Jorge L. Alió · Dimitri T. Azar
Editors

Management of Complications in Refractive Surgery

Springer

Jorge L. Alió · Dimitri T. Azar (Eds.)

Management of Complications in Refractive Surgery

Jorge L. Alió · Dimitri T. Azar (Eds.)

Management of Complications in Refractive Surgery

With 250 Figures and 44 Tables

Springer

Jorge L. Alió, M.D., Ph.D.
Professor and Chairman of Ophthalmology
Medical Director
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain
E-mail: jlalio@vissum.com

Dimitri T. Azar, M.D.
Professor and Head
Department of Ophthalmology and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.138 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA
E-mail: dazar@uic.edu

ISBN 978-3-540-37583-8 e-ISBN 978-3-540-37584-5
DOI 10.1007/978-3-540-37584-5

Library of Congress Control Number: 2007939906

Cover design: Frido Steinen-Broo, eStudio Calamar, Spain

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

Foreword

My interest in corneal lamellar surgery began in 1985 when I observed Lee Nordan perform a freeze keratomileusis in Houston with Josè Ignacio Barraquer's freeze technique. At that time, however, I realized that this type of surgery was subject to too many variables, and that for the most part these were independent of the ability and the competence of the surgeon. A more controllable technique was necessary.

Luck would have it that just a few months later I was invited by Philippe Sourdille to Nantes to perform live cataract surgery. In the adjoining room, Jorg Krumeich performed a no-freeze keratomileusis. My interest for corneal lamellar surgery was stimulated further, where a few weeks later in Germany, I observed this new technique, and started to use it myself just a few months after.

But times were hard, particularly when I look back on them now.

The microkeratomes were precise instruments, but they were rudimentary, they were difficult to use and were also potentially risky. The lamellar cut had to have a thickness of at least 300 μm, the lamella had to be fixed to a workbench, and the refractive cut had to be performed on the stromal face with the microkeratome. The optic zones were extremely small particularly in consideration that the target corrections were in excess of 10 D.

Thinking about all that today makes me cringe…

However, Barraquer's idea was brilliant, and what followed on later proved that it was a winner.

The technique with the surgical correction of refraction, with the variant by Antonio Ruiz and others, stayed alive until the excimer laser appeared on the scene. At that point, everything changed–luckily for surgeons over the world and to the enormous satisfaction of the patients!

When Theo Seiler in Berlin demonstrated the use of this machine and despite the fact that everyone had their attention fixed on its use on the surface tissue, I had an idea…finally, I would be able to perform the refractive step of keratomileusis with a repetitive instrument of micrometric precision. Then in 1989, I performed the first operation (the first case anywhere in the world) of intrastromal ablation, using the excimer laser.

At that time, we were all still tied to the concept of performing the refractive step on the stroma of the cut lamella and that is what I did. However, this was not the road to the future, and it was Joannis Pallikaris who had the brilliant idea of performing the step on the in situ stroma. The idea was to cut a thinner lamella and ingeniously preserve a hinge to avoid losing continuity with the cornea.

However, the hinge was in a nasal position because the cut progressed from the temporal side to the internal canthus. Unquestionably, it would have been preferable to have the uncut zone at the top to avoid dislocation of the flap during blinking. I decided to perform the operation with a "traditional" microkeratome–again the first ever worldwide in 1989–proceeding with the microkeratome, in an extremely well-exposed eye, from downward up.

Immediately afterwards, we saw the appearance of the first microkeratome with a fixed plate. What a relief! Finally, the anxiety and worry of creating a perforating lamellar cut had disappeared; we had the option of creating a superior hinge. The laser-assisted in situ keratomileusis (LASIK) down-up technique was born.

We then reached the modern era where improvements to the excimer laser appeared every couple of months; there was the transition from the mono-zone to the multi-zone, from a flying-spot treatment to a wave front, with the subsequent addition of the eye tracker and the recognition of the iris, as well as a whole series of minor innovative changes all geared to improving the end result.

We have reached the state of surgical fiction. However, unfortunately, patients do not participate correspondingly. In fact, laser refractive surgery went extremely well for a number of years and then unexpectedly hit a period of calm or stagnation.

Had we possibly created excessively high expectations?

Had we possibly operated on patients who were not suitable?

Had we possibly induced too many complications?

There is no doubt that on reading this book we can find the solution to many of the mistakes that all of us, to a greater or lesser degree, had made in the past, and we can find many useful and positive suggestions. However, more importantly, we find the necessary information for preventing or reducing the complications, both intraoperative and postoperative, even through the more attentive selection of the patients to be subjected to surgery.

In today's world, refractive surgery commands an extremely important place in eye-surgery practice.

Some techniques are still in their infancy, others have been used for more than 10 years, some have almost disappeared totally from the operating rooms, and more will be developed in the future.

The results of any surgical procedure, even those not related to ophthalmology, were evaluated exclusively from a quantitative point of view; in our specific case, the measurement was how many decimals were recovered by the eye after surgery.

Then surgeons realized that the quality of vision is also extremely important and only an evaluation of this could explain some of the often-incomprehensible complaints the patients would make.

Having a clear picture of how a person's quality of life can be changed by the onset of complications becomes of utmost importance, even in consideration of the person's job or leisure activities, as these can be contraindications to certain types of surgery.

The most popular operation is LASIK: The surgical step that, more than any other, causes problems is the cut with the microkeratome.

Are there still problems with the flap?

Yes! Thin flap, non-uniform flap, perforated flap, incomplete flap, etc. This is due to the fact that this step is mechanical, and by definition not precise, and also because it depends on the surgeon skills.

So who makes more mistakes, the surgeon or the machine?

One essential ingredient of refractive surgery is that the treatment is efficacious and achieves the preset objectives. However, even more important is that it is associated with very few complications, and that these will be acceptable to both the patient and the surgeon. This is particularly true if we consider that these operations are not essential but a question of choice; they are not strictly necessary from a medical point of view.

It is therefore important to publish a book that deals specifically with the complications of refractive surgery, their treatment, and how to prevent them.

The first chapter is essential; it presents the refractive results and the complications from surgery. It describes the risk–benefit ratio that allowed refractive surgery to be accepted and listed among the most popular surgical techniques being used at present.

The second of the introductory chapters is original and specific; it takes a separate look at the effect the complications may have on the quality of life.

A number of chapters on the complications of LASIK follow. It makes sense that these form the main bulk of the book, given that this is the most widespread technique on the international scenario.

First, we have an encyclopedic review of the intraoperative problems of the flap, and then the precocious and late-onset postoperative problems.

All the well-known complications are described.

The problems of complications associated with the flap have been greatly reduced since the currently available microkeratomes have been used. These are more reliable and safer; however, possibly a cut that was independent of mechanical instruments would be a better solution. This led to the development and launch of the femtosecond laser that could perform the work of the microkeratome but with greater precision and fewer risks.

In addition to the anatomical complications, specific chapters examine the calculation errors in refractive correction; again, in the past these topics were not dealt with in sufficient detail.

Finally, there are chapters on the complications of the eye, which actually create the subjective problems for the patients and leave them dissatisfied with the results of the operation.

The femtosecond laser can contribute to reducing these and other problems.

What are the advantages associated with this laser? First of all, the lack of blades! In addition, the possibility of no complications in the event of technical problems, and the option of repeating the operation just a short time later.

Potentially, it can also prevent ectasia; subject to the precise preoperative measurement of the corneal thickness, the cut can be performed uniformly over the entire area and that is not all…

Further improvements to the equipment and the software permit greater improvements to the ablation techniques; aberrometers that are more suitable allow the elimination of the optical aberrations; more advanced pupillometers will reduce the patients' functional problems and improve the end result.

However, additional problems persist: scarring, melting, etc., the etiopathogenesis of which must be examined in depth to enable surgeons to identify the key factors for resolving them.

The book also contains descriptions of topics that were previously not treated specifically: nummular keratitis, fluid in the interface, and ptosis. The latter complication is rightly considered, given the complaints it elicits from patients.

