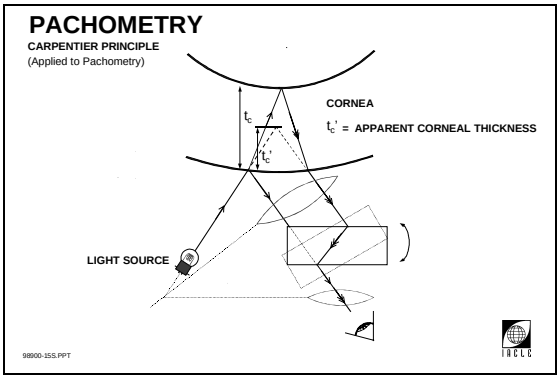
The primary reason for the large apparent thickness of the glass plates is the scale of the corneal thickness used in these diagrams. In reality, the glass plates are of the order of 5-6 mm thick while the cornea is only about 0.5 mm centrally.

The Carpentier principle (see Carpentier (Scheimpflug) Photography, Section VIII) has the potential to overcome another disadvantage of optical pachometry, namely the difficulty of getting the front and back surfaces of the cornea in focus simultaneously. A suggested system is shown in slide 73.

73



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By rotating the biprism eyepiece, and possibly the objective about their posterior nodal points it should be possible to improve the quality of the focus from the front to back of the corneal section. Further, by tilting the instrument objective, it should be possible to exaggerate the width of the apparent thickness as viewed by the operator. It remains to be seen whether the glass plates can be mounted in front of the slit-lamp (as is done currently) or 'in board' as shown in slide 73.

74

ULTRASONIC PACHOMETERS

- Sonomed MicropachTM 200A
- Biovison Pocket
- Tomey SP-2000
- Cilco Sonometric
- Storz Omega Biometric Ruler
- UltraPach
- DGH 500
- Humphrey

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75

9L10071-98

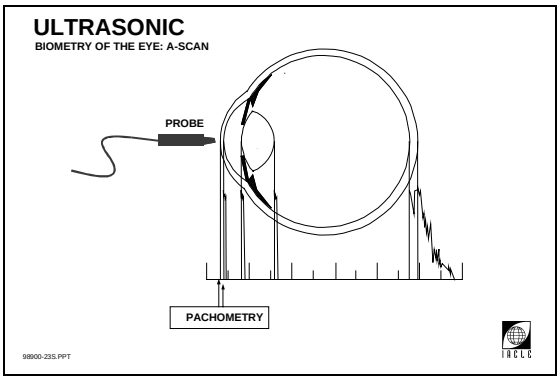
Pachometers: Ultrasonic (Non-Optical)

Most pachometers that use alternative technologies are based on ultrasound. Ultrasound was first applied to the eye by Mundt and Hughes in 1956 (Cavallerano and Calderon, 1992) to investigate intraocular tumours. Its application to biometry followed, while its use in pachometers is even more recent.

Some instruments available include:

- Sonomed Micropach™ 200P (USA). This is a portable device with graphical display and alphanumeric keyboard. Each determination of corneal thickness is actually the mean and standard deviation of 256 measurements, with 1 µm resolution and a claimed accuracy of ±5 µm. The hand-held probe has a tip diameter of 1.75 mm. Memory holds up to 33 corneal locations. Each measurement takes under one second.
- BVI's Biovision™ Pocket Pachometer (France). This instrument (see slide 75) operates at 20 MHz and utilizes a small hand-held probe. The instrument has a digital display. A map of corneal zones and their designations are used as the memory map of the instrument. Measurements are triggered by a foot-switch.
- Tomey SP-2000 Ultrasonic Pachymeter. This portable pachometer operates at 20 MHz and has a hand-held probe with a 1.5 mm flat face. Accuracy is claimed to be ±5 µm and the instrument has a standard serial port (RS-232C) for connection to an external computer system. Operation is automatic, i.e. no footswitch or button is required to trigger the measuring process. Data from up to nine corneal positions is recordable.
- Cilco Sonometric (formerly the VIDA-55) Ultrasonic Pachometer. This instrument has been available for some time and has a 3.5 mm diameter probe.
- Storz Omega Biometric Ruler.
- Eye Technology Inc. UltraPach Pachometer.
- DGH Technology Inc., DGH 500 Ultrasonic Pachometer.
- Allergan Humphrey Model 850 Ultrasonic Biomicroscope (a 50 MHz B-Scan device).

76



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Ultrasonography: A and B-Scans

Most instruments used for corneal thickness measurement use frequencies in the range 15 to 20 MHz. While this is traditionally regarded as radio frequency, the probe operates in a 'mechanical' mode rather than as an emitter of electromagnetic radiation.

Traditionally, ultrasonic devices are divided into two categories. These are:

- A-Scan. A-Scan ultrasonography is an axial one-dimensional measuring system using ultrasonic echoes along the axis of the instrument's probe to determine length (thickness). It is a time-amplitude system of measurement (see slide 76). The echoes result from any interface across which a change in ultrasonic velocity occurs, i.e. the tissues have different acoustic impedances (analogous to the optical changes induced by an interface between media of differing refractive indices).
- B-Scan. B-Scan ultrasound involves a two dimensional scanning of the object of regard. The most familiar B-Scan results are those taken during routine human pre-natal obstetric care, i.e. the ultrasonographs and videos of the human foetus *in vivo.* B-Scan ultrasonography, which can involve frequencies as low as 5 to 10 MHz, is not normally used to assess corneal thickness and will not be dealt with further in this lecture.

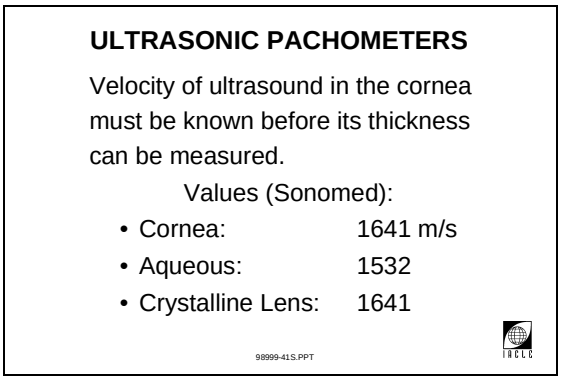
Pachometers are usually A-Scan devices, i.e. they provide a limited range, one-dimensional axial data set based on the first echo received by the probe. The time to the first echo is the analogue of the distance from the probe's face and the cornea/anterior chamber interface. High resolution devices operating at 100 MHz have also been developed (see Pavlin *et al.,* 1990).

As a form of sound is used, i.e. cycles of compression and rarefaction, the probe face must be coupled well to the cornea. This is achieved by careful applanation of the cornea by the probe with a minimum of pressure to avoid compression of the corneal tissue.

The probes are usually based on piezo-electric transducers which behave as transceivers, i.e. the one component behaves as both a transmitter and a receiver of ultrasonic energy.

Because the human cornea is a minus meniscus, care must be taken when positioning the probe if repeated measurements are to be made of the same corneal zone. Most instruments have hand-held probes and repeatability of corneal location is difficult. Theoretical, it is possible to mount the probe in some form of manipulator attached to a chin rest. A fixation target would complete the minimum requirements for repeatability.

77



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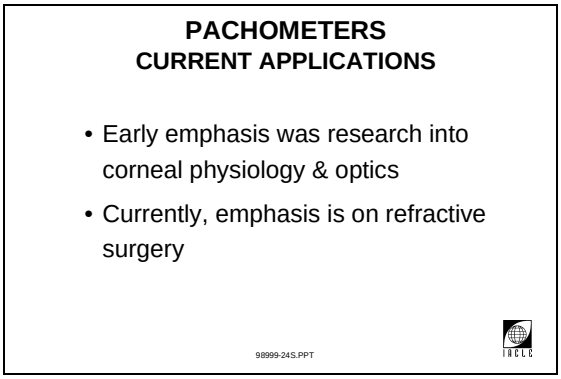
Ultrasonic Pachometers: Thickness Measurement

Before any measurements are possible, the velocity of the ultrasonic wave in the tissue of interest must be determined. Once the velocity is found by calibration (usually done by the manufacturer) all that is required to measure a length is to measure time (velocity = length / time).

Ultrasonic velocities in human corneas presented in the literature vary between 1502 and 1641 m/s (see Chan-Ling and Pye, 1994 and Sonomed literature). Sonomed gives the velocity in a PMMA IOL as 2718 m/s while the aqueous and vitreous are 1532 and the crystalline lens is 1641 m/s.

78



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Pachometers: Current Applications

In more recent times, the applications of pachometry have undergone a shift in emphasis. In the past, pachometry was frequently used for research purposes, e.g. to determine the effects of contact lenses of various oxygen transmissibilities on corneal thickness, or to help estimate the contribution the cornea made to the eye's overall optical characteristics.

Because much is now known about the relationship between Dk, lens thickness and corneal thickness, fewer studies still include pachometry, especially optical pachometry, in their protocols.

More recently, the main application, especially of ultrasonic instruments, has been in the evolving area of refractive surgery.

The recent appearance of interferometric methods (Hitzenberger *et al.,* 1992 and 1994), especially the Scanning Partial Coherence Interferometric non-contact pachometer (SPCI pachometer), ushers in a new era of very accurate optical pachometry. With claims of a more than ten fold improvement in precision for central measurements (optical: 13 µm, ultrasonic: 5µm, SPCI: 0.29 µm) (Drexler *et al.,* 1997), the utility of this technology in refractive surgery and elsewhere, is obvious.

Other developments include the Optical Low-Coherence Reflectometry (OLCR) method which can be used for biometry of the anterior eye including pachometry. The claimed precision is 3.4µm (Wälti *et al.,* 1998).

As yet, neither of these technologies is available in commercial instruments. However, in view of their promise of precision and very low inter-observer variability (Hitzenberger *et al.,* 1994), commercial availability is expected in the future.

VI Specular Microscopes

79

SPECULAR MICROSCOPES

- Non-contacting
  (includes slit-lamp-based instruments)
- Contacting Specular microscopes
  - standard
  - wide-field
  - scanning wide-field

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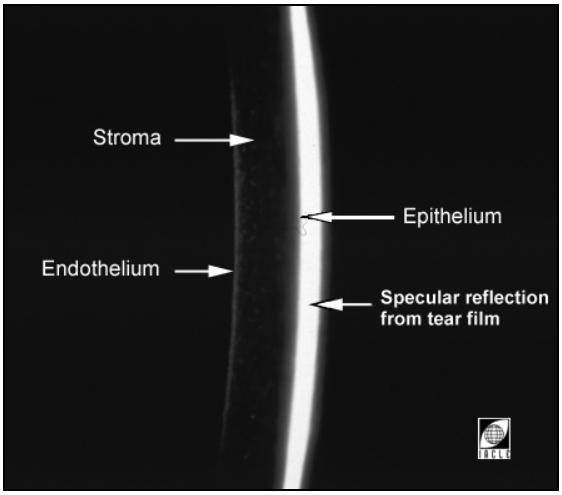
Specular Microscopes

There are two main types of ophthalmic specular microscopes. These are:

- Non-contacting specular microscopes (including slit-lamp-based devices). Other instruments such as the Nikon AS-1 also belong to this category.
- Contacting Specular microscopes
  - standard
  - wide-field
  - scanning wide-field.

80



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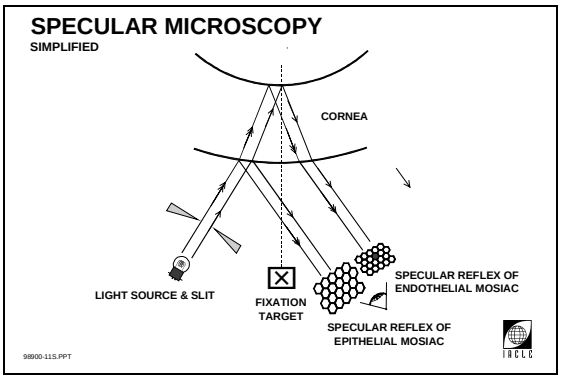
Slide 80 shows an optical section of the cornea. Noteworthy is the specular reflection from the front surface of the tear film (Purkinje-Sanson Image #1).

Specular reflection is important because of its negative effects on both image quality and the ease of observation of adjacent structures.

81



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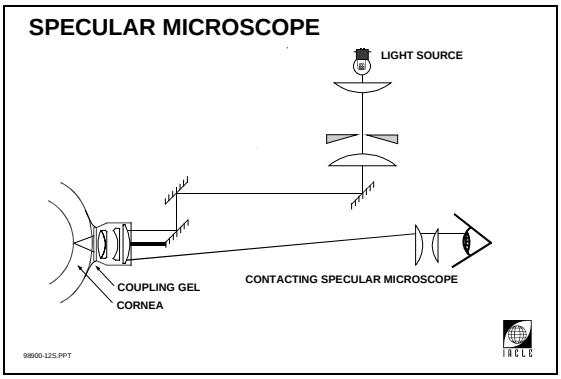
82



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83

9L12259-93

Specular Microscopy: Concept

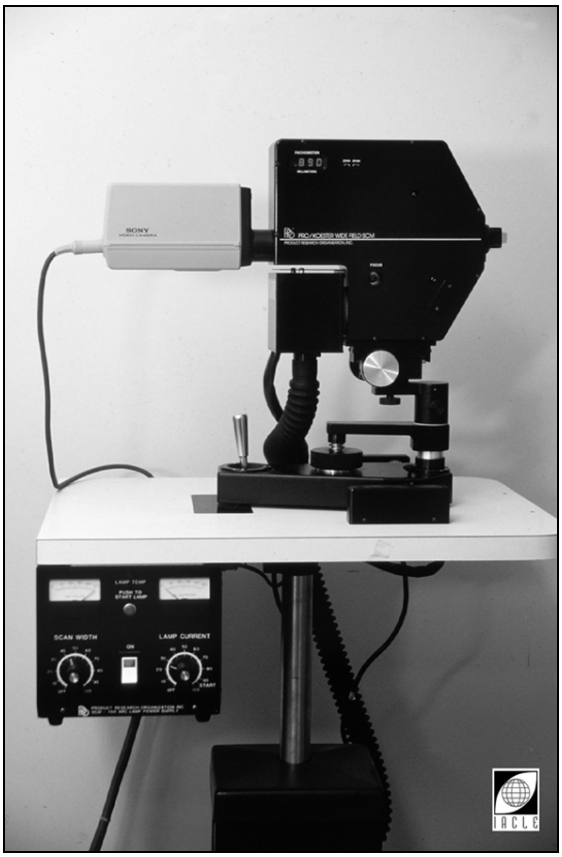
This overview of specular microscopy ignores most of the optics necessary to actually image the structures shown. While specular reflection can be used to image any structure in the anterior eye, the layers of most interest are the epithelium and the endothelium. Their proximity to the tear film reflex makes them difficult to observe or image when using a non-contact microscope (e.g. a slit-lamp). Generally, a non-contacting system will not allow the epithelial mosaic to be observed. Such a system will only demonstrate the specular reflex of the illumination system from the tear film. To observe the epithelial mosaic, a contacting instrument is required.

The use of a contacting system to eliminate the tear film reflex is covered here. For the use of non-contact systems, the reader is referred to Module 1, Lecture 1.4.

In its simplest form, a contacting specular microscope consists of a split-field contacting biological microscope objective and separated slit illumination and viewing light paths (slide 82). This technique eliminates the tear film reflex problem and can provide a high contrast, high magnification image, albeit with a narrow field-of-view.

Such an instrument, e.g. the Heyer-Schulte, is shown in slide 83.

84



9L12260-93

Koester Scanning Wide-Field Specular Microscope

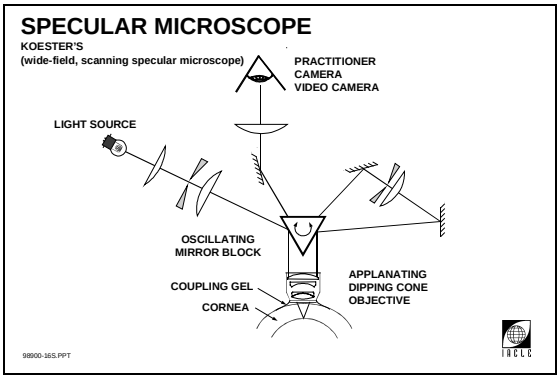
Maurice (1974) and later Koester (1980) designed instruments which aimed to provide a combination of high magnification and a wide field-of-view.

Slide 84 shows a PRO-Koester wide-field scanning microscope. Its optical principles are presented in slide 85.

The centre piece of this design is the rapidly oscillating triangular mirror block which is featured in the incident and reflected light paths. This instrument is capable of providing high contrast, wide-field, high magnification images (visual, video or still) of the corneal endothelium. Because the dipping cone objective applanates the cornea locally, simple apparent-depth optics applies (slide 64) to the apparent corneal thickness. This instrument, along with the Konan (slide 86), offers corneal thickness measurement among its features.

A minor disadvantage of the Koester instrument is the noise made by the oscillating mirror (similar sound to some scanning laser ophthalmoscopes).

85



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86

9L12435-93

Keeler-Konan Contact Specular Microscope

This is another contacting microscope which applanates the cornea with a dipping cone objective. It is not of a wide-field or scanning design.

87

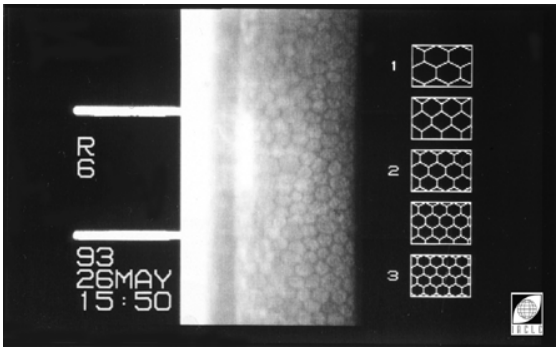
9L12945-93

Topcon SP-1000 Specular Microscope and Endothelial Mosaic Analyser

This is a convenient non-contact specular microscope incorporating a video imaging system. It can also perform an analysis of the image of the endothelial mosaic.

A typical screen image is shown in slide 88. A comparison scale is an integral part of the display.

88



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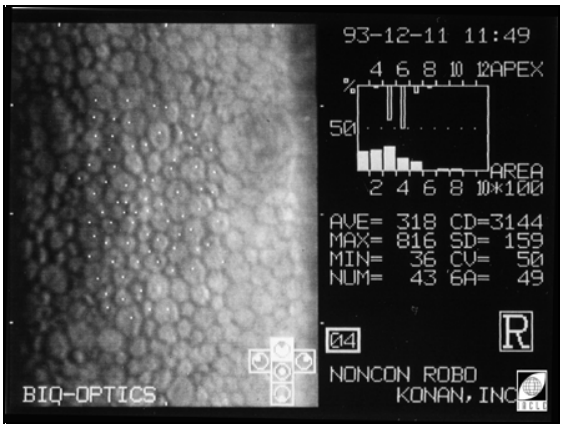
89



9L12318-94

Konan Robo Non-Contact Specular Microscope

This device is similar to the Topcon instrument. It produces results with a higher magnification and a greater level of automated analysis of the endothelial mosaic (slide 89).

VII Carpentier (Scheimpflug) Photography

90

CARPENTIER PRINCIPLE

- Patented by Jules Carpentier, Paris, 1901
- Further patents by Theodor Scheimpflug, Vienna, 1904
- Technical paper by Scheimpflug 1906.
- German publication International PhotoTechnik applies the name Scheimpflug to the principle

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91

CARPENTIER PRINCIPLE
OPTHALMIC APPLICATIONS

- Anjou & Krakau, 1960
- Drews, 1964
- Brown, 1967-1971
- Hockwin, Niesel, Sasaki, Dragomirescu and others, 1970 onwards

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Carpentier or Scheimpflug Principle?

Traditionally, the name associated with those aspects of photography involving non-aligned and/or non-parallel object and film planes is that of Theodor Scheimpflug, an Austrian. More recently (Merklinger, 1996), it has been revealed that Jules Carpentier, a Frenchman, patented the concept in 1901, some three years before Scheimpflug patented aspects of the same principles, and five years before he published his paper detailing them. Further, Scheimpflug actually references Carpentier's patent in his original patent and articles. Scheimpflug's treatment is regarded as the more scholarly.

Later, the name Scheimpflug was applied to all aspects of view camera movements by the German photographic magazine *International Photo Technik* (Radford, 1978), a publication associated with the Linhof large-format and view camera company.

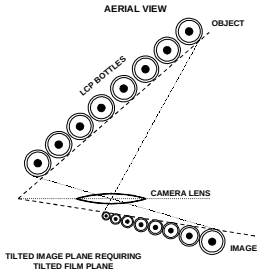
The application of the Carpentier Principles to ophthalmic photography occurred much later. Anjou and Krakau (1960) were the first to apply the principles, followed by Drews (1964) (both papers referenced in Long, 1984).

Later, Brown (circa 1975) described a project spanning 1967-1971 in which two slit-lamp-based Carpentier Principle anterior eye cameras were constructed and pressed into routine hospital service.

Subsequent work by Hockwin *et al.* in particular, resulted in prototypes based on Zeiss equipment and a production model which was manufactured by Topcon (SL-45, current availability unknown). Rodenstock also had a production model (Long, 1984).

92

CARPENTIER (SCHEIMPFLUG) PRINCIPLE
THIN LENS



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Carpentier (Scheimpflug) Principle: Thin Lens

The simplest way of stating the main Carpentier principle is: 'A tilted object plane results in a tilted image plane. Best images and photographs result from tilting the film plane to match the tilted image plane.'

An explanation of the relevant principle using a simple thin lens is shown in slide 92. The key issue is the 'pivot point or line' (albeit virtual) common to the lens plane, object plane and image plane. The image will be in focus from side-to-side as long as these three planes intersect along a common line. If some or all of these planes are not parallel, the situation becomes more complex and side-to-side and top-to-bottom focus is no longer necessarily achievable. A smaller lens aperture stop is then necessary to achieve the depth-of-field required.

93

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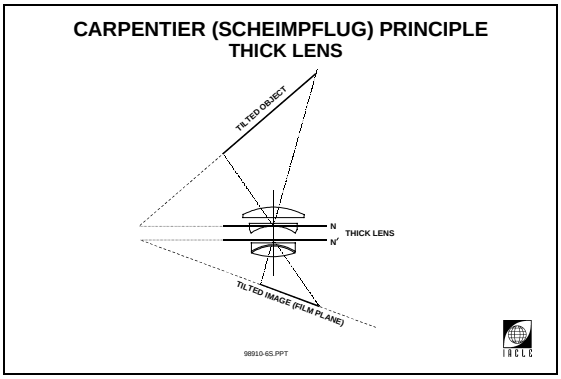
Carpentier Photograph

This photograph shows the depth of field that can be achieved by tilting the film plane until it aligns with the tilted image plane. All bottles are in focus despite the use of only a modest aperture stop.

94



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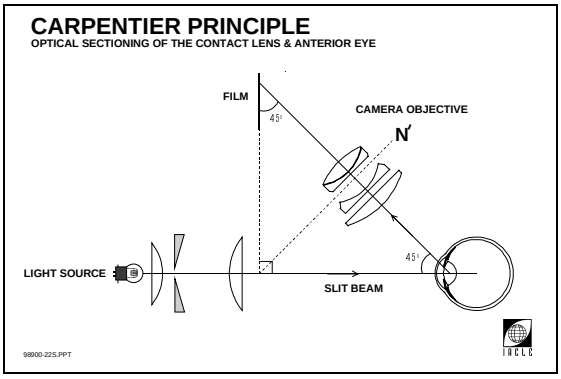
Carpentier Principle: Thick Lens

In practice, the simplistic approach of a simple thin lens is inappropriate. By using a nodal plane-approach, a more valid analysis is possible. However, even this approach, based on paraxial theory, is still only an approximation of the more complicated reality involving oblique and non-paraxial peripheral light rays. For the purposes of this lecture, such complexities will be ignored.

95



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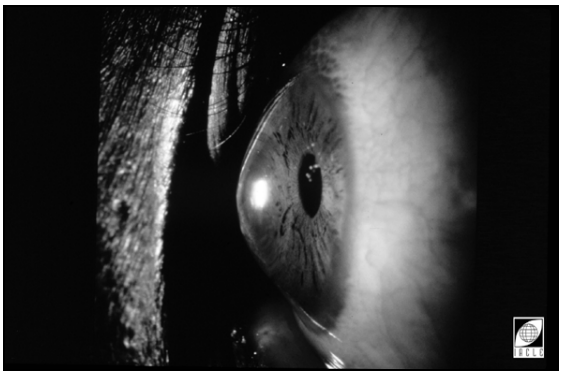
Carpentier Photography of the Anterior Eye

In applying the Carpentier Principle to anterior eye photography, difficulties can be expected because of the optical effects of the peripheral cornea, anterior chamber contents and the crystalline lens viewed obliquely.

In the diagram opposite, the film plane is shown at 90° to the optical axis of the slit. This is theoretical only and ignores completely the effects of the optics of the anterior eye. In Brown's instrument (circa 1975) the actual angle was set at 102.5° rather than the 90° shown here.

96



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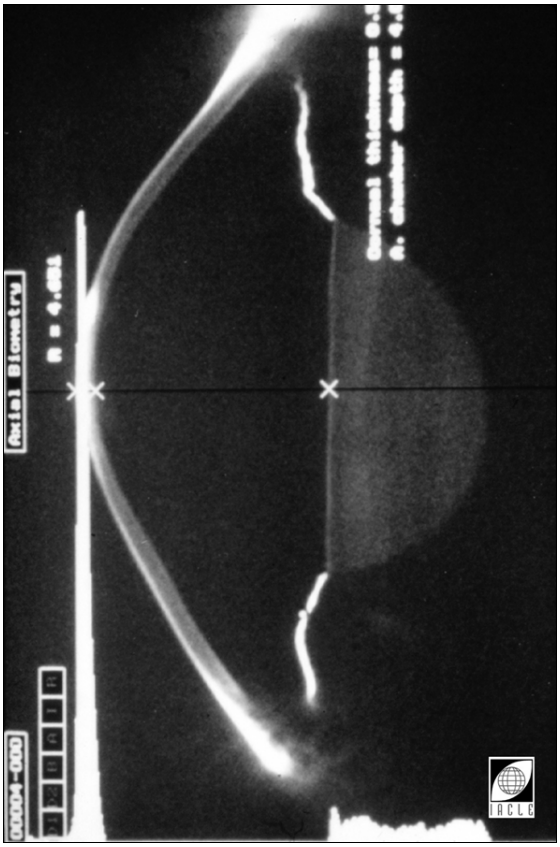
97



9L10061-98

Examples of the Application of Carpentier's Principle to Photography of the Anterior Eye.

An anterior eye photograph of a keratoconic eye is shown in slide 96. A photograph of the same eye taken with a Carpentier anterior eye camera appears in slide 97.

Photodensitometric data acquired from the image also appears in the photograph (appearance of this data is similar to ultrasonography echoes).

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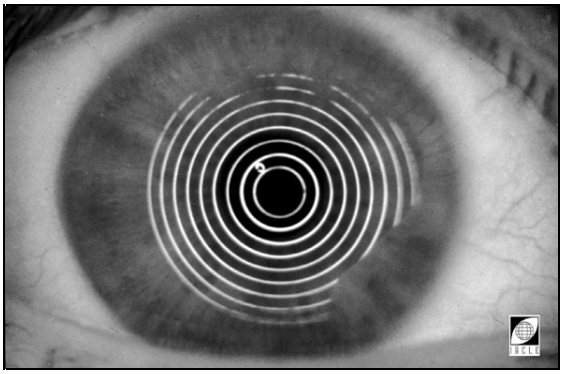
98



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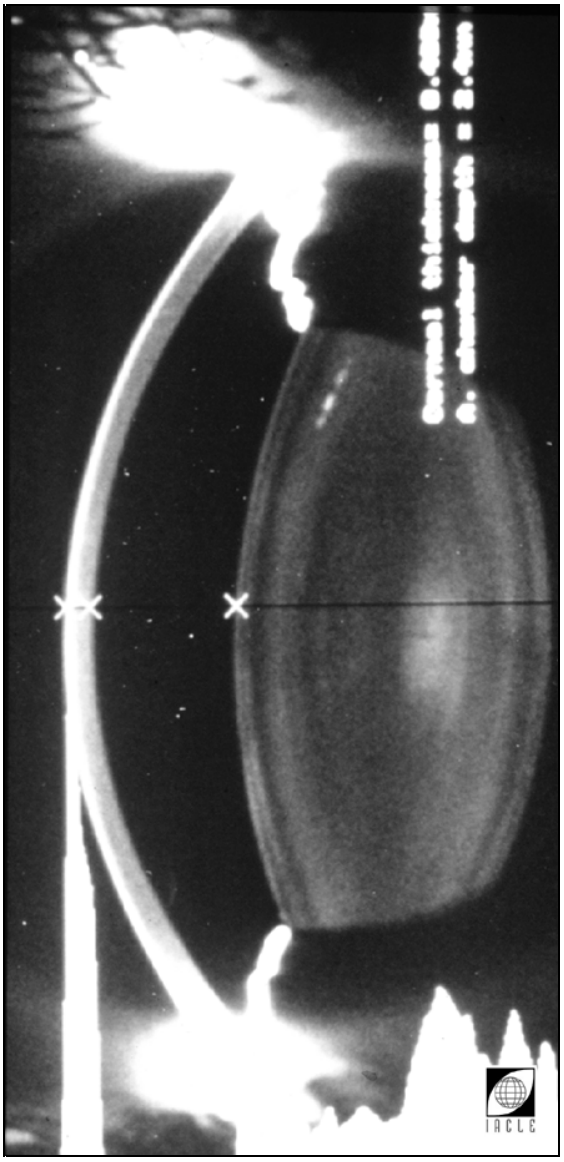
Slide 98 shows a photokeratograph of an eye whose K readings are 43.25 D with an HVID of 11.2 mm. The vignetting of the image by the nose (lower right hand side) is noteworthy.

The Carpentier photograph of this eye appears in slide 99.

99



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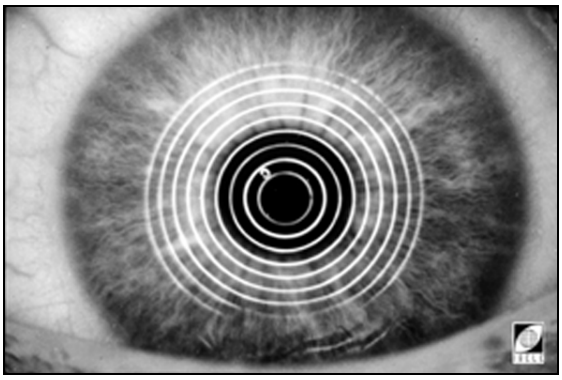
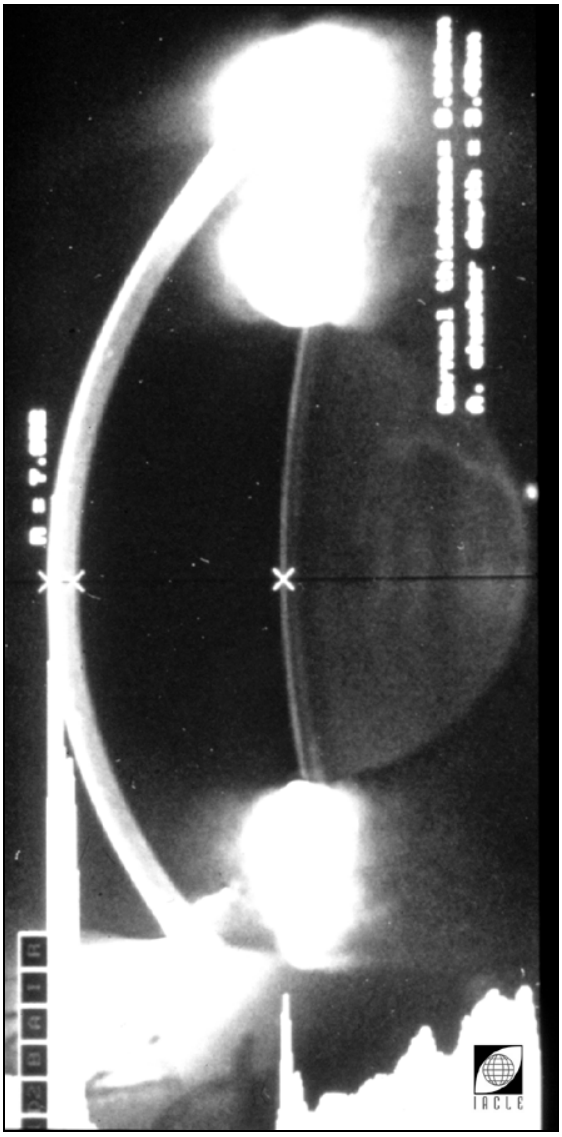
100



9L0065-98

Slide 100 shows a cornea with the same K reading (43.25D) but whose HVID is 12.2 mm. The matching Carpentier photograph is presented as slide 101. Note the difference in the anterior chamber depth (apex of posterior cornea to anterior vertex of crystalline lens). The photographic method also seems to have a greater reach in the case of shallower anterior chambers (cf. the thickness of the crystalline lenses rendered in each photograph).

101



9L10066-98

(Slides 96 to 101 supplied by Prof. Patrick Caroline and reproduced with permission).

VIII Confocal Microscopes

102

CONFOCAL MICROSCOPES
APPLICATIONS

- Confocal microscopes have the following advantages:
  - Have 0.5 to 0.7 X *better* transverse resolution
  - Higher contrast
  - Can section transparent tissue optically
  - Present a wide field of view
  - Render 'sharper' images

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Confocal Microscopes: Applications

Confocal microscopes are a relatively recent innovation in general microscopy, and a very recent innovation in *in vivo* ocular microscopy. Confocal microscopy has the following advantages:

- Has 0.5 to 0.7 X better transverse resolution than 'conventional' microscopy.
- Provides higher contrast images.
- Can section transparent, and to a lesser extent translucent, tissue optically.
- Wide field-of-view.
- Eliminates the majority of glare emanating from out-of-focus objects thereby rendering images 'sharper'.

Disadvantages of confocal microscopes are listed in slide 103.

103

CONFOCAL MICROSCOPES
DISADVANTAGES

- Complex
- Very light inefficient
- Expensive

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104

CONFOCAL MICROSCOPES
HISTORY

- Nipkow, 1884, rotating, perforated disk for scanning
- Minsky, 1957, scanning confocal microscope
- Petran and Hadravsky, 1968, Tandem Scanning Optical Microscope
- Maurice, 1974, scanning-slit microscope for transparent tissue
- Kino and Xiao et al., 1987, Real-Time Scanning Optical Microscope
- 1980s, Computerized image rendering

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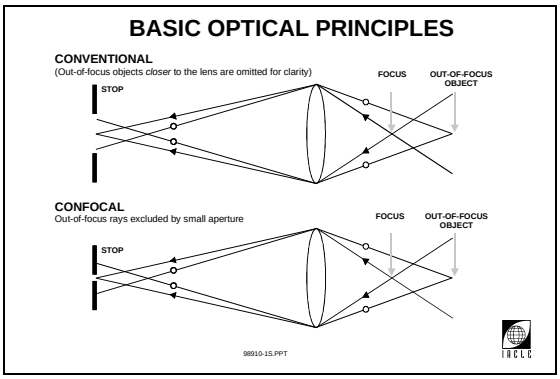
Confocal Microscopes: History

105



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Basic Optical principles: Introduction

The key advantage offered by the principle of confocal microscopy is the deliberate rejection of light emanating from out-of-focus objects. In a system with a finite aperture, light from the object of interest and light from objects adjacent to the object are involved in image formation.

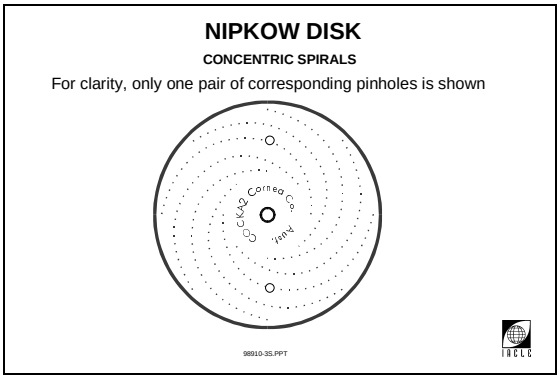
In a confocal system the principle is: 'a point source of light will form a point image'.

To achieve this, a small area of the object is illuminated at any one time, and a small aperture is included in the imaging system to physically reject light from out-of-focus objects which just happens to reflect the small illuminating beam (bottom of slide 105).

The results of confocal imaging include:

- Increased axial resolution.
- Increased resolution overall.
- Improved image contrast.
- Very shallow depth of field.
- Reduced contribution to image from out-of-focus objects.
- Better imaging in translucent tissue.

106



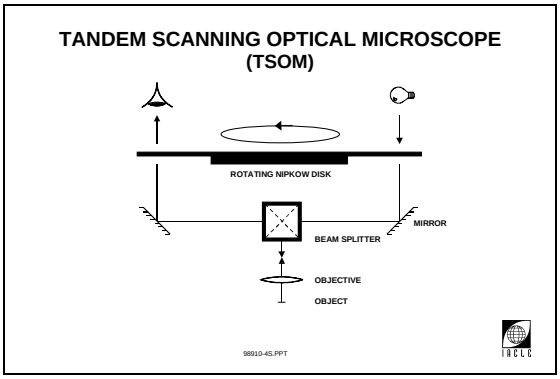
9L198910-3

Nipkow Disc

Illuminating a very small area of a large object at any given time is of little use to microscopists. To image a larger area, the image from the points must be 'built-up' over time so that the whole becomes apparent.

One way of illuminating the object sequentially is to use a series of fine holes arranged along a series of concentric spirals on a rotating disc. The Nipkow (1884) disc is such a device.

107

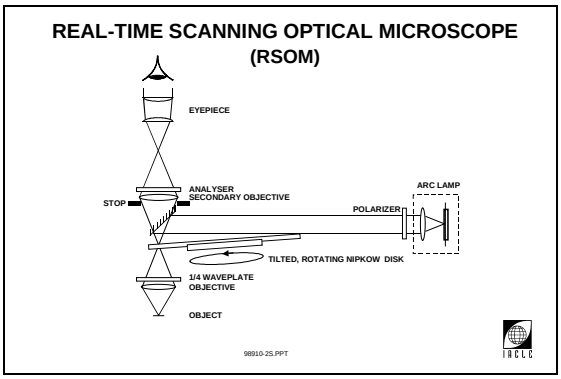


9L198910-4

Tandem Scanning Optical Microscope

The simplest confocal microscope is the Tandem Scanning Optical Microscope (TSOM) (Petran and Hadravsky, 1968 cited in Masters and Kino, 1990). In this device, the illuminating and imaging light paths are separated. The disadvantage of such a system is the need for very precise alignment (correspondence) of the pairs of holes used for each light path so that the same areas are harmoniously and simultaneously illuminated and viewed.