Then, ample space is given to the problem of dry eye, which was underestimated when this surgical technique was initially developed.

Rare complications are also examined such as optic neuropathy and the problems of eye motility.

Can any problems related to infection be resolved with the use of disposable instruments, on the understanding that these must have the same validity and competitive costs as their repeated-use/sterilizable counterparts? Will that be enough? I do not think so. However, if we improve the preoperative diagnosis and the medical preparation of the patient, there is no doubt that we will be able to reduce the frequency of the problems.

The photorefractive keratectomy (PRK) technique, which is still popular, is examined with its main complications, namely haze and regression.

Improvements in laser-assisted sub-epithelial keratectomy (LASEK) are unquestionably linked to finding a way, probably chemical, to attain, precise detachment of the corneal epithelium while respecting the cell vitality.

Will EpiLASIK be able to distance the doctor and patient from the postoperative difficulties similar to those associated with PRK and bring them closer to LASIK?

What will the future hold for the techniques with phakic intraocular lenses (IOLs)?

Surgery that began more than 20 years ago, and then abandoned because of too many complications, has come back into fashion not merely because elevated defects could not be suitably treated with the laser, but mainly due to the improvements in the materials and the design of the phakic IOLs in addition to the better knowledge in the anatomy and physiology of the eye.

Further improvements in the shape, thickness, and dimensions of the IOL and their foldability can avoid complications such as glaucoma, cataract, and corneal decompensation. However, the reduction in problems is also associated by better pre- and postoperative instrumental analysis of the eye; instruments such as Visante and the like must be constantly used and applied in this type of surgery, taking into consideration that, generally speaking, a phakic IOL is not designed to remain in the eye for the rest of the patient's life.

The manufacturers must also aim to develop an IOL that is easy to remove if necessary.

Possibly the most important step will be to produce a precise definition for contraindications for the phakic IOLs and whether the existence of three types of IOLs is justified. The future will tell whether only one of these should be used. By analyzing the complications associated with each one of them, we should be able to provide answers to these questions.

In addition, the more recent surgical techniques for the correction of severe visual defects and presbyopia will be increasingly oriented to the replacement of a human crystalline with a multifocal artificial lens.

However, is this ethically and deontologically correct? And will it be possible to further reduce the residual problems associated with this surgery, namely, capsular opacity and problems with the retina?

The definition of the etiopathogenesis of macular edema and neovascularization present in the eye will allow us to reduce some of these problems.

Dedicated software will avoid the refractive surprises associated with previous corneal refractive surgery.

Four chapters on lesser-used techniques follow: radial keratotomy, conductive keratoplasty, intracorneal segments, and intracorneal inserts.

Specifically for radial keratotomy, a technique that is no longer being used, the chapter describes the problems the surgeon has to face in the event of a repeat refractive operation and/or cataract surgery.

Last but not of least importance in today's scenario, the final three chapters.

Understanding whether the patient will be happy with the result or not is essential for surgery of this type, and associated with this problem is the informed consent.

The final chapter compares the complications presented in the literature over the past 10 years, permitting a comparison of the various techniques and a visualization of how experience and technological progress has led to a reduction in the complications that resulted from the initial inexperience of the surgeons and the learning curve associated with this new technique.

In other words, this book summarizes in a clear, complete, and updated manner all the information associated with this subject. It provides a practical and not an empirical approach to the various problems examined. It is more comprehensive with respect to previous publications, covering every aspect of refractive surgery.

The high quality of the images only serves to augment the validity of the book.

The various chapters were written impartially by experts on the specific subject.

The updated, complete information contained in this book makes it an important publication for all our colleagues who are specialized in this field of ocular surgery.

Another important stimulus from this book is that we must fuel the desire to continue along this road of improvement for these refractive techniques.

However, this subject is constantly evolving and therefore the various chapters will act as a stimulus for additional research and improvements to the techniques: The book contains all we know to date and highlights the areas that still need to be explored.

On behalf of all refractive surgeons, I would like to thank the Aliò Foundation and its staff for its enormous contribution to the improvements and the developments seen in refractive surgery. I would also like to thank them for the effort and commitment to improving the expertise of our colleagues, which in the final analysis is translated into an advantage for the patients.

Lucio Buratto

Preface

The reader will find in this book a modern perspective on complications in refractive surgery. The environment and the perspective of the topic have been changing continuously in the last 10 years, most notably in the last 5 years. Many traditional complications such as flap complications are now in decline, whereas other new complications are appearing. The overall frequency and epidemiology of the different complications of refractive surgery have dramatically changed with the different technological innovations that have been introduced into the practice of corneal refractive surgery. However, not all complications followed this decrease, but rather have increased in their frequency; traditional problems such as endothelial cell loss and cataract induction in some phakic IOL models remain concerns of refractive surgeons, and new forms of inflammatory complications of refractive surgery have emerged. Refractive complications such as aberrations induced by previous procedures, decentrations, and others are now properly treated due to significant technological improvement and knowledge of the performance of eye physiology and optics. This book is aimed at providing current and future refractive surgeons with up-to-date information on the pathogenesis of potential refractive surgical complications and at offering an approach to their prevention and treatment.

In addition to our own experience in refractive surgery, we have relied on the invaluable experience of many friends and colleagues who have authored several chapters within this book. Our author list represents the best of the best in refractive surgery. This unique panel of unparalleled international experts has clearly contributed to the science and the practice of refractive surgery. We would like to thank them for the service and contributions to refractive surgery, to patients, and through their respective chapters, to advancing the knowledge of refractive surgery.

It is our hope that the reader will find in this book the requisite links between the science and practice of refractive surgery. The acceptance of refractive surgery as a separate subspecialty in ophthalmology is higher than ever, thanks to the attention being paid to surgical complications and their management. The surgical outcomes and quality of life of patients undergoing refractive surgery has steadily improved.

The promise of refractive surgery rests in our singular focus on our patients' quality of life and quality of vision. Continued improvements in our field are dependent on enhanced technologies and superior training. To this end, we offer this book as a complement in order to assist our field in becoming better educated about the complications that we face, by providing better tools to solve them, and by increasing knowledge of how to prevent them, all to benefit our patients.

We would like to thank Springer for its support to this edition and ongoing support for refractive surgery. We also offer our heartfelt thanks to our families for their support, which has allowed us to devote our attention to the edition of this book.

Jorge L. Alió
Alicante, Spain

Dimitri Azar
Chicago, Illinois

January 2008

Contents

List of Contributors

Natalie A. Afshari, M.D.
Assistant Professor of Ophthalmology
Duke University Medical Center
Box 3802
Durham, NC 27710, USA
Email: Natalie.afshari@duke.edu

César Albarrán, O.D.
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain
and
Refractive Surgery Department
Instituto Oftalmológico de Alicante
Miguel Hernández University
Alicante, Spain

Jorge L. Alió, M.D., Ph.D.
Professor and Chairman of Ophthalmology
Miguel Hernández University, Medical School
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain
E-mail: jlalio@vissum.com

Waleed A. Allam, M.D.
Research Fellow, Ophthalmology
Refractive Surgery Department
New England Eye Center,
Tufts University School of Medicine
750 Washington St., Box 450
Boston, MA 02111, USA
E-mail address: WAllam@tufts-nemc.org

Norma Allemann, M.D.
Professor, Department of Ophthalmology
Federal University of São Paulo
Paulista School of Medicine
São Paulo, Brazil

Noel Alpins, M.D., F.R.A.C.S., F.R.C.Ophth., F.A.C.S.
Centre for Eye Research Australia
The University of Melbourne
Departmentof Ophthalmology
c/- Royal Victorian Eye & Ear Hospital
Locked Bag 8
East Melbourne, VIC 8002, Australia
E-mail: nalpins@unimelb.edu.au

Renato Ambrosio, Jr., M.D., Ph.D.
Department of Ophthalmology
Fluminense Federal University
Niterói, Brazil
and
Medical Director
Instituto de Olhos Renato Ambrósio
Visare Personal Laser & Refracta-RIO
Rua Conde de Bonfim 211/712
Rio de Janeiro, Brazil 20520-050
E-mail: renatoambrosiojr@terra.com.br

J. Fernando Arevalo, M.D., F.A.C.S.
Edif. Centro Caracas PH-1
Av. Panteon, San Bernardino
Caracas 1010, Venezuela
E-mail address: arevalojf@movistar.net.ve

Jean Louis Arne, M.D.
Professor of Ophthalmology and Head of Department
Service d'Ophtalmologie
Hôpital Purpan
Toulouse, France
University of Toulouse
Toulouse, France
E-mail: Jean-louis.arne@wanadoo.fr

Dimitri Azar, M.D.
Professor and Head
Department of Ophthalmology and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.138 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA
E-mail: dazar@uic.edu

Julio Baviera, M.D.
Paseo de la Castellana 20
28046 Madrid, Spain
E-mail: jbaviera@clinicabaviera.com

Michael W. Belin, M.D.
Professor
Director of Refractive Surgery
Albany Medical College
Cornea Consultants of Albany
1220 New Scotland Rd., Suite 101
Slingerlands, NY 12159, USA

Laurie Brown, C.O.M.T., C.O.E.
1550 Oak St., Suite 5
Eugene, OR 97401, USA
E-mail: finemd@finemd.com

Marlane J. Brown, O.D., F.A.A.O.
Minnesota Eye Consultants
710 E. 24th Street, Suite 106
Minneapolis, MN 55404, USA

Lucio Buratto, M.D.
Piazza Repubblica 21
20124 Milano, Italy
E-mail: lucio@buratto.com

Wallace Chamon, M.D.
Professor, Department of Ophthalmology
Federal University of São Paulo
Paulista School of Medicine
São Paulo, Brazil
E-mail: visus@pobox.com

Arturo S. Chayet, M.D.
CODET Vision Institute
Padre Kino 10159
Tijuana, Mexico 22320
E-mail: arturo.chayet@codetvision.com

Beatrice Cochener, M.D.
Centre Hospitalier Universitaire de Brest
Brest Cedex, France
E-mail: Beatrice.Cochener-lamard@chu-brest.fr

Antonio Calossi, D.O.
via 2 Giugno 52
50053 Certaldo (FI), Italy
E-mail: calossi@tin.it

José de la Cruz, M.D.
Assistant Professor
Department of Ophthalmology
and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.164 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA
E-mail: josedlc@uic.edu

Elizabeth A. Davis, M.D.
Assistant Clinical Professor of Ophthalmology
Minnesota Eye Consultants
710 E. 24th Street, Suite 106
Minneapolis, MN 55404, USA
and
University of Minnesota
Minneapolis, MN USA

David Fahd, M.D.
Research Fellow
Department of Ophthalmology and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.138 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA

I. Howard Fine, M.D.
Clinical Professor of Ophthalmology
Casey Eye Institute
1550 Oak St., Suite 5
Eugene, OR 97401, USA
E-mail: finemd@finemd.com

Eric E. Gabison, M.D.
Fondation Ophtalmologique A.
de Rothschild and Bichat Hospital, APHP
25–29 rue Manin
75940 Paris Cedex 19, France
and
CNRS UMR 7149
University Paris XII
Paris, France

Reinaldo A. Garcia, M.D.
Clinica Oftalmologica Centro Caracas
Edif. Centro Caracas PH-1
Av. Panteon, San Bernardino
Caracas 1010, Venezuela

Bruno M. Fontes, M.D.
Instituto de Olhos Renato Ambrósio
Visare Personal Laser & Refracta-RIO
Rua Conde de Bonfim 211/712
Rio de Janeiro, Brazil 20520-050
and
Department of Ophthalmology
Federal University of São Paulo
"Escola Paulista de Medicina"
São Paulo, Brazil

Rafael A. Garcia-Amaris, M.D.
Clinica Oftalmologica Centro Caracas
Edif. Centro Caracas PH-1
Av. Panteon, San Bernardino
Caracas 1010, Venezuela

Javier Gaytan, M.D.
Instituto de Microcirugía Ocular
Departamento de Cornea
c/Munner 10, 10 CP 08022,
Barcelona Spain

Oscar Gris, M.D.
Instituto de Microcirugía Ocular
Departamento de Cornea
c/Munner 10, 10 CP 08022,
Barcelona Spain

José L. Güell, M.D., Ph.D.
Instituto de Microcirugía Ocular
Departamento de Cornea
c/Munner 10, 10 CP 08022,
Barcelona Spain
E-mail: guell@imo.es

Joelle Hallak, B.Sc.
Research Specialist
Department of Ophthalmology and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.138 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA
E-mail: joelle@uic.edu

David R. Hardten, M.D.
Adjunct Associate Professor of Ophthalmology
Minnesota Eye Institute
710 E. 24th Street, Suite 106
Minneapolis, MN 55404, USA
Email: drhardten@mneye.com,
with copy to srrust@mneye.com

Sadeer Hannush, M.D.
Attending Surgeon
Wills Eye Hospital
Department of Ophthalmology
Philadelphia, PA
and
Cornea Consultants of Albany
1220 New Scotland Rd., Suite 101
Slingerlands, NY 12159, USA
E-mail: SBHannush@comcast.net

Thanh Hoang-Xuan, M.D.
Professor of Ophthalmology
University of Paris 7
Director, Cornea, External Diseases
and Refractive Surgery Services
Fondation Ophtalmologique A.
de Rothschild and Bichat Hospital, APHP
25–29 rue Manin
75940 Paris Cedex 19, France
E-mail: hoangxuant@aol.com

Richard S. Hoffman, M.D.
1550 Oak St., Suite 5
Eugene, OR 97401, USA
E-mail: finemd@finemd.com

Teresa S. Ignacio, M.D.
IntraLase Corp.
9701 Jeronimo Rd.
Irvine, CA 92618, USA
E-mail: tignacio@intralase.com

Sandeep Jain, M.D.
Assistant Professor in Ophthalmology
Department of Ophthalmology and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.164 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA
E-mail: jains@uic.edu

Daniela Jardim, M.D.
Instituto de Olhos Renato Ambrósio
Visare Personal Laser & Refracta-RIO
Rua Conde de Bonfim 211/712
Rio de Janeiro, Brazil 20520-050

Vikentia J. Katsanevaki, M.D., Ph.D.
Head of Refractive Department
Vardinoyannion Eye Institute
University of Crete Medical School
Voutes P.O. Box 1352
Heraklion, Crete, Greece
E-mail: vikatsan@med.uoc.gr

Bharavi Kharod, M.D.
Duke University Medical Center
Box 3802
Durham, NC 27710, USA

Michael Knorz, M.D.
Professor of Ophthalmology
FreeVis LASIK Center
Medical Faculty Mannheim
of the University of Heidelberg
Femto LASIK Professional
Theodor Kutzer Ufer 1–3
68167 Mannheim, Germany
E-mail: knorz@eyes.de

Takashi Kojima, M.D.
Research Fellow, Ophthalmology
Department of Ophthalmology and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.138 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA

Richard Lindstrom, M.D.
Professor of Ophthalmology
Minnesota Eye Consultants
710 E. 24th Street, Suite 106
Minneapolis, MN 55404, USA
and
Medical Director
University of Minnesota
Minneapolis, MN USA
E-mail: rllindstrom@mneye.com

Carlo F. Lovisolo, M.D.
San Raffaele University Hospital
Quattroelle Eye Centres
Milan, Italy
E-mail: loviseye@fastwebnet.it

Antonio A.P. Marinho, M.D., Ph.D.
R. Crasto 708
4150-243 Porto, Portugal
E-mail: marin@mail.telepac.pt