108



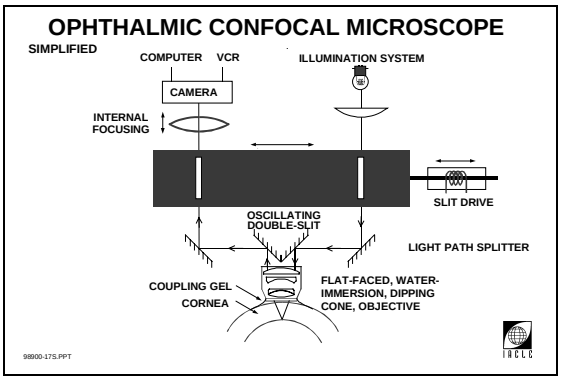
9L198910-2

Real-Time Scanning Optical Microscope

The need for a real-time scanning system is obvious. This was provided by Xiao *et al.* (1987, cited in Masters and Kino, 1990). Instead of tandem paths, the microscope uses the same aperture in the Nipkow disc. The paths are effectively separated by differentially polarizing them. The disc is tilted to remove unwanted reflections from the disc's surface. The speed of rotation of the disc determines how close to real-time the instrument gets.

Such instruments are very light inefficient (about 1%). For more details, see Masters and Kino, 1990.

109



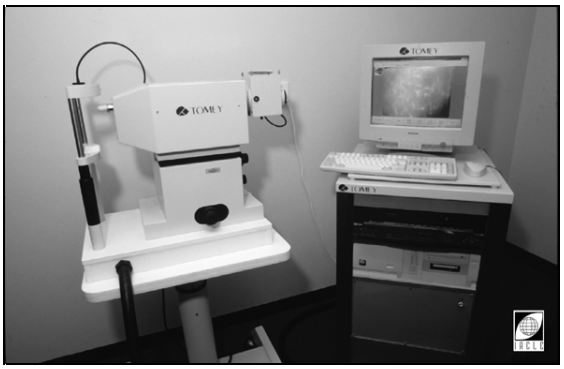
9L198900-17

Ophthalmic Confocal Microscope

Maurice (1974) developed a laboratory scanning-slit microscope for examining the corneal endothelium *in vitro* but not in real-time (i.e. the image was built-up section by section, over time). Such an instrument cannot be used on live subjects.

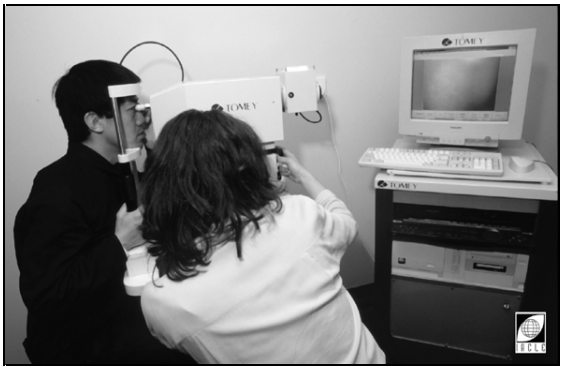
Relatively recently, several manufacturers have produced real-time ophthalmic confocal microscopes. The basic layout of one such instrument is shown opposite. The basis of the instrument is a tandem oscillating slit which moves harmoniously in the split illuminating and imaging paths.

110



9L10004-98C

111



9L10005-98

Tomey Confocal Microscope

This is one of the current ophthalmic confocal microscopes for real-time *in vivo* imaging. The instrument has a high (by video standards) resolution video camera feeding signals to both a video cassette recorder and a computer-based image analysis system.

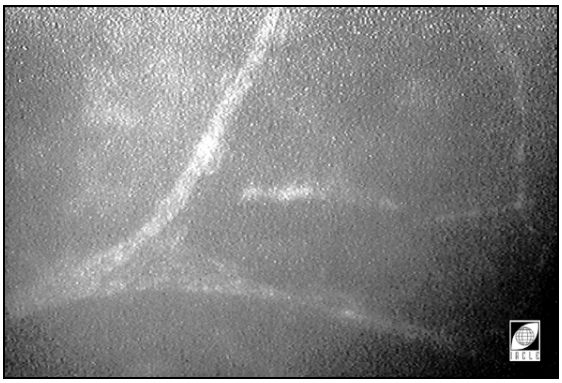
The images produced are unlike anything produced by conventional ophthalmic microscopy. Details of living cells can also be captured.

Slide 110 shows the instrument and slide 111 shows it in use. The subject is on the left and the microscope is operated from the side

Usually, the session is recorded onto high resolution videotape for later analysis.

The computer supplied with the instrument has a software suite which can provide the standard image analysis functions as well as some specialized ones for the corneal epithelium and endothelium.

112



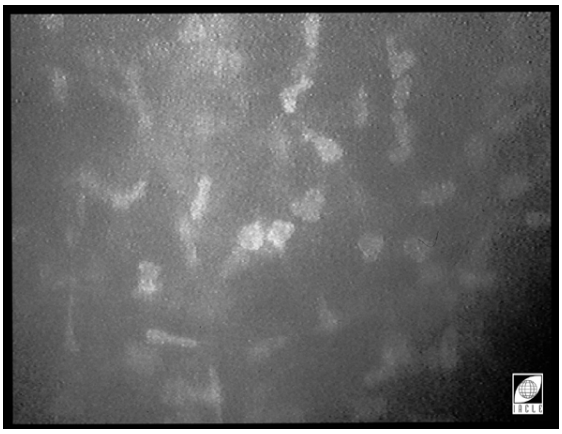
9L10052-98

Confocal Microscopy: Results

The following sequence shows some typical confocal images.

Slide 112 shows a corneal nerve fibre at higher magnification and in more detail than is possible with alternative techniques.

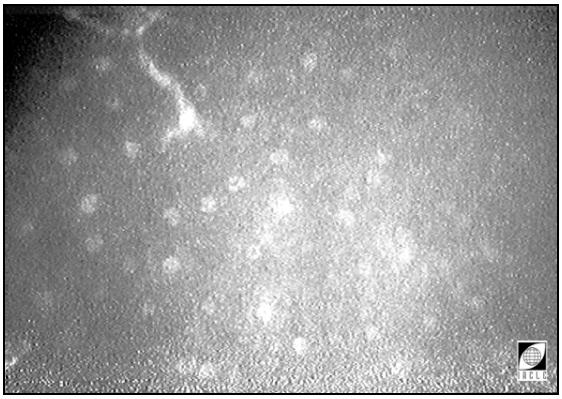
113



9L10050-98

Slide 113 shows anterior stromal keratocytes. This image could not be captured by conventional methods.

114



9L10051-98

Slide 114 shows cell nuclei in the superficial epithelium.

IX Tear Film Analysers

115

TEAR FILM ANALYSERS

- Hemispherical bowls
- Tearscope, Tearscope Plus
- Other

98999-37S.PPT

9L198999-37

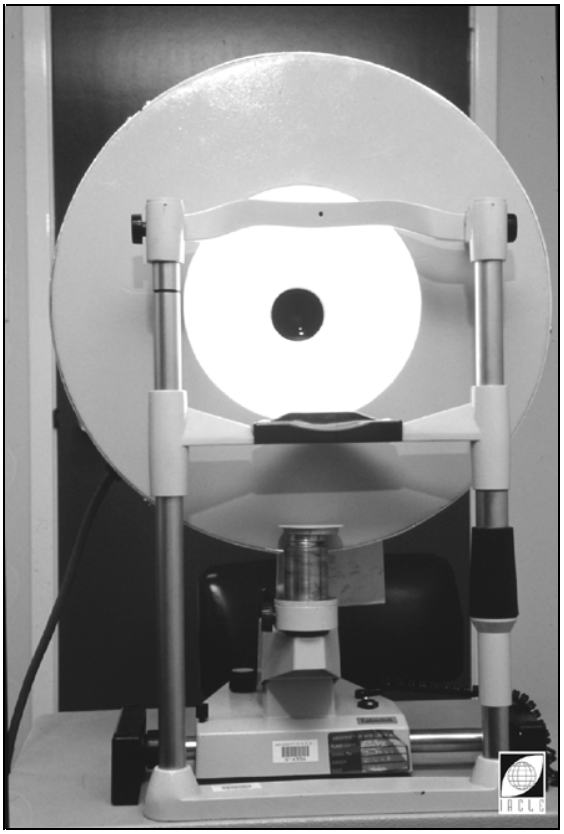
Tear Film Analysers

Tear film analysers are used to assess the tear film both quantitatively and qualitatively. They may be either stand-alone devices or attachments for slit-lamps.

The two main types are listed in the slide opposite but other devices are known to be under development.

Tear film analyser patterns, particularly those from the Tearscope, are covered in more detail in Module 4, Lecture 4.1.

116



9L11321-93

Hemispherical Bowl Tear Film Analysers

Like most tear film analysers, this type of instrument is designed to provide a clear, uniformly illuminated view of the tear film's surface. The bowl and its illumination system are usually attached to, or used in association with, a slit-lamp so that the tear film surface can be view at low to medium magnification.

Excessive illumination must be avoided as this can stimulate reflex tearing and alter the tear film state which is to be observed.

Many workers have created bowl-based analysers. Some have experimented with additional features such as a pattern (typically square or diamond-shaped grids) to increase the likelihood of detecting the first break in the tear film, regardless of its location.

Except for special applications, it is important that the whole of the corneal surface be visible at all times. If a higher magnification is required, a wider field microscope must be employed.

Slide 116 shows the instrument. Slide 117 shows it in use.

117

9L11327-95

118

9L10070-98

A small slit-lamp attachment based on the design of JP Guillon has been released by Keeler. The device, under the trade name of Tearscope and Tearscope Plus (slide 118), uses a digital stopwatch to measure the BUT.

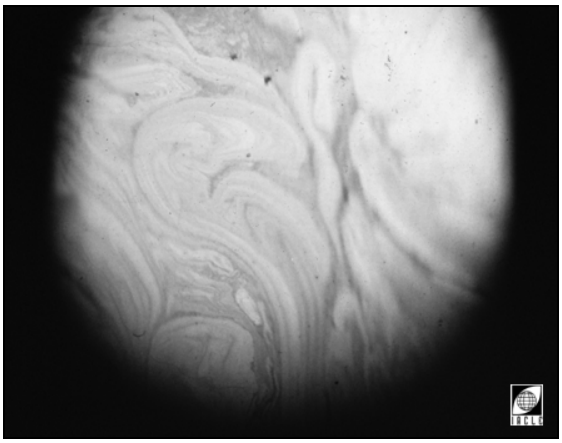
The Tearscopes feature a cold cathode white light source which produces a low level white uniform light, without significant heat being generated locally.

A grading scale is provided by the manufacturers (see background of slide 118) to aid in standardizing the rating and assessments made with the device.

Additional grid targets are supplied with the instrument as roll-up liners to be fitted inside the diffuser cone.

The right hand image shows the patient's view of the instrument and the left shows the practitioner's view.

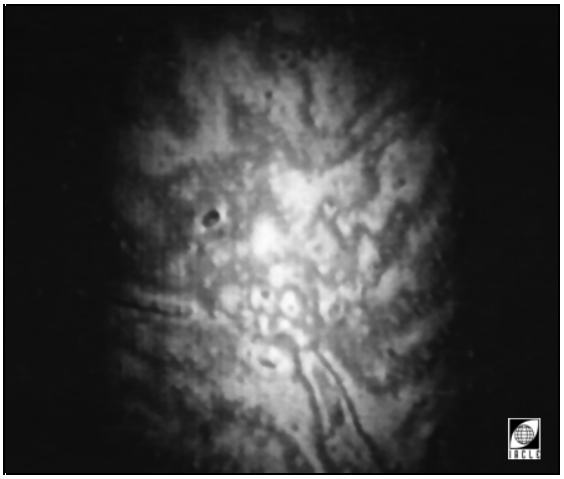
119



9L10117-93

Slide 119 is an example of a flow pattern suggesting a lipid layer thickness of 30-80 nm.

120

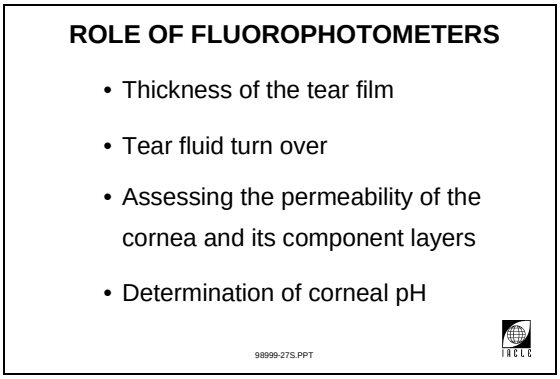


9L10507-94

Slide 120 shows a pattern of coloured fringes which may result from lipid layer thicknesses of 80-370 nm).

X Fluorophotometers

121



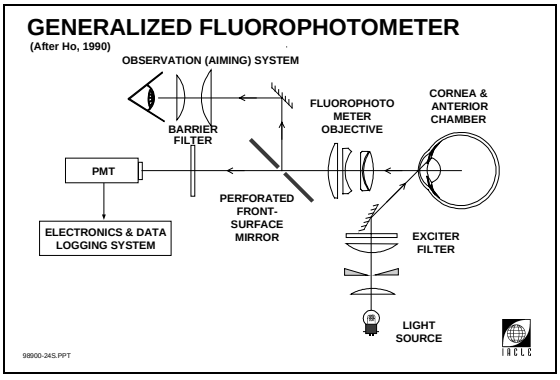
9L198999-27

Role of Fluorophotometers

Fluorophotometry may possibly be considered a laboratory or research technique rather than a clinical technique. Fluorophotometry has been used for:

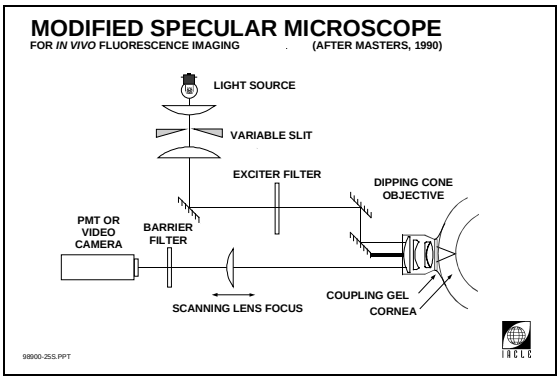
- Measuring the thickness of the tear film.
- Assessing tear fluid turn-over in normal and contact lens-wearing conditions.
- Assessing the permeability of the cornea in general and its component layers in particular in:
  - the normal eye
  - the diseased eye
  - the dystrophic eye
  - the contact lens-wearing eye
  - experimental conditions.
- Indirect determination of corneal pH.
- Studying corneal autofluorescence.

122



9L198900-24

123



9L198900-25

Generalized Fluorophotometers: Non-Scanning and Scanning.

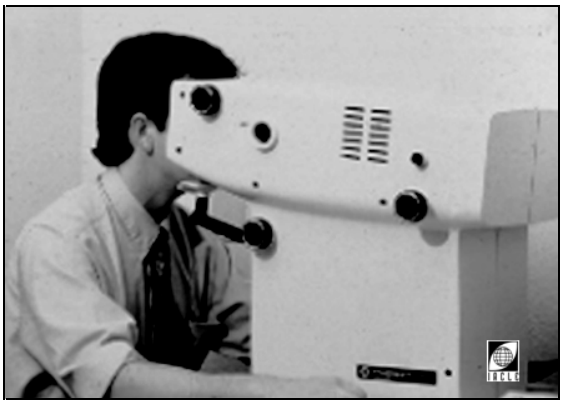
A generalized, simplified fluorophotometer is depicted in slide 122. Fluorescing agents (fluorophores) are instilled into the tears before measurements are taken. The exciting light is viewed in either specular or general conditions after passing through an exciter filter. The viewing and measuring system is split with the aid of a perforated front-surface mirror. After passing through a barrier filter (the exciter and barrier filters are analogous to those used in fluorescein photography of the external eye with a camera or slit-lamp), the photomultiplier tube (PMT) or other specialized low-light detector has its output amplified and recorded by external, often computer-based, systems.

To ascertain the *in vivo* viscosity of tears a polarization technique can be incorporated into fluorophotometers - fluorescence polarization (Paugh, 1997). To facilitate such a determination, a water-soluble (the aqueous is the bulk of the tear volume and is largely water), high molecular weight (to resist absorption by the cornea) fluorescing 'probe' (chemical entity) is used.

Furukawa *et al.* (1976) took a spot light meter approach by tapping the observation light path with a fibre optic bundle which was in turn coupled to a PMT. Using an eyepiece graticule whose centre was conjugate with the fibre optic input aperture, it was possible for the observer to ascertain which area was being assessed, with great accuracy.

If a more general area of the cornea needs to be

124

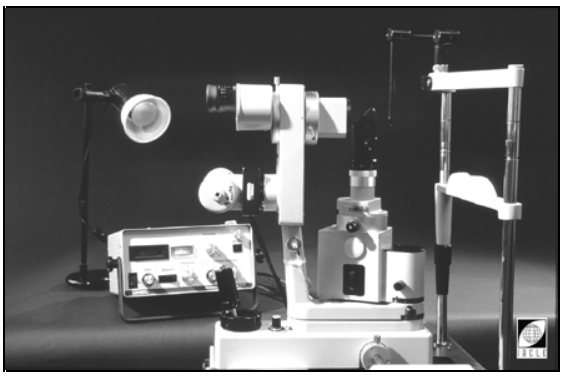


9L12249-94

examined, especially where the area has a significant thickness (e.g. the stroma), a scanning-focus system may be employed in which the object plane may be varied rapidly between two set limits by an internal focusing mechanism (slide 123) (Zeimer *et al.,* 1983). Such a system is employed in the OcuMetrics, Inc Fluorotron™ Master instrument (slide 124).

Some instruments use a light-chopping technique to overcome the effects of extraneous light, 'noise' in their electronic systems (i.e. to improve the signal-to-noise ratio) and to null the effects of background fluorescence.

125



9L10300-97

Fluorophotometer: Residence Time Fluorometer (Meadows, Joshi, Paugh, 1994 and Joshi, Meadows, Paugh, 1997. Most of hardware by Oriel Corp.)

This device is conceptually similar to the generalized instrument depicted in slide 122. This particular instrument was developed for clinical research purposes. The key optical elements of the device are mounted in and on a Nikon FS-2 photo slit-lamp. The electronics and data recording systems are mounted external to the slit-lamp and include a lamp stabilization circuit developed for the purpose.

The exciter filter is an interference type with a peak transmission wavelength of 488 nm. The barrier filter is a Schott glass #OG515 filter.

XI Contact Lens Analysers

126

CONTACT LENS ANALYSERS

- Humphrey Model 355 Lens Analyzer
- ConTest and Brass 2 by Rotlex Ltd.
- Visionix 2000/2001
- Optical Quality Analyser (Ho/CRCERT)

98999-38S.PPT

9L198999-38

Contact Lens Analysers

Aspects of routine contact lens analysis were introduced in Module 2, Lecture 2.6: Contact Lens Verification.

The instruments to be covered here are listed in the slide opposite.

127

9L10006-98

Humphrey Model 355 Lens Analyzer for Contact Lens Manufacturers

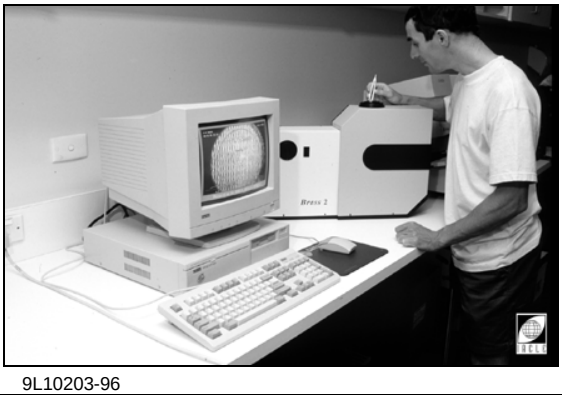
This automated objective instrument measures contact lenses in a production situation.

The device can be interfaced with a host computer system (see insert in slide opposite) using proprietary InterChange™ software via an ANSI-standard interface (American National Standards Institute). This also allows for the attachment of external devices such as barcode scanners (of any technology), printers, etc.

With suitable software in the computer, the device can also function as a go/no go gauge according to pre-set criteria.

The Model 355 incorporates an X-Y stage to allow the precise control of lens position within the instrument. Output information includes sphere, cylinder, axis and prism. An inbuilt function can calculate wet lens powers based on dry measurements.

128



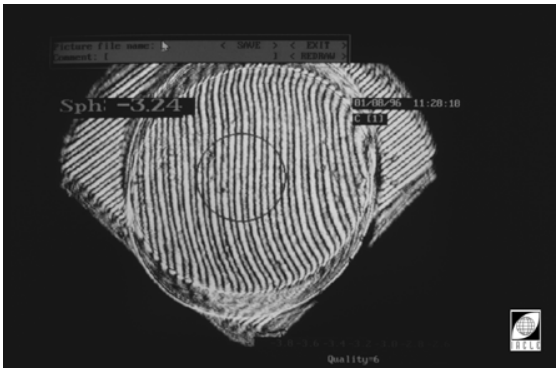
9L10203-96

Brass 2™ A-T (for buttons and molds) and ConTest™ (for rigid and soft lenses), (Rotlex Ltd., Israel)

The Brass 2 instrument (slide 128) uses Moiré fringes (Moiré Deflectometry™) to assess power, BOZR, FOZR, sagittal heights (depths) and optical quality of lens buttons, lens molds and contact lenses. Essentially, it is a surface testing device using reflection rather than transmission.

Spherical, aspherical, toric and multifocal tools and buttons can be assessed.

129



9L10208-96

130

9L10209-96

The ConTest instrument uses technology similar to that of the Brass 2 and measures finished lenses, soft lenses in a wet cell (filled with an appropriate solution) and RGP lenses in air. The ConTest use light transmission rather than reflection for its measurements.

Accuracies of 0.1D are claimed over areas of 2 to 13 mm in diameter. An autocentring feature can be invoked to automate lens assessment in a production environment.

Slide 129 shows a ConTest image of a contact lens exhibiting quite good optical quality. Local deviations from uniformity appear as local deviations from a vertical straight line

Slide 130 shows the result from a contact lens demonstrating poor optical quality. As can be seen, large deviations from the vertical are apparent.

131

9L10073-98

POWERMAP **- VC-2000/2001 (Visionix, Israel)**

This instrument series uses a 2-D Hartmann waveplate sensor to assess the power profile of a lens. RGP lenses are assessed in air while soft lenses are assessed in a wet-cell containing saline or similar compatible solution. The VC-2001 is specifically designed to measure multifocal RGP and soft contact lenses (spherical, aspheric and toric), including implanted-segment RGP bifocals.

Progressive, multifocal, spherical, aspherical and toric lenses can be measured. Cylinder axis, powers, prism and optical quality can all be assessed and presented by this instrument.

The VC-2000 and 2001 can be set up to behave as a yes/no gauge in a production environment with little or no special knowledge required of lens-production staff.

The instrument uses micro-optical technology based on a 2-D Hartmann waveplate sensor which can assess either transmitted or reflected light. Each micro-element of the Hartman plate acts as an interferometer which measures distortion of the local wavefront.

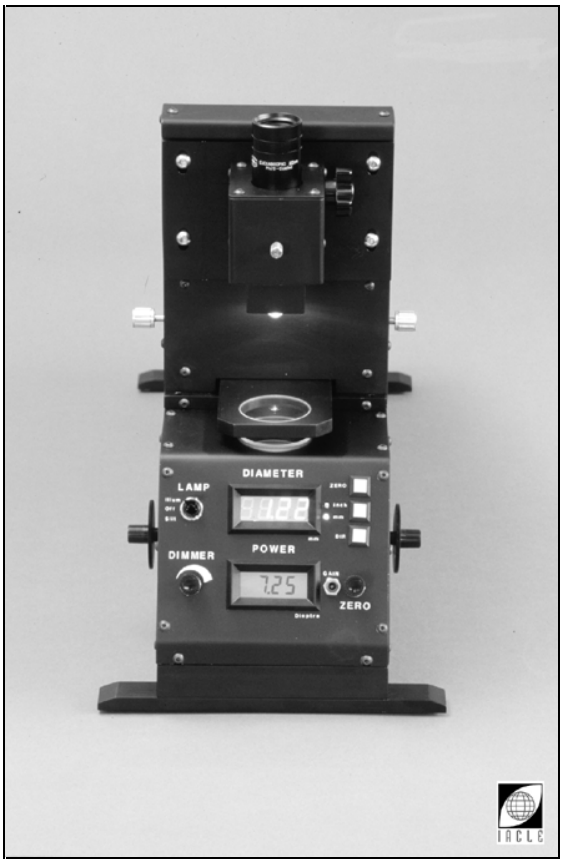
By comparing the local fronts assessed by multiple micro-elements (all of which are equally spaced) with a local reference, a map of the whole of a contact lens' optical performance can be realized. Using computer graphics, a visualization of the lens behaviour can be presented (details based on information available from the manufacturer's website – www.visionix.com, file: vis2112.htm).

Additional computer-generated information such as cross sections, local data and average power over manually selected areas, are available.

A repeatability of 0.01D is claimed for RGP and low water SCLs and 0.05D for high water SCLs.

While the VC-2000 can measure the actual cylinder axis it can also relate such measurements to any axis reference marks that appear on a lens.

132



9L11570-94

Optical Quality Analyser (Ho)

This custom-built device was designed by Ho (of CRCERT, Sydney). Basically, it is a modified Foucault knife-edge test (see Longhurst, 1973).

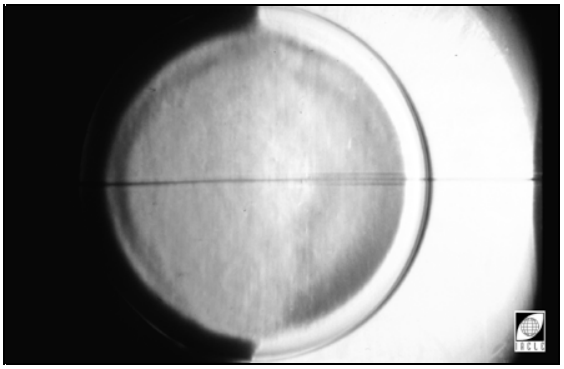
The device may be considered as a focimeter with a knife-edge target instead of the line or circle-of-dots target normally used (see Jalie, 1977, Douthwaite, 1995).

When used with RGP lenses, the resolution is <0.1D. With SCLs the results depend on the refractive index of the material and the optics of any wet-cell used to mount the lens in.

Ostensibly, the OQA is not intended as a device to measure BVP. Rather, it is intended to reveal the optical quality, regularity and likely visual outcome that can be expected from the use of the lenses measured.

An examination of the images recorded through the device (slides 133 to 136) will confirm its main application even though other parameters (e.g. diameter and power) can be ascertained with the device (see instrument panel in slide 132).

133

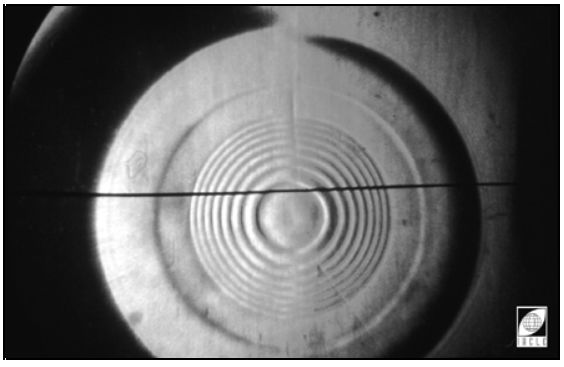


9L11943-92

Optical Quality Analyser: Images

Slide 133 shows the instrument view of a contact lens with good optical properties (regular, symmetrical, centred).

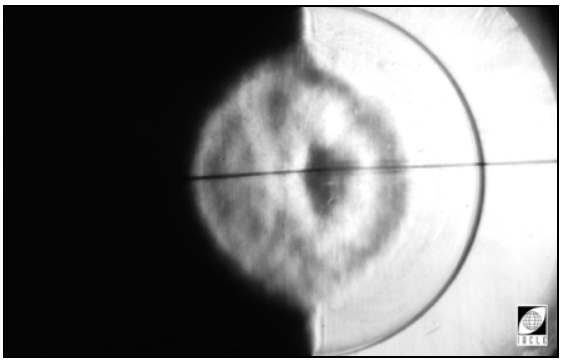
134



9L10831-91

Slide 134 shows a soft 'diffractive' bifocal. Again the image suggests good optical quality. From a knowledge of the capabilities and sensitivities of the instrument, it is possible to state that the depth (or height) of the rings are of the order of 2-3 µm.

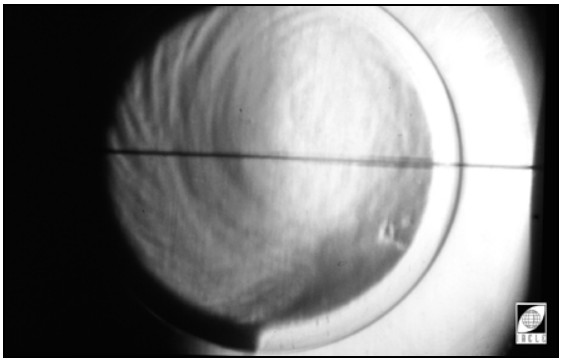
135



9L11945-92

Slide 135 shows a poor contact lens optic. The result suggests irregularity, asymmetry and a shape anomaly right of centre.

136



9L12314-94

Failure of an experimental polishing method is apparent in this image. It is conceivable that the method has resulted in localized heating leading to surface distortion resulting in this poor image.

XII Computers - General

137

COMPUTERS

- Programmable calculators
- Pocket computers
- Hand-held computers
- Desk-top computers
- Networked computers

98999-42S.PPT

9L198999-42

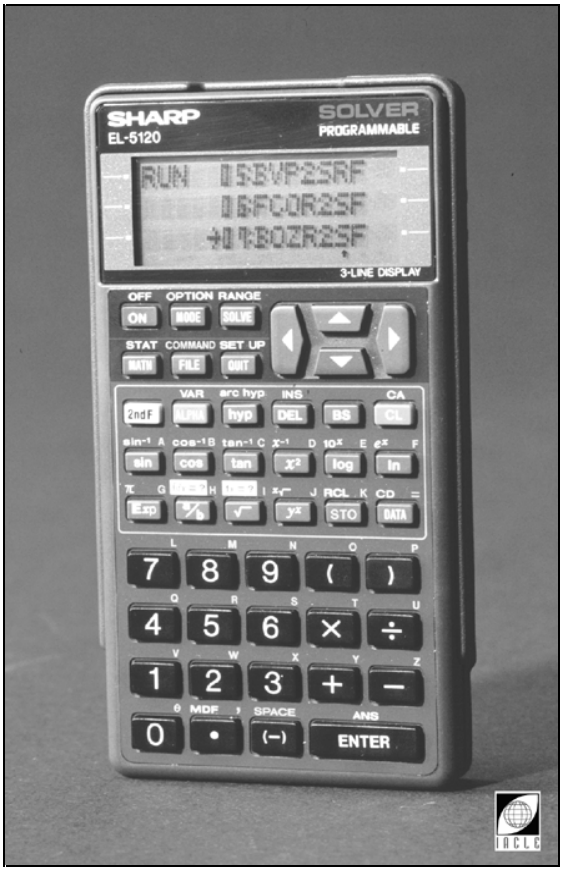
Computers: General

With the ready availability of affordable hand-held and pocket computers, some contact lens suppliers/laboratories supply their major customers with pre-programmed computers. The programs calculate:

- Initial and subsequent lens orders.
- Vertex distance corrections.
- Edge lifts and clearances.
- BOZRs based on particular fitting philosophies and calculated from keratometric or videokeratoscopy data.
- Orthokeratology initial and 'next lens' suggestions.
- Lens thicknesses, junctional thicknesses, etc.

Desktop personal computers are now a common item in modern eyecare practices. They fill all roles from practice management to image analysis and manipulation. Their connection to a practice-based network is covered later in this unit.

138



9L10228-97

Simpler Computational Answers

For most paraxial calculations used in routine contact lens practice (i.e. repetitive calculations using only a few variables), simple programmable devices are adequate. Programmable calculators/pocket computers using either proprietary or high level languages are available for such purposes. Such devices are relatively inexpensive, small, provide answers quickly and offer levels of precision well beyond that required for contact lens calculations.

This example uses tokenized (simplified) BASIC and offers a simple menu to select the programs available (see display).

Typical applications include:

- Calculating curvatures of toric rigid lenses (i.e. FCORs, BOZRs.
- Crossed-cylinder calculations.
- Calculation of BVPs.
- Vertex-distance compensation of BVP.
- Calculating axial and radial edge lifts.
- Lens thickness determination at specified points.
- Spectacle magnification and RSM calculations.
- Exact (paraxial) tear lens powers.
- Converting Ks to radii and vice versa.

139

9L10003-98

More Complex Computation

For more complex or lengthy calculations, or those requiring some form of graphical and/or printed output, more powerful devices are available. These include desktop computers (PCs), some personal organizers as well as more powerful “pocket-sized” devices.

Commercial Software: Contact Lens Optics

More recently, several contact lens and contact lens optics textbooks which include suitable software have become available, e.g. Douthwaite (1995) and Phillips and Speedwell (1997). The latter supplies a companion CD-ROM of software, the theoretical basis of which is presented in its text. The CD-ROM is also available as a stand-alone product (software authored by Hough). The programs supplied probably exceed the requirements of most users. If this is not the case, they provide an excellent starting point for custom applications in both interface and content.

Douthwaite’s programs avoid the computer ‘overheads’ incurred by having a graphical user interface (GUI). It is probable that such programs can be converted to a GUI relatively easily (using a developer’s kit or a console compiler). The Hough product already includes a GUI suite of programs.

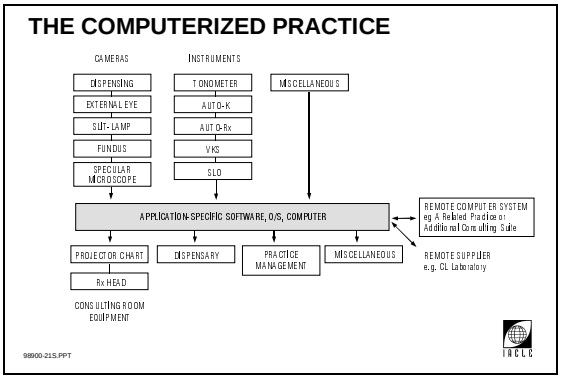
If a GUI is required, several software packages are available which are based on BASIC, Pascal or other existing languages. These allow the development of custom applications, although considerable effort may be required to do so.

Other commercial ophthalmic optics software packages are available and more can be expected to be developed.

Optics and lens design software is available for the design and optimization of complex or multi-element optical systems (e.g. Kidger-Sigma, Zemax, Photonics, Optec, Optiwerks, Code V, Solstis, etc.).

XIII Connectivity & Image Networking

140



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Connectivity: Applications

The widespread use of personal computers (laptop and desktop), has led to their greater involvement in contact lens and clinical areas. Manufacturers have now made available software protocols which allow the reception and transmission of data and images over industry-standard networks and computer hardware.

Computer and clinical equipment integration now makes possible an in-practice network (slide 140) which links all image-generating (fundus camera, slit-lamp, external eye camera dispensing aids, etc.) and data-generating (autorefractor, autokeratometer, videokeratoscope, etc.) to consulting room hardware (refractor head, projector chart, room lighting, etc.). Record keeping can be aided or even automated by the logging of all transactions. Dispensing data can also be generated.

It is conceivable that in the future, prescriptions will be 'written' to 'smart cards' rather than on paper. Dispensing data can then be downloaded at dispensing time at the site of dispensing (in-house or third party). Already, the concept of 'telemedicine' is in regular use, i.e. images and/or data are relayed to a remote site for a second opinion, specialist diagnosis, storage or confirmation.

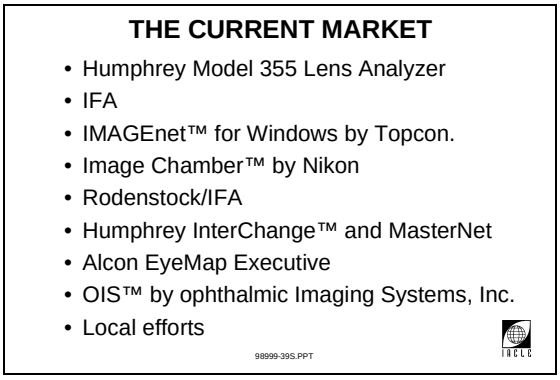
A nascent application of computers to contact lens practice involves the forwarding of videokeratoscopic data to a contact lens lab or the forwarding of parametric data following in-house videokeratoscopic data processing. From this data an automated contact lens order (especially for RGP lenses) is generated.

Connectivity: Requirements

The requirements for the systems alluded to here are quite significant. The fine detail and subtlety of ocular images are such that high resolution and colour fidelity are essential. This translates to large image files which require significant computing power to process, large capacity storage and which have lengthy transmission times over conventional telephone lines. Data back-up and security are also critical and difficult issues for such systems. Applications involving automated ordering of contact lens, spectacles, etc. have much lower system requirements and many such systems are in regular use already.

If a total integrated approach is not taken, simpler systems can be utilized. A simple system may include practice management software to administer the business side of the practice while other systems may log images and/or data from slit-lamp, fundus camera, external eye camera, videokeratoscope, etc.

141



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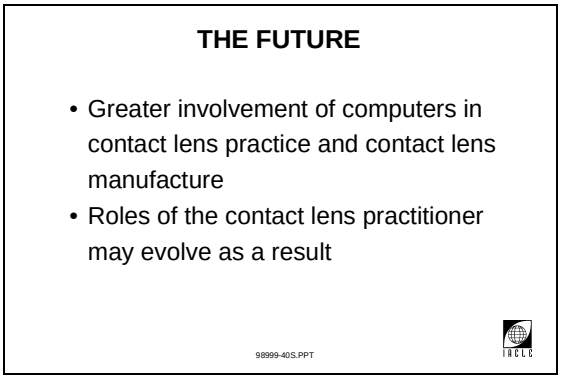
The Current Market

This is a short summary of the systems and protocols available currently. It is by no means exhaustive and for obvious reasons cannot hope to cover local initiatives from all parts of the world.

- IFA™. IFA offers a total practice integration package which endeavours to link all devices in the consulting room with the other aspects, including business, of a practice. A barrier to all such endeavours is the lack of any standardization (physical, protocol and other interface matters) of connectivity. As a result, proprietary interfaces are proliferating and the linking of hardware with hardware and software solutions is problematic.
- IMAGEnet™ and OptiLink™ for Windows by Topcon. This is an example of a proprietary system from a major manufacturer of a comprehensive range of ophthalmic instrumentation.
- Image Chamber™ by Nikon. At the time of writing this was an Apple Macintosh™-only system
- Rodenstock. Through a partial shareholding, Rodenstock and IFA have cooperated in making their instrumentation and software compatible.
- Humphrey InterChange™, MasterNet™ and Communicom™. This is a set of proprietary protocols covering videokeratoscopy and lens (contact lens and other) analysers. The latter allows the linking of lens analysers (focimeters) to refractor heads and keratometers from the same company.
- Alcon EyeMap Executive™. Again a proprietary protocol for the transmission of videokeratoscopic data.
- OIS™ by Ophthalmic Imaging Systems, Inc. This system is a general ophthalmic consulting room system designed for use with any instrument which produces images and/or data of any aspect of the eye.
- EyeSys Directlink™. This communications software links EyeSys System 2000 videokeratoscopes to external consultants, laboratories and refractive surgery suites.
- Local efforts. Currently, these are more likely to involve spectacle frame and lens data. Such initiatives often lead to diversification into other areas such as contact lenses. The increasing familiarity of practice staff with such possibilities augers well for the use of such systems by practitioner and ancillary staff alike.

XIV The Future

142



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The Future:

The rapid progress in computers, computing power and software programming environments will mean their inclusion and/or involvement in more and more ophthalmic equipment.

Consulting room and contact lens practice equipment will become more automated, more reliable and simpler to apply. This will mean an improvement in the quality of eyecare delivered, a greater involvement of ancillary staff in the routine matters of contact lens practice and patient care, and more time available to the practitioner.

The latter may mean either a greater patient load or an increase in the time spent with patients, answering their questions and taking a proactive role in patient eyecare education.

Such evolution may also bring about changes in the spectrum of roles played by contact lens practitioners.

The actual prescribing of contact lenses is becoming easier, safer and more reliable, due largely to the ingression of computers into the contact lens industry.

Practical 9.1.1

(2 Hours)

Pachometry

Practical 9.1.1: Pachometry

Practical Session

The type of pachometer to be used in this practical depends on local availability of a suitable device. While the choice is straightforward, i.e. optical or ultrasonic, it is probable that an ultrasonic instrument will be more readily available either within the institution, or from local ophthalmic equipment suppliers. Broadly, this practical will cover both types.

Instructions:

1. Confirm the chosen instrument's calibration using either the calibration test piece(s) supplied with the instrument or a series of lenses of various known thicknesses. If the instrument is within manufacturer's tolerance the practical can proceed.
   If the instrument is out of calibration, either adjust the instrument according to manufacturer's instructions or create a calibration curve from which accurate data can be derived. In the case of an ultrasonic device set the 'velocity' according to the material from which the test lens series is fabricated. In the case of an optical pachometer, correct the thickness scale for the difference in refractive index between the test lens material and the human cornea.
2. The educator should demonstrate the instrument to the group before undertaking the practical. The precautions required during use, the taking of measurements, fixation control and contamination control (for ultrasonic probes) should all be covered.
   Instructions in the correct use of the instrument should then be given.
3. The students should familiarize themselves with the correct operating procedures for the instrument. If a fixation target system is part of the instrument, they should ascertain its mode of operation.
4. If a fixation target system is not an instrument feature, an alternative fixation control method needs to be developed. Markers on walls or ceilings will usually suffice.
5. For optical pachometry, only measurements in the horizontal meridian are possible. It is suggested that central, mid-peripheral and peripheral locations be measured (five in total). For ultrasonic instruments the mid-periphery and periphery of the vertical meridian should also be included (making a total of nine). The designations for these peripheral zones are often shown on the instrument panel as these are used as the internal memory locations when logging the data. Each measurement should be repeated three times. However, some instruments may require the taking of a complete set of single measurements at each point in any one sitting. The mean of the three determinations should be noted in the record form. The time of day should also be noted.
6. If a suitable pro forma is not available for recording the data, an alternative is included in this practical.
7. Both normal and abnormal corneas should be measured. Where possible, a keratoconic cornea should be included as an example of the latter.
8. Draw conclusions as to the normalcy of the data.

Discussion and Review of:

- **The Use of Pachometry**
- **Pachometers**
- **The Findings of this Practical**

Practical Session

RECORD FORM

Name:_____ Date: ____--_____--____
YY Month DD

Time:_____

PACHOMETRY RESULTS

RIGHT EYE**:**

Central:

Meridian:	**Positions** Mid-Peripheral	Peripheral
0		
90		
180		
270		

LEFT EYE**:**

Central:

Meridian:	**Positions** Mid-Peripheral	Peripheral
0		
90		
180		
270		

Practical 9.1.2

(2 Hours)

Tear Film Analysis

Practical 9.1.2: Tear Film Analysis

Practical Session

As for Practical 9.1.1, the type of instrument to be used depends on local availability of a suitable device. The J-P Guillon-designed Tearscope™ is more likely to be available either within the institution, or from local ophthalmic equipment suppliers. Whichever instrument is chosen, the same basic principles apply and the same factors can be assessed. A slit-lamp-mounted instrument is assumed.

Instructions:

1. The educator should demonstrate the tear film analyser to the group before undertaking the practical. Instructions in the correct use of the instrument should then be given along with advice on the correct magnification to use, i.e. a setting which allows the whole of the cornea to be examined simultaneously. Advice about direction of gaze (fixation control) and the instructions to be issued regarding blinking, withholding a blink, etc., should be detailed.
2. The students should familiarize themselves with the correct operating procedures for the instrument to be used. They should resolve the issue of fixation control before starting the practical proper.
3. In addition to the appearance of the tear film, the tear break-up time (BUT), lacrimal lake (tear reservoir), lid and lash appearances and the effect of contact lenses can be assessed. Tear prism height can also be estimated. Other factors which can be assessed with a tear film analyser include: the effects of different types of contact lenses, tear film contamination by cosmetics/face creams, eye ointments and ophthalmic pharmaceuticals. If a Tearscope is to be used, the grading scale poster which accompanies the instrument contains a wealth of information regarding these and other issues. A scale for estimating the tear film thickness based on the thin-film interference pattern colours, is also included in the poster.
4. Both normal and abnormal tear films should be included in the population of subjects to be assessed. If contact lens wearers are not well represented within the student group, some students should be fitted with RGPs and SCLs monocularly so that the effects of contact lens wear on the pre-lens tear film can be ascertained. Quantitative assessments should be made after the tear film has apparently stabilized. The time of day should also be noted.
5. If a suitable pro forma is not available for recording the data, an alternative is included in this practical.
6. Draw conclusions as to the normalcy of the data.

Discussion and Review of:

- **The Use of Tear Film Analysis**
- **Tear Film Analysers**
- **The Findings of this Practical**

Practical Session

RECORD FORM

Name:_____ Date: ____--_____--____
YY Month DD

Time:_____

Type of Lenses Worn (If Any):_____

TBUT RESULTS

RIGHT EYE:

No Lens

BUT:_____ Location of First Break:_____

Assessment of Lacrimal Lake:

Tear Prism Height:_____

Assessment of Lipid Layer:

Tear Film Thickness:_____

Appearance of Eyelids, Eyelashes, Lid Margins:

Contamination by Lipids, Mucus, Particulates, Cosmetics, Pharmaceuticals ? :

LEFT EYE:

No Lens

BUT:_____ Location of First Break:_____

Assessment of Lacrimal Lake:

Tear Prism Height:_____

Assessment of Lipid Layer:

Tear Film Thickness:_____

Appearance of Eyelids, Eyelashes, Lid Margins:

Contamination by Lipids, Mucus, Particulates, Cosmetics, Pharmaceuticals ? :

RGP-Wearing EYE:

BUT:_____ Location of First Break:_____

Assessment of Lacrimal Lake:

Tear Prism Height:_____

Assessment of Lipid Layer:

Tear Film Thickness:_____

Other Observations:

SCL-Wearing EYE:

BUT:_____ Location of First Break:_____

Assessment of Lacrimal Lake:

Tear Prism Height:_____

Assessment of Lipid Layer:

Tear Film Thickness:_____

Other Observations:

Practical 9.1.3

(2 Hours)

Aesthesiometry

Practical 9.1.3: Aesthesiometry

Practical Session

As for previous practicals, the type of instrument to be used depends on local availability of a suitable device. The Cochet-Bonnet Aesthesiometer is more likely to be available either within the institution, or from local ophthalmic equipment suppliers.

Instructions:

1. If the manufacturer of the chosen instrument suggests a calibration test or procedure, it should be performed. If the instrument is within manufacturer's tolerance, proceed with the practical. If the instrument is out of calibration, rectify according to the manufacturer's directions.
2. The educator should demonstrate the instrument to the group before undertaking the practical. The precautions required during use, the taking of measurements, fixation control and contamination control (for contacting instruments) should all be covered. Instructions in the correct use of the instrument should then be given.
3. The students should familiarize themselves with the correct operating procedures for the instrument to be used. They should develop a fixation control method. Markers on walls or ceilings will usually suffice.
4. Mid-peripheral and peripheral locations should be measured in both the horizontal and vertical meridians (eight in total). Central readings may be difficult or impossible with some instruments and may be included if feasible. Sensitivity in the oblique meridian can be determined if time permits. The mean of three determinations at each location should be noted in the record form.
5. If a suitable pro forma is not available for recording the data, an alternative is included in this practical. The time of day should also be noted.
6. Measurements should be made *before* and *after* lens wear in both contact lens wearers and non-wearers.

Discussion and Review of:

- **The Use of Aesthesiometry**
- **Aesthesiometers**
- **The Findings of this Practical**

Practical Session

RECORD FORM

Name:_____ Date: ____--_____--____
YY Month DD

Time: _____

Type of Lenses Worn : _____

AESTHESIOMETRY RESULTS

RIGHT EYE**:**

	BEFORE	**AFTER**
Meridian:	Central: Mid-Peripheral Peripheral	Central: Mid-Peripheral Peripheral
0		
90		
180		
270		

LEFT EYE**:**

	BEFORE	**AFTER**
Meridian:	Central: Mid-Peripheral Peripheral	Central: Mid-Peripheral Peripheral
0		
90		
180		
270		

Tutorial 9.1

(2 Hours)

Industry Presentations of Contact Lens-Related Products

Tutorial 9.1:

Introduction:

Local suppliers of relevant ophthalmic equipment as well as contact lens laboratories and/or contact lens manufacturers' agents should be invited to address the student group. Such addresses should be scheduled for one day, a practical time allocated (of the order of 20 minutes is usually sufficient) to each presenter and guidelines issued on what areas of interest should be covered in the allotted time.

Guidelines should also strongly imply that the presentation be presented professionally rather than commercially, covering the features and advantages of the products being highlighted. Product comparisons, product denigration and other competitive 'behaviour' sometimes exhibited 'outside' academia should be expressly prohibited. Failure to comply with such a request should mean automatic exclusion from subsequent presentation days.

Where companies have lenses and lens care products, it is left to the discretion of the educator whether or not they allow individual time slots for each product category where time permits.

Products:

- Soft lenses
- RGP lenses
- SCL lens care products
- RGP lens care products
- Contact lens accessories
- Ophthalmic pharmaceuticals including tear supplements and treatments
- Contact lens-related consulting room equipment
- Contact lens-related laboratory or workshop equipment
- Contact lens-related computing equipment and software
- Promotional material related to any of the above (practitioner and patient oriented)
- In-practice and 'new in practice' promotional offers, special deals, etc.
- Technical, professional and clinical services offered by the companies
- Other products, information, services deemed appropriate by the educator

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Unit 9.2

(1 Hour)

Lecture 9.2: Contact Lenses for Sporting Activities

Course Overview

Lecture 9.2: Contact Lenses for Sporting Activities

I. Fitting the Athlete with Contact Lenses

II. Eye Protection

III. Patient Management and After-Care

Lecture 9.2

(1 Hour)

Contact Lenses for Sporting Activities

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Acknowledgment: This lecture on Sports Vision is, in large part, taken from 'Bausch & Lomb's Olympic Vision', a Sports Vision Program of Bausch & Lomb, edited by Fred Edmunds, 1992.

I Contact Lenses and Sports

I.A Contact Lenses *versus* Spectacles

1

CONTACT LENSES AND SPORT

- Fastest identifiable improvement in visual and athletic performance
- Not just for the serious athlete

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Contact Lenses and Sports

Generally, vision correction is recognized as having a significant role to play in improving an athlete's visual and athletic performance. In both these performance areas visual correction generally, and contact lenses specifically, provide faster identifiable improvements than any of the other three elements of sports vision: visual performance screening, visual performance enhancement and eye protection.

Contact lenses are the ideal vision correction device for virtually anyone involved in sporting activities, whether it is soccer, cricket, football, golf, tennis, or water sports. They are not just for the serious athlete but are beneficial to anyone participating in any type of sport or sporting activity.

2

BENEFITS OF CONTACT LENSES OVER SPECTACLES

- Increased peripheral vision and peripheral awareness
- Reduced spatial distortion
- More 'real world' visual information
- Improved depth perception
- Move with the eyes even during vigorous activities

95620-12S.PPT

9L295620-12

3

BENEFITS OF CONTACT LENSES OVER SPECTACLES

- No reflections, fewer aberrations & less glare
- Do not slip down the nose, fall off, fog up or become covered with sweat, rain, dust
- Normal goggles, sunglasses or protective eyewear can be worn over contact lenses
- Psychologically, less encumbering than spectacles

95620-13S.PPT

9L295620-13

Benefits of Contact Lenses Over Spectacles

For athletes, contact lenses offer important advantages over spectacle lenses. Contact lenses allow a more natural, unrestricted field of vision with reduced peripheral and spatial distortion.

- Object size is more consistent with 'real-world' size (that is, less minification or magnification).
- Because contact lenses remain in place under dynamic conditions and during collisions, they allow for more stable vision and enhanced depth perception.
- Contact lenses wearers do not experience negative visual effects from spectacle lens reflections and aberrations.
- Contact lens wearers usually experience less glare.
- Contact lenses do not slip down the nose, fall off, fog up or become covered with sweat, rain, dust or mud. In addition, goggles, sunglasses or protective eyewear can be worn over contact lenses.
- Contact lenses also offer psychological advantages over spectacles for the athlete. The contact lens wearing athlete has no risk of ocular injury from broken frames or spectacle lenses. As a result their confidence and self-image improve.

While hydrogel contact lenses, as an alternative to spectacles, have not been shown to demonstrate any measurable advantage in visual performance, they do offer a psychological advantage which may help in sports-oriented visual performance (Schnider *et al.*, 1993).

4

9L20556-95

The visual demands on, and visual skills of, an athlete are often greater than those of non-athletes. Consequently, contact lenses can be an advantage for the athlete. Optimizing the performance of contact lenses for athletes is the challenge facing the contact lens practitioner.

Some knowledge of an athlete's sport assists the choice of lens design and fit.

For the relevant sporting activity(s), practitioners should ascertain the associated visual demands. They should then identify the most important visual skills and define how contact lenses might affect those skills. This will also help practitioners anticipate the difficulties contact lens wear may present to the athlete and enable him to take measures to prevent/address such difficulties.

5

CONTACT LENSES FOR ATHLETES

- Fit for optimum performance
- Tailor exam and fit to meet special athletic needs
- Visual acuity and on-eye performance are critical
- Visual demands on athlete often greater

95620-14S.PPT

9L295620-14

Contact Lenses for Athletes

Some considerations, both general and specific, that require addressing when considering contact lenses for sports, are presented in the slides opposite.

6

CONTACT LENSES FOR ATHLETES

- Understand sport-specific demands
- Become more familiar with the relevant sport(s)
- Identify sport-specific visual demands
- Anticipate contact lens challenges

95620-15S.PPT

9L295620-15

7

VISUAL SKILLS ENHANCED BY CONTACT LENS WEAR

- Dynamic visual acuity
- Depth perception: efficient correction of refractive anisometropia
- Peripheral vision: 15% increase over spectacles

95620-16S.PPT

9L295620-16

8

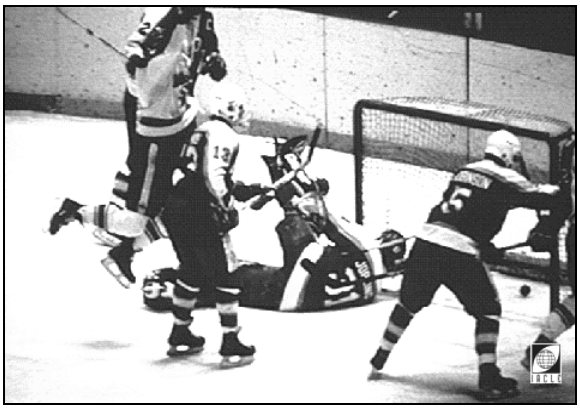
VISUAL SKILLS ENHANCED BY CONTACT LENS WEAR

- Eye-hand/body/foot coordination
- Peripheral awareness:
  - requires good peripheral vision
  - spatial localization

95620-17S.PPT

9L295620-17

9



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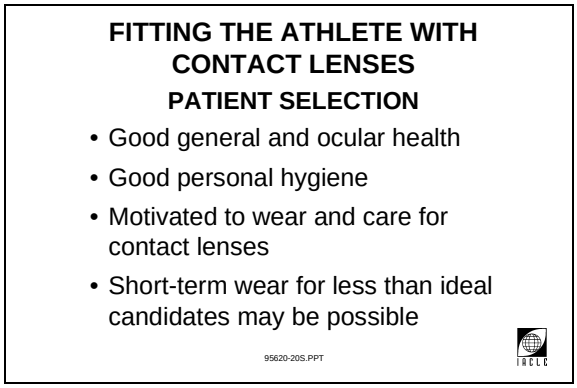
Visual Skills Enhanced by Contact Lens Wear

Some visual skills may be enhanced by contact lens wear. These include:

- Dynamic visual acuity. Contact lenses provide excellent visual stability under dynamic conditions.
- Depth perception. This may be affected by anisometropia (even relatively small amounts). If the anisometropia is refractive in origin, contact lenses provide the brain with a more accurate, 'real-world' image size. If the error is axial, spectacles are more desirable optically (see Relative Spectacle Magnification (RSM), Lecture 2.3).
- Peripheral vision. Spectacles restrict the visual field. Contact lenses increase the peripheral field by about 15% compared with spectacles.
- Eye-hand/body/foot coordination. Better peripheral vision improves peripheral awareness.
- Spatial localization. Knowing where things are (opponents, team mates, ball, etc.) relative to others depends on the athlete's depth perception and peripheral awareness. Contact lenses can improve both.

I.B Contact Lens Fitting Considerations

10



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Fitting The Athlete with Contact Lenses

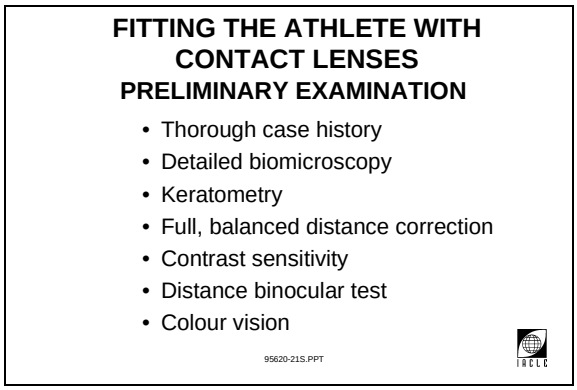
Patient Selection

Not all athletes may be suitable candidates for wearing contact lenses for normal periods of wear. Only those meeting the basic criteria for contact lens wear should be fitted for routine contact lens wear (slide 10).

However, it is possible that patients who are marginal contact lens candidates, or even those who should not wear lenses regularly, may be fitted with contact lenses successfully if contact lens use is restricted to the relatively short periods required for their athletic activity(s). Patients with dry eyes, chronic blepharitis, and even those with problems such as Giant Papillary Conjunctivitis (GPC) may be included in this category. Soft lenses are the best choice for these patients.

Generally, RGP lenses are not well tolerated when worn on a part-time basis because of the recurring challenge of adapting to the physical presence of the lenses.

11



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Fitting the Athlete with Contact Lenses: Preliminary Examination

The preliminary eye examination leading to the fitting of contact lenses to athletes is substantially the same as for a non-athlete patient. A comprehensive eye and vision examination should be performed, including a thorough case history.

The examination details are listed in slide 11.

This information will form a significant part of the foundation upon which the decisions will be made about choice of lens, fitting relationship, wearing mode, lens care routine and replacement schedule.

12

9L295620-22

Fitting the Athlete with Contact Lenses: Fitting the Appropriate Lens Type

Usually, a normal preliminary examination precedes the fitting of an athlete with contact lenses. A well-fitted contact lens for everyday use may also be the best choice for a particular athlete.

However, sometimes this is not the case. Indiscriminate fitting choices can actually have an adverse effect on athletic performance.

Any special visual demands must be met or the athlete may not perform optimally. These demands need consideration when lens fitting characteristics are being finalized.

13

SPORTS CHALLENGE CATEGORIES

- Sports which present environmental challenges
- Sports requiring lens stability upon impact
- Sports requiring lens stability in extreme eye and body positions

95620-23S.PPT

9L295620-23

Sports Challenge Categories

Sport-specific demands of the athlete should be considered when choosing the proper lens. Dividing sporting 'challenges' into the categories listed in slide 13 may help in making the correct lens type and fitting decisions.

14

9L20560-95

15

SPORTS WHICH PRESENT ENVIRONMENTAL CHALLENGES

WATER	WIND	SUN	DUST/DIRT
swimming	sailing	surfing	motocross
scuba	track & field	sailing	mountain biking
wind surfing/surfing	wind surfing	football	track & field
water skiing	bicycling	baseball	baseball
kayaking	sky diving	tennis	rock climbing
water polo	skiing	soccer	rugby

95620-24S.PPT

9L295620-24

Sports which Present Environmental Challenges

As an example of sport-specific lens choice, a runner in a track and field competition wearing RGP lenses may be disrupted by having particles of dust trapped behind the lenses, causing reflex tearing which would obstruct vision and incapacitate the runner during the race. Such disruption may be prevented if large diameter RGP lenses or soft lenses are worn.

16

SPORTS REQUIRING STABILITY ON IMPACT

- Football
- Rugby
- Pole vaulting
- Equestrian
- Wrestling
- Boxing
- Karate
- Water skiing

95620-25S.PPT

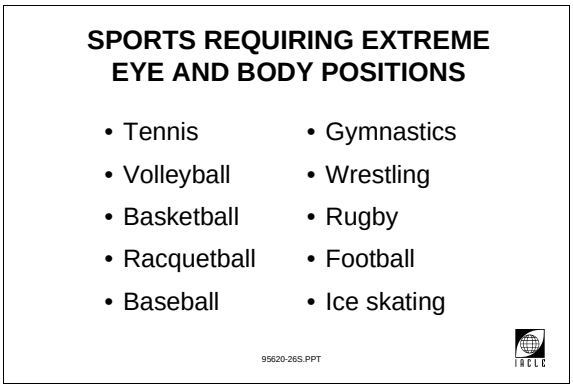
9L295620-25

Sports Requiring Stability on Impact

The effect of lens loss or displacement during competition may not be as serious for some player positions and/or in some sports, and depends on the magnitude of the prescription.

Generally, large diameter soft lenses are more resistant to displacement or dislodgement and consequently are usually the lens of choice for most athletes in these sports.

17



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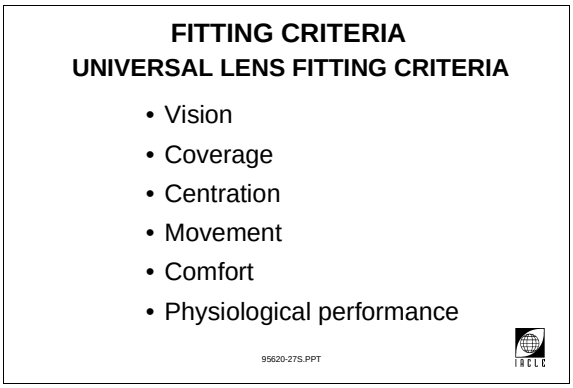
Sports Requiring Extreme Eye and Body Positions

Again, large diameter soft lenses are more resistant to mislocation or loss from the eye resulting from extreme positions of gaze or rapid eye movements. Consequently, soft lenses are usually the lens of choice for most athletes in these sports.

18



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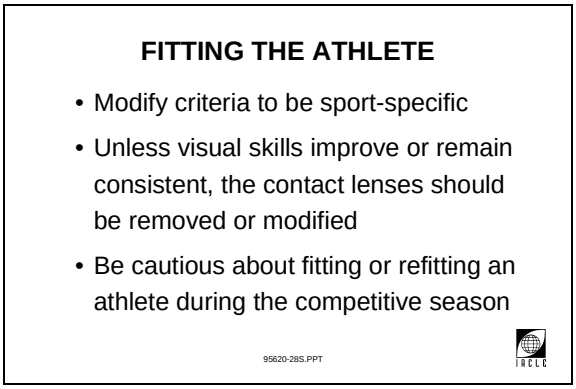
Fitting Criteria

Generally, when evaluating a lens on-eye, the fitter should assess the universal lens fitting criteria of vision quality, coverage, centration, movement, comfort and physiological performance.

19



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Fitting the Athlete: Points to Note

Because there are always exceptions to generalizations it may be beneficial to modify the fitting criteria in slide 18 slightly, to fulfil the performance requirements of a particular athlete or sport.

It is prudent to test the visual skills of the athlete before fitting contact lenses, and again following adaptation. Two weeks of adaptation is usually adequate. Unless the visual skill improves, or at least remains consistent, the contact lenses should be removed or modified.

The practitioner should be cautious when fitting or re-fitting an athlete during the competitive season. When changes are made to an athlete's visual system, they may respond poorly during the adaptation period. For a baseball or hockey player, this could mean four or five games during which they are learning to deal with their new 'visual world'.

I.C Lens Options and Replacement Schedules

20

PRESCRIPTION DECISIONS

- Maximise visual acuity
- Correct all myopic & significant hyperopic refractive errors
- Correct anisometropia ≥ 0.50 D
- Correct astigmatism > 0.50 D with toric or RGP lenses

95620-30S.PPT

9L295620-30

21

PRESCRIPTION DECISIONS

- For lens dryness or dehydration, use a thicker high water or a thin low water lens
- Fit lenses to maintain optimum physiology
- Avoid extended wear
- Fit toric soft lenses for contact or high-risk sports

95620-32S.PPT

9L295620-32

22

PRESCRIPTION DECISIONS

- Soft lenses are ideal for part-time wearers
- Colour-differentiating lenses for colour deficient athletes may prove useful
- Tinted lenses optional for adverse lighting
- Assess blink adequacy and suggest use of re-wetting drops

95620-33S.PPT

9L295620-33

Prescription Decisions

To ensure athletically-active patients maximize their visual performance so that they can reach their peak athletic performance, the following guidelines are relevant:

- Maximize visual acuity for all athlete patients.
- Correct all myopic and significant hyperopic refractive errors, even those which are minor (≥0.25 D). This is especially important in sports that have strong distance vision demands. Without correction, the eyes may become fatigued or athletic performance may deteriorate over time.
- Anisometropia ≥ 0.50 D should be corrected. In sports where depth perception and dynamic visual acuity are important, it is imperative that the eyes work together well to achieve peak performance.
- Astigmatism > 0.50 D generally should be corrected with a toric soft lens or an RGP lens. Even if a patient can read 6/6 at distance with a spherical lens, their visual acuity and contrast sensitivity may be improved with a toric SCL or RGP lens.
- If lens dryness or dehydration is a problem, the athlete experiences lens awareness and intermittent foggy vision. A thicker, high water lens, a lower water lens or a lens material less prone to dehydration should be considered in this case. This situation occurs frequently in sports where intense concentration results in blink suppression.
- Fit lenses which maintain optimum physiology. Extended wear (EW) of lenses should be avoided even if EW lenses are used.
- Soft toric lenses may be more appropriate for RGP lens wearers who play contact or high-risk sports.
- Soft contact lenses are ideal for the part-time or occasional wearer because there is no need to readapt to lenses on each occasion they are worn.
- Colour deficient athletes may be fitted with a single ‘colour differentiating’ lens to help them discriminate between different colours.
- Dark tinted contact lenses (70% absorption) for bright sunlight conditions may be fitted to athletes whose sports prohibit the wearing of sunglasses.
- Assess blink adequacy and suggest the use of re-wetting drops. This is especially important for sports that demand intense concentration. High water content lenses should generally be avoided in these cases.

23

DISPOSABLE AND FREQUENT LENS REPLACEMENT PROGRAMMES

Frequently replaced lenses offer convenience, safety and healthy lens wear, to the average patient and the athlete

95620-34S.PPT

9L295620-34

24

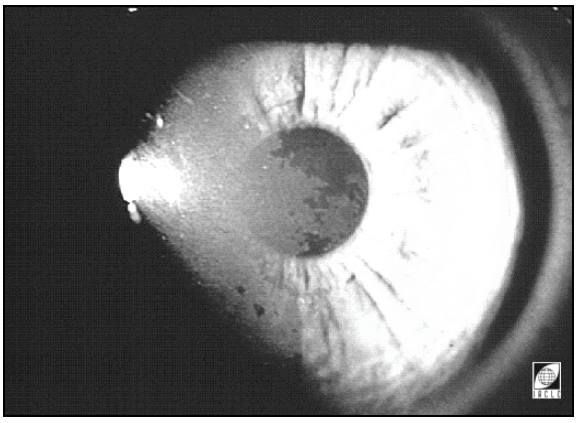
DISPOSABLE AND FREQUENT LENS REPLACEMENT PROGRAMMES

- Eliminate problems of soiled or deposited lenses
- Maintain
  - contrast sensitivity
  - visual acuity
  - comfort
  - ocular health

95620-35S.PPT

9L295620-35

25



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Disposable and Frequent Lens Replacement Programmes

Frequently replaced lenses offer convenient, safe and healthy lens wear to the average patient and athlete. Disposable and frequent replacement programmes are ideally suited to the athletic lifestyle.

Lenses that have been worn for some time become soiled. This can affect visual acuity and comfort, and possibly lead to ocular conditions which prohibit lens wear (for example, Contact Lens-related Papillary Conjunctivitis (CLPC) or Giant Papillary Conjunctivitis (GPC).

A fresh, clean lens enhances vision and comfort and reduces complications like CLPC.

Contrast sensitivity, a critical visual skill for athletes who participate in sports under poor lighting conditions, e.g. night baseball or skiing in poor visibility, is reduced by soiled or deposited lenses.

Disposable and frequent replacement lenses also make it easy for the athlete or the team trainer to carry spare lenses in case of loss or damage. Then, should a lens be lost or damaged during competition, the most significant impact on the team will be the absence of the athlete for only as long as it takes to replace the lens.

Often, starting a competition with a new pair of lenses gives the athlete a psychological edge as they enter the contest with 'renewed' vision.

Frequently replaced lenses can also be a benefit to the athlete's contact lens practitioner. Often, due to busy schedules and, in some cases extensive travel, athletes may neglect proper lens care and follow-up visits. Both disposable and frequent replacement programmes enhance compliance and improve patient management. Such lenses can usually be maintained with less complex lens care systems. To receive fresh lenses, the athlete has to return to the practice at which time an after-care examination can be given.

Single use, daily disposable lenses that are worn once and then thrown away require no care system and may, therefore, offer some athletes an even more convenient contact lens wearing option. This may be the preferred option for athletes who only wear contact lenses during their competitive activities.

26

DISPOSABLE AND FREQUENT LENS REPLACEMENT PROGRAMMES

- Spare lenses
- Free athlete from worry
- New lenses before competition
- Enhance compliance
- Benefit practitioner

95620-36S.PPT

9L295620-36

II Specific Fitting Considerations

27

SPECIAL CONTACT LENS APPLICATIONS

- Alternative fitting guidelines
- Assess demands specific to dynamic sports
- Consider fitting different lenses for sports-only use
- Lenses must be stable in extreme environments and body positions

95620-37S.PPT

9L295620-37

Specific Fitting Considerations

Lenses fitted for everyday wear are often appropriate for sporting activities. However, due to the specific demands of the sport, a different lens may be required.

The conditions encountered by the athletically active patient can include snow, wind, rain, dust, poor lighting, glare, heat, haze, sudden physical impact and close encounters with small, very fast moving objects.

The ideal lens must be dimensionally stable in many environments and offer consistent performance in all eye and body positions. The lens should not decentre or fold under unusual eyelid pressures and must be large enough to be retained by the lids during water sports and in windy conditions.

28

CONTACT LENSES AND WATER SPORTS

- Ensure optimal safety and performance
- Lens loss is frequent
- Complications are rare

95620-38S.PPT

9L295620-38

Contact Lenses and Water Sports

Generally, contact lens manufacturers do not recommend contact lens wear for water sports. However, a literature search shows that complications are rare and lens loss rates associated with water sports are between 0 and 12% (see Solomon, 1977, 12%, Stein and Slatt, 1977, 7% without adaptation, 0% with adaptation, Soni *et al.,* 1986, 3.6%).

Patients who choose to wear lenses in the water should be taught how to ensure optimal safety and performance of their lenses in that environment. Precautions include:

- Wearing swimming goggles if at all possible (Dyer *et al.,* 1989).
- If the use of goggles is not feasible, encourage the athlete to close their eyes immediately prior to head immersion and while underwater.
- Flushing the eyes with a re-wetting solution or other suitable sterile solution after cessation of in-water activities.
- Using a strong surfactant contact lens cleaner as soon as practical after leaving the water.
- Using a powerful lens disinfectant after the cleaning step.
- Using disposable lenses, including daily disposables, and discarding them as recommended by their practitioner.

29

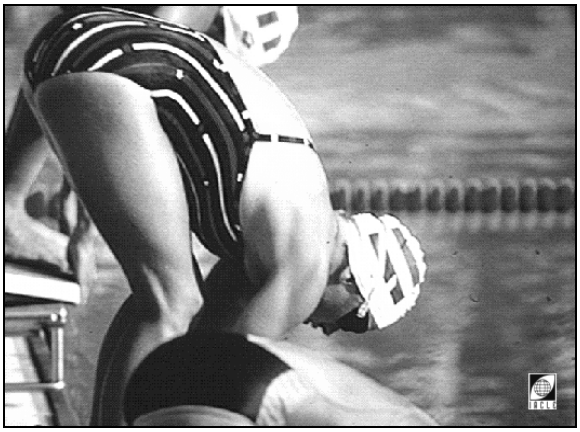
CONTACT LENSES AND WATER SPORTS

- Patient must be confident
- Reduce risk of loss:
  - eye closure on impact with water
  - full squint
  - wipe water from eyes after surfacing
  - irrigate eyes
  - remove and disinfect lenses after 20-30 min

95620-39S.PPT

9L295620-39

30



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Contact Lenses and Water Sports

Recommendations

Patients must be confident and positive about lens wear during water sports. If they have doubts or concerns, lens wear should be discouraged. They must understand that the practitioner cannot guarantee that a lens will never be lost in the water. The risk of loss can be greatly reduced if the patient practises facial immersion first and follows a few simple rules:

- Eye closure on impact with water.
- Full squint with head pointing in direction of gaze while under water.
- Upon surfacing, gently wipe water from closed lids prior to opening.
- Irrigate eyes with fresh sterile saline or re-wetting solution immediately after leaving the water.
- Remove and disinfect lenses promptly, after waiting 20-30 minutes for lens mobility on the eye to return (Difenbach *et al.,* 1988).

31

FITTING LENSES FOR WATER SPORTS

- Avoid rigid lenses
- Fit larger diameter lenses
- Consider thicker lenses
- Consider spherical lenses for toric patients
- Recommend disposable lenses
- Carry spare lenses

95620-40S.PPT

9L295620-40

32

9L20565-95

Fitting Lenses for Water Sports

While there are a number of fitting considerations common to both fresh and salt water conditions, there are also a few distinctions. First, some general fitting guidelines:

- Avoid rigid lenses. These are much easier to lose.
- Larger diameter SCLs may be better retained, but are not always necessary.
- Consider thicker SCLs, as ultra-thin lenses can wrinkle or fold on some patients.
- Consider spherical lenses for toric patients as they are less expensive to replace.
- Disposable, especially daily disposable lenses are ideal for relatively long-term exposure to water, especially fresh water SCUBA (Self-Contained Underwater Breathing Apparatus). They may be discarded following a single use.
- A spare pair of contact lenses or spectacles should be carried at all times.

33

FITTING LENSES FOR WATER SPORTS

FRESH WATER FITTING

- Consider looser fit
- Eye rinse upon leaving water
- Allow lens to equilibriate (20-30 min)
- Remove, clean and disinfect lenses promptly
- Consider goggles

95620-41S.PPT

9L295620-41

Fitting Lenses for Water Sports: Fresh Water Fitting

- A hypotonic environment may cause an SCL to 'adhere' to the eye (Diefenbach *et al.,* 1988).
- Consider a looser fit, since the lens will tighten.
- Rinse eye with a re-wetting solution or sterile saline upon leaving water.
- Wait 20-30 minutes after leaving the water before removing lenses (Diefenbach *et al.,* 1988). This allows the lenses to equilibrate with the tears.
- Due to greater risk of contamination (e.g. *Acanthamoeba*), remove, clean and disinfect lenses following use in water.
- Consider the use of goggles for all water activities (Dyer *et al.,* 1989).

34

FITTING LENSES FOR WATER SPORTS

SALT WATER FITTING

- Not necessary to fit steep
- Remove, clean and disinfect lenses after lens mobility returns
- Consider goggles

95620-42S.PPT

9L295620-42

Fitting Lenses for Water Sports: Salt Water Fitting

- Generally, it is not necessary to fit lenses steeply. The hypertonic environment will usually also result in SCL 'adherence' (Diefenbach *et al.,* 1988).
- Remove, clean and disinfect lenses after lens mobility is restored (20-30 minutes).
- Consider goggles for all water activities.

35

CONTACT LENSES FOR WINTER SPORTS

- Environmental challenges
- Altitude may require high oxygen transmissibility
- UV absorption
- Disposable and frequent replacement lenses

95620-43S.PPT

9L295620-43

Contact Lenses for Winter Sports

Like water sports, winter sports present the athlete with a unique set of environmental challenges. These may include:

- Cold.
- Wind.
- Falling snow.
- Rain.
- Lower oxygen level at high altitude.
- Low relative humidity.
- High ambient visible light levels.
- Intense UV exposure.

Many people remove their spectacles before participating in their winter sport. Some patients do not want to be bothered by fogging lenses or snow-covered spectacles, while others may worry about injury or damage to their eyes and eyewear in a fall. Athletes who require vision correction should be strongly discouraged from participating without their contact lenses or spectacles.

Less oxygen at high altitude means that lenses with higher oxygen transmissibilities may be

necessary to maintain proper corneal physiology.

The 'thinner' atmosphere allows much greater levels of ultraviolet (UV) light to reach the eye. To protect the eye from UV keratitis, the practitioner should strongly recommend the use of UV absorbing sunglasses or goggles. Alternatively, UV absorbing contact lenses may be dispensed.

Low humidity, commonly associated with cold and high altitudes, can cause lenses to dry quickly, leading to discomfort and compromised vision. Low water content lenses are generally better than high water lenses at maintaining their normal level of hydration and 'dry out' less readily. Lens re-wetting drops should be recommended.

Contrast sensitivity, necessary for athletes to read terrain and detect subtle visual cues, is extremely important to many winter sports. Disposable and frequent replacement programmes help maintain this important skill by ensuring the contact lenses used are always in good condition and provide optimum visual acuity.

Sports with high-G forces, such as bobsled and luge, may cause toric lenses to rotate on the eye. However, there is no research data to support this postulation.

Due to the dynamic movement involved in many winter sports, soft lenses are often preferred to RGP lenses.