Marguerite McDonald, M.D., F.A.C.S.
Clinical Professor of Ophthalmology Tulane University
School of Medicine
New Orleans, LA, USA
and
Rockville Centre
Ryan Medical Arts Building
2000 North Village Avenue, Suite 402
Rockville Centre,
NY 11570, USA
Margueritemcdmd@aol.com

Merce Morral, M.D.
Instituto de Microcirugía Ocular
Departamento de Cornea
c/Munner 10, 10 CP 08022,
Barcelona Spain

Felicidad Manero, M.D.
Instituto de Microcirugía Ocular
Departamento de Cornea
c/Munner 10, 10 CP 08022,
Barcelona Spain

Fabio Mazzolani, M.D.
Quattroelle Eye Centers
Via Cusani 7
20121 Milano, Italy
E-mail: carlo.lovisolo@quattroelle.org

Orkun Muftuoglu, M.D.
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain

Alessandro Mularoni, M.D.
Ospedale Maggiore
Largo Negrisoli 2
40133 Bologna, Italy
E-mail: alessandro.mularoni@ausl.bologna.it

M. Emilia Mulet, M.D., Ph.D.
Department of Ophthalmology
Miguel Hernández University, Medical School
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain

Rudy M.M.A. Nuijts, M.D., Ph.D.
Department of Ophthalmology
Academic Hospital Maastricht
P. Debyelaan 25
6202 AZ, Maastricht, The Netherlands
E-mail: rnu@compaqnet.nl

David P.S. O'Brart, M.D., F.R.C.S., F.R.C.Ophth.
Department of Ophthalmology
St. Thomas' Hospital
London, UK
DavidOBrart@aol.com

Tatsuya Ongucci, M.D.
Research Fellow, Ophthalmology
Department of Ophthalmology and Visual Sciences
Illinois Eye and Ear Infirmary
University of Illinois at Chicago
3.138 EEI MC 648
1855 W. Taylor Street
Chicago, IL 60612, USA

Mark Packer, M.D., F.A.C.S.
Clinical Associate Professor
Oregon Eye Institute
1550 Oak St., Suite 5
Eugene, OR 97401, USA
E-mail: finemd@finemd.com

David Piñero, O.D.
Department of Ophthalmology
Miguel Hernández University, Medical School
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain

Konrad Pseudovs, Ph.D.
NH&MRC Centre for Clinical Eye Research,
Department of Ophthalmology,
Flinders Medical Centre and Flinders University
Bedford Park, South Australia 5045, Australia
E-mail: Konrad.Pesudovs@flinders.edu.au

Jerome C. Ramos-Esteban, M.D.
Eye Institute
Cleveland Clinic
9500 Euclid Avenue
Cleveland, OH 44195, USA

J. Bradley Randleman, M.D.
Assistant Professor of Ophthalmology
Emory University Department of Ophthalmology
1365 B Clifton Road NE, Suite 4500
Atlanta, GA 30322, USA
E-mail: Jrandle@emory.edu

Emanuel Rosen, M.D., F.R.C.S.Ed.
10 St. John Street
Manchester M3 4DY, UK
E-mail: ERosen9850@aol.com

José Mª Ruiz-Moreno, M.D., Ph.D.
Miguel Hernández University, Medical School
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain

James J. Salz, M.D.
Medical Director
Laser Vision Medical Associates
240 South La Cienega Blvd., Suite 250
Beverly Hills, CA 90211, USA
E-mail: drsalz@drsalz.com

Juan G. Sanchez, M.D.
Clinica Oftalmologica Centro Caracas
Edif. Centro Caracas PH-1
Av. Panteon, San Bernardino
Caracas 1010, Venezuela

Mohamed H. Shabayek, M.D, M.Sc.
Department of Ophthalmology
Miguel Hernández University, Medical School
Vissum Corporation
Avda de Denia s/n
Edificio Vissum
03016 Alicante, Spain
and
Research Institute of Ophthalmology
Giza, Egypt

Bryan S. Sires, M.D., Ph.D.
Allure Facial Laser and Medispa
University of Washington
Clinical Associate Professor
Kirkland, WA 98033, USA
E-mail: bsires@u.washington.edu

Stephen Slade, M.D.
3900 Essex Lane, Suite 101
Houston, TX 77027, USA
E-mail: sgs@visiontexas.com

Roger F. Steinert, M.D.
Professor of Ophthalmology
Professor of Biomedical Engineering
Department of Ophthalmology
118 Med Surge I
University of California, Irvine
Irvine, CA 92697-4375, USA
E-mail: steinert@uci.edu

Charles Wm. Stewart, D.O.
LIGI Tecnologie Medicali S.p.A.
via Luigi Corsi, 50
74100 Taranto, Italy

Karl G. Stonecipher, M.D.
Medical Director
TLC Greensboro
3312 Battleground Ave.
Greensboro, NC 27410, USA
E-mail: StoneNC@aol.com

Kody G. Stonecipher
1009 Country Club Drive
Greensboro, NC 27408, USA
E-mail: stonenc@gmail.com

R. Doyle Stulting, M.D., Ph.D.
Professor of Ophthalmology
Emory University Department of Ophthalmology
1365 B Clifton Road NE, Suite 4500
Atlanta, GA 30322, USA
E-mail: ophtrds@emory.edu

Jonathan H. Talamo, M.D.
Associate Clinical Professor of Ophthalmology
Harvard Medical School
Talamo Laser Eye Consultants
Reservoir Place, Suite 184
1601 Trapelo Rd.
Waltham, MA 02451, USA
E-mail: jht1@comcast.net; jtalamo@lecb.com

Gustavo E. Tamayo, M.D.
Bogota Laser Refractive Surgery
Calle 114 #9-45 Torre B, Suite 906
Bogota, Colombia
E-mail: gtvotmy@telecorp.net

Nayyirih G. Tahzib, M.D.
Department of Ophthalmology
Academic Hospital Maastricht
P. Debyelaan 25
6202 AZ, Maastricht, The Netherlands

Luis F Torres, M.D., Ph.D.
INOVA Vision Institute
Department of Surgery,
Biomedical Center, Autonomous
University of Aguascalientes
Sierra Morena 238, Bosques del Prado
Aguascalientes, Ags, Mexico 20127
E-mail: ftorresb@yahoo.com

Vance Thompson, M.D., F.A.C.S.
Director
Sioux Valley
Clinic, Talley Building
Sioux Falls, SD, USA
and
Sanford Clinic Vance Thompson Vision
1310 West 22nd Street, 2nd Floor
Sioux Falls, SD 57105, USA
E-mail: thompsov@siouxvalley.org

Gemma Walsh, B.Optom.
Centre for Eye Research Australia
The University of Melbourne
Department of Ophthalmology
c/- Royal Victorian Eye & Ear Hospital
Locked Bag 8
East Melbourne, VIC 8002, Australia

Steve Wilson, M.D.
Eye Institute
Cleveland Clinic
9500 Euclid Avenue
Cleveland, OH 44195, USA
E-mail: WILSONS4@ccf.org

Helen K. Wu, M.D.
Assistant Professor of Ophthalmology
New England Eye Center,
Tufts University School of Medicine
750 Washington St., Box 450
Boston, MA 02111, USA
E-mail: HWu@tufts-nemc.org

George O. Waring III, M.D., F.A.C.S., F.R.C.Ophth.
Clinical Professor of Ophthalmology
Emory University, School of Medicine
Atlanta, Georgia, USA

Chapter 1

Refractive Surgery Outcomes and Frequency of Complications

1

Wallace Chamon and Norma Alleman

Contents

Core Messages

- There is no risk-free surgical procedure.
- There are enough data in literature to determine the risk for the majority of the refractive surgery procedures.
- Refractive surgery risks and benefits should be evaluated individually in order to choose the surgical approach properly.
- Not only incidence, but also morbidity of each possible complication should be considered in this choice.
- Decision making in refractive procedure is an individualized process that should be based on scientific knowledge, patient's characteristics, and surgeon experience.

1.1 Common Complications Associated with Refractive Surgery

Some complications are implicit to any surgical procedure, varying only in their incidence and morbidity. Such complications will be evaluated here according to their characteristics in each group of refractive surgical procedures.

1.1.1 Refractive Imprecision and Loss of Spectacle-Corrected Visual Acuity

The most frequent complication observed in any refractive procedure is the lack in achieving accurate refraction outcome. As a rule, accuracy decreases with the amount of refractive error. Photoablative procedures tend to be the most accurate ones for low ametropias. Photorefractive keratectomy (PRK) and laser-assisted in situ keratomileusis (LASIK) deal with different variables that may affect predictability: corneal wound healing and stromal bed elasticity, respectively [1].

Although results minimally favor LASIK, we may expect that in any photoablative procedure, approximately 60–70% of eyes will achieve 20/20 uncorrected visual acuity and will be within +/–0.50 D after surgery. If we analyze only low myopias (under 6.00 D), approximately 70–80% will achieve 20/20 uncorrected visual acuity (Table 1.1) [1–9].

A general evaluation of surgical safety should consider spectacle-corrected visual acuity (SCVA). One to 5% of eyes will lose at least two lines of SCVA 6 months after surgery, but 1% or less of all eyes will achieve less than 20/40 of SCVA. One to 2% of eyes that achieved, preoperatively, 20/20 of SCVA will achieve less than 20/25 SCVA after surgery (Table 1.2) [1–9].

Phakic intraocular lenses (IOLs) tend to present less accurate refractive correction; although, since they are nor-

Table 1.1. LASIK versus PRK for correction of myopia

	UCVA 20/20				+/– 0.50 D				UCVA 20/20 (low myopia)			
	LASIK		PRK		LASIK		PRK		LASIK		PRK	
	n	%	n	%	n	%	n	%	n	%	n	%
Literature: 6 months postoperative												
Wang et al. [4]	109	81.7	335	71.6					109	81.7	335	71.6
Hersh et al. [5]	61	26.2	68	19.1								
El-Magrabi et al. [7]	28	67.9	28	42.9	59	27.1	68	29.4				
Forseto et al. [6]	8	100	9	88.9	8	87.5	9	88.9	8	100	9	88.9
Hjordtal et al. [1]	25	4	20	15	25	20	20	25				
Literature: 12 months postoperative												
Wang et al. [4]	103	82.5	307	72	103	70.9	307	61.2	103	82.5	307	72
El-Magrabi et al. [7]	30	66.7	30	53.3	30	73.3	30	66.7				
el Danasuri et al. [8]	24	79.2	24	62.5	24	87.5	24	83.3	24	79.2	24	62.5
Forseto et al. [6]	15	73.3	15	53.3	15	93.3	15	86.7	15	73.3	15	53.3
Hjordtal et al. [1]	25	4	20	15	25	16	20	30				
FDA: 6 months postoperative	6,615	59.4	3,173	59.9	7,207	69.9	3,296	62.7				
FDA: 12 months postoperative	2,774	58.1	2,094	54.5	2,985	61	2,065	56.3				
6 months total	6,846	59.4	3,633	59.9	7,299	69.4	3,393	61.9	117	82.9	344	72.1
6 months literature total	231	57.6	460	60	92	30.4	97	34	117	82.9	344	72.1
6 months FDA total	6,615	59.4	3,173	59.9	7,207	69.9	3,296	62.7	0	NA	0	NA
12 months total	2,971	58.8	2,490	56.4	3,182	61.4	2,461	57.3	142	81	346	70.5
12 months literature total	197	69	396	66.4	197	68	396	62.4	142	81	346	70.5
12 months FDA total	2,774	58.1	2,094	54.5	2,985	61	2,065	56.3	0	NA	0	NA

Data set modified from Shortt et al. [3]

PRK photorefractive keratectomy, UCVA 20/20 eyes that achieved post treatment uncorrected visual acuity (UCVA) of 20/20, +/– 0.50 D eyes within 0.50 D of target refraction, UCVA 20/20 (low myopia) eyes that achieved post treatment UCVA of 20/20 in a subgroup of myopia ≤6 D, FDA US Food and Drug Administration, NA not applicable

Table 1.2 LASIK versus PRK for spectacle-corrected visual acuity (SCVA)

	Loss of ≥2 lines				SCVA < 20/40				SCVA < 20/25			
	LASIK		PRK		LASIK		PRK		LASIK		PRK	
	n	%	n	%	n	%	n	%	n	%	n	%
Literature: 6 months postoperative												
Wang et al. [4]	307	3.9	103	1								
Hersh et al. [5]	68	11.8	59	3.4	68	1.5	61	0	68	1.5	59	1.7
El-Magrabi et al. [7]	27	7.4	27	7.4	27	3.7	27	0	27	3.7	27	3.7
Forseto et al. [6]	24	0	24	0	24	0	24	0	24	0	24	0
Hjordtal et al. [1]	20	10	25	4	20	0	25	0	20	0	25	0
FDA: 6 months postoperative	4,412	3.2	7,554	1.1	4,414	0.3	7,810	0.3	4,299	2.4	7,612	1.4
6 months total	4,858	3.4	7,792	1.2	4,553	0.4	7,947	0.3	4,438	2.3	7,747	1.4
6 months literature total	446	5.4	238	2.5	139	1.4	137	0	139	1.4	135	1.5
6 months FDA total	4,412	3.2	7,554	1.1	4,414	0.3	7,810	0.3	4,299	2.4	7,612	1.4

Data set modified from Shortt et al. [3]

PRK photorefractive keratectomy, loss of ≥2 lines eyes that lost of ≥2 lines of SCVA, SCVA < 20/40 final SCVA worse than 20/40, SCVA < 20/25 final SCVA worse than 20/25 when preoperative best SCVA ≥ 20/20, FDA US Food and Drug Administration, NA not applicable

mally used to correct higher ametropias, an expected result with most of the patients within +/–1.00, should be appreciated [10–14]. Image magnification after correcting high-myopic eyes with IOLs generate a confounding factor in evaluating pre- and post-SCVA; therefore, information published on this subject lacks credibility [15].

The only procedure that does not rely on clinical refraction to determine total correction is clear lens extraction. Its predictability depends on how accurately we can determine corneal power, axial length, and the effective position of the implanted IOL. Approximately 95% of normal eyes should present less than 1.00 D of refractive error [16]. Predictability reduces greatly when operating eyes that underwent corneal refractive surgery, but new approaches for calculating IOL power have improved the results [17, 18].

1.1.2 Infection

Determining the risk of infection on photoablative procedures is a difficult task due to misdiagnoses and lack in laboratorial information. We may expect an incidence between 0.1:10,000 and 1:10,000, favoring LASIK over PRK [19–21]. Infection has been reported after LASIK with femtosecond laser [22]. Bilateral simultaneous keratorefractive procedures are considered standard of care [23, 24], but the risk of bilateral infection may add extra damage to this potentially devastating complication. Risk of infection in intraocular surgeries should follow the incidence of infection in cataract surgery that is approximately 1:1,000 [25–27]. Intracorneal implants are theoretically more susceptible to infection due the difficulty of the immune system to act in an intrastromal fashion [28–30].

1.1.3 Infection and Contact Lenses

Risk of infection in contact lenses wearers should be considered when evaluating incidence of infection in refractive surgery. The risk of keratitis in contact lenses wearers depends on the modality of use (daily wear or extended wear) and the lens type. Literature has shown that, per year, the risk of presenting a severe keratitis will vary from 3:10,000 to almost 100:10,000 [31], and the risk of presenting loss of visual acuity is 3.6:10,000 among silicone hydrogel extended wearers [32].