36

CONTACT LENSES FOR DYNAMIC SPORTS

- Centre lens precisely
- Minimal movement without blur upon blinking
- Stability in extreme positions of gaze and body orientations

95620-44S.PPT

9L295620-44

Contact Lenses for Dynamic Sports

Dynamic sports may be defined as those which involve a great amount of body movement and speed. Examples include:

- Cycling.
- Running.
- Tennis.
- Skiing.

These sports generally require lenses with extra stability on the eye. This may necessitate precise fitting. Avoid fitting rigid lenses in these cases, as their on-eye stability is often inferior to that of SCLs. Rigid lenses may also be forced out of the eye upon impact or during unusual eye movement.

The lens fitting should have the characteristics shown in slide 36.

A cyclist, for example, rides with a head-down stance and thus lens centration in upgaze is important. Additionally, cyclists without goggles are exposed to windy, dusty conditions, adding lens drying and awareness to their contact lens wearing challenges.

Spectacles and sunglasses are contraindicated in many of these sports. If exposure to the sun is intense, consider lenses with a dark custom tint and/or UV blocker.

37

CONTACT LENSES FOR RISK SPORTS

- Extreme body contact
- Small, fast moving objects
- Avoid rigid lenses
- No spectacles
- Recommend eye protection
- Good centration
- Stability
- Minimal movement

95620-45S.PPT

9L295620-45

38

9L20567-95

Contact Lenses for Risk Sports

In 'high risk' sports, the athlete is often knocked about by blows to the head or body. They may have to avoid small, fast flying objects which potentially can damage the eyes. Examples of 'risk sports' include:

- Hockey.
- Football.
- Karate.
- Kung fu
- Boxing.

Since impacts can be frequent, RGP lenses should be avoided as they may be dislodged by such occurrences. Spectacles should never be worn. They are likely to damage the face if hit or broken. In some cases, i.e. hockey, a cage or mask should be utilized for full-face protection. Lens fitting should be similar to that for dynamic sports, i.e.:

- Good centration.
- Stability.
- Minimal movement.

Spare lenses are essential and the athlete's coach or trainer should be schooled in emergency removal procedures.

39

CONTACT LENSES FOR SPEED SPORTS

- High speeds involve high risks
- Require intense concentration
- Lens stability critical
- Minimal lens movement
- Soft contact lenses preferred

95620-46S.PPT

9L295620-46

Contact Lenses for Speed Sports

Speed sports may be characterized by high speeds and include activities such as:

- Car or motorcycle racing.
- Alpine skiing.
- Sky diving.
- Cycling.

These sports require intense concentration and often the athlete blinks very infrequently.

Lens stability is critical. Visual acuity cannot be allowed to vary with blinking. The lenses need to be fitted steeply enough to avoid decentring and displacement under high-G loads, but not so steep as to cause variable vision when blinking.

Soft lenses are preferred to RGPs. However, either is superior to spectacles which limit peripheral vision, fog up, may slip down, or cause injury in an accident.

If a practitioner is concerned that a patient's toric lenses may rotate under high-Gs, they can choose a steeper lens or evaluate a different design.

40

CONTACT LENSES FOR INDOOR SPORTS

- Dryness may be a problem
- Reduced contrast sensitivity
- Consider the use of a lens lubricant
- Recommend disposable or frequent replacement lenses
- Recommend eye protection

95620-47S.PPT

9L295620-47

Contact Lenses for Indoor Sports

Indoor or arena sports such as hockey, figure skating, racquetball, squash and basketball all have:

- An artificial atmosphere which may promote dryness.
- Artificial lighting which can affect contrast sensitivity (light fittings produce veiling glare).

Lens lubricants should be available to re-wet lenses if distracting dryness occurs. Disposable and frequent replacement lenses help maintain good contrast sensitivity.

For those sports that involve exposure to small, fast moving objects or another player's piece of equipment, eye protection, such as a pair of goggles or a face mask, is strongly recommended.

41

RGP LENSES AND SPORT

- Excellent visual acuity
- Lens loss more likely
- Avoid with:
  - dynamic sports
  - high-risk sports
  - contact sports

95620-49S.PPT

9L295620-49

RGP Lenses and Sports

- RGP lenses provide excellent visual acuity.
- There is a risk of the lenses being dislodged from the eye during contact sports.
- RGP lenses are not recommended for part-time wear due to the adaptation period required.

42

RGP FITTING AND SPORT

- Large diameter lenses
- Large optic zone
- Fit slightly steep
- Dispense spare pair

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9L295620-50

RGP Fitting and Sports

In fitting RGP lenses for sports, the following guidelines are useful:

- Fit large diameter lenses (9.2 to 10.5 mm) with superior lid attachment for improved stability and a lower potential for loss.
- Use large optic zone (≥8.0 mm) to reduce flare.
- For additional stability, fit slightly steep and avoid excessive edge lift.
- Dispense patient with a spare pair in case of loss.

43

SCLERAL LENSES FOR SPORT

- Very large lens
- RGP or PMMA material
- Do not get 'lost' or decentre
- Ideal for dynamic water sports

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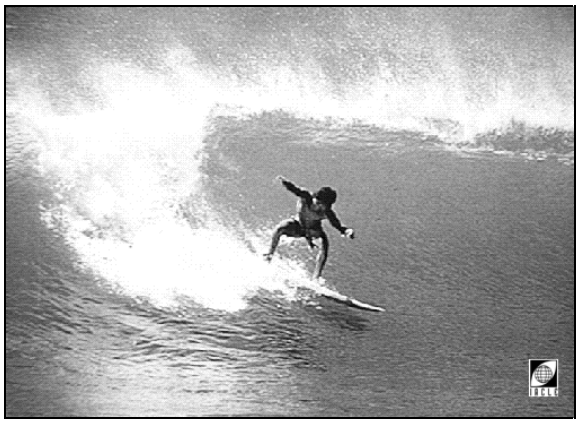
9L295620-51

Scleral Lenses for Sports

In recent years, the scleral lens has been 're-discovered' for its sporting applications. These large lenses (18 - 24 mm) may be made in either RGP or PMMA materials. The size of these lenses virtually eliminates any chance of mislocation or loss. This is especially important in certain dynamic water sports, such as water polo, surfing or water skiing.

Scleral lenses are intended for wear of limited duration. They can be difficult to fit, are labour-intensive to fabricate and are relatively expensive.

44



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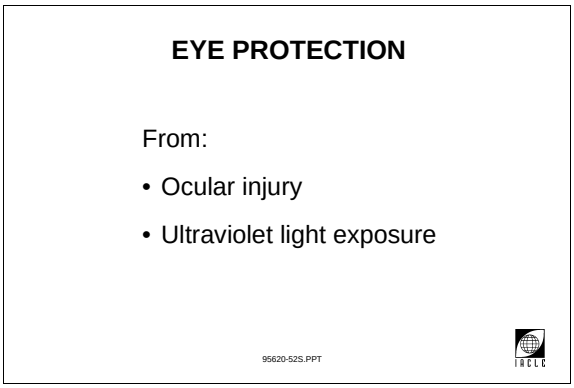
III Eye Protection

45



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Eye Protection

The potential for ocular injury from physical trauma during many sporting activities makes protective eyewear, with or without optical prescription, an important part of any general or sports vision contact lens practice.

In addition, the risk of photo-injury from ultraviolet (UV) light exposure in many outdoor sporting activities is an important consideration. Protection from UV radiation can often be accomplished, along with glare reduction for improved visual performance, by means of tinted and perhaps polarized ophthalmic lenses (sunglasses).

Eye protection in sports parallels general considerations of eye protection from physical and photo injury and is covered in Unit 9.3: The Working Environment and Contact Lenses.

IV Management of the Sporting Patient

46

MANAGEMENT OF THE SPORTING PATIENT

- Stress necessity of good contact lens care
- Improve regimen compliance by using simple care systems
- Emphasize personal hygiene and appropriate lens handling
- Do not compromise on follow-up care

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9L295620-63

Management of the Contact Lens-Wearing Sporting Patient

47

EDUCATING COACHES & TRAINERS

- Vision correction does not represent a 'defect'
- Athlete may try to hide vision problems
- Signs of visual problems:
  - squinting
  - headaches
  - eye rubbing
  - misjudgment of depth
  - inconsistent performance

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Educating Coaches and Trainers

Visual problems of athletes should be openly discussed with coaches and trainers. Athletes should be invited to seek professional care, especially if they are experiencing visual difficulties. Coaches and trainers should be educated to appreciate that athletes requiring vision correction are only limited in their performance when their vision is uncorrected.

Team personnel should be encouraged to have all players evaluated, perhaps during a team screening. All players should be made aware of the signs of visual disturbances (slide 47).

48

EDUCATING COACHES & TRAINERS

- Lens handling
- Lens insertion and removal
- Manage ocular emergencies
- Incorporate contact lens 'care kit' in medical supplies

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At least one team staff member should be instructed in the handling and care of contact lenses, as well as ocular emergency procedures. They should have a list of those athletes wearing contact lenses, as well as lens type and prescription details. Trainers and/or medical staff should be encouraged to incorporate a contact lens 'care kit', as well as spare contact lenses for their lens-wearing athletes, in their medical supplies.

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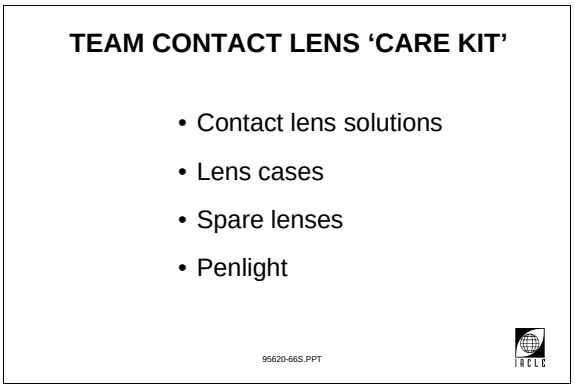

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Team Contact Lens 'Care Kit'

A useful 'on site' contact lens care kit for athletes might include the following:

- Contact lens solutions.
  - soft lens cleaner, storage and saline solution or a multi-purpose solution
  - RGP lens cleaner and conditioning/wetting solution
  - comfort or re-wetting drops
  - eye irrigation solution.
- Contact lens cases (for RGP and SCL lenses).
- Spare contact lenses.
- Contact lens accessories.
  - suction cup contact lens remover
  - hand cleaning towels
  - mirror
  - tissues.
- Penlight.

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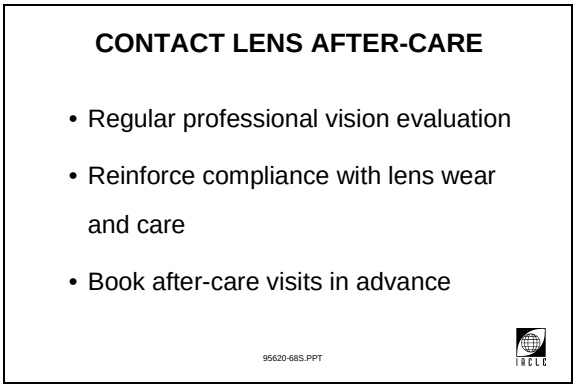

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Contact Lens After-Care

The after-care of the sports vision patient is not substantially different from that of other patients.

Regular professional eye and vision evaluations should be conducted, and compliance with lens wear and lens care ascertained. The appropriate procedures should be reinforced at every opportunity. Booking after-care visits in advance may be a prudent strategy to encourage attendance. Lens reorders, particularly for disposable and frequent replacement lenses, could be tied to after-care visits.

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Unit 9.3

(1 Hour)

Lecture 9.3: The Working Environment and Contact Lenses

Course Overview

Lecture 9.3: The Working Environment and Contact Lenses

I. Environmental Advantages of Contact Lenses
II. Environmental Hazards
III. Contact Lenses in the Workplace
IV. Protection From Eye Injury
V. Choice of Lenses
VI. Task Considerations
VII. Contact Lens Emergencies and First Aid

Lecture 9.3

(1 Hour)

The Working Environment and Contact Lenses

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II Potential Hazards and Contact Lens Wear 114
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II.B Mechanical Hazards 118
II.C Physical Hazards 120
III Dehydration Effects on Hydrogel Lens Fitting 129
IV Task Considerations 130
V Determining Advisability of Contact Lens Wear at Work 131
VI Contact Lenses in the Workplace 132
VII Failure to Remove Contact Lenses in Hazardous Environments 133
VIII Contact Lens Emergencies and First Aid 134

I Advantages of Contact Lenses Over Spectacle Lenses

1

ADVANTAGES OVER SPECTACLE LENSES

- Better performance in rain or mist
- Fewer breakages or losses
- No fogging with sudden change of temperature
- No reflections and distortion
- Easier use of ocular instruments

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2

ADVANTAGES OVER SPECTACLE LENSES

- No potential hazard from broken lenses
- Safer in unclean environments
- No perspiration problems
- Easier use of face masks and other industrial safety equipment
- No artificial visual field limitations

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3

ADVANTAGES OVER SPECTACLES

- No 'jack-in-the-box' effect
- No ring scotomata
- Improved visual acuity
- Use of plano safety lenses/glasses

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Advantages of Contact Lenses Over Spectacle Lenses

Contact lenses are prosthetic devices which offer a number of advantages over spectacle lenses for many occupations and activities.

II Potential Hazards and Contact Lens Wear

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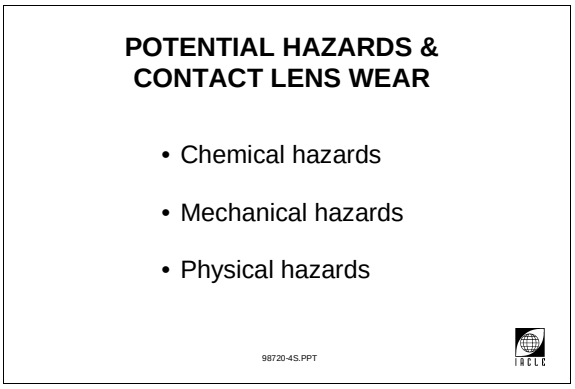

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Potential Hazards and Contact Lens Wear

Potentially, there are many environmental issues which may affect contact lenses and/or pose a threat to the safety of contact lens wear. When deciding to fit a patient with contact lenses, a knowledge and understanding of the occupational surroundings is necessary to the determination of the risks. Not all are obvious to the lay person and some can require considerable expertise. In some cases, knowledge drawn from disciplines outside contact lens practice is required.

Generally, environmental hazards are classified as chemical, mechanical or physical.

II.A Chemical Hazards

5

CHEMICAL HAZARDS

- Gases
- Fumes
- Vapours
- Liquids

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Chemical Hazards

Occupational health and safety standards usually require eye protection measures such as goggles and eyewash stations in workplaces such as laboratories where chemical hazards exist. Eye protection guidelines work with other protective measures in the workplace and should be strictly enforced.

Eyewash stations should be designed according to an accepted standard, e.g. ANSI (American National Standards Institute) recommendations. They should also be labelled clearly with an eyewash sign, and ease of access must be ensured under all circumstances.

Chemicals may be trapped behind rigid contact lenses or may be absorbed, concentrated and released into the tear film by hydrogel lenses.

Chemical Burns

It has not been shown that chemical burns experienced while wearing contact lenses are worse than burns from the same chemical applied directly to the eye.

It is possible that the presence of a lens on the eye could prevent adequate irrigation following a chemical injury. However, this is unlikely if safety goggles (slide 6) or spectacles (slide 7) are worn in conjunction with contact lenses.

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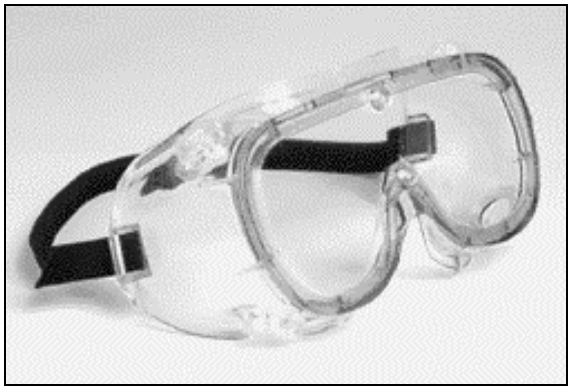

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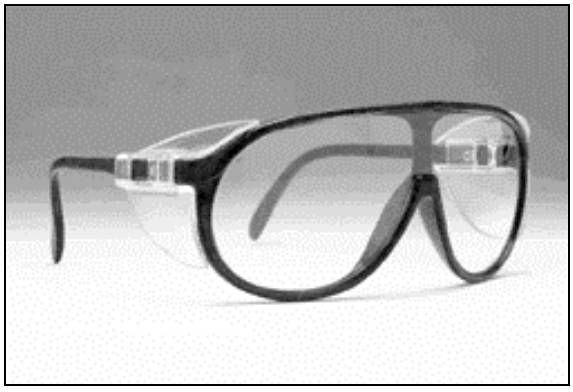

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CHEMICAL HAZARDS
FUMES & VAPOURS

Capable of binding to, and being absorbed into, contact lenses

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Chemical Hazards: Fumes and Vapours

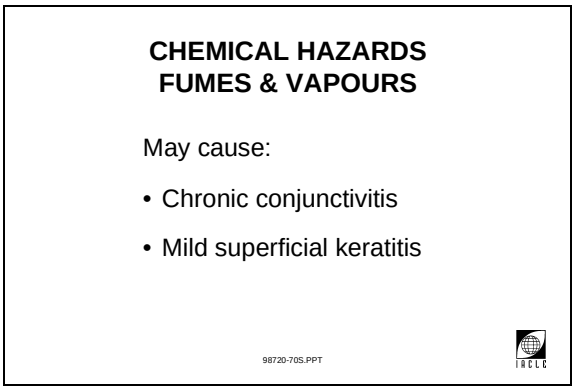
Ocular Impact and Response

Some noxious gases, vapours, fumes, aerosols and smoke have the ability to seep behind inappropriate or ill-fitting protective devices and affect the outer layers of the eye directly. As with other types of chemical injury, the ocular response varies with the concentration and the physical and chemical properties of the agent.

Highly toxic substances stimulate the protective mechanisms of:

- Blepharospasm, which limits access to the eye.

9



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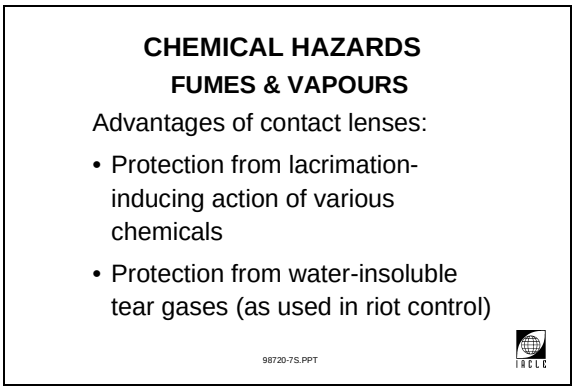

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- Lacrimation, which dilutes the concentration of the chemical.

Volatile organic compounds (VOCs) have been found to mix with reactive chemicals such as ozone and cause the 'sick building syndrome'. Patients working in environments where this is a problem may experience eye and airway irritation (Baker, 1997).

Chemical Hazards: Hydrogel Lenses

Water soluble gases, fumes and substances capable of binding to, or being absorbed into, hydrogel lens materials may cause prolonged exposure resulting in a potentially severe or chronic response. Such insidious long-term exposure may produce chronic conjunctivitis, possibly with a mild superficial keratitis.

It is unlikely that individuals subjected to such environments would be able to wear contact lenses comfortably. For example, contact lens-wearing beauticians and hairdressers, when exposed to the fumes of some beauty and hair care products which may adhere to the surface of contact lenses, are likely to discontinue lens wear if ocular irritation occurs regularly.

Chemical Hazards: RGP Lenses

Some oily mists which can be adsorbed onto hydrogel contact lenses causing permanent damage to them, may wash off rigid contact lenses. It is improbable that the corneal response to volatile substances would be significantly affected by the wearing of a rigid contact lens, since these substances would be eliminated rapidly by the tear flow they stimulate.

Advantages of Hydrogel Lenses

Many hydrogel contact lens wearers have reported that they are able to peel onions without the usual excessive tearing, thus demonstrating protection by the lenses against the lacrimation-inducing action of the allyl disulphides present in onions.

Some tear gases also tend to be insoluble in water, and hydrogel contact lenses have been found to be effective in protecting the eye from the tear gas CS (ortho-ChloroBenzylMalononitrile). It is also probable that hydrogel lenses will at least delay the effects of other tear gases such as CN (omega-ChlorAcetoPhenone) and OC (Oleoresin Capsicum or Capsaicin).

11

CHEMICAL HAZARDS
FUMES & VAPOURS

- Contact lenses create 'barrier' effect
- Contact lenses should not be used as a substitute for protective eyewear

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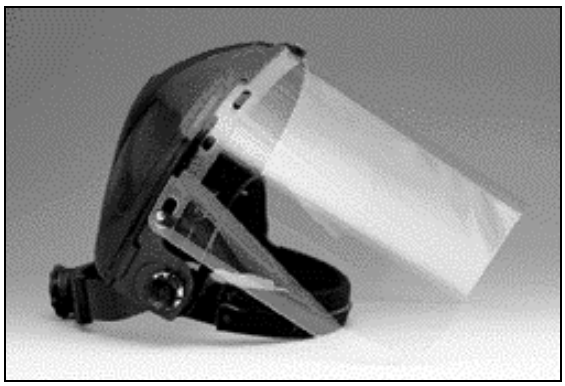
12



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Chemical Hazards: Chemical Splash

The accidental splashing of toxic chemicals into the eye is one of the most frequent causes of serious eye injury. Splash goggles are recommended even when face shields are worn (slide 12).

Studies of chemical (acid and alkali) splashes in the eyes, with and without contact lenses, have shown that wearing lenses may offer some eye protection and that contact lenses do not worsen the condition. It has been postulated that chemicals may not be trapped behind the lenses. In fact, the blepharospasm induced by the chemical irritation may act to tighten the lens against the cornea, making the lens act as a barrier.

Contact lenses should not be used as a substitute for protective eyewear where there is a chemical hazard. However, a contact lens wearer with appropriate protection is at no greater risk than a non-contact lens-wearing colleague in the same circumstances.

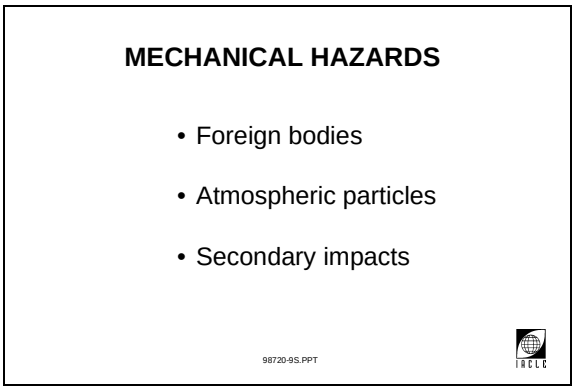
The protection provided by high plus hydrogel lenses against the effects of 20% and 40% HCl (hydrochloric acid) may reduce corneal damage by as much as 75%. In one reported case, splashed boiling acid from a test tube produced a punctate burn on the cheek and 'pit-marked' a corneal lens but had no effects on the cornea.

Workers in chemically hazardous situations must be reminded that even seemingly trivial eye injuries have potentially disastrous results and that established emergency procedures must be followed. An incident on record tells of a worker who did not irrigate their eyes after a chemical splash for fear of losing their contact lenses.

A laboratory inspection checklist such as the Chemical Safety Laboratory Checklist from Michigan State University (ORCBS, 1997 - see Appendix A) is useful for maintaining safety standards. Making patients aware of these standards in their workplace also teaches them to be responsible for their own safety.

II.B Mechanical Hazards

13



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Mechanical Hazards

Mechanical injuries to the eye result from contusion and concussion, foreign bodies (which may be superficial or perforating), exposure to atmospheric dust and particles, and wounds (which include abrasions, cuts and lacerations). These may occur as isolated incidents or in combination.

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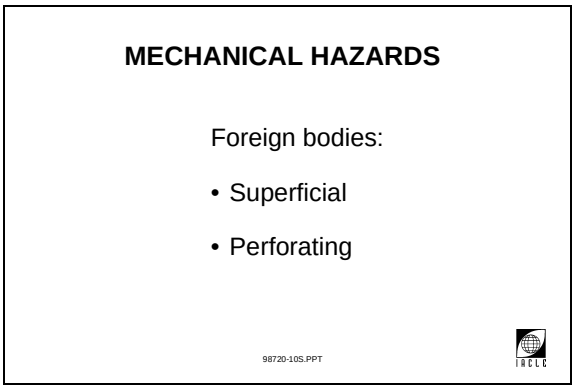

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Mechanical Hazards: Foreign Bodies

A superficial corneal foreign body is one of the most common minor ocular injuries. A foreign body may abrade or penetrate the cornea or sclera or actually perforate the globe.

The symptoms of pain, foreign body sensation and lacrimation are readily alleviated by removal of the offending particle(s).

While foreign bodies may be trapped behind rigid lenses, this rarely happens with hydrogel lenses unless the debris is inserted with the lens.

15

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Protection Afforded by Contact Lenses

Both rigid and hydrogel lenses provide protection from airborne metal particles. The corneal protection afforded by a contact lens depends on the thickness and rigidity of the lens.

Hydrogel lenses offer little protection to an eye hit by a larger sharp projectile, yet the presence of a low water content lens increases the eye's resistance to corneal perforation by about 50% (32 mJ of energy required, compared with 21 mJ for the unprotected eye).

Hard lenses shatter when energy levels reach 8.3 mJ. Splinters of plastic may enter the cornea, thereby introducing a complicating factor. However, a case has been reported in which a rigid lens wearer was attempting to reduce the length of a screw using a hammer and chisel. The screw broke and flew into the eye. The lens was badly fractured but the eye sustained only a slight central abrasion. Had the lens not been present, it is probable that the eye would have been penetrated. In a similar accident, an aircraft riveter was struck in the eye with a rivet. There was a gouge in the lens but the eye sustained no damage.

For a comprehensive review of cases (total 128) confirming the role of contact lenses in apparently protecting the eyes in the absence of more

appropriate eye protection, see Rengstorff and Black (1974). For a typical case report, with an illustration of a shattered rigid lens and the offending projectile, see Nathan (1981).

Contact Lenses and Mechanical Hazards: Conclusion

Eyes, whether wearing contact lenses or not, should be protected against hazardous flying objects. If the situation is unsafe for the naked eye, it should be regarded as being equally unsafe for the lens-wearing eye. Any protection afforded by contact lenses is a bonus, not a substitute for proper protection.

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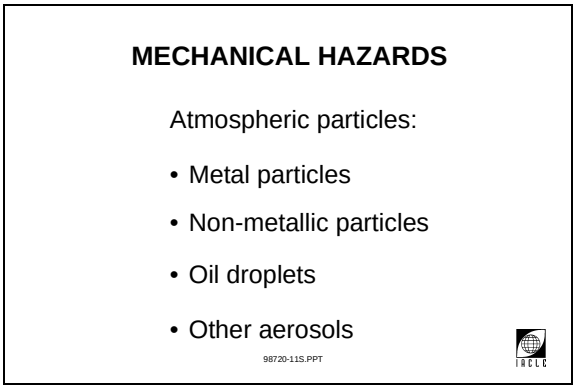

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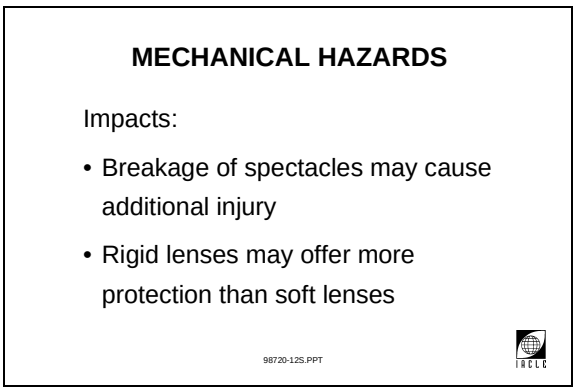
Mechanical Hazards: Atmospheric Particles

It is possible for hydrogel contact lenses to sustain the impact of a metal particle or exposure to oil droplets without the eyes being harmed and without the wearer complaining.

Sometimes it is possible to wear hydrogel lenses safely in environments which generally may contraindicate the use of RGP lenses e.g. transiently dusty, enclosed air spaces.

17



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Mechanical Hazards: Impacts

Contact lenses may offer better protection from impacts or blows than spectacles. This is because any blow about the face is liable to strike the spectacles and break the frame and/or lenses which may, in turn, injure the eye. This is particularly true of missiles flying towards the eye.

Potentially, a glancing blow across the brow and cheek causes injury from contusion by/or breakage of the spectacles.

In the case of a more direct impact on the eye, a rigid lens may offer more corneal protection than a soft lens, particularly from a sharp object.

II.C Physical Hazards

18

PHYSICAL HAZARDS

- Radiation
- Barometric pressure
- Temperature
- Humidity
- Wind
- Air pollution
- Vibration and acceleration stresses
- Cosmetics

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Physical Hazards

There are a wide range of hazards which are neither chemical nor mechanical, including those listed on slide 18. Each of these is discussed below.

19

PHYSICAL HAZARDS
RADIATION

- Ionizing
- Non-ionizing

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Physical Hazards: Radiation

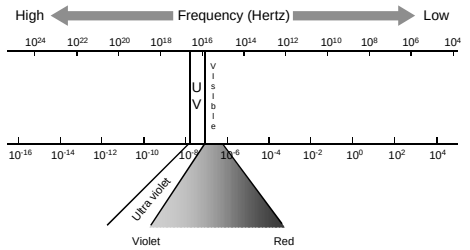
Natural background radiation emanates from cosmic, solar and terrestrial energy sources. Radiation energy is either ionizing or non-ionizing, with the former (high energy) posing a possible hazard to health because of the decay it causes in structures such as tissue cells.

Ionizing radiation occurs at the high frequency end of the energy spectrum. It produces electrically charged particles in materials (atoms) it strikes by removing tightly bound electrons from their orbits (ionization). Types of ionizing radiation and their sources are:

- X-rays and γ (gamma) rays (solar).
- α (alpha) particles (terrestrial - radioactive elements).
- β (beta) particles (terrestrial - radioactive elements).
- Neutrons (terrestrial - radioactive elements).
- Cosmic radiations (cosmic - outer space).

20

RADIATION ENERGY SPECTRUM



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Non-ionizing radiation belongs to the lower frequency end of the energy spectrum and is insufficient to produce any ionization. The following types of non-ionizing radiation in the order of their wavelengths (descending) are discussed in the sections below:

- Ultraviolet (UV-A, UV-B, UV-C).
- Visible light.
- Laser (Light Amplification by the Stimulated Emission of Radiation).
- Infrared (IR).
- Microwaves.
- Ultrasound/radiowaves.

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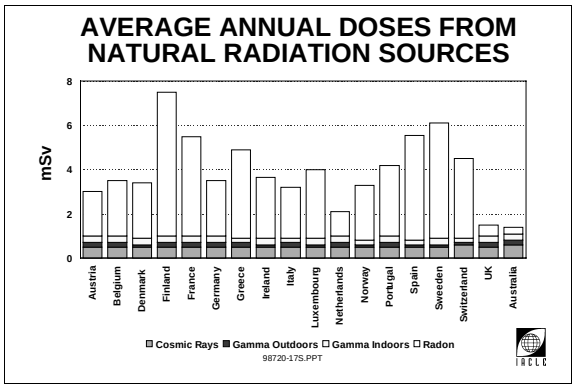

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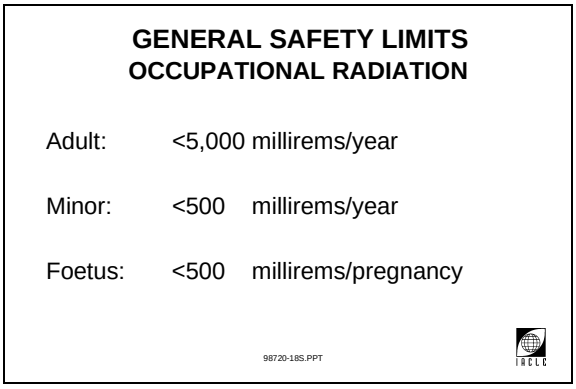

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Physical Hazards: Radiation

General Safety Limits

Humans are exposed to natural radiation every day, everywhere. Any cellular damage it causes is usually quickly repaired by the body (Busby *et al*, 1996). US Federal standards (1994) for permissible levels of occupational radiation exposure to the whole body (including natural background and medical radiation) set the following limits (Masse, 1997; slide 23):

- Adult: The occupational limit of exposure is 'as low as reasonably achievable; however, not to exceed 5,000 millirems more than the natural radiation exposure of 300 millirems per year and any medical radiation.'

- Minor: For a person under 18 years of age, limitation to occupational radiation exposure is 500 millirems per year plus the limit to natural and medical radiation.

- Foetus: The most recent US Federal regulations established radiation exposure limits for the foetus or embryo of a woman exposed to radiation at work to be 500 millirems for the pregnancy or 50 millirems per month.

  Note: Since 1980, the SI unit for radiation exposure is the sievert (Sv).
  1 Sv = 100 rem = 1 joule/kg.
  The rem, (Röntgen equivalent man (or mammal)), is a quantity of ionizing radiation imparted to living matter with a predefined effectiveness.

Contact Lenses

The absorption characteristics of a contact lens determine whether the lens provides any protection against a particular form of radiation.

Specific considerations for contact lens wearers in relation to radiation exposure are discussed later.

Contact Lenses: Harmful Effects

There is no scientific (nor optical) rationale to support the notion that a contact lens is capable of concentrating any waveband of electromagnetic radiation (EMR) onto the cornea.

23

PHYSICAL HAZARDS
IONIZING RADIATION

- Soft x-rays and α-particles
- High energy β-radiation
- γ-rays and X-rays

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Physical Hazards: Ionizing Radiation

Soft X-rays, and α-particles have low penetrating capabilities. Consequently, they produce damage to the superficial corneal and conjunctival epithelia with associated hypoaesthesia, hyperaemia and oedema similar to the response to UV-C, but with a longer latent period.

Any contact lens provides some protection against such irradiation and also against low energy β-radiation. Higher energy β-radiation may damage the corneal epithelium and endothelium resulting in corneal oedema. The presence of a contact lens on the eye would not influence the ionizing response.

Appropriate protection is required from therapeutic γ (gamma) rays and X-rays used in and around the eye.

24

PHYSICAL HAZARDS
ULTRAVIOLET RADIATION

A UV-absorbing contact lens provides full UV protection to the area of the anterior eye it covers

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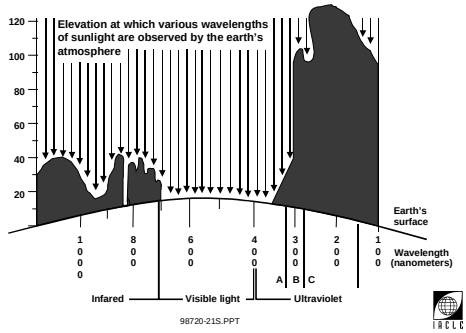
25

ULTRAVIOLET RADIATION



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Physical Hazards: Non-Ionizing Radiation

Ultraviolet

The ultraviolet (UV) end of the energy spectrum is divided into three wavebands:

- UV-A (315 - 400 nm) is transmitted because it is not absorbed by ozone in the atmosphere. It does not cause any adverse biological effects unless applied in pure doses by artificial sources.
- UV-B (290 - 315 nm) is mostly absorbed by the ozone gas in the earth's stratosphere. However, some reaches the earth and can cause damage at the molecular level, including genetic damage, skin melanoma, erythema and cataract. UV-B absorption is dependent upon latitude, altitude/elevation, cloud thickness and the proximity to an industrial area. Elevations at which various wavelengths of sunlight are absorbed by the earth's atmosphere are shown in slide 26. The US National Weather Service and the Environmental Protection Agency have developed an Ultraviolet Index for safety measures (EPA, 1995; slide 27).
- UV-C (220 - 290 nm) is the most dangerous UV band. However, it is completely absorbed by ozone and oxygen.

Protective goggles/spectacles such as those shown in slide 27 provide 100% UV protection. Most contact lens materials provide little protection from UV radiation. In recent years, a number of rigid and hydrogel contact lenses have been released which offer various levels of protection from UV according to the absorption characteristics of the incorporated UV absorber and the thickness of the lens.

Hydrogel contact lenses which absorb all incident radiation of experimental wavebands have been shown to provide complete protection to the area of the cornea covered. Evaluation of the protection afforded by a UV-absorbing RGP lens has shown that the area of the cornea covered by the lens

26

EPA ULTRAVIOLET INDEX

Exposure Category	UV Index Value	Precautions
Minimal	0-2	hat
Low	3-4	hat, sunscreen (15+)
Moderate	5-6	hat, sunscreen (15+) shady areas
High	7-9	hat, sunscreen (15+) shady areas
Very High	10+	stay indoors as much as possible, other precautions when outdoors

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27

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during irradiation was spared, while the exposed areas of the cornea and conjunctiva were damaged.

28

PHYSICAL HAZARDS
VISIBLE LIGHT RADIATION

- No significant difference in contrast sensitivity
- UV-absorbing lenses provide better visual comfort
- Lenticular fluorescence produces glare and photophobia when ratio between ambient UVA and visible light is high

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Physical Hazards: Non-Ionizing Radiation

Visible Light

Contact lens wearers frequently complain of increased photophobia when wearing their lenses. The reasons for this are unclear. The light incident on the cornea can be calculated, using Fresnel's equation, to be approximately 8% higher than with spectacle lenses. Since this increase is insignificant when the dynamics of retinal adaptation are considered, it is unlikely to be the causal factor.

While no significant differences in contrast sensitivity between spectacle lens wearers, UV-absorbing and non-UV-absorbing contact lens wearers are apparent under laboratory conditions, subjects wearing UV-absorbing lenses are significantly more comfortable visually and experience less glare in snow conditions on sunny days. This suggests that when the ratio of ambient UV-A to visible light is high, ocular lenticular fluorescence will be sufficient to produce veiling glare and photophobia.

29

PHYSICAL HAZARDS
LASER RADIATION

- UV < 290 nm and IR > 1400 nm
- Neodymium
- Argon, Krypton, He-Ne and Ruby laser

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9L398720-24

Physical Hazards: Non-Ionizing Radiation

Lasers

The transmittance of laser light by the ocular media corresponds to the transmittance of incoherent light of the same wavelength. Thus, transmittance (and absorption) studies of the human eye may be used to predict the action of a laser on a given ocular tissue. Similarly, the absorption data for contact lenses may be employed to determine whether a given lens contributes to eye protection.

The high absorption of UV shorter than 290 nm and IR beyond 1400 nm by the anterior corneal structures, results in photoablation or 'burning' of the cornea by lasers with sufficient power, e.g. excimers, CO and CO_2.

Neodymium, YAG and Argon lasers have the ability to damage intraocular structures, intentionally or unintentionally. Argon, Krypton, He-Ne and Ruby laser light reach the retina and some of these lasers are used for laser coagulation of the retina and other structures. IOLs have been damaged during laser capsulotomy. Most contact lens materials will absorb some incident excimer, CO or CO_2 laser radiation. However, the power would probably result in lens disintegration.

30

PHYSICAL HAZARDS
INFRARED RADIATION

- Drying
- Tighter fitting
- Instill sterile saline or re-wetting solution before lens removal

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9L398720-25

Physical Hazards: Non-Ionizing Radiation

Infrared (IR)

Infrared heaters used in the automotive and other industries for drying paint, produce very little or no visible light and raise the temperature of the corneal surface whether or not a soft HEMA-type lens is worn. Such exposure to infrared radiation can cause hydrogel lenses to dry although corneal damage is not associated with this effect.

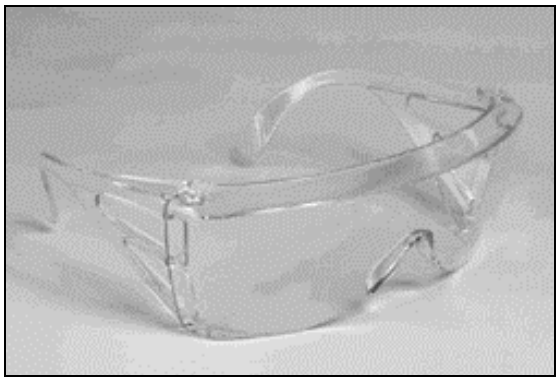
Ultraviolet (UV)

Welding arcs can have the same effect as exposure to IR. However, such exposure should never occur, since complete protection from this effect is provided by the use of an appropriate welding filter (slide 31).

In the unlikely event of a hydrogel contact lens wearer being exposed to arcs for long periods of time without protective equipment, the lenses may dry a little and tighten on the eye. Instillation of a few drops of a sterile saline (or a non-hypertonic re-wetting solution) will rehydrate the lenses and assist lens removal.

In routine contact lens practice, the urban myth of contact lens and cornea 'bonding', as a result of unprotected exposure to welding arcs or switchboard arcing, needs to be refuted regularly. The 1967 incidents which gave rise to the myth were reported incorrectly. Despite refutation from a number of experts over many years, the myth persists.

31



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32

PHYSICAL HAZARDS
MICROWAVE RADIATION

- EHF and UHF microwaves do not cause damage to contact lens wearers
- Some drying may occur

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Physical Hazards: Non-Ionizing Radiation
Microwaves

At the molecular level, the principal effects of microwaves on ocular tissues *in situ* are vibration and rotation, resulting in a thermal response. Distribution and absorption of microwave radiation is dependent on its wavelength, the size and shape of the total structure (or subject) and the chemical nature of the tissue irradiated.

Extra high frequency (EHF) and super high frequency (SHF) radio waves produce superficial injury to the cornea and adnexa. Even ultra high frequency (UHF) damage is confined to the anterior segment.

No microwave damage to the eye has been reported amongst workers wearing contact lenses. One may reasonably speculate that the superficial heating effect on high water content lenses would result in similar drying to that produced by infrared radiation. Also, theoretical considerations negate the possibility of microwaves 'welding' a contact lens to the cornea or selectively evaporating the pre-corneal/post-lens tear layer.

33

PHYSICAL HAZARDS
ULTRASONIC RADIATION

No effect on the eye

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9L398720-27

Physical Hazards: Non-Ionizing Radiation

Ultrasound

The presence of a contact lens on the eye will affect an ultrasonogram in accordance with the acoustic impedance and absorption of the lens/lens material. No increased risk is created and there have been no reports of corneal damage resulting from airborne ultrasound. Ultrasonic pachometry is used routinely in pre and post-surgery eye examinations.

34

PHYSICAL HAZARDS
BAROMETRIC PRESSURE

- Climbing
- Diving

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9L398720-28

Physical Hazards: Barometric Pressure

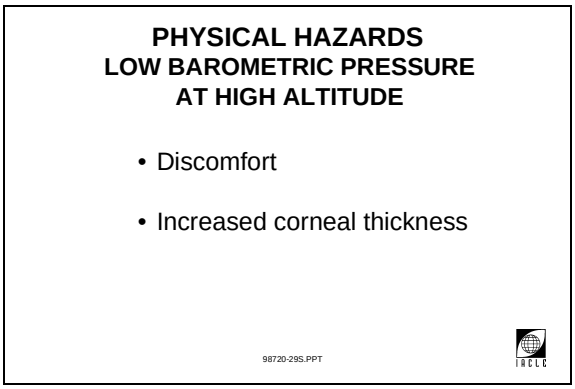
Many patients want to wear their contact lenses at high altitudes, when flying or climbing (low pressure) and during a variety of underwater activities (high pressure).

Low Barometric Pressure

Discomfort among some contact lens-wearing air travellers may be due to the effect of low atmospheric pressure resulting in relative hypoxia (the pressure in a modern commercial aircraft corresponds to a modest 2,000 -3,000 m of altitude). However, it is more likely to be due to the low relative humidity (RH) in aircraft cabins.

The physiological responses of the cornea to hydrogel contact lens wear (e.g. corneal thickening) are greater at high altitudes (low levels of atmospheric oxygen). Two climbers of Mount Everest wore their continuous wear hydrogel lenses for over 50 days up to an altitude of 7,925 m with no observed corneal problems.

35



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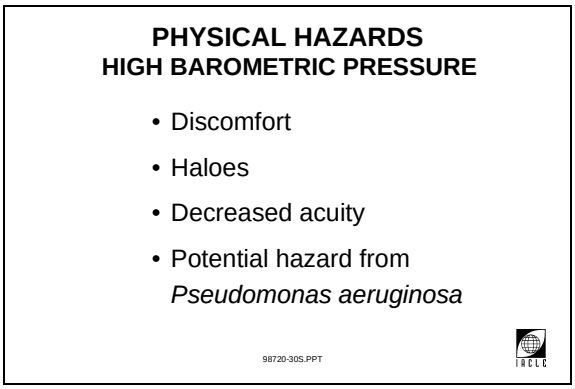

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High Barometric Pressure

With diving, despite adherence to standard decompression schedules, it is not unusual for hard (PMMA) contact lens wearing divers to complain of ocular discomfort, haloes and decreased acuity immediately after decompression. These symptoms may persist for several hours.

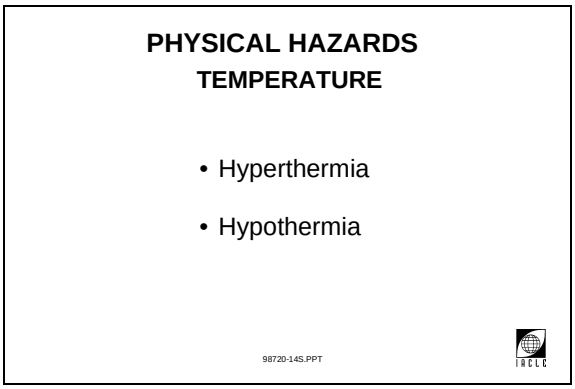
Small bubbles may form beneath hard (PMMA) lenses as divers rise to the surface from great depths (>21 m). Such bubbles may coalesce as the surface is approached and disappear after 30 minutes at sea level leaving nummular patches of corneal epithelial oedema. These lesions, presumed to be secondary to the trapping of nitrogen between the epithelium and the lens, may persist for up to two hours.

Such bubbles do not seem to form in the pre-corneal tear film if no contact lenses are worn, but may occur under hydrogel lenses and RGP lenses during decompression in a hyperbaric chamber.

Usually, contact lenses are not displaced during dives, suggesting that it is relatively safe for military and sport divers to wear contact lenses in lieu of the cumbersome modifications otherwise necessary to diving masks.

Hydrogel lenses are preferable for divers and they may be used with care by experienced divers for sports and commercial diving. However, due to the potential hazard from *Pseudomonas aeruginosa*, which apparently thrives on the inside walls of pressure chambers, contact lenses should not be permitted for saturation diving (Bennett, 1984).

37



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Physical Hazards: Temperature

Hyperthermia

The air temperature in a sauna may rise as high as 80 - 100°C without affecting contact lens wear. In a dry sauna, evaporation of the tear film and drying of hydrogel contact lenses may be partially managed by increasing the blink rate.

Contact lenses would not have a significant effect on the severity of high temperature burns. Haptic or hydrogel lenses may offer some protection to the critical limbal region in moderate thermal burns, however such protection would be short-term only.

Hypothermia

Contact lenses may be acceptable and even offer protection to eyes from wind-driven ice and snow in cold, especially extremely cold, environments.

38

PHYSICAL HAZARDS
HUMIDITY

- No effect on cornea from high humidity
- Low humidity causes drying especially with thin, high water lenses
- Corneal dessication
- Comfortable humidity range: 40% – 60%

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Physical Hazards: Humidity

Under normal circumstances, neither temperature nor high relative humidity (RH) are important factors for contact lens wearers. However, **low RH** is often associated with drying symptoms, particularly with hydrogel lenses. Very thin, high water content contact lenses leave the cornea particularly susceptible to changes in humidity. This type of lens dries and distorts, thereby contributing to corneal desiccation in conditions of low RH. Non-contact lens wearers, especially those with dry eye syndromes, also experience increased symptoms under conditions of low RH.

The optimum humidity range for comfort is between 40% and 60%.

It has been suggested that the low cabin RH experienced in aircraft contributes more than other environmental factors to the discomfort of hydrogel contact lenses while flying.

RH has been found to decline rapidly, e.g. <28% in <30 minutes (Williams, 1992). Typically, RH depends on location within the aircraft and the number of passengers at that location. Rocher (1995) presented figures of 11% in economy, 7% in business class, 5% in first class and only 2% in the cockpit after 'hours of flying'.

Useful strategies for improving comfort in a dry environment are frequent lens replacement, 'loose' fitting techniques and the use of enzymatic cleaners to optimize the lens surface wettability.

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PHYSICAL HAZARDS

- Wind:
  - drying
  - tearing
- Air pollution

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Physical Hazards: Environmental

Environmental elements have been reported to cause discomfort for contact lens wearers:

Wind can be expected to have two effects on the eye, drying and stimulation of tearing. Wind and other air currents may also exacerbate problems with dust.

Air pollution may cause problems for contact lens wearers depending upon the nature of the pollution. Airborne pollution may include the chemical hazards of fumes and vapours, and the mechanical hazards of atmospheric particles, as discussed previously.

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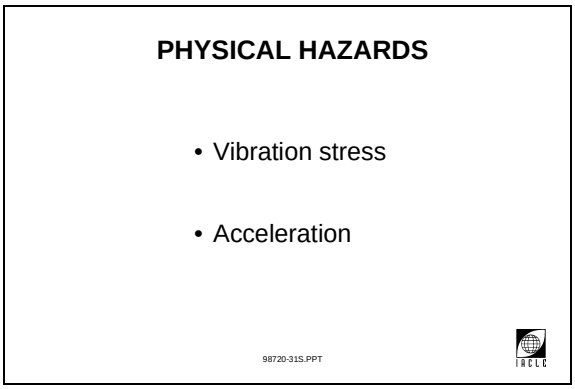

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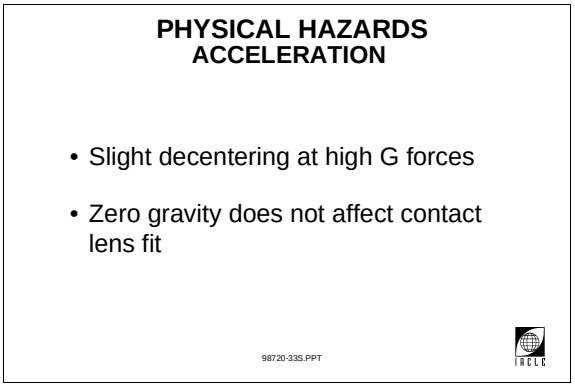

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Physical Hazards: Occupational/Recreational

Occupational/recreational factors such as vibration stress and acceleration also influence lens performance.

Vibration stress may be encountered while operating machinery such as pneumatic drills or chain saws, or while travelling in or on modes of transportation ranging from low capacity motorcycles to aerospace vehicles. High frequency (rapid) vibration will reduce visual acuity depending on frequency and compensatory or associated involuntary head and eye movements. Considering the relative stability of a contact lens and its closer proximity to the nodal points of the eye less visual disturbance might be anticipated with contact lens wear than with spectacles, especially for higher corrections.

Contact lenses do not dislodge from the cornea with high **acceleration**. While lenses may decentre slightly as a consequence of G forces, visual acuity is not significantly affected. Jet fighter pilots may be exposed to acceleration forces of up to +12G for brief periods during combat manoeuvres, yet hydrogel contact lenses have been worn successfully under these circumstances. In addition, hydrogel contact lenses have been successfully worn in the zero gravity environment of space flight. This is not unexpected, since gravity has little role in contact lens location.

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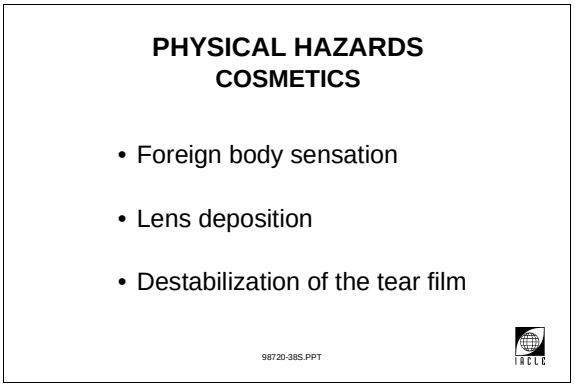

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Physical Hazards: Cosmetics

The particles and other constituents of **eye and skin cosmetics** may find their way onto the eyelid margins and into the tear film, potentially causing problems such as foreign body sensations, deposition on contact lenses and destabilization of the tear film.

The products used to remove facial and eye make-up may disrupt the tear film or have a negative effect on contact lens surface wetting.

The adhesives used in applying false eyelashes may damage contact lens surfaces.

III Dehydration Effects on Hydrogel Lens Fitting

44

CAUSAL FACTORS OF LENS DEHYDRATION

- Environment
- Patient factors
- Tear characteristics
- Lens factors

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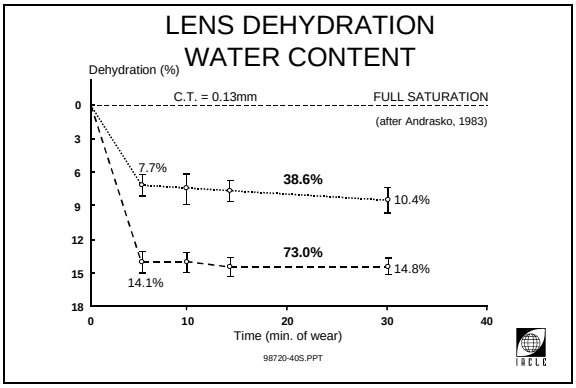

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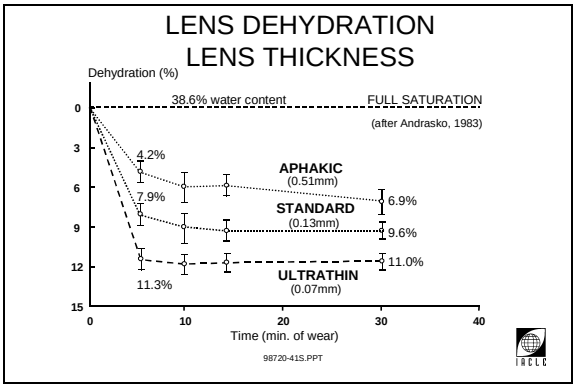

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47

DEHYDRATION

Effects of dehydration can be summarized as:

- Instability and thinning of the pre-lens tear film
- Reduced wettability and shorter tear break-up time
- Tighter soft lens fit with reduced tear exchange
- Increased lens awareness
- Reduced acuity due to altered lens front surface properties
- Feelings of 'dryness'

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Causal Factors of Lens Dehydration

Hydrogel lens dehydration affects lens movement, lens fitting, patient comfort and physiological performance.

Several factors interact to dehydrate the lens. They are generally divided into the following groups:

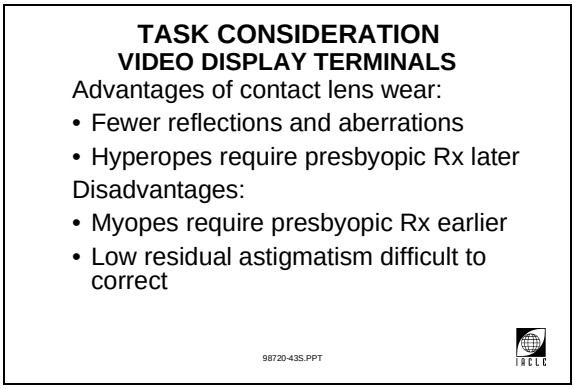
- Environmental.
  Lens dehydration is affected by environmental factors such as temperature, humidity, and wind speed. All hydrogel lenses undergo dehydration in low humidity environments.
- Patient characteristics.
  Patient characteristics that may influence lens dehydration include efficiency of blink and blink rate, length of wearing time and visual tasks being performed. Reduced blinking causes drying of lenses. It is characteristic of people engaged in near or distance visual tasks requiring concentration.
- Tear characteristics.
  In addition to other patient factors, poor tear quality and quantity characterized by an unstable tear lipid layer contribute to lens dehydration.
- Lens characteristics.

  The environment may have a greater effect on lenses of higher water content since these lenses tend to undergo more dehydration than lenses of lower water content. However, Pritchard and Fonn (1995) showed no direct relationship between water content and changes in water content during lens wear (e.g. at 7 hours of wear, etafilcon A, 58% dehydrated significantly more than surfilcon A, 74%). Thinner lenses undergo more dehydration than thick lenses (Andrasko, 1983; slides 45 and 46).

  Other variables include polymer type, ionicity, lens form and lens surface quality.

IV Task Considerations

48



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Task Considerations

Video Display Terminals

The Video Display Terminal/Unit (VDT/VDU) user who wears contact lenses experiences fewer reflections and none of the aberrations associated with spectacle lenses.

However,

- Myopic incipient presbyopes require a presbyopic addition earlier (see Module 2, Lecture 2.3).
- Small amounts of residual refractive astigmatism are often ignored, despite findings that these may contribute to VDT user discomfort.
- Problems of binocularity may be treated as being insignificant, particularly with a monovision correction.
- VDT tasks requiring concentration may reduce the blink rate, which in turn can reduce lens movement and increase drying effects.

V Determining Advisability of Contact Lens Wear at Work

49

DETERMINING ADVISABILITY OF CONTACT LENS WEAR AT WORK

- Is there an actual eye hazard ?
- Does the wearing of a contact lens place the eye at greater risk than a naked eye ?
- Does the necessity for contact lens removal increase the risk to the eye or increase its susceptibility to insult ?

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50

DETERMINING ADVISABILITY OF CONTACT LENS WEAR AT WORK

- Is the risk different for various contact lens designs and materials ?
- Are there risks associated with contact lens removal on the job ?
- Do contact lenses decrease the effectiveness of other safety strategies ?

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Determining Advisability of Contact Lens Wear at Work

Questions to ask when considering the advisability of wearing contact lenses in a given work environment are listed in slides 49 and 50.

The question of whether or not contact lenses increase the risk of severe ocular trauma in the event of an accident involving the eyes, has been posed ever since contact lenses became widely available.

It is a common misconception that if a patient is injured while wearing contact lenses, the lenses contribute to the extent of the injury. There is no evidence to support such a claim. The evidence which does exist shows the opposite, i.e. in most cases, wearing contact lenses is far safer than wearing spectacles.

In addition to considering the nature of the work to be undertaken, some thought needs to be given to the place of work as well. In enclosed interior spaces where poor air quality contributes to the so-called ‘sick building syndrome’ it is logical to anticipate that factors involved (temperature, relative humidity, air movement, CO_2 levels and airborne pollutants) could also affect contact lens wear adversely.

VI Contact Lenses in the Workplace

51

RECOMMENDATION FOR CONTACT LENS WEARERS IN INDUSTRY

Silberstein, 1962

- Selective appointment to jobs and tasks in hazardous environments
- Elsewhere, unrestricted employment providing appropriate supervision given
- Adequate training in contact lens use and industrial eye safety

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Contact Lenses in the Workplace

Recommendations for hard contact lens wearers in industry were prepared by Silberstein (1962) and are still appropriate:

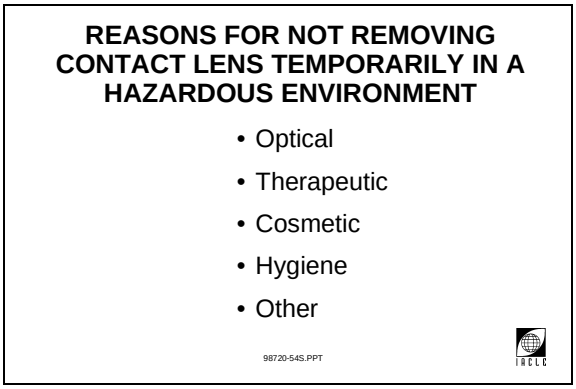
1. Contact lens wearers in industry should not be permitted to work in certain jobs and particular environments that are specifically, and peculiarly, hazardous to them. Such situations are rare. One possible example is an environment from which a gaseous or vapourous irritant accumulates in a soft contact lens, and leaches from the lens subsequently, thereby extending the eye's exposure to the irritant. The initial delay in detecting the irritant due to the all-enveloping nature of soft lenses may necessitate lens removal once the problem becomes apparent. Arguably, the eyes should not be exposed to such an environment, with or without contact lenses.
2. In the field of visual rehabilitation, contact lenses offer unique advantages to industrial employees as well as to others and they can be used successfully in full-time, unrestricted industrial employment providing administrative, medical and safety supervision is exercised.
3. Contact lens wearers can be employed safely and efficiently in a wide variety of industrial positions, provided they are adequately trained in the use of their lenses and they observe normal industrial eye-safety practices. Issues peculiar to specific lens types, e.g. the possibilities of RGP lens decentration and/or dislodgement, need to be taken into account when considering particular industrial situations.

The wearing of eye protection in eye-hazardous areas should be enforced in accordance with regulations. Safety regulations enforced in the workplace should allow the safe wearing of contact lenses on the job. Suitable facilities for contact lens wearers should be available in the work environment, including clean areas with sink, soap, towels and mirror where workers are able to wash their hands and remove/replace their lenses.

Employers who formulate regulations indiscriminately banning contact lens wear in the work environment may be unfamiliar with the nature and performance of contact lenses in different environments. Such actions are not an indictment of contact lenses but rather an indication of the need for additional education for all involved.

VII Failure to Remove Contact Lenses in Hazardous Environments

52



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Why Patients Might Not Remove Their Contact Lenses in Hazardous Environments

Practitioners need to educate their patients as to safe wearing environments and practices. Patients should also know about the occupational health and safety practices in their particular workplace. Patients tend to be dependent on their contact lenses and there are many reasons why an individual would choose not to remove his or her contact lenses in the workplace or in an environment where contact lens wear is contraindicated. These reasons may be optical, therapeutic, hygienic, cosmetic or simply a failure to accept or recognize the potential risk. Practitioners should be aware of these reasons and discuss the safest course of action in a hazardous environment with their patients.

Optical

- No alternate spectacle correction.
- Spectacle blur resulting from long-term wear of PMMA lenses (this is less of a problem with RGPs).
- Oblique astigmatism.
- Irregular astigmatism.
- Change in depth perception.
- Change in spatial localization.

Therapeutic

- Albinism.
- Aniridia.
- Aphakia - monocular and binocular.
- Keratoconus.
- Nystagmus.
- Bandage lens.
- Ptosis.

Cosmetic

- Prosthesis.
- Cosmetic shells.
- Scars.

Hygiene

- No access to clean facilities.
- No hand care facilities.
- No lens care products.

Other

- Overly rigid adherence to wearing schedule.
- Lenses used to aid colour differentiation.
- Unable to remove lens due to poor instruction.
- Ignorance of hazards.

VIII Contact Lens Emergencies and First Aid

53

CONTACT LENS EMERGENCIES AND FIRST AID

- Exposure to fumes or vapours
- Chemical splashes/spills
- Foreign bodies
- Dust in eyes
- Blunt trauma
- Uncomfortable lenses, red or sore eyes

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Contact Lens Emergencies and First Aid

Lens wearers, their co-workers and supervisors (especially those responsible for first aid) should be aware of appropriate first aid measures for contact lens-related emergencies.

Simple and specific instructions such are listed in this section should be available in work and home first aid cabinets.

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CONTACT LENS EMERGENCIES AND FIRST AID

- Tight/adherent lenses
- Dry eyes or environments
- Exposure to welding or other electrical arcs
- Blurred vision
- Lost or displaced lenses

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55

CONTACT LENS EMERGENCIES AND FIRST AID

Exposure to noxious fumes or vapours:

- Remove, clean and rinse lenses
- Reinsert if no irritation experienced
- Seek practitioner advice before reinsertion if irritation experienced, or substance known to cause irritation

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Contact Lens Emergencies and First Aid:

Exposure to Noxious Fumes or Vapours

Either as a result of eye irritation, or in anticipation of an adverse response to a known eye irritant, lenses should be removed for a thorough cleaning and rinsing.

If no eye irritation was experienced, the lenses may be reinserted providing past experience does not contraindicate such action.

Seek professional advice if doubts exist.

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CONTACT LENS EMERGENCIES AND FIRST AID

Chemical splashes:

- Irrigate continuously (esp. if an alkali)
- Referral

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Contact Lens Emergencies and First Aid:

Chemical Splash

The eye(s) should be irrigated with copious amounts of water while holding the lids apart. No-one should worry about losing the contact lens(es). If the lens(es) remains after initial flushing remove it (them) or slide it (them) onto the conjunctiva and re-irrigate, then refer to emergency professional management. For caustic splashes, irrigation should begin immediately and be continued during transportation.

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CONTACT LENS EMERGENCIES AND FIRST AID

Foreign bodies:

- Remove lenses
- Examination prior to reinsertion

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Contact Lens Emergencies and First Aid:

Foreign Bodies

Remove the lens and irrigate the eye if indicated. If the eye remains uncomfortable, assume that the foreign body has remained in the eye. If vision is blurred, the eye should be examined by an eyecare practitioner prior to continuation of lens wear. All cases of high-speed flying particles entering the eye should be carefully evaluated professionally.

58

CONTACT LENS EMERGENCIES AND FIRST AID

Dust in eyes:

- Remove lenses
- Clean lenses
- Consult practitioner

98720-60S.PPT

9L398720-60

Contact Lens Emergencies and First Aid:

Dust in Eyes

Remove the contact lenses and irrigate the eyes. Clean lenses and reinsert them if the eyes are not red or uncomfortable. If the eyes are red or reinsertion causes discomfort, consult a contact lens practitioner before wearing lenses.

59

CONTACT LENS EMERGENCIES AND FIRST AID

Blunt trauma:

- Professional evaluation

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9L398720-61

Contact Lens Emergencies and First Aid:

Blunt Trauma

Swelling or lacerations may make lens (or pieces of lens) removal difficult. Professional evaluation of the whole eye by a contact lens practitioner, or an ophthalmologist if the trauma is more serious, is indicated. Generally, a medical practitioner or suitably trained nurse is probably best suited to initial emergency care. Once this phase of care is complete, specialist attention should be sought.

60

CONTACT LENS EMERGENCIES AND FIRST AID

Uncomfortable lenses, red or sore eyes:

- Do not wear lenses
- Consult practitioner

98720-62S.PPT

9L398720-62

Contact Lens Emergencies and First Aid:

Uncomfortable Lenses, Red or Sore Eyes

Do not wear the lenses. Seek advice from the prescribing practitioner.

61

CONTACT LENS EMERGENCIES AND FIRST AID

Tight/adherent lenses:

- Do not remove lenses until rehydrated adequately

98720-63S.PPT

9L398720-63

Contact Lens Emergencies and First Aid:

Adherent Lenses

If lens adherence is due to drying of the hydrogel material by hyperthermia, infrared radiation, wind or low humidity environments, do not attempt to remove the lenses until they have been re-hydrated. This may be accelerated by the insertion of sterile saline or appropriate eye drops (non-hypertonic).

62

CONTACT LENS EMERGENCIES AND FIRST AID

Dry eyes or environments:

- Sterile saline or re-wetting/lubricating eye drops

98720-64S.PPT

9L398720-64

Contact Lens Emergencies and First Aid:

Dry Eyes or Environments

Increase humidity if possible. Request the practitioner prescribe suitable lubricating/re-wetting eye drops.

63

CONTACT LENS EMERGENCIES AND FIRST AID

Exposure to welding or other electric arcs:

- Remove lenses
- Consult practitioner

98720-65S.PPT

9L398720-65

Contact Lens Emergencies and First Aid:

Exposure to Welding or Other Arcs

If protective filters were not in place then remove lenses prior to the onset of photokeratitis. If there are no symptoms, resume contact lens wear in 24 hours. Otherwise, a contact lens practitioner should be consulted before wearing lenses again.

64

CONTACT LENS EMERGENCIES AND FIRST AID

Blurred vision:

- Remove and clean lenses
- Consult practitioner

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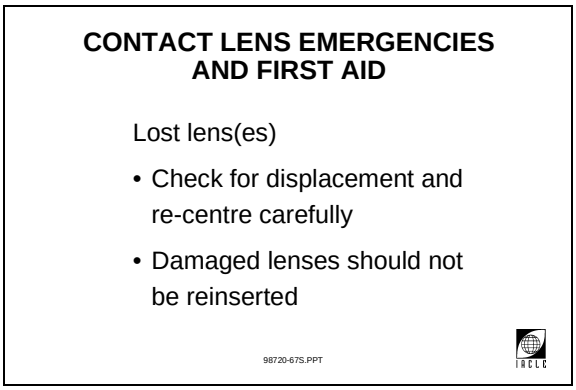
Contact Lens Emergencies and First Aid:

Blurred Vision

Remove and clean the lenses. If on reinsertion vision remains blurred, consult the prescribing practitioner.

65



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Contact Lens Emergencies and First Aid:

Lost Lens(es)

Check that the lens is not displaced onto the conjunctiva. If it is, carefully re-centre the lens. If not, check clothing and surrounding floor.

If the lens is found, clean it and evaluate it for damage. If it is undamaged, reinsert it. If this causes discomfort or if the lens is damaged, consult a contact lens practitioner.

MICHIGAN STATE UNIVERSITY

CHEMICAL SAFETY LABORATORY CHECKLIST

Room:_____ **Building:**_____

Safety Rep:_____

PI:_____ **Inspection Date:**_____

Dept:_____ **Inspected By:**_____

GENERAL	**YES**	**NO**	**N/A**
1. Emergency phone numbers are posted on the laboratory door.	____	_____	
2. Warning signs are posted on doors.	____	_____	
3. Right-to-Know law bulletin is posted within department.	____	_____	
4. All personnel know how to obtain MSDS's.	____	_____	
5. All personnel have received Lab Specific Training.	____	_____	
6. All personnel have received ORCBS Lab Safety Training.	____	_____	
7. Lab coats are available.	____	_____	
8. Chemical protective gloves are available.	____	_____	
9. Safety glasses/goggles are available.	____	_____	
10. An eyewash fountain is present.	____	_____	
11. An emergency shower is present.	____	_____	
12. Food and Beverages are not stored or used in lab.	____	_____	
13. Aisles are uncluttered and without a tripping hazard.	____	_____	
14. Chemical spill kits are available.	____	_____	
15. Non-contaminated sharp objects in labelled, puncture-proof containers.	____	_____	
16. Fume hoods have current ORCBS inspection sticker.	____	_____	
17. All exits are free and unobstructed.	____	_____	
18. Fire extinguishers are available and unobstructed.	____	_____	
19. Fire extinguishers have DPS tag and are sealed.	____	_____	
20. Current inventory of chemicals is available.	____	_____	

MSDS: Material Safety Data Sheet

ORCBS: Office of Radiation, Chemical & Biological Safety

DPS: Department of Public Safety

NFPA: National Fire Protection Association

CHEMICAL STORAGE AND HANDLING

1.	Gas cylinders are properly secured.	____	_____
2.	No leaking containers are present.	____	_____
3.	All chemical containers are properly labelled.	____	_____
4.	Chemicals are stored according to compatibility.	____	_____
5.	Peroxide forming reagents are dated when opened.	____	_____
6.	Peroxide forming reagents are disposed of or tested after expiry date.	____	_____
7.	Flammable storage area(s) is labelled.	____	_____
8.	Flammables are kept away from sources of heat, ignition, flames, etc.	____	_____
9.	Corrosive chemical storage area(s) is labelled.	____	_____
10.	Corrosive materials are stored low to the ground.	____	_____
11.	Carcinogen storage area(s) is labelled.	____	_____
12.	Chemicals in the open are kept to a minimum.	____	_____
13.	Flammable/Combustible liquids do not exceed NFPA storage limits.	____	_____
14.	Flammable/Combustible liquid total volume is not greater than 10 gallons (about 38 L).	____	_____
15.	Flammable gases are not present.	____	_____
16.	Poisonous gases are not present.	____	_____

CHEMICAL WASTE

1.	Hazardous waste containers are labelled and have closed lids.	____	____	____
2.	Hazardous waste tags are complete.	____	____	____
3.	Hazardous wastes are not stored beyond 90 days.	____	____	____

COMMENTS_____

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Unit 9.4

(1 Hour)

Lecture 9.4: Fitting Scleral Lenses

Course Overview

Lecture 9.4: Fitting Scleral Lenses

I. Historical Background

II. Indications for Fitting Scleral Lenses

III. Types of Scleral Lenses

IV. Impression Taking

V. Fitting Assessment

VI. Modification and After-Care

Lecture 9.4

(1 Hour)

Fitting Scleral Lenses

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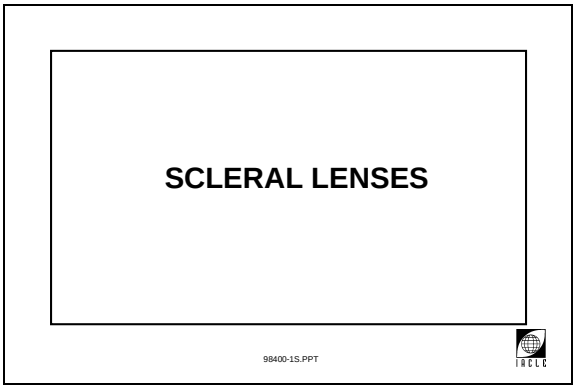
I Scleral Lens History

1



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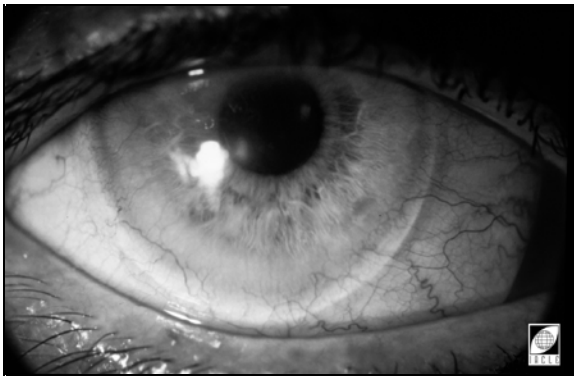

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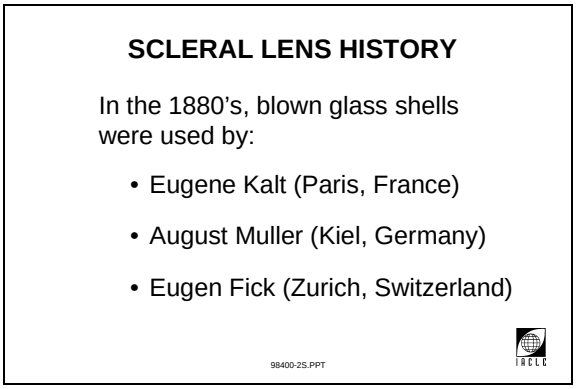
Scleral Lenses

Scleral contact lenses, the earliest form of contact lens, extend over the anterior ocular surface (Slide 2). They rest mainly on the conjunctiva/sclera with minimal clearance between the optic/corneal portion of the lens and the cornea and limbus.

The scleral lens is also known as a 'haptic lens'.

3



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Blown Glass Shells

According to recorded history, scleral contact lenses were the first contact lenses created.

Working independently, three men in the 1880s used blown glass hemispherical shells to accomplish different objectives:

- Eugene Kalt (Paris, France) attempted to reduce the ectasia of a keratoconic cornea by using the shell to compress the cone.
- August Müller (Kiel, Germany) investigated the correction of high myopia with a corrective lens applied directly to the cornea. He attempted to eliminate the problems of image reduction and chromatic aberration associated with a spectacle correction (he was a 14 to 15 D myope).
- A. Eugen Fick (Zurich, Switzerland) corrected irregular astigmatism optically, by replacing a deformed cornea with another regularly curved surface.

4

SCLERAL LENS HISTORY
LIMITING FACTORS

- Tolerance problems
  - discomfort
  - limited wear
- Sattler's veil
  - oedema
  - vision problems

98400-3S.PPT

9L498400-3

Scleral Lenses: Limiting Factors

Little activity occurred in the contact lens field from the 1880s until scleral lenses came into general use in the late 1930s (primarily through the introduction of PMMA material and the work of both Josef Dallos and Norman Bier).

It was then found that limiting factors for lens wear included variable wearing time (tolerance problems) and Sattler's veil (Fick's phenomenon) which is caused by corneal swelling (oedema).

Sattler's veil is defined as mistiness of vision accompanied by the appearance of rainbow-coloured haloes seen around lights, during or after lens wear.

5

SCLERAL LENS HISTORY
ATTEMPTS TO INCREASE WEARING TIME

- Use of buffer solutions
- Changes in lens parameters
- Channels, fenestrations, slots and ducts were trialled

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Attempts to Increase Wearing Time

To combat these limiting factors, most practitioners in the 1940s looked for the correct type and balance of contact lens solution combined with ample clearance between the cornea and the lens. The buffer solution (sodium bicarbonate), rather than the lens, was thought to be responsible for the veiling of vision and the limitation to wearing time.

Different strengths and hundreds of compositions of buffer solutions were tried, yet Sattler's veil and limited tolerance were experienced with all solutions.

Eventually, it became evident that the fit (too flat or steep) and corneal diameter (too large or too small) of the lens had some effect on veiling. When the physical fit was optimized, varying the buffer solution made little difference. Efforts to find the correct buffer solution were pursued while variations in the fluid chamber 'shape' were ignored.

It was also noticed that a bubble trapped between the lens and the eye had a beneficial effect on the veiling problem and the ventilated or fenestrated, 'solutionless' contact lens resulted in the 1940s. Channels, perforations, slots and ducts in different positions and sizes were all tried. A single fenestration was found to be as effective as other options. It functioned best when positioned inter-palpebrally rather than under the lids.

6

SCLERAL LENS HISTORY
CORNEAL LENSES (1940s)

- Rapid acceptance
- Importance of corneal metabolism and health understood
- Smaller lenses allowed better oxygen supply

98400-5S.PPT

9L498400-5

Corneal Lenses

The smaller corneal lens was developed in the late 1940s. Following this, the use of scleral lenses in the United States was virtually abandoned, except in some advanced physical and physiological conditions. Scleral lenses continued to be used in the United Kingdom and elsewhere in the world.