1.1.4 Subjective Complaints

Subjective complaints such as halos, glare, starburst, and low-contrast sensitivity maybe correlated to low- and high-order optical aberrations [33, 34] as well as to optical characteristics of the implanted IOL [35–38] and the diameter of the pupil [39]. All refractive procedures present the risk of subjective complaints, but special attention should be paid in keratorefractive surgeries in eyes with larger pupil diameter, since this procedure is performed further from the pupil plane, when compared with phakic intraocular implants or clear lens extraction.

1.1.5 Retinal Detachment

Retinal detachment has been associated with LASIK [40–44]; but, so far, it is not possible to detect a cause–effect relationship nor to determine a higher incidence of vitreoretinal pathological conditions post-LASIK.

Cataract extraction increases the cumulative risk of retinal detachment an average of fourfold. There is no difference between patients who underwent extracapsular cataract extraction and phacoemulsification. The risk increases in myopic [45], younger men (less than 50 years old) [46, 47]. It has been suggested that phakic IOLs implantation may be related to a higher risk of retinal detachment [48, 49].

1.2 Keratorefractive Procedures

1.2.1 Photorefractive Keratectomy

1.2.1.1 Haze

Incidence of haze and treatment regression is associated to the attempted correction and may be expected to be up to 2% in the first year post-PRK [50]. Although it is commonly suggested that haze may be less incident with newer lasers, there is no scientific evidence that it is true [51].

1.2.1.2 Mitomycin C

The use of intraoperative mitomycin C has raised the expectation for treating higher ametropias with PRK [52–57]. Potential risks associated to its use are the consequences of keratocyte depletion [58] as well as endothelium and anterior chamber toxicity [59, 60].

1.2.1.3 Keratectasia

Although there are reports of keratectasia that occurred in normal eyes after PRK [61], most the few cases reported so far are of forme fruste keratoconus that progressed after PRK [62–64] or phototherapeutic keratectomy (PTK) [65, 66]. It is still to be proven if the procedure influences the progression of the disease.

1.2.2 LASIK

1.2.2.1 Microkeratome-Related Complications

Irregular flaps related to the microkeratome cut maybe presented as incomplete flaps, free caps, buttonholed flaps [67], thin flaps, thick flaps, and partially cut flaps. Irregular flaps are expected in less than 1% of the procedures performed with new microkeratomes [23, 68–72]. Microkeratome-related complications depend on the learning curve and may be two or three times more frequent in the first 1,000 surgeries [69]. Initial microkeratomes had a complication rate of up to 6%; their evolution, with new safety concerns, decreased the incidence [70, 72]. Outcomes after an irregular flap are improved if photoablation is not carried out at the time of the complication [73, 74].

1.2.2.2 Femtosecond Laser

Most of the literature shows that reliability in flap creation has increased with the use of femtosecond laser [75–77], but some articles do not differentiate the outcomes between microkeratome and femtosecond laser [78, 79]. A new entity, transient light-sensitivity syndrome (TLSS), was reported in approximately 1% of the eyes with femtosecond laser-created flaps [80, 81].

1.2.2.3 Dislocated Flap

Flap dislocation is a complication encountered in approximately 2% of the procedures [71, 82] and has been reported up to 30 months after the surgery [83–85].

1.2.2.4 Diffuse Lamellar Keratitis

Diffuse lamellar keratitis (DLK) is a disease of unknown pathophysiology [86–88] that was first described in 1998 [89]. It occurs in an average of 0.7% of the procedures, and it is most frequently present in outbreaks [90]. A hyperopic shift and increased optical aberrations are expected in patients that presented DLK [91, 92].

1.2.2.5 Keratectasia

Although there are reports of ectasia that occurred in eyes without known risk factors [93], approximately 90% of the eyes that develop ectasia have preoperative signs of forme fruste keratoconus [94]. Besides the diagnosis of forme fruste keratoconus and residual stromal bed of less than 250 µm [94], known topographical risk factors for corneal ectasia post-LASIK are corneal curvature, pachymetry, oblique astigmatism, posterior corneal surface elevation, difference between inferior and superior corneal dioptric power, and correlation between anterior and posterior best-fit sphere [95]. Treatments for corneal ectasia include rigid contact lenses, intrastromal corneal rings [96], keratoplasty, and collagen cross-linking [97, 98].

1.3 Phakic Intraocular Lenses

1.3.1 Endothelial Cell Loss

Anterior chamber angle-supported phakic IOLs present an initial decrease in endothelium cell density of 5–10% in 2 years, with a slightly higher than normal decrease after that [99–102]. Iris-supported lenses appear to present continuous decrease in cell density at longer follow-up, achieving between 10 and 15% at 2 years [99, 103, 104]. Although posterior-chamber IOLs have a lower risk of endothelial cell loss, a decrease of 5 to 10% may be expected 2 years after surgery [105]. Careful follow-up of patients who have undergone phakic implants should allow lenses to be removed before any clinical symptoms present, if damage of the endothelium persists.

1.3.2 Pupillary Block Glaucoma

Pupillary block glaucoma has been reported in anterior chamber iris-supported [106], angle-supported [107, 108], and posterior chamber phakic IOLs [109–111]. Preoperative iridectomy is mandatory, but pupillary block has been reported even in the presence of effective iridectomy [111].

1.3.3 Iris Atrophy and Pupil Ovalization

Eyes with anterior chamber angle-supported phakic IOLs have a tendency to present sectorial iris atrophy and consequent pupil ovalization [100–102, 107]. Its frequency depends on the limits accepted, but up to 40% ovalization (difference of 0.5 mm in orthogonal diameters) may be expected [101].

1.3.4 Chronic Inflammation

Chronic inflammation is present in all phakic IOL models. It has been reported to be higher than are controls in anterior chamber iris-supported and anterior chamber angle-supported at 12, 18, and 24 months after surgery [101, 112]. Aqueous flare was slightly better for the angle-supported group.

In posterior chamber IOLs, aqueous flare increased by 49.19% in the first postoperative month in relation to preoperative values, decreasing afterward, but remaining above preoperative values up to 2 years postoperatively [105].

1.3.5 Intraocular Lens Dislocation

Traumatic and spontaneous IOL dislocations have been described in anterior chamber iris-supported phakic IOLs [113, 114].

1.3.6 Cataract

Anterior subcapsular cataracts are related to posterior chamber phakic IOLs implants and are present in 8.2% of the eyes [115–118]. Most of the eyes that presented cataract were operated on in the beginning of the surgeon's learning curve [117]. Nuclear cataract has been reported in anterior chamber angle-supported IOLs [118, 119], but it has not possible to determine a cause–effect relationship.

1.3.7 Pigment Dispersion

Pigment dispersion has been observed in approximately 3% of eyes that underwent posterior chamber phakic IOL implants [110, 120, 121]. There are no reports of glaucoma in eyes that presented pigment dispersion.

1.3.8 Posterior Luxation (in Phakic Refractive Lens™)

Spontaneous luxation to the vitreous of one specific model of silicone posterior chamber phakic IOL (Phakic Refractive Lens, PRL™) is a severe complication related to the weakening of the zonule [122, 123].

Take-Home Pearls

- Refractive surgery provides a variety of elective procedures to be performed in otherwise healthy eyes. The knowledge of their possible complications is mandatory to inform our patients of their options.