The importance of oxygen for corneal metabolism and health was discovered in the early 1950s. In retrospect, it was apparent that Sattler's veil with scleral lenses was due to hypoxia from the non-oxygen permeable lens materials used in their fabrication – a situation no buffer solution could have helped.

II Terminology

7

TERMINOLOGY

- Haptic
- Haptic lens
- Scleral lens
- Haptic (scleral) portion
- Optic (corneal) portion
- Transition
- Fenestrated (ventilated) lens

98400-6S.PPT

9L498400-6

8

TERMINOLOGY

- Channelled lens
- Preformed lens
- Impression lens
- Contact shell
- Cosmetic (prosthetic) haptic lens
- Cosmetic (prosthetic) shell

98400-7S.PPT

9L498400-7

Terminology

Terminology relating to large corneo-scleral lenses includes:

- Haptic - from the Greek word meaning 'to fasten' or 'attach'.
- Haptic lens - A contact lens with a haptic portion. The main bearing portion of the lens is over the sclera. Also known as a scleral lens.
- Scleral lens - A haptic contact lens.
- Haptic (scleral) portion - that part of the lens which overlays the sclera/conjunctiva.
- Optic (corneal) portion - the central part of the lens which covers the cornea and limbus.
- Transition - the area of change in curvature/section of the lens between the central optic and the peripheral haptic.
- Fenestration - a hole in the lens to assist fluid exchange.
- Channel - a furrow on the back surface of the lens to enhance tear exchange.
- Preformed lens – a semi-finished stock lens, a lens constructed with a predetermined standardized back surface form/shape.
- Impression lens - a lens molded from a cast of the anterior surface of the eye for which it is intended.
- Contact shell - contact lens shape without optics.
- Cosmetic (prosthetic) haptic lens - a haptic contact lens designed to change or improve the appearance of the patient and having optical power.
- Cosmetic (prosthetic) shell - cosmetic haptic shell without optics. Usually fitted over an irregular, damaged or deformed globe.

III Indications for Scleral Lenses

9

INDICATIONS FOR SCLERAL LENSES

- Patients involved in active water sports
- Vigorous sporting and dusty environments
- People who require easier care, handling and wear
- Greatly decentred pupils

98400-8S.PPT

9L498400-8

10

INDICATIONS FOR SCLERAL LENSES

- Poorly centred lenses
- Advanced keratoconus
- High toric powers and prisms
- Pathological and disfigured eyes
- Aged (arthritis, tremors, etc)
- Epithelial protection
- Special effects for the performing arts

98400-9S.PPT

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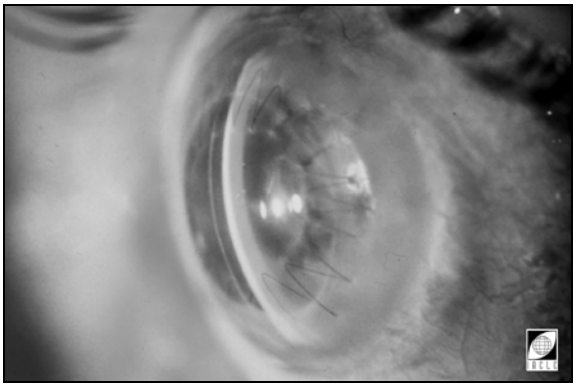
11



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Indications For Scleral Lenses

Scleral lenses are used if an irregular ocular surface and/or high refractive error make it impossible to fit conventional contact lenses. Preformed scleral lenses do not always achieve a perfect fit and may require the use of impression molding (discussed below). Today, there are still indications for the use of scleral lenses because they offer several advantages:

- Scleral lenses won't wash out, absorb contaminants, or change their fitting characteristics during water sports.
- Ease of care and maintenance, handling and wear.
- Protect the anterior segment.
- Fit over the bulk of the anterior ocular surface thereby promoting fitting stability.
- Easier to find and handle for patients with poor unaided visual acuity.
- Cosmetic properties can be added to the scleral lens.
- Full corneal-clearance fitting can be achieved satisfactorily.

These advantages are significant for:

- Patients with significant refractive error who swim, dive, water ski, etc.
- Patients engaged in vigorous sports or those exposed to dusty environments.
- Manual workers in heavy industry.
- Infants and young children.
- Patients with greatly decentred pupils.
- Patients experiencing poor centring with other lenses.
- Advanced keratoconic patients, especially with decentred cones and/or irregular corneas.
- Patients requiring toric powers and prisms.
- Patients who suffer from pathological and disfigured eyes:
  - disrupted, distorted or dry eyes due to lid deformities
  - ptosis, crutch (ledge) on superior haptic portion
  - prevent symblepharon with corneal and conjunctival burns
  - cosmesis (scarred, shrunken; create parallelism in strabismus, blind eyes).
  - nystagmus and albino patients.
- Aged patients who may be suffering from arthritis, tremors, etc.
- Patients with epithelial fragility who may tolerate only a full corneal-clearance haptic lens.
- Cinema and television special effects.

Pathology Requiring Scleral Lenses

Pullum (1984) has identified four main conditions that may require scleral lenses:

- Aphakia.

  Patients in this group are usually elderly, have reduced mobility and poor manual dexterity. Scleral lenses make lens handling easier and more manageable.

- Keratoconus and other corneal distortions.

  Conventional contact lenses are difficult to fit in this group because of the conical or irregular corneal shape. Success may be higher with scleral lenses, although central touch is unavoidable with the conic cornea and increases with the lens settling back onto the cornea. If the lens is too tight, this can cause severe restrictions to tear exchange at the limbus.

- Post-operative corneal grafts (Slide 11).

  Corneal grafts are usually accompanied by high astigmatism or protrusion of the donor cornea making soft contact lenses impossible, and RGP lenses difficult, to fit.

- High myopia.

  Commonly, high myopes are not fitted with scleral lenses because they:

  – belong to a younger age group and have fewer problems with lens handling

  – are more accustomed to spectacle distortions than are new aphakes for example.

12

SCLERAL LENSES
DISADVANTAGES

- Long fitting time
- Greater expense
- Limited availability
- Specialist fitters

98400-11S.PPT

9L598400-11

Disadvantages of Scleral Lenses

The use of scleral lenses is generally limited to specialist contact lens practitioners who regularly deal with cases suited to their use.

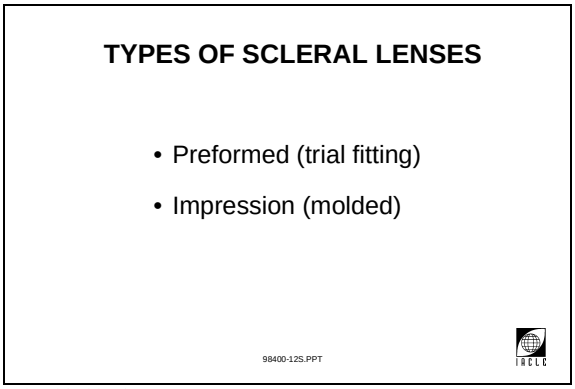
The long fitting time, especially with molded lenses, and their significantly greater expense, makes these lenses less available to those patients who could benefit most from their use.

The availability of preformed RGP scleral lenses may promote their use by a greater number of practitioners, though the high cost factor will always be an obstacle to their wider adoption.

IV Types of Scleral Lenses

IV.A Preformed Scleral lenses

13



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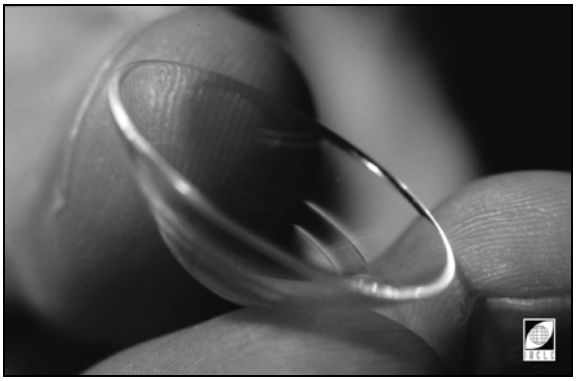

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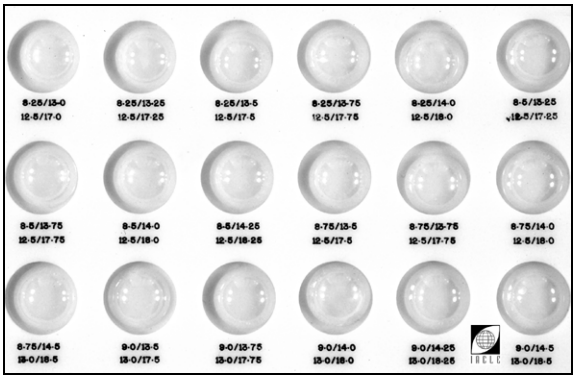

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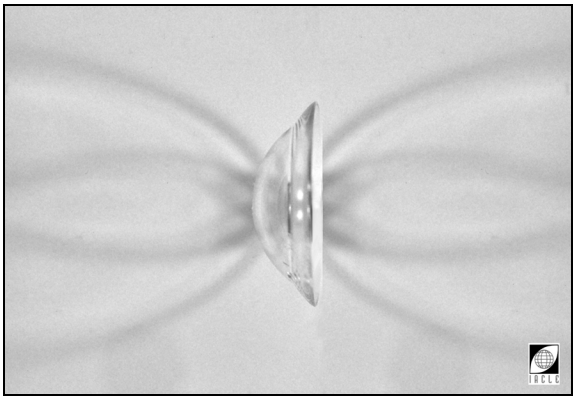
Types of Scleral Lenses

Historically, scleral lenses were either preformed or pressed from a molded cast of the patient's eye (slide 14). Such lenses were typically made from PMMA and had no effective oxygen transmission to the cornea except from tear exchange through the fenestration(s).

Rigid gas permeable scleral lenses (slide 15) which offer higher oxygen transmissibilities, are now made by computer-controlled lathes interfaced to corneal/anterior eye topographical data. Compared with the impression technique, trial fitting sets (slides 16) and trial lenses (slide 17) provide a simplified approach to fitting scleral lenses.

17



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18

PREFORMED SCLERAL LENSES
ADVANTAGES

- Precise lens specifications are known
- Patient can experience lens prior to fitting
- Can over-refract
- Can be made thinner than molded lenses

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9L498400-13

19

PREFORMED SCLERAL LENSES
ADVANTAGES

- Modifications simpler and easier to specify
- Adequate limbal clearance easier to achieve

98400-14S.PPT

9L498400-14

20

PREFORMED SCLERAL LENSES
DISADVANTAGES

- Difficult to fit highly toric or irregularly shaped eyes
- Capital outlay for fitting set
- Few manufacturers

98400-15S.PPT

9L498400-15

Preformed Scleral Lenses

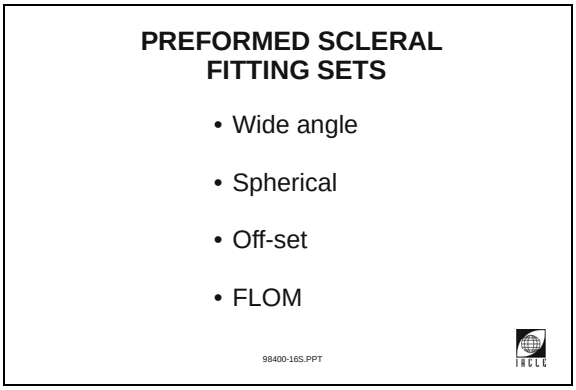
Advantages

- Precise specifications are reproducible because trial fitting is based on standardized design parameters, using spherical haptic and transition curves.
- Patients can experience lens wear prior to fitting to help alleviate any apprehension and determine adaptability. It is often helpful to let the patient feel the scleral lens edge against the sclera prior to insertion, to help reinforce cooperation and confidence.
- With the use of fenestrated lenses for optic measurement (FLOMs), an over-refraction can be performed to determine the desired Back Vertex Power (BVP).
- Preformed scleral lenses can be made thinner than molded lenses.
- Modifications are simpler and easier to specify since spherical haptic and transition curves are used and the curvatures of the different sections (zones) are known.
- Adequate limbal and corneal clearance may be easier to achieve with preformed lenses.

Disadvantages

- Difficult to fit highly toric or irregularly shaped eyes due to the presence of harsh bearing areas on the cornea, or the formation of large bubbles under the lens.
- There is a very large capital outlay for a trial or fitting set. This makes fitting preformed scleral lenses economically viable only for practitioners fitting large numbers of patients with scleral lenses.
- There are very few manufacturing laboratories capable of producing scleral lenses.

21



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Types of Scleral Fitting Sets

The fitting of preformed haptics or scleral lenses is based on a series of trial haptic lenses in which the parameters (back scleral radius, transition zone and back scleral diameter) are standardized. Various forms of trial fitting lenses have been developed:

- Wide angle haptic lenses; the cone angle dictates the vaulting over the corneal surface.
  A typical wide angle fitting set (after Woodward, 1989) is as follows:

BSZR*(mm)	BOZR(mm)
12.50	8.00 – 8.50 (Δ 0.25)
12.75	8.00 – 8.50 (Δ 0.25)
13.00	8.00 – 8.75 (Δ 0.25)
13.25	8.00 – 9.00 (Δ 0.25)
13.50	8.00 – 9.00 (Δ 0.25)
13.75	8.25 – 9.00 (Δ 0.25)
14.00	8.50 – 9.00 (Δ 0.25)
14.25	8.50 – 9.00 (Δ 0.25)

  *Back Scleral Zone Radius
- Spherical haptic lenses; generally tricurve or tetracurve designs.
  A typical spherical fitting set (after Woodward, 1989) is as follows:

BSSize*(mm)	BSR**(mm)
22.50	12.50 – 14.00 (Δ 0.50)
24.00	13.00 – 14.50 (Δ 0.50)

  *Back Scleral Size **Back Scleral Radius
- Off-set haptic lenses; the centre of curvature of the haptic zone does not lie on the axis of revolution of the central optic zone.
- Fenestrated lenses for optic measurement (FLOMs); small lenses dedicated to determining the correct optical radius.
  A typical FLOM fitting set (after Woodward, 1989) is as follows:

BOZR(mm)	Primary Optic Diameter(mm)
8.00	13
8.25	13.00 – 14.00 (Δ 0.25)
8.50	13.25 – 14.25 (Δ 0.25)
8.75	13.50 – 14.50 (Δ 0.25)
9.00	13.50 – 14.75 (Δ 0.25)
9.25	13.75 – 14.75 (Δ 0.25)
9.50	14.75

These design variations were primarily aimed at trying to fit the limbal and scleral curves so that there is satisfactory limbal clearance and adequate tear exchange.

Preformed lens types (generally fenestrated) may be based on the following:

- Designed for minimum clearance.
- Haptic fitting and optic fitting performed with the same lenses.
- Haptic portion fitted with one lens and optic portion fitted with an entirely different type of optic-measuring lens.

22

ACCEPTABLE SCLERAL LENS FITS

- Flush fit
- Semi-sealed fit
- Ventilated fit
- Sealed fit

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Types of Acceptable Scleral Lens Fit

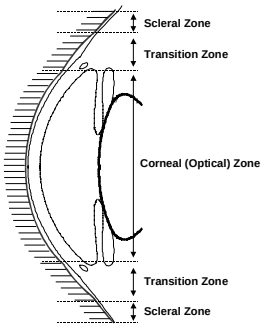
There are four types of acceptable scleral lens fit. These are:

- Flush fit. A haptic shell or lens which closely parallels the shape of the anterior eye.
- Semi-sealed fit. A haptic shell or lens incorporating modifications to allow the post-lens tear film to escape to the lens edge. Such modifications include grooves, furrows, channels, etc. located in the haptic zone of the lens.
- Ventilated fit. A fenestrated haptic shell or lens. The fenestrations are located in areas with some clearance (typically in the limbal zone) to allow atmospheric air in under the lens.
- Sealed fit. For physiological reasons at least, this is an unacceptable fit. Essentially, the lens is sealed against the eye precluding tear exchange and limiting lens movement to an insignificant or zero level. Such a fit is only used in rare and special circumstances.

23

SCLERAL LENS ZONES

**Note: Only back surface shown*



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24

IDEAL SCLERAL LENS FIT

- Scleral zone a little flatter than alignment
- Edge zone slightly flatter again
- BOZR flatter than average Ks by ≈ 1 mm
- Fenestration in limbal zone between lids
- Limbal zone ≈ 2 mm wide, 0.1 - 0.2 mm clearance
- Air bubble should be present
- Tear exchange must be demonstrated

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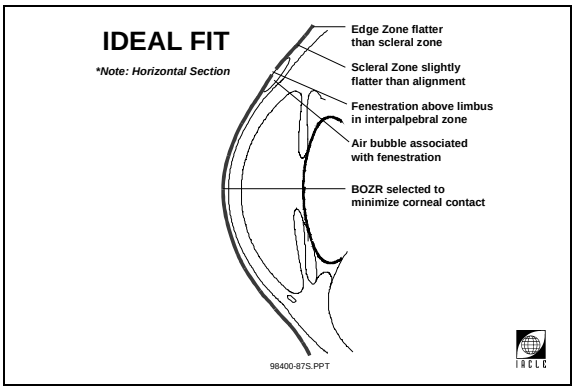
The Ideal Scleral Lens Fit

The zones of a scleral lens are presented diagrammatically in slide 23.
The characteristics of a good fit (after Ruben, 1994) are presented in slide 24 and represented diagrammatically in slide 25. They are:

- The scleral zone fits the eye a little flatter than alignment.
- The edge zone should fit a little flatter again in the interests of tear exchange under the lens.
- The BOZR should be flatter than average Ks by at least 1 mm to keep contact with the cornea to a minimum, and such contact should occur only in extreme eye positions and movements.
- The fenestrations should be about 1 mm in diameter and be located in the limbal zone that is not normally covered by the lids, i.e. the interpalpebral zone.
- Air should enter the lens whenever the lens moves off the eye such as occurs in extreme eye positions.
- The limbal zone, which is the transition between optic and scleral zones (slide 24), should be about 2 mm wide (2 – 3 mm) with a clearance of 0.1 – 0.2 mm.
- Fluid movement, and the characteristics of air bubbles under the lens, should be demonstrable with the aid of sodium fluorescein dye applied to the exposed anterior eye just outside the lens edge. The rate at which the post-lens tear space fills provides an assessment of the tear exchange behind the lens. Figures of 1 minute to fill and 5 minutes to empty are desirable.

25



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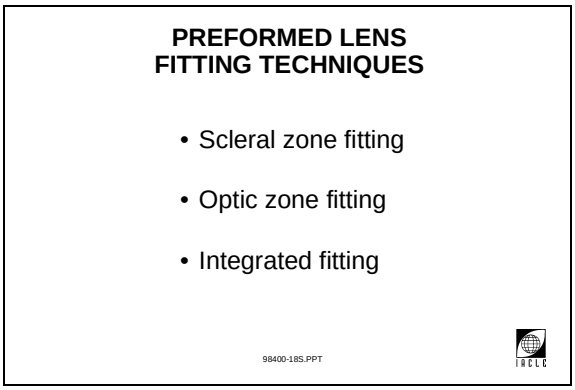

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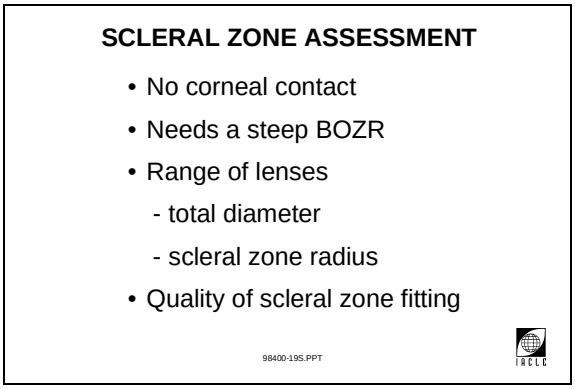

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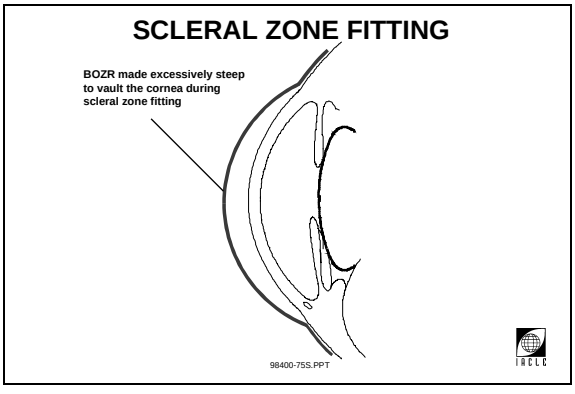

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Scleral Zone Assessment

When fitting the haptic (scleral) portion of the lens it is important that the central (corneal) zone vaults over the cornea and limbus (slide 28). Any contact on the cornea will alter the fitting relationship between the haptic and the sclera/conjunctiva.

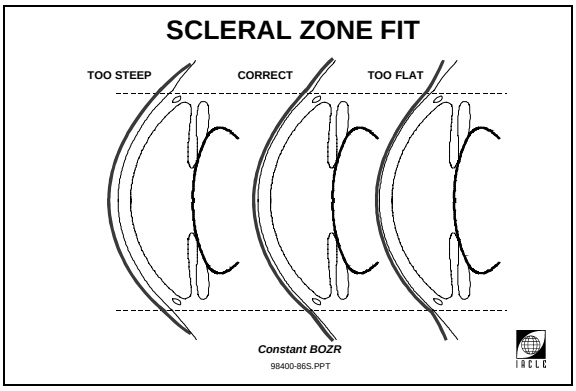
Excessive pressure or bearing by the scleral flange (sometimes referred to as a 'tight' fitting) will result in areas of blood vessel compression. This compression produces a typical local blood vessel blanching. On removal of a tight lens, the conjunctiva may show signs of a 'lens imprint' or so-called conjunctival indentation.

A lightly or variable fitting haptic (sometimes referred to as a 'loose' fitting may result in bubble formation due to excessive clearance in the areas fitting poorly. These areas may also exhibit froth or frothing.

Discomfort from heavy bearing at the lens edge may also occur if the edge fit is not optimal.

The range of scleral zone fits is depicted in slide 29.

29



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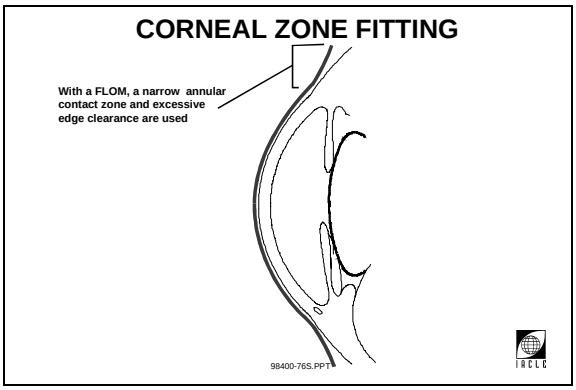

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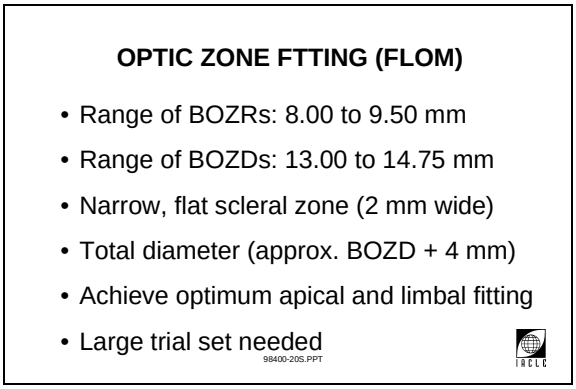

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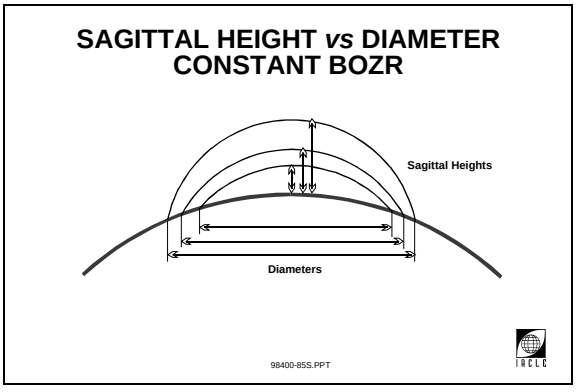

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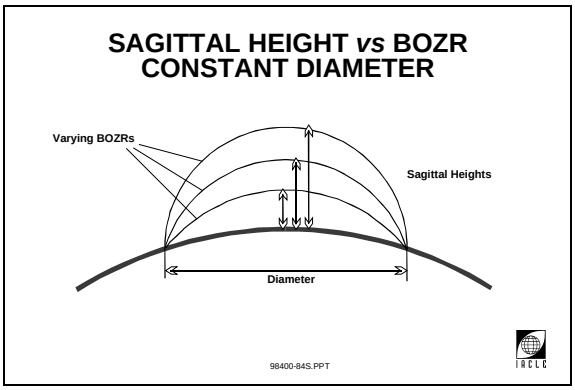
Optic Corneal Zone Fitting (FLOM)

The small diameter FLOM lenses allow the practitioner to assess the relationship between the cornea and the optical portion of the lens without the scleral zone (haptic) influencing the fitting (Slide 30).

A typical range of lenses required is detailed in slide 31. A large number of trial lenses are required (28 with the Woodward set detailed previously).

The desired fitting is achieved when the fluorescein pattern shows slight corneal and limbal clearance. Clearance can be affected by alterations of the BOZR and/or the diameter (presented in slides 32 and 33). Alterations in either or both of these corneal zone parameters follow the rules-of-thumb applicable to RGP contact lenses (see Lecture 3.4.2).

33



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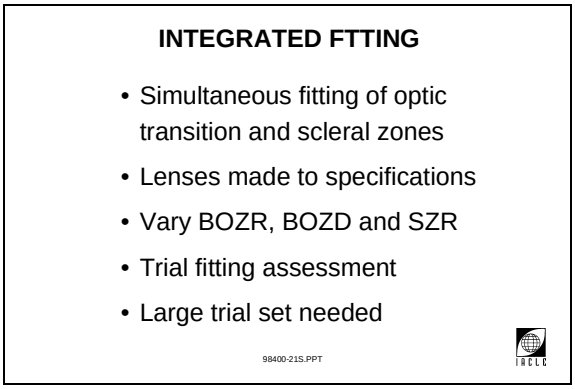

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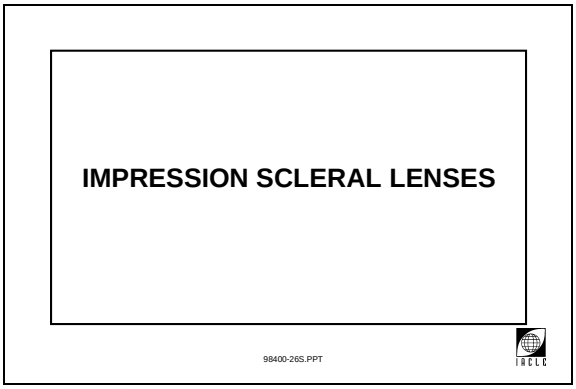
Integrated Fitting

Preformed scleral lenses with known optic, limbal, transition and haptic zone parameters permit the practitioner to trial fit the patient in a manner similar to corneal lens fitting. Observation and interpretation of the dynamic and static characteristics dictates the specific parameters for the lens to be ordered for that eye.

IV.B Impression Scleral Lenses

IV.B.1 Development of Eye Impression Techniques

35



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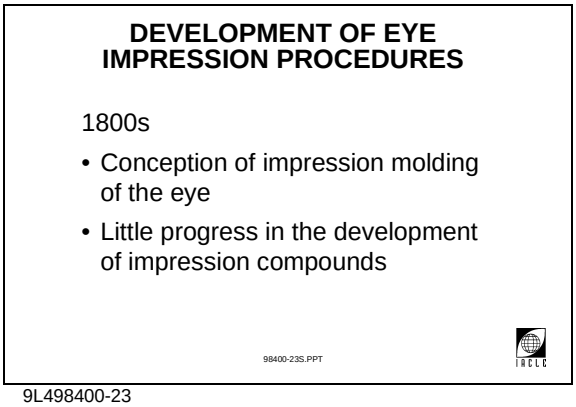
Impression Scleral Lenses

Haptic lenses are made to fit precisely over the eye by pressing plastic sheeting (PMMA or some RGP materials) over a dental cast of the eye. This requires taking a mold of the patient's eye. Although computer generated RGP scleral lenses fabricated from over-sized buttons have now been developed, there is still a need to perform impression molding of the eye in cases of markedly disfigured eyes or for custom-fitted ocular prostheses (Unit 9.5).

36



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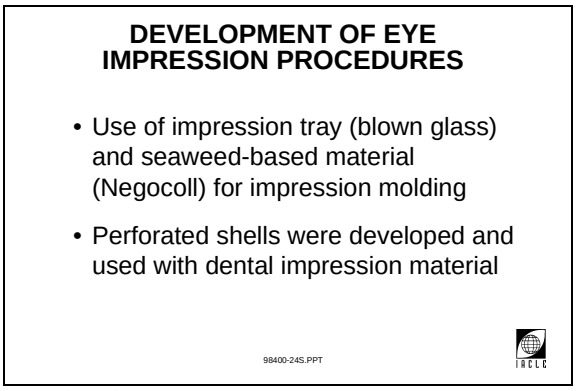

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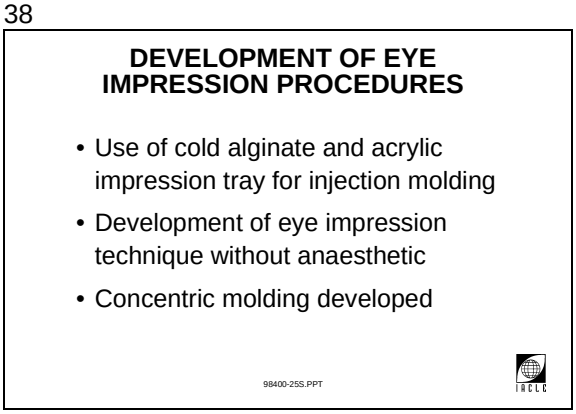

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Development of Eye Impression Techniques

1845	Sir John F. N. Herschel discussed the concept of impression molding.
1888	August Müller suggested that plaster of Paris could, potentially, be a suitable impression material, yet the only topical anaesthetic available at the time was cocaine which was toxic to the epithelium.
1890-1930	Little progress was made in attempts at refining the technique. Other potential impression materials, such as cocoa butter, whole fat and paraffin were investigated.
1931	Josef Dallos of Budapest, Hungary, made use of material derived from seaweed ('Negocoll') intended for preparation of surface impressions to make anatomical models. He used a Müller blown glass lens as an impression tray and, after some years, he amassed a large collection of lenses. These were divided into various 'types'. Dallos concluded that it is 'not the initial selection nor initial impression which provides the finished lens, but careful tailoring of this preliminary form to the precise requirements of the individual eye.' To this modification procedure (then a new branch of prosthetics), Dallos gave the title 'Haptics' in 1936.
1939	Perforated shells were developed and improvements were made in impression materials. Reversible hydrocolloid gels (originally for dental use at 100 - 104^{o} F) were used on the eye. Ice water finalized the mold.
1943	Theodore Obrig developed *Ophthalmic Moldite,* the first cold, alginate

impression material specifically for ophthalmic work.
He used acrylic impression trays which were perforated and had hollow tubular handles.
He introduced the 'injection' method to Great Britain in 1947.

1948 Steele developed a technique of taking eye impressions without anaesthetic.

1953 Wesley and Jessen developed 'Concentric Molding', which used a contact lens-like impression tray with no handle and 4 large apertures in the haptic portion. This tray could then centre itself and patient fixation was not important.

Other materials which have been used with reasonable success for ophthalmic impressions are:

- Ophthalmic Zelex (a lumpy paste).
- Tissuetex.
- Kromopan (violet color, turns pink when ready to cast in shell, turns white when set).

IV.B.2 Ocular Impression Techniques

39

EQUIPMENT & MATERIALS

- Molding powder
- Molding shells
- Syringe
- Rubber bowl
- Stainless steel spatula
- Distilled water
- Dental stone
- Ocular irrigation solution

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Ocular Impression Techniques: Equipment and Materials

The purpose of taking an impression is to obtain an exact reproduction of the anterior surface of the eye and then to make a positive cast of the negative impression. From this positive cast, a scleral contact lens is created and is 'ventilated' with a fenestration (hole).

The equipment and materials required for taking impressions of the eyes are listed in slide 39.

40

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41

PATIENT PREPARATION

- General advice on technique
  - relaxation
  - need for fixation
- Use preformed lens as a demonstration
- Topical anaesthetic

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Preparation of the Patient

- The patient should be assured that the taking of an impression is no more uncomfortable than the insertion of a trial contact lens. The patient must keep their:
  - contralateral eye open and fixated on a predetermined point to centre the cornea properly.
  - eyes wide open without squeezing the eyelids during the molding process.
- It is advisable to use a topical anaesthetic with patients who are apprehensive.

42

MOLDING SHELLS

- Shells used to support the impression material and to handle the impression
- Consider design specification of impression shells or trays
- Decide on using injection *vs* insertion impression shells
- Consider the size and location of holes
- Note and properly use markings on the shell

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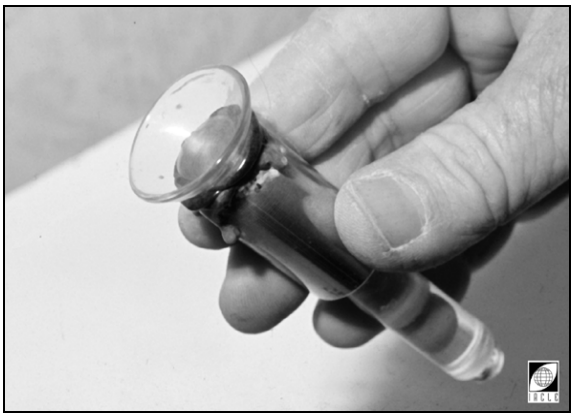
9L498400-30

Shells (Impression Trays)

- Shells must be used to support the impression material and to handle the impression.
- Designs of impression shells or trays include:
  - solid handle, hollow handle, or no handle
  - perforations
  - 29 x 27 mm oval or 27 x 25 mm oval
  - thickness (easier to use when thin) (0.6 mm)
  - shape (conical necessary for keratoconics)
  - usually three sizes are available (small, medium, and large).

43



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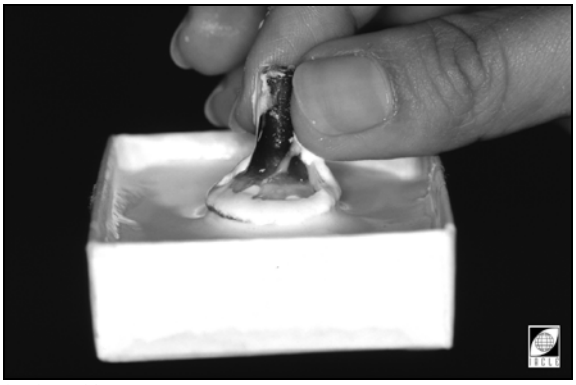

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- Injection *versus* insertion impression shells:
  - shells used with injection molding must have a hole in the handle to inject the impression material through (Slide 43)
  - shells used with insertion molding can have solid or hollow handles or a suction cup can be used as a handle (slide 44).
- Size and location of holes:
  - there must be holes in the shells so that excess impression material can ooze through them, locking the impression to the shell
  - various numbers of holes are located in the periphery of the shells.
- Markings on the shells:
  - a red line is usually on the temporal haptic of the right shell
  - a green line is usually on the temporal haptic of the left shell.

45

9L4208-95

Techniques

Injection Method

Advantages

- Easier technique to learn and master, especially for beginners (Slide 44).
- Longer working time with shell already on eye.
- Easier to control the impression material when working with tight lids or small palpebral apertures.
- Larger shells can be used to generate a greater surface area.

Disadvantages

- Potential to make an uneven impression by inadvertently pressing the shell against one section of the globe.
- May be more difficult to remove from the eye, especially when larger shells are utilized.

Insertion method

Advantages

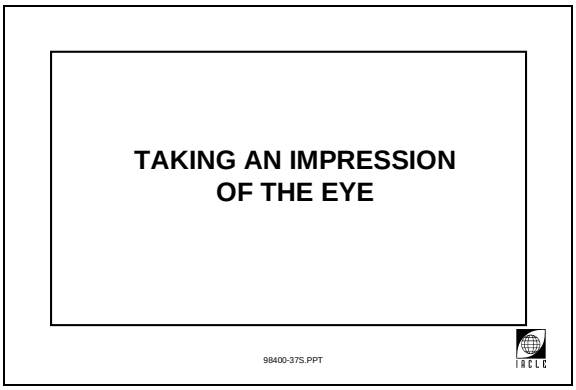
- More time to position and arrange fixation of the eye after insertion of the material
- Removal may be easier due to the smaller size and reduced ‘suction’.

Disadvantages

- Less surface area is molded due to the smaller shell size.
- Tight lids/small palpebral apertures are difficult to manage.
- May be difficult to control the position of the shell.

IV.B.3 Taking an Impression of the Eye

46



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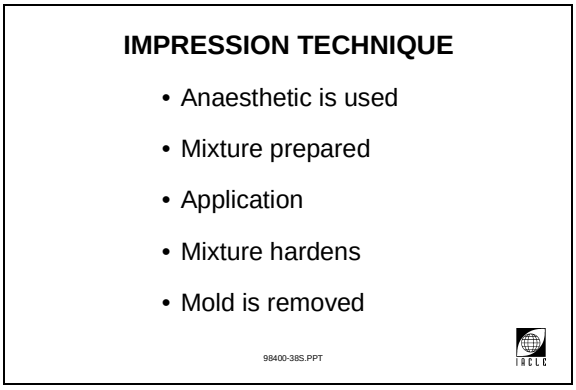

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Taking an Impression of the Eye

1. The patient is placed in a supine position, either in a treatment chair or on a table.
2. If an anaesthetic is used, it is instilled at this point.
3. The eye to be molded is covered so as to block the vision while allowing the operator to observe the position of the covered eye (this permits the assessment of any phoria or tropia).
4. The uncovered eye fixes on a target. The target is moved until the proper position of the eye to be molded is assumed. This allows for compensation of a patient's heterophoria or heterotropia.
5. The molding material is prepared by spatulating the molding powder with distilled water in the rubber bowl (Slide 48).
6. The mixture is placed in the syringe with the spatula. Alternatively, the mixture can be drawn into the syringe. This is less messy and reduces the potential for air bubbles to be trapped in the mixture.
7. When placing the molding shell (impression tray) on the eye, the patient is instructed to look down towards the chin. The upper lid is retracted and the shell is inserted underneath the upper lid (nasal marking on the shell held toward the inner canthus). The patient looks upward, the lower lid is retracted and the shell is gently placed under the lower lid.
8. The tip of the syringe is inserted into the handle of the molding shell.
9. The plunger is pressed slowly and gently, allowing the material to settle on the eye. Avoid applying excessive pressure to the shell or the eye at this stage.
10. As soon as the mixture reaches the horizontal edges of the shell, the syringe is detached. Surplus molding material will push the shell from under the lids.
11. The shell is gently pushed down to allow excess material to flow through the perforations (slide 49).
12. The uncovered eye focuses on the target until the shell is ready to be removed.