References

1. Hjortdal JO, Moller-Pedersen T, Ivarsen A, Ehlers N (2005) Corneal power, thickness, and stiffness: results of a prospective randomized controlled trial of PRK and LASIK for myopia. J Cataract Refract Surg 31:21–29
2. Shortt AJ, Allan BD (2006) Photorefractive keratectomy (PRK) versus laser-assisted in-situ keratomileusis (LASIK) for myopia. Cochrane Database Syst Rev CD005135
3. Shortt AJ, Bunce C, Allan BD (2006) Evidence for superior efficacy and safety of LASIK over photorefractive keratectomy for correction of myopia. Ophthalmology 113:1897–1908
4. Wang Z, Chen J, Yang B (1997) Comparison of laser in situ keratomileusis and photorefractive keratectomy to correct myopia from −1.25 to −6.00 diopters. J Refract Surg 13:528–534
5. Hersh PS, Brint SF, Maloney RK, Durrie DS, Gordon M, Michelson MA (1998) Photorefractive keratectomy versus laser in situ keratomileusis for moderate to high myopia. A randomized prospective study. Ophthalmology 105:1512–1522, discussion 1522–1523
6. Forseto AS, Nosé RA, Nosé W (2000) PRK versus LASIK for correction of low and moderate myopia [in Portuguese]. Arq Bras Oftalmol 63:257–262
7. El-Maghraby A, Salah T, Waring GO III, Klyce S, Ibrahim O (1999) Randomized bilateral comparison of excimer laser in situ keratomileusis and photorefractive keratectomy for 2.50 to 8.00 diopters of myopia. Ophthalmology 106:447–457
8. el Danasoury MA, el Maghraby A, Klyce SD, Mehrez K (1999) Comparison of photorefractive keratectomy with excimer laser in situ keratomileusis in correcting low myopia (from −2.00 to −5.50 diopters): a randomized study. Ophthalmology 106:411–420; discussion 420–421

9. US Food and Drug Administration (2006) Lasik eye surgery. Available via http://www.fda.gov/cdrh/LASIK/. Cited 22 March 2007
10. Roy S, Tritten JJ (2002) [Myopic implant of the posterior chamber using a flexible Collamer lens]. Klin Monatsbl Augenheilkd 219:196–200
11. Liekfeld A, Friederici L, Klotz O (2005) [Monocentric two-year results after phakic posterior chamber lens (PRL) implantation in myopic patients]. Klin Monatsbl Augenheilkd 222:888–893
12. Leroux-Les-Jardins S, Ullern M, Werthel AL (1999) [Myopic anterior chamber intraocular lens implantation: evaluation at 8 years]. J Fr Ophtalmol 22:323–327
13. Lackner B, Pieh S, Schmidinger G, Hanselmayer G, Dejaco-Ruhswurm I, Funovics MA, (2003) Outcome after treatment of ametropia with implantable contact lenses. Ophthalmology 110:2153–2161
14. Benedetti S, Casamenti V, Marcaccio L, Brogioni C, Assetto V (2005) Correction of myopia of 7 to 24 diopters with the Artisan phakic intraocular lens: two-year follow-up. J Refract Surg 21:116–126
15. Garcia M, Gonzalez C, Pascual I, Fimia A (1996) Magnification and visual acuity in highly myopic phakic eyes corrected with an anterior chamber intraocular lens versus by other methods. J Cataract Refract Surg 22:1416–1422
16. Holladay JT, Prager TC, Chandler TY, Musgrove KH, Lewis JW, Ruiz RS (1988) A three-part system for refining intraocular lens power calculations. J Cataract Refract Surg 14:17–24
17. Aramberri J (2003) Intraocular lens power calculation after corneal refractive surgery: double-K method. J Cataract Refract Surg 29:2063–2068
18. Chamon W (2004) A new approach to correct an inherent error in IOL calculation formulas for eyes submitted to keratorefractive procedures. Invest Ophthalmol Vis Sci 45(Abstr):341
19. de Oliveira GC, Solari HP, Ciola FB, Lima AL, Campos MS (2006) Corneal infiltrates after excimer laser photorefractive keratectomy and LASIK. J Refract Surg 22:159–165
20. Wroblewski KJ, Pasternak JF, Bower KS, Schallhorn SC, Hubickey WJ, Harrison CE (2006) Infectious keratitis after photorefractive keratectomy in the United States army and navy. Ophthalmology 113:520–525
21. Moshirfar M, Welling JD, Feiz V, Holz H, Clinch TE (2007) Infectious and noninfectious keratitis after laser in situ keratomileusis Occurrence, management, and visual outcomes. J Cataract Refract Surg 33:474–483
22. Lifshitz T, Levy J, Mahler O, Levinger S (2005) Peripheral sterile corneal infiltrates after refractive surgery. J Cataract Refract Surg 31:1392–1395
23. Gimbel HV, van Westenbrugge JA, Penno EE, Ferensowicz M, Feinerman GA, Chen R (1999) Simultaneous bilateral laser in situ keratomileusis: safety and efficacy. Ophthalmology 106:1461–1467, discussion 1467–1468
24. Huang D, Krueger R, Stulting RD (2000) Correlation between eyes in bilateral LASIK. Ophthalmology 107:1962–1963
25. Kattan HM, Flynn HW, Jr., Pflugfelder SC, Robertson C, Forster RK (1991) Nosocomial endophthalmitis survey. Current incidence of infection after intraocular surgery. Ophthalmology 98:227–238
26. Marty N, Malavaud S (2002) [Epidemiology of nosocomial infections after cataract surgery and role of the Infection Control Committee in prevention]. Bull Acad Natl Med 186:635–645, discussion 645–648
27. Haapala TT, Nelimarkka L, Saari JM, Ahola V, Saari KM (2005) Endophthalmitis following cataract surgery in southwest Finland from 1987 to 2000. Graefes Arch Clin Exp Ophthalmol 243:1010–1017
28. McAlister JC, Ardjomand N, Ilari L, Mengher LS, Gartry DS (2006) Keratitis after intracorneal ring segment insertion for keratoconus. J Cataract Refract Surg 32:676–678
29. Mondino BJ, Rabin BS, Kessler E, Gallo J, Brown SI (1977) Corneal rings with gram-negative bacteria. Arch Ophthalmol 95:2222–2225
30. Hofling-Lima AL, Branco BC, Romano AC, Campos MQ, Moreira H, Miranda D (2004) Corneal infections after implantation of intracorneal ring segments. Cornea 23:547–549
31. Morgan PB, Efron N, Hill EA, Raynor MK, Whiting MA, Tullo AB (2005) Incidence of keratitis of varying severity among contact lens wearers. Br J Ophthalmol 89:430–436
32. Schein OD, McNally JJ, Katz J, Chalmers RL, Tielsch JM, Alfonso E (2005) The incidence of microbial keratitis among wearers of a 30-day silicone hydrogel extended-wear contact lens. Ophthalmology 112:2172–2179
33. Chalita MR, Chavala S, Xu M, Krueger RR (2004) Wavefront analysis in post-LASIK eyes and its correlation with visual symptoms, refraction, and topography. Ophthalmology 111:447–453
34. Chalita MR, Krueger RR (2004) Correlation of aberrations with visual acuity and symptoms. Ophthalmol Clin North Am 17:135–42, v–vi
35. Chiam PJ, Chan JH, Aggarwal RK, Kasaby S (2006) ReSTOR intraocular lens implantation in cataract surgery: quality of vision. J Cataract Refract Surg 32:1459–1463
36. Casprini F, Balestrazzi A, Tosi GM, Miracco F, Martone G, Cevenini G (2005) Glare disability and spherical aberration with five foldable intraocular lenses: a prospective randomized study. Acta Ophthalmol Scand 83:20–25
37. Bellucci R, Morselli S, Pucci V (2007) Spherical aberration and coma with an aspherical and a spherical intraocular lens in normal age-matched eyes. J Cataract Refract Surg 33:203–209
38. Tester R, Pace NL, Samore M, Olson RJ (2000) Dysphotopsia in phakic and pseudophakic patients: incidence and relation to intraocular lens type(2). J Cataract Refract Surg 26:810–816
39. Oshika T, Tokunaga T, Samejima T, Miyata K, Kawana K, Kaji Y (2006) Influence of pupil diameter on the relation between ocular higher-order aberration and contrast sensitivity after laser in situ keratomileusis. Invest Ophthalmol Vis Sci 47:1334–1338
40. Ruiz-Moreno JM, Perez-Santonja JJ, Alio JL (1999) Retinal detachment in myopic eyes after laser in situ keratomileusis. Am J Ophthalmol 128:588–594
41. Arevalo JF, Freeman WR, Gomez L (2001) Retina and vitreous pathology after laser-assisted in situ keratomileusis: is there a cause-effect relationship? Ophthalmology 108:839–840
42. Lin J, Xie X, Du X, Yang Y, Yao K (2002) [Incidence of vitreoretinal pathologic conditions in myopic eyes after laser in situ keratomileusis]. Zhonghua Yan Ke Za Zhi 38:546–549
43. Suzuki CR, Farah ME (2004) Retinal peripheral changes after laser in situ keratomileusis in patients with high myopia. Can J Ophthalmol 39:69–73
44. Faghihi H, Jalali KH, Amini A, Hashemi H, Fotouhi A, Esfahani MR (2006) Rhegmatogenous retinal detachment after LASIK for myopia. J Refract Surg 22:448–452
45. Sheu SJ, Ger LP, Chen JF (2006) Axial myopia is an extremely significant risk factor for young-aged pseudophakic retinal detachment in taiwan. Retina 26:322–327
46. Erie JC, Raecker MA, Baratz KH, Schleck CD, Burke JP, Robertson DM (2006) Risk of retinal detachment after cataract extraction, 1980–2004: a population-based study. Ophthalmology 113:2026–2032
47. Olsen G, Olson RJ (2000) Update on a long-term, prospective study of capsulotomy and retinal detachment rates after cataract surgery. J Cataract Refract Surg 26:1017–1021
48. Martinez-Castillo V, Boixadera A, Verdugo A, Elies D, Coret A, Garcia-Arumi J (2005) Rhegmatogenous retinal detachment in