The molding mixture gels in about two minutes. This can be determined by testing the overflow material with the fingers. The gelled mixture has the consistency of a hard-boiled egg.

IV.B.4 Removing the Impression

50

IMPRESSION REMOVAL TECHNIQUE

- Separate lashes from impression
- Break any 'suction'
- Remove superior edge from under upper lid
- Remove the impression
- Irrigate and clean eye

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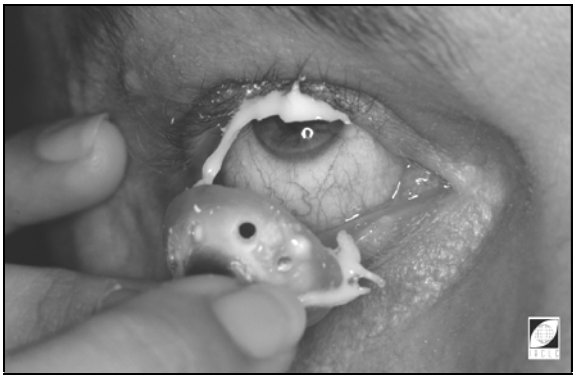

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Removing the Impression

1. The patient looks down and the upper lid is retracted. This separates the eyelashes from the gel.
2. The patient looks up and the lower lid is retracted. This releases the excess material adhering to the lower lid.
3. The excess material is removed.
4. With the fingers of the left hand, the lower lid is retracted as far as possible. The molding shell handle is grasped with the thumb and index finger of the right hand.
5. The patient continues to look up.
6. While gently drawing the shell handle towards the eyebrows, the shell is rotated very slightly from side to side until 'suction' is broken.
7. When the shell is released from under the lower lid, the patient looks down while the shell is removed from under the upper lid.
8. After the shell containing the negative impression is removed from the eye (slide 51), it is placed in water while the dental stone is prepared.
9. The eye is irrigated to remove any particles of molding material (slide 52).
10. Inspect the eye to determine if any damage has been caused.

IV.B.5 Making the Positive Casting

53

POSITIVE CAST

- Dental stone used
- Cast hardens in the impression
- Orientation marks required
- Any roughness requires smoothing

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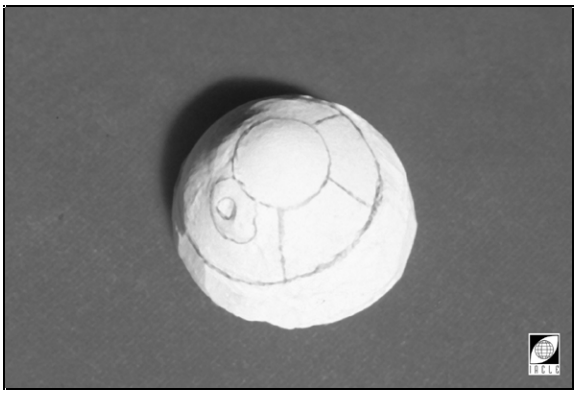

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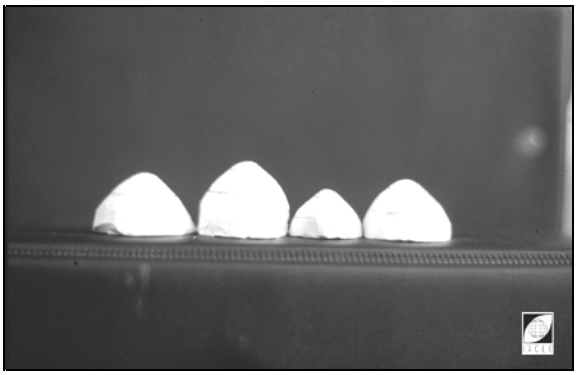

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Making the Positive Casting

For best results, the castings should be made immediately. However, impressions may be set aside and shrinking avoided by soaking in water should later pouring of the dental stone become necessary.

1. When the molds (right and left) for each eye have been made, mix the dental stone (plaster of Paris and water).
2. Spatulate thoroughly for two or three minutes. Tap the bowl on a hard surface to force any air bubbles to the surface.
3. Remove the water from the molds, and dry with cotton or tissue. Place the molding shell or tray upside down, supported by the mouth of a bottle or a supporting column.
4. Pour the dental stone into the negative mold from the side, without contact with the molding material or the molding shell. This can be done by pressing the rubber bowl into a spout and alternately pressing on and releasing the spout, so that the material is forced into the molds. A slight push with a spatula often helps.
5. When the mold is filled with dental stone, gently tap the bottle (used as support) to allow the air bubbles to escape.
6. Allow the mixture to harden for about twenty minutes.
7. Draw a horizontal line from the inner to the outer canthus with a pencil or stylus. Hold the casting in the shell as if it were removed from the eye with the nasal mark directed toward the inner canthus.
8. Above the line, engrave an ‘N’ for the nasal side and a ‘T’ for the temporal side. In the centre, indicate whether it is for the right or left eye by ‘R’ or ‘L’. The patient's name can be written below the line (slide 54).
9. Allow the castings to set for at least an hour before separating the positive from the negative mold. Do not trim off the edges of the finished castings any more than necessary.

With practice and adherence to a definite routine, good molds and castings can be obtained (slide 55).

IV .B.6 Production of PMMA Shells

59

STAGES OF PRODUCTION
FLUSH FITTING SHELL

- PMMA sheet heated
- Sheet pressed over the cast
- Sheet cut to size
- Edge shaped and polished

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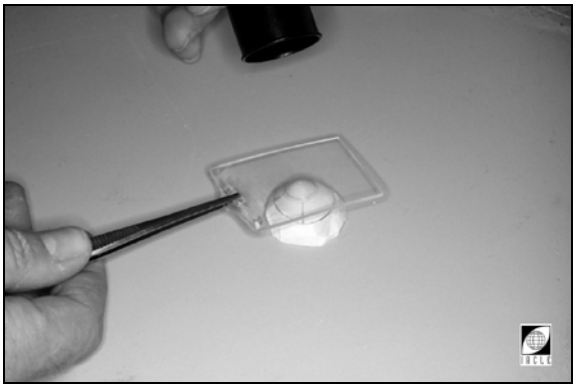

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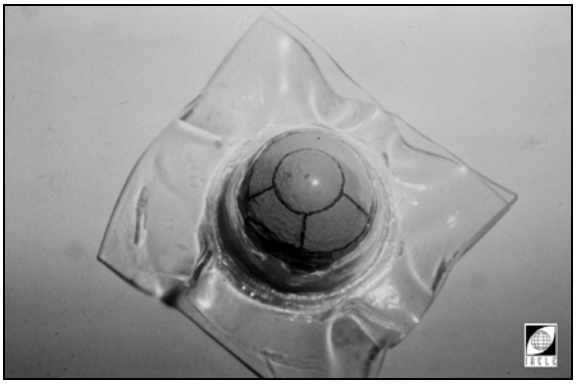

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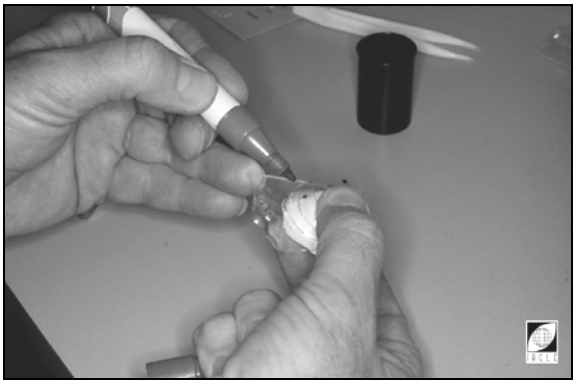

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Flush Fitting Shell

1. A sheet of PMMA material is softened by heating it to approximately 140° C (slide 60).
2. The sheet is then pressed over the cast and allowed to cool (slide 61).
3. The perimeter of the shell is marked and then cut to size (slide 62).
4. Polishing of the inside and outside edges is performed at this stage of the process.

This process results in a flush fitting shell with no clearance between the optical zone and the corneal surface. The lens can be placed on the eye for a preliminary inspection.

Optic Zone Clearance

At this stage of the manufacturing process an optic zone clearance is created. This is achieved by grinding the flush-fitting shell with spherical lapping stones with an appropriate radius of curvature. The final step is to polish the BOZR.

The fitting can then be assessed more fully by applying the lens to the eye after filling the shell with saline and fluorescein.

The optimum back surface shape should be derived prior to generating the optical power (by applying an appropriate front surface radius to the corneal zone).

Optical Power Production

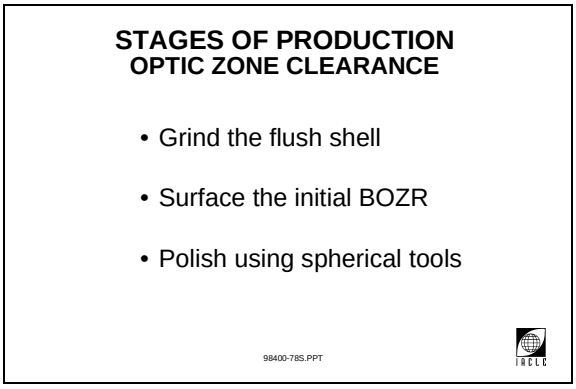
Similar principles apply to the calculation and production of the BVP of scleral lenses and RGP corneal lenses.

Accurate refractive data must be derived in order to produce the optimum lens power. This can be achieved in the following ways:

- Using a FLOM lens
- Using a preformed scleral lens

Once the front optic zone is cut and polished, the lens is applied to the eye for further assessment of the fitting and visual performance.

63



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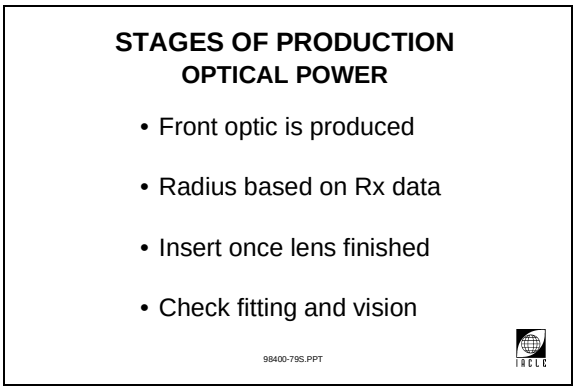

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V Rigid Gas Permeable Scleral Lenses

65

OXYGEN-PERMEABLE SCLERAL LENSES

- Lathe cut from large buttons
- Can not be heat molded
- High Dk materials available
  - minimize corneal swelling
  - non-fenestrated option

98400-39S.PPT

9L498400-39

66

9L42079-95

Rigid Gas Permeable Scleral Lenses

An advantage of scleral lenses currently available is that they may be made from gas (oxygen) permeable materials to improve the physiological and wearing responses to such large lenses (slide 66). Numerous papers have been written on the merits of gas-permeable scleral lenses (e.g. Ezekiel, 1983, Ruben and Benjamin, 1985), Bleshoy and Pullum, 1988)

The use of highly oxygen transmissible RGP materials in the production of preformed scleral lenses has a number of advantages. These include:

- Better oxygen supply, even though the lenses are thick.
- Non-fenestrated designs can be used.

67

CUSTOM-MADE COMPUTER DESIGNED HAPTICS

- Rigid gas permeable scleral lenses
- Junctionless posterior surface based on corneal topography data
- Manufactured by a computer driven lathe

98400-40S.PPT

9L498400-40

Custom-Made Computer Designed Haptics

RGP scleral lenses may be custom designed and generated from a computerized analysis of the topography of the anterior eye.

A US patent was awarded in January 1995 to Boston Eye Technology, Inc. for a customized contact lens design (this lens has a junction-free posterior surface) manufactured by a computer-driven lathe. The lathe interfaces with corneal topography data for a custom-designed fitting.

VI Fitting Criteria

68

BASIC FITTING CRITERIA

- Minimum apical clearance
- Limbal clearance
- Uniform scleral bearing pressure
- Small limbal bubble (if present)
- Settling back is likely

98400-41S.PPT

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Basic Fitting Criteria

- Haptic lenses spread weight and pressure evenly over scleral surface.
- Corneal clearance must be minimal (0.04 - 0.08 mm) but definite when the lens is settled fully.
- Limbal clearance allows good tear exchange and flushing of debris from underneath the scleral lens.

69

FACTORS NECESSARY FOR A GOOD FIT

- Corneal clearance essential
- Fenestration necessary
- Influx of atmospheric O_2 to the cornea and limbus
- Efflux of dissolved CO_2

98400-45S.PPT

9L498400-45

Factors Essential for a Good Fit

A well balanced fit and acceptable tolerance depends on the factors listed in the slide opposite.

70

FACTORS NECESSARY FOR A GOOD FIT

- Adequate tear layer thickness
- Absence of bubbles, especially in the pupillary area
- No perilimbal touch
- Lens tolerance, good vision and continued comfort

98400-46S.PPT

9L498400-46

71

GENERAL APPEARANCE OF A WELL FITTED SCLERAL LENS

- Uniform pressure over scleral area to prevent blanching of blood vessels
- Corneal clearance from the centre to periphery (up to 1 - 2 mm beyond limbus)

98400-47S.PPT

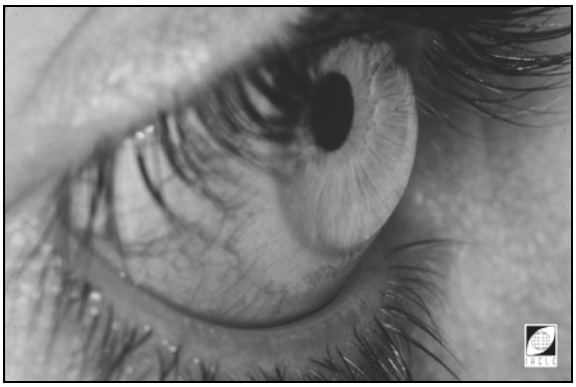
9L498400-47

General Appearance of a Well Fitted Scleral Lens

Independent assessment of corneal and scleral fit should be performed noting the following:

- The scleral portion of the lens should rest evenly on the sclera (conjunctiva) without obstructing flow through the blood vessels. Localized blanching of the conjunctival blood vessels will cause constriction of the blood vessels (slide 72). The white (blanched) areas become more prominent if slight pressure is applied to the front of the lens. Having the patient fixate in different directions of gaze helps to detect areas of blanching.

72



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9L42076-95

74

GENERAL APPEARANCE OF A WELL FITTED SCLERAL LENS

- Observe the size and mobility of any bubble formation
- Haptic area should not show any clearance
- Negative pressure or 'cling' should be avoided
- Fenestration should be in the corneal section near transition zone, 1-2 mm from temporal upper lid margin

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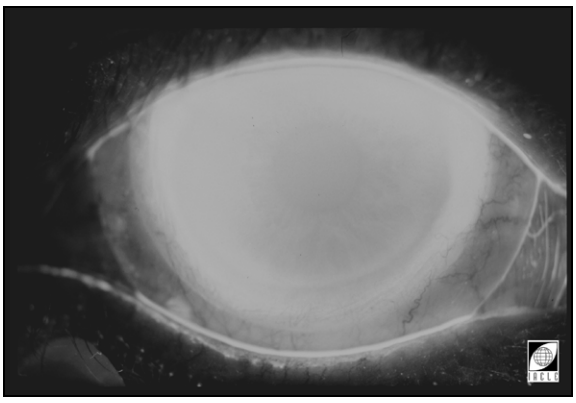

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- The corneal section should arch (vault) over the cornea with minimal clearance but sufficient to prevent bearing on the cornea (slide 73). The fit of the lens should be examined using fluorescein. It is best to place the fluorescein in the solution in the lens before it is inserted. The patient should be allowed to wear the lens several minutes before the fit is evaluated.
- The fluorescein pattern should show an even clearance over the corneal area and from 1 - 2 mm peripheral to the limbus. The limbus must be cleared completely if the lens is to be comfortable (slide 75).
- While a bubble may be present, it is not necessary to have a bubble for a good fit. If there is a bubble, it is likely to be sausage-shaped, and should be located over the corneo-scleral junction. The best location for a bubble is temporal or superior. Ideally, it should not be in the lower nasal or inferior positions, since this may interfere with vision during reading and close work.
- The bubble must be mobile in different directions of gaze but should not encroach into the pupil zone. The size of the bubble enlarges with version eye movements. Under the haptic portion of the lens, there should be minimal fluorescein. If the haptic has localized areas of clearance, fluorescein will pool in these areas. If there is edge stand-off, fluorescein will be seen under the haptic edge and the regional fit must be altered.
- The fit should be examined for 'cling' (the relative negative pressure under the lens due to a 'glove-like' or perfect fit of the haptic). If a suction cup is applied to the front of the lens, one should be able to lift the lens away from the eye easily. If there is 'cling', removal will be difficult and the eyeball will even move forward as one tries to pull the lens forward from the eye.

When the eye is in the primary gaze position, the lens fenestration should be 1-2 mm below the margin of the temporal upper lid and be in the corneal section near the corneo-scleral transition zone.

VII Application and Removal of Lenses

76

SCLERAL LENS INSERTION

- Fill lens with saline
- Instruct patient to:
  - lean forward
  - head bowed
  - eyes looking straight ahead
  - lens not tilted

98400-51S.PPT

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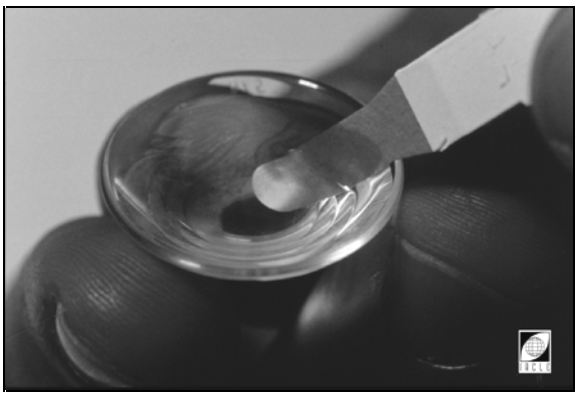
77



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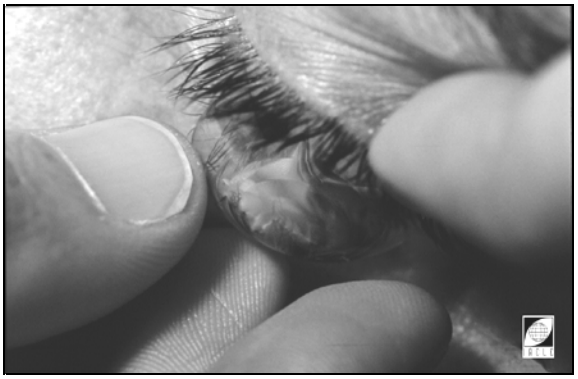

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79

REMOVAL OF LENS

- Patient looks down
- Upper lid pushed behind lens edge
- Slight upward pressure from lower lid

98400-52S.PPT

9L498400-52

Application of the Lens:

1. Fill the lens with sterile, gas (propellant) bubble-free saline solution and hold it on its edges with your fingers (orient the lens so that the back surface parallels and approaches the cornea). If the lens fitting is to be assessed, fluorescein should be added before insertion (slide 77).
2. Instruct the patient to lower their head, tilting forward so that it is horizontal with the ground.
3. Raise the upper lid.
4. Slide the lens under the upper lid and hold the lens in position (slide 78).
5. Have the patient look straight down while gently pulling the lower lid down to allow the lens to be pushed gently onto the eye.
6. Release the upper and lower lids.
7. The patient should then return their head to the upright position.

Removal of the Lens:

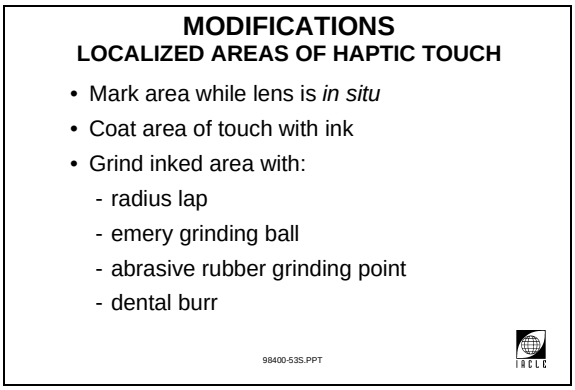
The simplest method for the practitioner to remove the lens from the patient's eye is by hand (without a suction cup).
Starting with the patient's right lens:

1. Instruct the patient to lower their gaze.
2. Place the thumb of the left hand under the lashes of the upper lid of the right eye (starting at the inner canthus).
3. Raise the upper lid with the thumb above the edge of the lens.
4. Slide the thumb along the margin of the upper lid towards the outer canthus.
5. While sliding the thumb along the margin of the upper lid, exert slight pressure towards the globe and down behind the lens.
6. The upper portion of the lens will separate from the globe.
7. The lens should drop into the practitioner's open right hand.

The procedures above are repeated for the patient's left lens. The practitioner may find it more convenient to use the opposite hands when removing the left lens.

VIII Modifications

80



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Tight Haptic Areas

If localized areas of touch occur, scleral injection and discomfort will result when the lens is worn for a significant period of time. These areas of touch must be relieved.

First, the area of touch is marked on the front surface of the lens with a felt-tipped marking pen while the patient is wearing the lens. The lens is then removed and the area on the back surface, where the plastic is to be removed, is coated with ink.

The plastic is ground away by either:

- Holding the lens against a diamond impregnated radius lap and selectively grinding the desired position.
- Using an emery grinding ball.
- Using an abrasive rubber grinding point.
- Using a dental burr.

After the desired amount of plastic is removed (only 0.05 - 0.10 mm is removed at a time depending on the harshness of the bearing or the clearance desired):

1. The area is smoothed using pumice on a small felt buff.
2. The lens is cleaned well before the next (polishing) stage since any pumice present will scratch the lens.
3. The area is polished on a small polishing wheel.
4. The lens is then reinserted and the fit reassessed.
5. If an area of touch remains, the procedure above must be repeated until the desired fit is achieved.

81

MODIFICATIONS
CENTRAL CORNEAL TOUCH

Corneal clearance may be attained by grinding out the corneal and limbal areas with the same tool used to fabricate the back optic of the lens

98400-55S.PPT

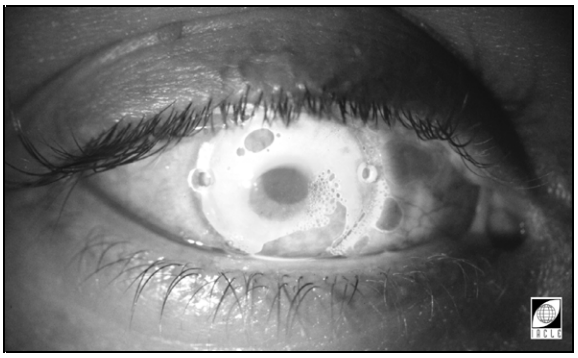
9L498400-55

Central Corneal Touch

As the patient builds up wearing time, the fitting of the lens will settle. A lens that had ample corneal clearance when first fitted may eventually need one or more corneal and/or limbal grindings to obtain a comfortable and satisfactory fit.

If any corneal touch is exhibited (slides 82 and 83), modify the lens-to-cornea fitting relationship. The clearance is increased by grinding the corneal section using a radius lap and employing the same procedure as used to fabricate the back optic. The same radius used to grind the back optic is selected. This results in a uniform increase in corneal clearance over the whole of the optic area.

82



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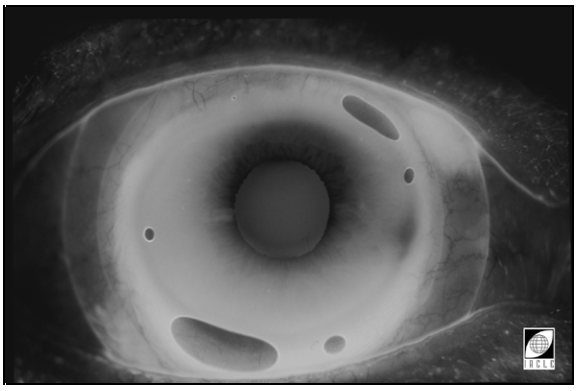

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84

MODIFICATIONS
EXCESSIVE CORNEAL CLEARANCE

Perform a 'haptic let-down' by uniformly removing plastic over the whole haptic area

98400-57S.PPT

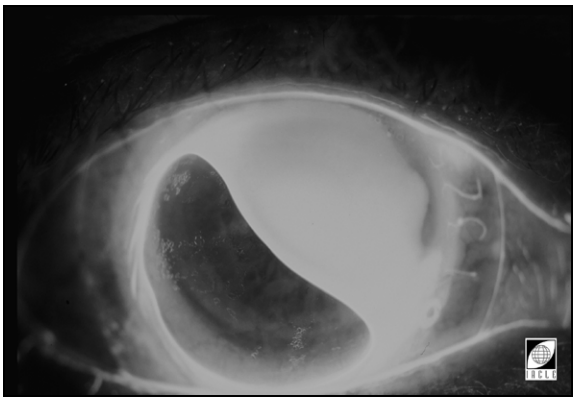
9L498400-57

Excessive Corneal Clearance

If the corneal clearance is too great, there will be a large bubble over most of the corneal area (slide 85). To correct this a 'haptic let-down' must be performed.

Plastic is removed uniformly over the whole haptic area, allowing the lens to settle back towards the eye and eliminating the excessive corneal clearance.

85



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86

MODIFICATIONS
LIMBAL TIGHTNESS

Limbal grind-out is done by:

- Marking the limbal areas of touch with lens *in situ*
- Covering the back optic area with tape to prevent scratching or distortion
- Coating area to be modified with ink
- Grinding (in small steps)
- Polishing ground areas

98400-59S.PPT

9L498400-59

Limbal Tightness

If the fluorescein pattern shows no limbal clearance immediately after fitting a lens or after a period of wear, a limbal grind is required.

The procedure is similar to eliminating a tight haptic area:

1. The area to be ground out is marked on the front surface with a felt pen while the patient is wearing the lens. The areas of touch and desired clearance must be marked as accurately as possible.
2. After removing the lens, the back optic should be protected from possible scratching or distortion during the grinding, pumice and polishing stages by covering it with a small piece of self-adhesive tape.
3. The area to be removed should be coated with ink (i.e. the inside surface), permitting the practitioner to see where the plastic has been removed by the grinding process.
4. The plastic in the marked area should be removed in small steps since the procedure can be repeated if the removal of more plastic is required. Obviously, the process cannot be reversed if too much is removed.

87

MODIFICATIONS
LENS CENTRATION & ROTATION

Centration:

- A large bubble might represent a tight peripheral area of touch opposite the bubble's location
- Relieve touch by grinding or narrowing the scleral flange if it is too wide

98400-61S.PPT

9L498400-61

88

MODIFICATIONS
LENS CENTRATION & ROTATION

Rotation:

- Loosen tight areas until vessel blanching disappears
- Reduce the nasal diameter if the nasal scleral flange touches the plica semilunaris or caruncle

98400-63S.PPT

9L498400-63

89

MODIFICATIONS
LENS CENTRATION & ROTATION

Rotation:

- Reduce the temporal diameter if the scleral flange touches the temporal conjuctival fold
- A large inferior flange can be reduced without introducing superior limbal touch

98400-64S.PPT

9L498400-64

Lens Centration and Rotation

If, after fenestration, the bubble is large, the lens may not centre correctly. In the lens position opposite the bubble, a peripheral zone of corneal touch may be detectable.

- First check for an area of touch peripheral to the bubble. A area of touch in this region will not allow the lens to centre correctly. It is the first area that should be 'corrected' (altered).
- If the bubble is temporal and the corneal touch is nasal, check the nasal flange width to determine if it is too wide, causing the lens to be pushed temporally. If this is the case, the flange width must be reduced.
- If no area of touch is found, treat the lens as if there is such an area in the region of the haptic peripheral to the bubble. Easing this area usually allows proper centration.

Slight rotation of the lens is unimportant but excessive rotation must be corrected.

90

MODIFICATION
LARGE, IMMOBILE BUBBLE WITH PROPER LENS CENTRATION

Perform a haptic 'let-down' on the area peripheral to the bubble

98400-65S.PPT

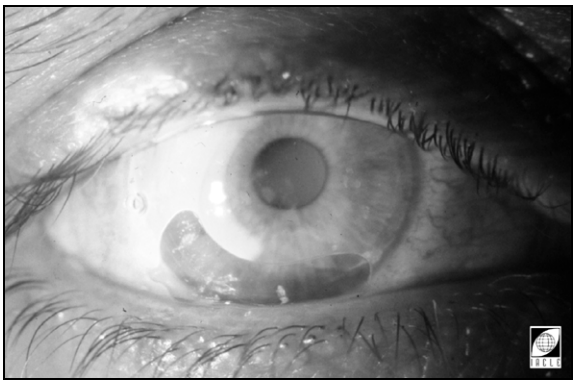
9L498400-65

Large, Immobile Bubble with Good Lens Centration

The bubble may be due to excessive clearance on one side of the corneal transition zone (slide 91). This may be corrected by doing a haptic 'let-down' on the haptic area peripheral to the bubble.

Usually an area of one-third to one-half the circumference of the haptic must be carefully ground away to achieve the 'let-down' required.

91



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MODIFICATIONS
OVERALL DIAMETER

If touch is observed, decrease the lens diameter on the same side as the touch, until touch is eliminated

98400-66S.PPT

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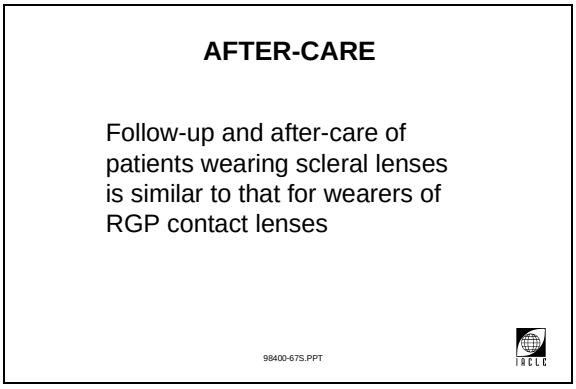
Overall Diameter

- For stability, the lens should be kept as large as possible. A wide inferior scleral portion prevents the lens from dropping and striking the superior limbus.
- If a touch zone appears at the nasal limbal area, the size of the nasal scleral flange should be reduced until the touch is eliminated.
- The same procedures can be performed for all other areas of limbal touch.

IX After-Care

93



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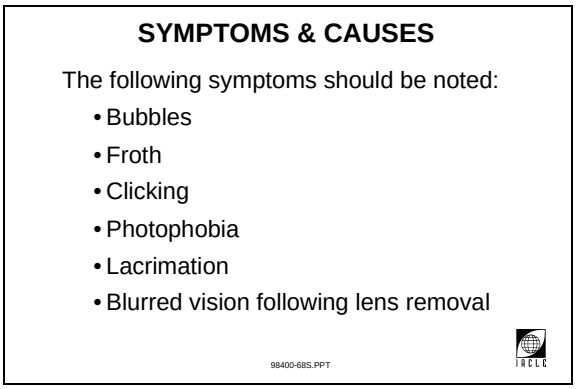
After-Care

94



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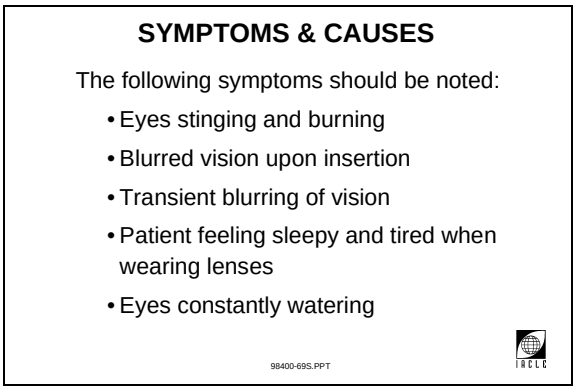

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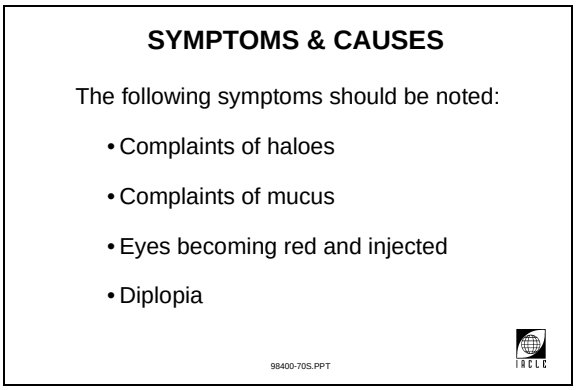

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Symptoms and Causes

Bubbles

- Improper placement or size of lens fenestration.
- Excessive apical clearance.

Froth

- Improper placement or size of lens fenestration.

Clicking

- Improper placement or size of lens fenestration. The clicking sound is caused by the bubble passing through the fenestration.

Photophobia

- Over-correction in prescription.
- Lack of tear exchange resulting in hypoxia.
- Hypoxia.
- Insufficient limbal clearance.

Lacrimation

- Corneal bearing, insufficient limbal clearance and lack of tear exchange.

Blurred Vision After Removing Lenses

- Insufficient tear exchange.
- Hypoxia.

Eyes Sting And Burn

- Insufficient tear exchange.
- Rough edges.
- Insufficient limbal clearance.
- Hypoxia.

Blurred Vision Upon Insertion

- Front surface of the lenses not properly wetting.
- Poor optics.

Transient Blurring of Vision

- Drying of the lens front surface.

Patient Feels Sleepy And Tired When Wearing Lenses

- Over-correction.
- Insufficient tear exchange.
- Not enough limbal clearance.

Eyes Constantly Watering

- Corneal bearing pressure.
- Insufficient tear exchange.

Complaints Of Haloes; Sattler's Veil

- Insufficient tear exchange.
- Hypoxia.

Complaints Of Mucus

- Corneal bearing.
- Rough edges.
- Lack of tear exchange.

Eyes Become Red And Injected

- Corneal bearing.
- Insufficient tear exchange.
- Insufficient limbal clearance.

Diplopia

- Optics not aligned.
- Poor centration.
- Monocular diplopia may be caused by a large bubble.

🕮 References

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Unit 9.5

(1 Hour)

Lecture 9.5: Fitting an Ocular Prosthesis

Course Overview

Lecture 9.5: Fitting an Ocular Prosthesis

I. Uses and Applications of Ocular Prostheses

II. Fitting Considerations and Procedures

III. Production Process and Techniques

IV. Refitting and After-Care

V. Problems and Complications

Lecture 9.5

(1 Hour)

Fitting an Ocular Prosthesis

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II Fitting Methods **189**
III Care and Maintenance **194**
IV Modification **196**
V Patient Management **199**
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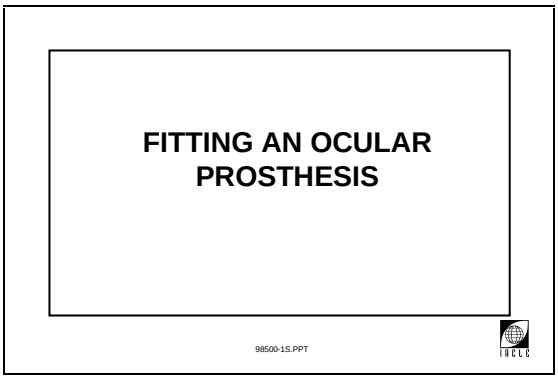
I Types of Ocular Prosthetic Devices

1



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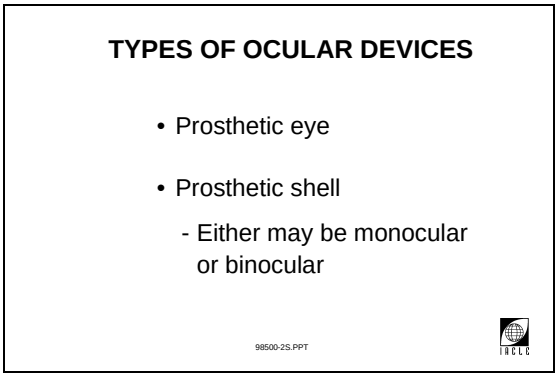

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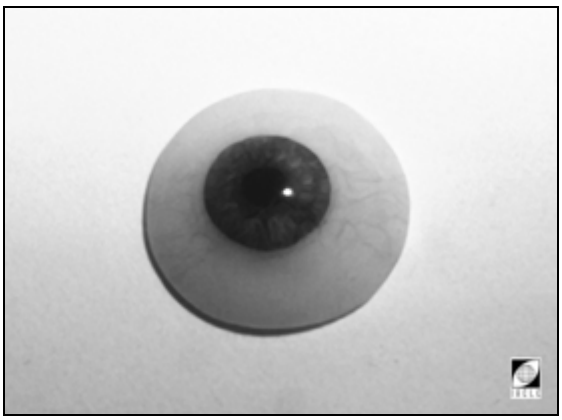

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Ocular Prostheses

An ocular prosthesis (artificial eye) is a non-optical device designed to improve the cosmesis of an individual who has had their eye removed or disfigured.

Such a prosthetic device may be either a prosthetic eye (artificial eye) or a prosthetic shell (a disguise for a disfigured eye).

Ocular prostheses are usually molded, painted (decorated to emulate the fellow eye) and polished to create a realistic appearance.

Prostheses are usually made of plastic because of its ease of fabrication, good biocompatibility and, should the prosthesis become scratched or deposited, its capacity to be re-polished.

A **prosthetic eye** is used after the removal of the whole eye and is designed to restore the natural appearance of the orbit and surrounding tissues. A prosthetic eye is typically fitted over an ocular implant that occupies the place of the removed eye. Prosthetic eyes may be made of blown glass or an acrylic (a plastic such as PMMA).

A **prosthetic shell** (slide 3) is a plastic ocular prosthesis that is essentially a painted haptic lens. A shell is thinner and lighter than a prosthetic eye and typically, is fitted over an existing globe which may be shrunken, blind or disfigured. The fitting of prosthetic shells incorporating a vision correction is similar to the fitting of haptic lenses, which is covered in Lecture 9.4.

4

PROSTHETIC CONTACT LENSES

- Healthy globe and socket
- Globe anomalies:
  - scarring
  - coloboma
  - albinism

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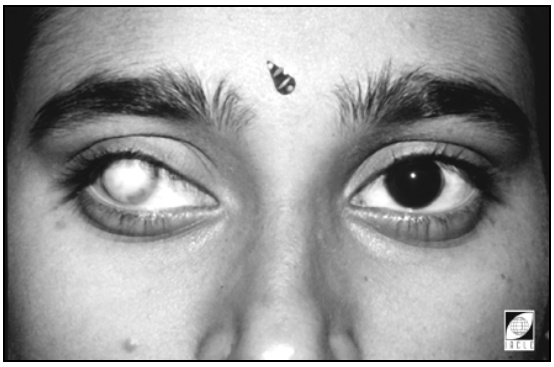

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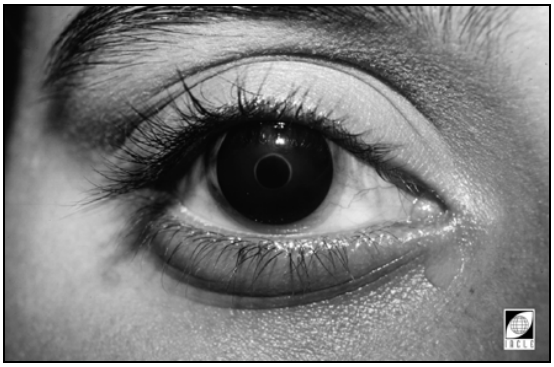

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Prosthetic Contact Lenses

A prosthetic contact lens (artificial iris) is a contact lens used on both sighted and non-sighted eyes to improve their cosmetic appearance. For example, after an iridectomy or in a case of iris coloboma, a prosthetic contact lens with artificial iris can be fitted to replace or augment an absent or incomplete iris. Such a lens can also mask a scarred cornea (slides 5-7).

For rigid lenses, the iris is hand-painted to the desired colour and laminated with a clear plastic overlay. For soft contact lenses, colours and shades can be custom-ordered from the laboratory.

For a detailed treatment of cosmetic contact lens fitting refer to Lecture 8.8.

8

PROSTHESES MAY BE REQUIRED AS A RESULT OF:

- Trauma
- Malignancy
- Developmental anomalies
- Degenerative conditions

98500-4S.PPT

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9

NON-OCULAR CONSIDERATIONS

- Patient requirements
- Psychology:
  - self esteem
  - interaction

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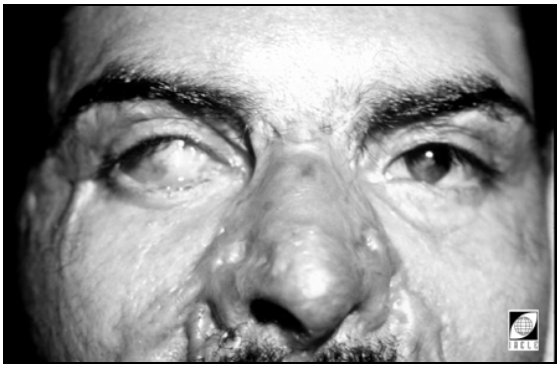

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The Need for Prosthetic Eyes/Shells

According to the World Health Organization (WHO) Program for the Prevention of Blindness (Thylefors *et al*., 1995), the most common causes of blindness are diseases that do not require removal of the eye. According to the WHO (1979), populations of under-developed countries have a shorter life expectancy and therefore have a lower overall prevalence of age-related blindness. For countries at the interim stage of development, industrial accidents are increasing. In developed countries, older people account for the greatest percentage of the blind.

Although the WHO criteria for blindness is $\leq$3/60 or its equivalent (with the inability to count fingers), the criteria employed in the decision to use an ocular prosthesis are often based on the absence of light perception and the cosmetic benefits that the patient may derive.

An ocular prosthesis is often required in cases such as:

- Trauma (e.g. corneal scarring (slide 10), penetrating injuries, leukomata).
- Malignancy (orbital melanoma, retinoblastoma).
- Developmental anomalies (e.g. anophthalmos, dermoid cysts).
- Degenerative conditions (e.g. panophthalmitis, failed keratoplasty, optic atrophy).

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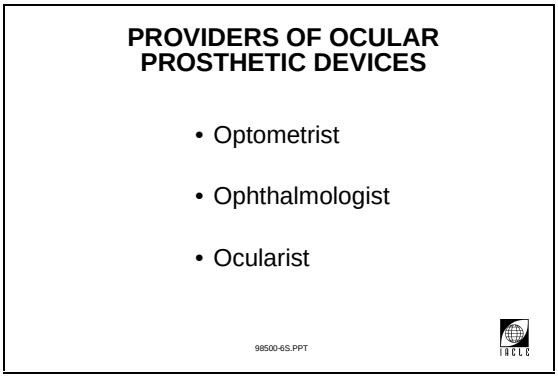

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Providers of Ocular Prosthetic Devices.

An ocular prosthetic device may be provided by an optometrist, ophthalmologist or ocularist. This is usually done as part of a cross-referral system.

The fitting of a prosthetic device requires patience, innovation and artistic skills, especially for conditions where custom-fitting of the prosthesis is required, as in cases of evisceration (e.g. orbital tumours) which involve surgically creating orbital structures to support the artificial eye.

Although some practitioners specialize in the art and science of ocular prostheses, an optometrist or ophthalmologist in a busy practice may not have sufficient time for the manufacturing process, and so may benefit from working in conjunction with an ocularist.

Considerable experience is necessary to master the skills required to achieve the desired cosmetic effects. This may be difficult in a limited, or non-specialist practice. Special tools, materials and equipment are also required beyond those normally used in regular contact lens practice.

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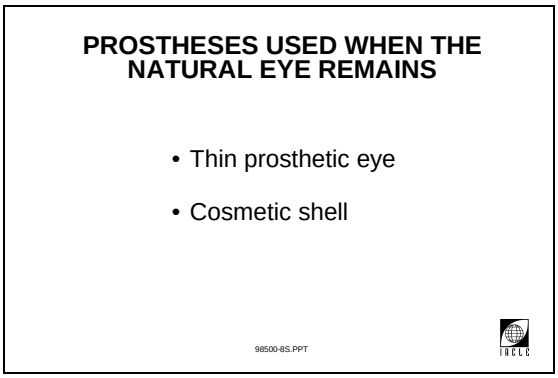

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Prostheses Used When the Natural Eye Remains

Cases of phthisis bulbi (slide 13) or a scarred blind eye may need a thin prosthetic eye or a cosmetic shell. Fitting/refitting procedures for the scleral shell are carried out over the blind, disfigured eye. The techniques are the same or similar to those for the molding and fitting of scleral contact lenses (covered in Lecture 9.4).

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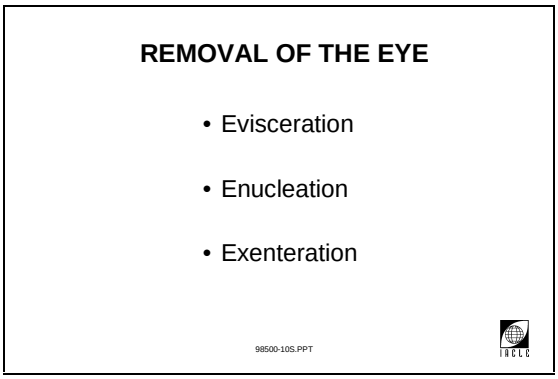

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Removal of the Eye

The surgical procedures and socket conditions necessitating a prosthesis are:

- **Evisceration** - removal of the global contents with retention of the scleral wall, muscles and cornea. The advantage of keeping the ocular muscles intact is retention of 'natural eye movements' with the prosthetic shell in place. This conservative form of surgery is not appropriate in cases of intraocular malignancy or when the chance of sympathetic ophthalmia is high. Two types of evisceration procedures exist. They are:
  - evisceration with insertion of an intra-scleral implant
  - evisceration without implant insertion.
- **Enucleation** - this procedure involves removal of the entire globe (slide 15). Enucleation is indicated for the following conditions:
  - intraocular malignancy
  - penetrating ocular injury which may cause sympathetic ophthalmia
  - painful, blind eye
  - disfigured, painless, blind eye.
- Following the enucleation procedure, several methods of socket restoration are utilized.
  - **Simple enucleation** (the eyeball is removed but no implant is used):
    The recti muscles are sutured together to form a 'stump' that will assist in prosthesis mobility. A sunken appearance may eventually manifest due to the lack of a space-occupying material. This is not the procedure of choice since it results in a large socket for which the prosthesis must be large and thick (and therefore heavy). Usually, the prosthesis exhibits little movement.
  - **Enucleation with implant** (this is the most common operation):
    The globe is removed and an implant inserted to replace the space previously occupied by the eye. The implant maintains the orbital structure and gives support to an overlying prosthetic eye/shell (slide 16). The implant is placed in Tenon's capsule with the conjunctiva sutured together in front of the implant. The extraocular muscles remain associated with Tenon's capsule and allow for movement of the implant in a manner similar to that of the natural eye.
- **Exenteration -** this procedure is the most radical. It involves removal of the entire orbital contents and usually occurs following severe trauma or malignancy. Facial restorations (slide 17) and socket impressions may be necessary to create some degree of facial symmetry.

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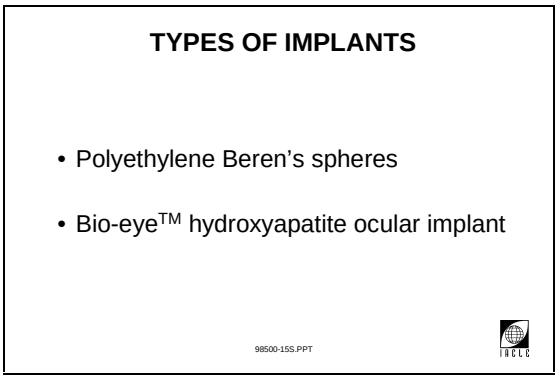

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Types of Implants

- Spherical implants made of plastic, glass or hydroxyapatite (similar to bone), which are placed within Tenon's capsule and conjunctiva.
- A variety of implants in the shape of a modified hemisphere with a flat or rounded top. The top is covered with an inert mesh (stainless steel or Teflon™ to which extra-ocular muscles are sutured.
- Selected types of implants include:
  - **Polyethylene Beren's spheres:** clear, non-water-absorbent spheres of 12 to 20mm diameter, used for implantation after evisceration or enucleation
  - **Bioeye™ydroxyapatite Ocular Implant:** (Integrated Orbital Implants, Inc., San Diego, USA), made of bone-like porous material derived from ocean coral. This implant allows tissue and blood vessel invasion which stabilizes the implant and encourages consistent positioning within the orbit. The latter also allows for relatively normal 'eye movement' of the implant and overlying prosthetic eye/shell. Once the implant is in position in the orbital socket, it is possible to drill a hole in the implant to receive the peg attached to the overlying prosthetic eye/shell. This also encourages fuller movement of the prosthetic eye/shell in tandem with that of the companion normal eye.

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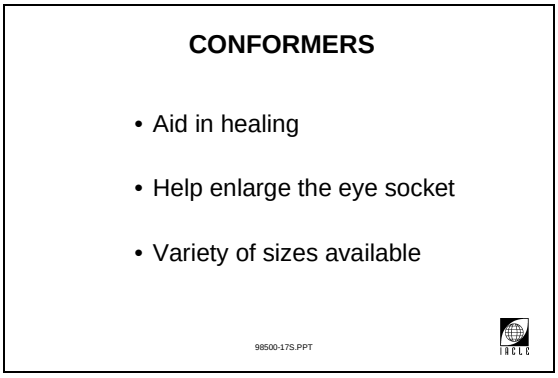

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Conformers

Conformers are clear, plastic, oval-shaped concave discs placed in the socket over the implant during the post-operative phase of treatment. Conformers form a pocket for the prosthesis, and hold the implant well back in the socket. They are inserted to prevent apposition of the sutures to the lids and to prevent irritation. Conformers are transparent. This allows healing of the tissues to be monitored, and scar tissue formation between the back of the lid and the conjunctival tissue over the implant to be curtailed.

Conformers are also used to enlarge a socket in a patient who has gone without a prosthesis for a long period of time, with subsequent shrinking of the socket. This enlargement is managed by using progressively larger shapes.

II Fitting Methods

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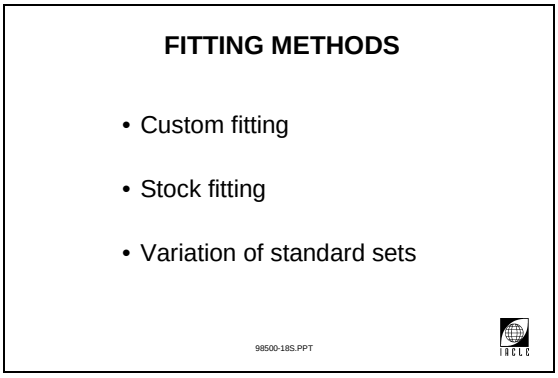

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Fitting Methods

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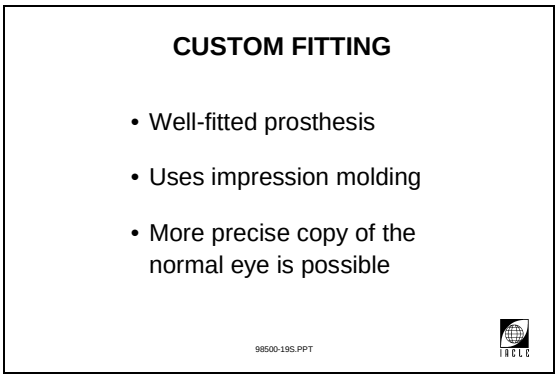

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Custom Fitting or Molding

This method is necessary after enucleation or exenteration. In such cases the whole socket must be filled by the prosthesis. It is also used with unusual orbital shapes and conditions.

This method is preferred for standard fittings of prosthetic eye/shells by many ocularists. It allows the efficient creation of a well-fitted prosthesis with a size, shape and back surface contour which 'fits' the socket. It provides better movement than is usually possible with a stock prosthetic eye/shell (even when a stock prosthetic eye/shell is 'customized').

To mold a prosthetic shell, the same impression material used for making a haptic lens is utilized (usually an alginate).

For a prosthetic eye/shell, molding of the socket will require more alginate material to be mixed and injected or inserted (slides 22, 23). A wax model (positive) is made from the alginate mold taken of the eye. A plaster negative (die) is made from the wax model and then a monomer (a liquid acrylic resin) and polymer (a powdered acrylic resin) are mixed into a dough and placed in the die.

The colour of the polymer should match the scleral colour of the normal eye. Colour can be added to make a bluish sclera for the younger patient and a yellowish sclera for the older patient. With heat and pressure, a plastic eye of the desired shape is formed. An iris recess is machined into the polymerized shell and a correctly-coloured iris button is inserted. 'Blood vessels' are added and laminated in a die by polymerizing with a clear mixture of liquid and powder acrylic resins.

Cutting, grinding, refining and polishing of the prosthetic eye follow, using different grades and shapes of burrs that conform to the various contours of the artificial eye. The final polish is done using a fine pumice.

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24

STOCK PROSTHETIC EYE/SHELLS

- AO Monoplex prosthetic eye
- Fitting set
- Order specifications based on a coding system

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Stock Prosthetic Eye/Shells

These are often available in fitting sets.

Sets of prosthetic eye/shells of given shapes and sizes can be obtained. The eye socket can be fitted from the sets with or without modification. Due to the wide range of shapes of globes and sockets, most prosthetic eye/shells need modification before dispensing.

Standard (basic) shapes are molded in white plastic. There is a depression in the front where the iris button is placed.

The iris button is a round disc of clear plastic to give the appearance of depth (emulating the anterior chamber depth). The iris button is painted on both sides. Mineral pigments rather than organic pigments should be used since the latter will fade with time, and may induce a reaction should they ever come in direct or indirect contact with the orbit or lids.

The scleral colouring (sometimes called a 'wash') and veining (usually fine red cotton thread) is added to the surface of the basic shape.

A common set is the **American Optical Monoplex prosthetic eyes**. These are fabricated from methyl methacrylate (PMMA), which is marketed as Perspex™, Plexiglass™, Lucite™, or Oroglas™, depending on the manufacturer and/or country.

American Optical (AO) distributes sixteen plastic Monoplex shapes: eight for the right eye and eight for the left. The categories are oval, standard and three-cornered, with dimension differences in thickness, curvature and peripheral construction noted.

All AO Monoplex prosthetic eyes have a 1 mm clear plastic layer over the scleral colouration, and a 3.5 - 4 mm clear cover over the iris centre.

Fifty iris colours currently exist in AO's inventory and special colours can also be generated. Thin red thread, or less desirably a special plastic pigmented mix, is used to simulate the scleral vessels as closely as possible.

AO Monoplex prosthetic eyes can be obtained in three sets, although special lot orders may be

requested. The Monoplex Eye Fitting Set consists of 35 prosthetic eyes including each of the 16 shapes available and 35 iris and scleral colour schemes. This set is adequate for the practitioner who does a limited amount of fitting. There are two Monoplex Stock Eye Units available for purchase containing 120 and 240 prosthetic eyes. Each of these sets is designed for practitioners who see a large number of patients and can dispense from stock.

The Monoplex Eye Code characterizes each device. Each prosthetic eye within the Monoplex sets contains a combination of numbers and letters on the upper temporal region indicating fabrication and colouration guidelines. For Caucasians or lightly-skinned individuals, a total of four or five letters and numbers indicate the size and shape of the prosthetic eye, whether a right or left eye is ordered and iris colour. There is one additional code for darkly pigmented individuals, consisting of one letter or a letter and number indicating scleral coloration.

Examples of the coding system:
EYE CODE: 5 R N10

[CODE KEY: 5 = *Size and Shape, R = Right Eye, N1O = Iris Colour (Dark Brown)*]

Since no additional code is listed for scleral colouration, this eye would be for a Caucasian or for other individuals lacking scleral pigmentation.

EYE CODE: 3 L T35 6Y

The inclusion of the extra code (6Y) suggests this eye would be used for a darkly pigmented individual.

[CODE KEY: *3 = Size and Shape, L = Left Eye, T35 = Iris Colour (Dark Green), 6Y =Scleral Colour of Eye (White Base, Light Hazel Yellow Wash)*].

The standardization of prosthetic eye colours, size and shapes and scleral colours makes large inventories unnecessary. Even the 35 prosthetic eye Monoplex fitting set contains a large array of commonly encountered ocular features. The larger sets contain all of the iris colours, leaving few colours or patterns to the interpretation of the clinician.

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VARIATION OF STANDARD SETS

- Use of dental wax during refitting and trial
- Routine build-up to improve fit

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Fitting Methods

Variation from Standardized Sets

The AO Monoplex eye sets offer clinicians a good starting point to determine the prosthetic eye to be ordered. However there are inherent problems when utilizing a generalized fitting set since orbits of different size, shape and depth have slight idiosyncrasies.

Dental wax is commonly used to add greater accuracy and comfort when improving the fit of the prosthesis. The material is easily attached to the existing trial prosthetic device and then inserted into the patient's orbit for evaluation.

Proper alignment of the prosthesis is sought in primary gaze and equal protrusion should be achieved without patient discomfort.

Matching of the iris colouration, scleral vasculature and colouration, and pupil size are then considered.

Usually, colour schemes are determined in the type of illumination most commonly experienced by the patient. If no exact colour match or pattern can be determined from the fitting sets, the clinician may consider photography (not particularly reliable for colour because of the number of uncontrolled variables involved in producing the final result) or diagrams as a means of providing information to the manufacturer. Special details such as pinguecula, pterygium, corneal arcus or unique iris or scleral details and patterns may be specially ordered from AO for an additional charge.

Modifications of the basic eye are necessary when:

- The shape does not match the socket condition well, and a routine build-up is required.
- A modified iris colour (iris freckles, etc.) is required.
- Special sclera colouration (bluish sclera for children for example) is required.
- Unusual iris or pupil shapes and sizes (keyhole pupil or small pupil for older patients for example) are required.

26

BASIC FITTING GOALS

- Optimum pupil diameter
- Orthophoric appearance
- Stability of fit

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Basic Fitting Goals

The optimum prosthetic pupil diameter is difficult to determine because it will not respond to varying illumination as the normal pupil does. It is best to choose a pupil diameter that is appropriate to an environment with high illumination, because this is when other people are more likely to notice the patient's eye. The 3.5 mm diameter pupil is optimum in most cases.

The patient must appear to be orthophoric with the prosthetic eye/shell (slides 28, 29). The best way to check this is to place the prosthetic eye/shell in the orbit and using a penlight, check the position of the

27

FITTING CONSIDERATIONS

- Overall size:
  - horizontal
  - vertical
  - exophthalmos
  - enophthalmos
- Smooth edges

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corneal reflex in the two eyes. If the iris position is not correct, it must be changed either by ordering it in the proper position or by modifying the prosthesis.

For custom-fitted prosthetic eye/shells, the iris diameter and position are measured by inserting the final wax model of the prosthetic eye/shell and measuring the pupillary distance of each eye from the bridge of the nose. A divider is used to mark the iris on the wax model, which then registers on the plaster cast (negative die).

Another important factor is to have the proper palpebral aperture size. The aperture should not be too wide, resulting in a staring appearance. The palpebral aperture is controlled by the size and thickness of the prosthetic eye/shell or wax model.

The prosthesis must not fall out with the patient looking in different positions of gaze or during active sports. When fitting the patient, instruct them to look in all directions while keeping their head steady. A quick change in the direction of gaze is helpful in testing the stability of the prosthesis during active sports. The prosthesis should not fall out or have a tendency to fall out. It is normal for misalignment of both eyes to become apparent while looking in different directions of gaze, especially if the eye excursions are extreme.

III Care and Maintenance

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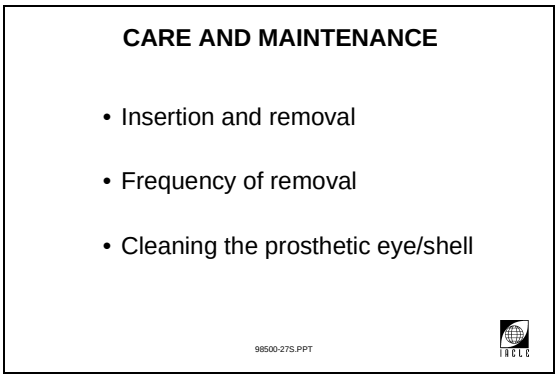

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Care and Maintenance

Aspects of the care and maintenance of prosthetic devices that require the attention of the practitioner are:

Insertion and removal:

- The prosthetic eye/shell is inserted and removed in the same manner as scleral lenses. Wetting solution is used on the prosthetic eye/shell prior to insertion.
- The patient should always wash their hands thoroughly before handling the prosthetic eye/shell.
- Usually the upper lid of the right eye is lifted with the thumb or forefinger of the left hand. The prosthetic eye/shell is slid under the upper lid as far as possible, then the lower lid is depressed to allow the prosthetic eye/shell to slip into the socket.
- To remove the prosthetic eye/shell, the lower lid is pulled down and outwards so that the lower edge of the prosthetic eye/shell slides out over the lower lid. A suction cup may be used to hold the prosthetic eye/shell, or it may be allowed to drop into the patient's hand.

Frequency of removal:

- The ocular prosthesis is designed for day and night wear. It is rarely necessary to remove the prosthetic eye/shell at night. Should this be necessary, the prosthetic eye/shell should be stored in a contact lens soaking solution to keep the plastic hydrated. In some exceptional cases, it may be necessary to remove the prosthetic eye/shell every day for cleaning.

Cleaning the prosthetic eye/shell:

- Antibacterial soap such as pHisoHex™ or a rigid contact lens cleaner and warm water is recommended for cleaning. The prosthetic eye/shell should be rubbed well with the thumb and forefinger.

Scratch and deposit removal:

Periodically, the prosthetic eye/shell should be dried using a damp tissue and examined under a strong light for deep scratches or surface deposits. The deposits are formed from tears and mucus, and appear as a dull film. If the deposit is heavy, it will irritate the lids and cause extra secretion. Usually the deposit can be removed by cleaning the shell. If this fails the prosthesis should be polished. Alcohol and other organic solvents should *never* be used to clean the prosthesis as this affects surface wettability. When scratches have developed, it is best to polish them out.

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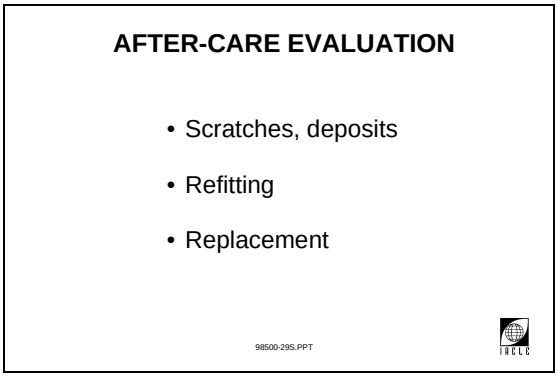

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After-Care Evaluations (Periodic Refitting and Replacement)

The prosthetic eye/shell should be checked by the practitioner at least once a year to determine if there are any scratches or surface deposits and to check the fitting. Children under eight years of age should have check-ups more frequently – every six months or thereabouts.

Socket changes may occur and adjustments to the size or shape of the device may be necessary. This can often be accomplished on the same prosthetic eye/shell. In young children, adjustments are usually due to growth.

Frequency of Replacement

How long a prosthetic eye/shell lasts depends on the patient's age, occupation, physical condition - and of course, how well they take care of their prostheses. Acrylic (plastic) prosthetic eye/shells decay over a period of years, and replacement/refitting should be expected at least every ten years or thereabouts.

IV Modification

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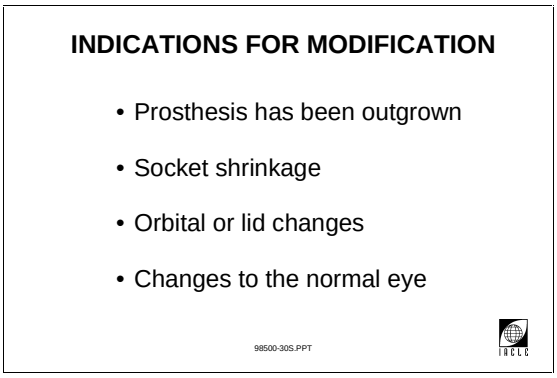

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Indications for Modification

Modifications to prosthetic eyes/shells may be indicated in one or more of the following conditions:

- Children who have outgrown their prosthesis will complain of the 'eye' falling out (expulsion).
- A reduction of the palpebral aperture occurs even though the prosthesis remains unaltered.
- Patients who have discontinued prosthesis wear for a long period may experience shrinkage of the socket. This causes a tight fit that may be uncomfortable and cause the 'eye' to fall out.
- Orbital or lid changes that cause a displacement or misalignment of the 'eye'.
- Changes to the normal eye that create a cosmetic difference between it and the prosthetic eye.

Modifications may involve the use of dental wax to provide additional bulk. Any modification (reduction or addition of material) to a prosthesis should be followed by testing of the stability of the prosthesis as described above.

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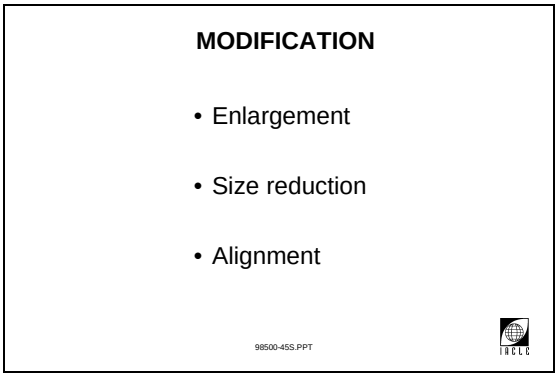

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Enlarging the Prosthesis

Provided that no other modifications are required, general enlargement of a prosthesis can be performed by adding a clear laminate over the entire back surface in the case of a prosthetic eye or increasing the diameter of a prosthetic eye/shell around its scleral rim. A negative mold can be made from the existing 'eye' modified by dental wax, prior to mixing and polymerization.

The addition of too much material can cause the eye to look proptosed. The excessive size may also cause it to fall out when the eyes change their direction of gaze.

Size Reduction of Prosthesis

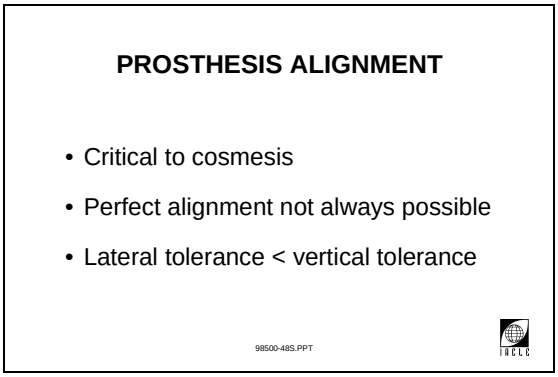
Size reduction should be performed using a carbide-tipped burr on the scleral part of the prosthesis. This requires the removal of the clear laminate.

If an overall reduction is required, an even amount of material should be removed around the equator and/or back surface of the prosthesis.

If tightness in a specific area is experienced, removal of material may lead to a misalignment of the eyes in some or all positions of gaze. This can be avoided by slowly reducing material in the area of tightness, rechecking the fit and assessing the need to add dental wax to the area opposite the region of tightness.

Once an adequate reduction has been achieved, the prosthesis is sent to the laboratory for lamination, grinding and polishing.

34



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Prosthesis Alignment

Alignment of the prosthetic eye/shell with the normal eye is central to achieving a satisfactory cosmetic result. However, perfect alignment is not always achievable, especially if facial restoration has also been required following trauma.

Trauma involving damage to the inferior orbit can be restored using a silicone bag or an abdominal fat implant in the orbital floor. This helps achieve better alignment of the prosthesis.

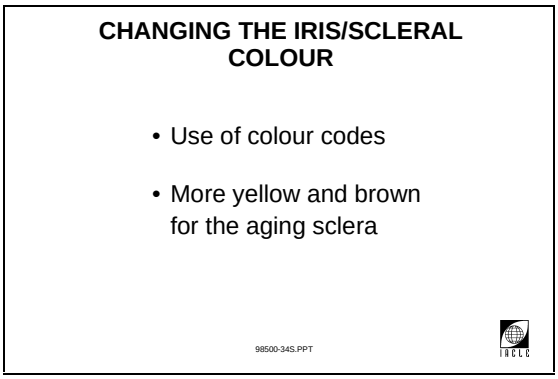
In the process of aligning the prosthesis, it is important to ensure that tightness does not occur. Tightness can cause discomfort and irritation of the orbital tissues.

Addition or reduction of material can be done using the procedure outlined previously. The use of dental wax over the prosthesis and fitting it to the patient is the safest approach.

If the pupillary centre of the prosthesis is too low, material can be added to the lower rim. The reverse is true for a prosthesis that sits high.

A nasal or temporal displacement can usually cause discomfort and tightness if too much material is added. The tolerance for lateral modifications is much less than for vertical adjustments.

35



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Changing the Iris/Scleral Colour

Over time, changes in the colour of the normal eye occur. Patients are usually the first to notice and complain of the prosthesis not looking 'normal'. These patients tend to be very sensitive and meticulous in regard to their appearance. It is important to be understanding and sympathetic to their concerns.

Instructions for colour changes can be given to the laboratory by using colour codes. If modifications are to be performed in-house, removal of the clear laminate is necessary before modifications to iris and scleral colour can be undertaken.

Slightly darker shades than the normal eye are usually painted as the clear laminate effectively lightens the colour tones. The addition of more yellow and brown may be necessary for the 'aging' sclera.

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ADDITIONAL OCULAR FEATURES

- Pterygium
- Arcus senilis
- Iris freckles
- Ptosis crutch (ledge)
- Artificial skin or cheek

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37

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9L59503-98

Addition of Other Ocular Features

Ocular features such as pterygium, arcus senilis and iris freckles can be added to match those that develop in the normal eye.

In traumatic cases, where the normal eye may also be affected by scarring or some form of disfigurement, it may be necessary to make the prosthetic eye/shell look less perfect in order to draw attention away from any difference between the eyes.

Lids may loosen with age and ptosis may develop. A ledge can be attached to the prosthesis to lift the upper lid.

In ocular malignancies that require removal of some facial bone, the prosthesis may be recessed in an artificial skin or cheek that fits into the orbital socket. A pair of spectacles can adequately conceal and camouflage the orbital prosthesis (slides 37, 38).

V Patient Management

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PATIENT MANAGEMENT

- History
- Test functional eye
- Inspection of orbit
- Cleaning and polishing of prosthesis

98500-37S.PPT

9L598500-37

Management of the Patient with an Ocular Prosthesis

If a patient presents with an ocular prosthesis the following management steps should be taken:

- History.
- Monocular testing of the functional eye.
- Inspection of orbit. Removal of the prosthesis (and subsequent reinsertion) is necessary. The technique is described in this lecture and in the lecture on scleral lenses (Lecture 9.4).
- Cleaning and polishing of prosthesis:
  - cleaning
  - soaking
  - wear schedule.

After-Care Routine

A suitable after-care plan includes an annual:

- Examination of the normal eye.
- Routine cleaning and polishing of the prosthesis, using normal RGP contact lens care products.
- Inspection of the eye socket.
- Assessment of, and if necessary, modifications to, the fitting due to any settling of the prosthesis.
- Assessment of the need for a periodic prosthetic eye/shell replacement.

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SUPPLIES AND EQUIPMENT

- CL modification unit
- Motorized spindle (at least 1000 rpm)
- Dental wax
- Alcohol lamp
- Dental burrs
- Sandpaper
- Dental tools

98500-38S.PPT

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Supplies and Equipment

After-care of the prosthetic eye/shell usually includes cleaning and polishing. The equipment and supplies required are the same as those used for modifying rigid contact lenses. For more extensive reductions and additions (lamination, grinding and polishing are usually performed at the laboratory), other supplies and equipment are necessary.

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THE EYE SOCKET

- Generally, a healed socket requires no extra care
- Usually, inflammation or infection is treated with the prosthesis *in situ*

98500-40S.PPT

9L598500-40

Issues Regarding the Eye Socket

Generally, once the socket is completely healed, no extra care is needed.

Treatment of an inflammation or infection (conjunctivitis) of the eye socket:

Any treatment of the eye socket is best done with the prosthetic eye/shell in place to allow the topical drops or ointment to be spread and held in contact with the conjunctiva. Without the prosthesis in place, any treatment applied would not be evenly distributed around the eye socket.

Giant papillary conjunctivitis associated with the wearing of an acrylic prosthetic eye/shell has been reported (Meisler *et al*., 1981). A rough prosthesis surface is highly likely to be a contributing factor in the development of such a condition. The prosthesis should be inspected, cleaned and polished and replaced if necessary. Pharmacological management with either a mast cell stabilizer such as cromolyn sodium or a topical steroid such as fluoromethalone might be considered.

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PATIENT EDUCATION

- Protection
- Vision/mobility
- Driving
- After-care

98500-41S.PPT

9L598500-41

Considerations

- Protection.

  Safety glasses (preferably with polycarbonate or other suitable ophthalmic plastic lenses) for protection of the good eye are strongly recommended, even though the patient may not need a corrective lens for the remaining eye. This is especially important for active children. Spectacles may also make the prosthetic eye/shell less noticeable. It has been suggested that the lens over the prosthetic eye/shell be made 1.00D more minus (or less plus) than the good eye so there is slightly less magnification or more minification.

- Vision/mobility.

  The patient learns to turn their head more frequently to compensate for their monocular, smaller field of vision.

- Driving.

  More effective use of the rear-view and outside mirrors can be important for awareness of surroundings. Increased head movements are also often helpful.

- After-Care.

  The normal eye should be checked regularly by an eyecare practitioner. The prosthetic device should be examined at least once a year by the prescribing practitioner.

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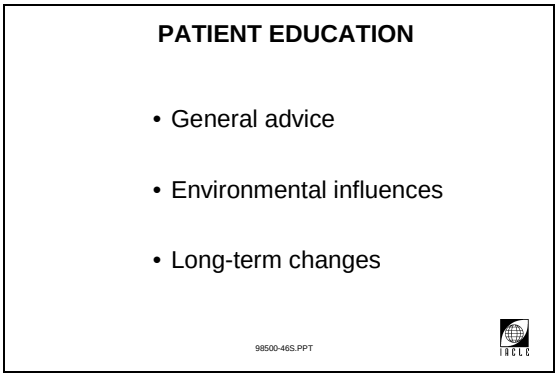

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General Advice to Patients:

- Use only soap and water when cleaning the prosthetic eye/shell, unless otherwise directed by your prescribing practitioner.
- Always wipe the eye towards the nose. Wiping outward can dislodge the device.
- Never leave prosthetic eyes or shells wrapped in tissues or paper. A clean-up may result in the eyes/shells being discarded along with their 'wrapper'.
- When swimming, keep your eyes closed while diving or underwater. Watch out for waves when surfing/swimming in the ocean.
- Cold, hot and dry weather and wind all tend to evaporate moisture from the surface of the prosthetic eye/shell which make blinking more difficult.
- Always practise extreme cleanliness when handling your prosthesis.
- Consult your practitioner immediately if difficulties arise.
- Have your prosthesis checked at least once a year.
- Have your normal eye and socket checked regularly by your eyecare practitioner.
- To make the prosthesis less noticeable, turn the head and not the eyes. When talking to others, keep the eyes on the same level as the other person. Also avoid a fixed stare and/or tilting the head to one side.
- If the lids have not been damaged, the lacrimal and accessory lacrimal glands will still be functioning and tears will flow normally.
- The amount of secretion varies individually and at times may be considerable. Head colds, wind, and temperature extremes can all cause excess secretion.
- Surface deposits, scratches, pits or roughness can cause irritation, which can result in infection of the socket.
- After several years of wear, increased secretion may occur, indicating that the prosthetic eye/shell may have reached its age limit and requires replacement.

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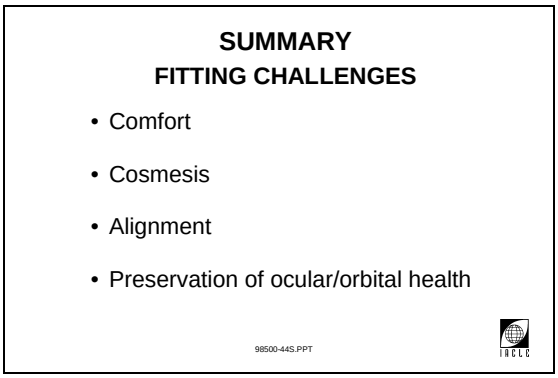

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Summary

- Prosthetic eye/shells are commonly fitted to patients whose eyes are surgically removed secondary to trauma, severe ocular disease or possible metastasis of a carcinoma.
- A prosthetic eye/shell is similar to a contact lens in many ways. The material is similar, the ocular tissues it interacts with are largely the same, the care is the same, and some of the wearing complications are the same, for example, GPC. Prosthetic eyes may be thought of as thick haptic shells. Of course the visual and physiologic considerations are different due to the absence of the eye and cornea.
- The fitting challenges include achieving good comfort, cosmesis (matching colour and appearance) and alignment, including when changing the direction of gaze.
- Preservation of ocular/orbital health should always be uppermost in the mind of both the practitioner and patient.

Table 1
AO Monoplex Eye Codes

Shape	Size	Code Number	Eye Size (mm)
Oval	Medium	2 (R or L)	21 x 26
	Large	3 (R or L)	24 x 28
Standard	Small	4 (R or L).	19 x 22
	Medium	5 (R or L)	22 x 26
	Large	6 (R or L)	22 x 27
Three-Cornered	Small	7 (R or L)	20 x 22
	Medium	8 (R or L)	24 x 25
	Large	9 (R or L)	25 x 27

American Optical Corporation,
Monoplex Eye Service,
14 Mechanics St.,
Southbridge MA 01550

P.O. Box 8007,
Southbridge MA 01550

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