phakic eyes after posterior chamber phakic intraocular lens implantation for severe myopia. Ophthalmology 112:580–585
49. Navarro R, Gris O, Broc L, Corcostegui B (2005) Bilateral giant retinal tear following posterior chamber phakic intraocular lens implantation. J Refract Surg 21:298–300
50. Kuo IC, Lee SM, Hwang DG (2004) Late-onset corneal haze and myopic regression after photorefractive keratectomy (PRK). Cornea 23:350–355
51. Fiore T, Carones F, Brancato R (2001) Broad beam vs. flying spot excimer laser: refractive and videokeratographic outcomes of two different ablation profiles after photorefractive keratectomy. J Refract Surg 17:534–541
52. Bedei A, Marabotti A, Giannecchini I, Ferretti C, Montagnani M, Martinucci C (2006) Photorefractive keratectomy in high myopic defects with or without intraoperative mitomycin C: 1-year results. Eur J Ophthalmol 16:229–234
53. Netto MV, Chalita MR, Krueger RR (2007) Corneal haze following PRK with mitomycin C as a retreatment versus prophylactic use in the contralateral eye. J Refract Surg 23:96–98
54. Netto MV, Mohan RR, Sinha S, Sharma A, Gupta PC, Wilson SE (2006) Effect of prophylactic and therapeutic mitomycin C on corneal apoptosis, cellular proliferation, haze, and long-term keratocyte density in rabbits. J Refract Surg 22:562–574
55. Carones F, Vigo L, Scandola E (2006) Wavefront-guided treatment of symptomatic eyes using the LADAR6000 excimer laser. J Refract Surg 22:S983–S989
56. Chalita MR, Roth AS, Krueger RR (2004) Wavefront-guided surface ablation with prophylactic use of mitomycin C after a buttonhole laser in situ keratomileusis flap. J Refract Surg 20:176–181
57. Carones F, Vigo L, Scandola E, Vacchini L (2002) Evaluation of the prophylactic use of mitomycin-C to inhibit haze formation after photorefractive keratectomy. J Cataract Refract Surg 28:2088–2095
58. Netto MV, Mohan RR, Ambrosio R, Jr., Hutcheon AE, Zieske JD, Wilson SE (2005) Wound healing in the cornea: a review of refractive surgery complications and new prospects for therapy. Cornea 24:509–522
59. Torres RM, Merayo-Lloves J, Daya SM, Blanco-Mezquita JT, Espinosa M, Nozal MJ (2006) Presence of mitomycin-C in the anterior chamber after photorefractive keratectomy. J Cataract Refract Surg 32:67–71
60. Morales AJ, Zadok D, Mora-Retana R, Martinez-Gama E, Robledo NE, Chayet AS (2006) Intraoperative mitomycin and corneal endothelium after photorefractive keratectomy. Am J Ophthalmol 142:400–404
61. Malecaze F, Coullet J, Calvas P, Fournie P, Arne JL, Brodaty C (2006) Corneal ectasia after photorefractive keratectomy for low myopia. Ophthalmology 113:742–746
62. Lovisolo CF, Fleming JF (2002) Intracorneal ring segments for iatrogenic keratectasia after laser in situ keratomileusis or photorefractive keratectomy. J Refract Surg 18:535–441
63. Javadi MA, Mohammadpour M, Rabei HM (2006) Keratectasia after LASIK but not after PRK in one patient. J Refract Surg 22:817–820
64. Seiler T, Koufala K, Richter G (1998) Iatrogenic keratectasia after laser in situ keratomileusis. J Refract Surg 14:312–317
65. Miyata K, Takahashi T, Tomidokoro A, Ono K, Oshika T (2001) Iatrogenic keratectasia after phototherapeutic keratectomy. Br J Ophthalmol 85:247–248
66. Dean SJ, McGhee CN (2002) Keratectasia after PTK. Br J Ophthalmol 86:486
67. Leung AT, Rao SK, Cheng AC, Yu EW, Fan DS, Lam DS (2000) Pathogenesis and management of laser in situ keratomileusis flap buttonhole. J Cataract Refract Surg 26:358–362
68. Nakano K, Nakano E, Oliveira M, Portellinha W, Alvarenga L (2004) Intraoperative microkeratome complications in 47,094 laser in situ keratomileusis surgeries. J Refract Surg 20(Suppl): S723–S726
69. Tham VM, Maloney RK (2000) Microkeratome complications of laser in situ keratomileusis. Ophthalmology 107:920–924
70. Walker MB, Wilson SE (2000) Lower intraoperative flap complication rate with the Hansatome microkeratome compared to the Automated Corneal Shaper. J Refract Surg 16:79–82
71. Yildirim R, Devranoglu K, Ozdamar A, Aras C, Ozkiris A, Ozkan S (2001) Flap complications in our learning curve of laser in situ keratomileusis using the Hansatome microkeratome. Eur J Ophthalmol 11:328–332
72. Jacobs JM, Taravella MJ (2002) Incidence of intraoperative flap complications in laser in situ keratomileusis. J Cataract Refract Surg 28:23–28
73. Pallikaris IG, Katsanevaki VJ, Panagopoulou SI (2002) Laser in situ keratomileusis intraoperative complications using one type of microkeratome. Ophthalmology 109:57–63
74. Sharma N, Ghate D, Agarwal T, Vajpayee RB (2005) Refractive outcomes of laser in situ keratomileusis after flap complications. J Cataract Refract Surg 31:1334–1337
75. Talamo JH, Meltzer J, Gardner J (2006) Reproducibility of flap thickness with IntraLase FS and Moria LSK-1 and M2 microkeratomes. J Refract Surg 22:556–561
76. Montes-Mico R, Rodriguez-Galietero A, Alio JL (2007) Femtosecond laser versus mechanical keratome LASIK for myopia. Ophthalmology 114:62–68
77. Binder PS (2006) One thousand consecutive IntraLase laser in situ keratomileusis flaps. J Cataract Refract Surg 32:962–969
78. Lim T, Yang S, Kim M, Tchah H (2006) Comparison of the IntraLase femtosecond laser and mechanical microkeratome for laser in situ keratomileusis. Am J Ophthalmol 141:833–839
79. Patel SV, Maguire LJ, McLaren JW, Hodge DO, Bourne WM (2007) Femtosecond laser versus mechanical microkeratome for LASIK: a randomized controlled study. Ophthalmology 114:1482–1490
80. Munoz G, Albarran-Diego C, Sakla HF, Javaloy J, Alio JL (2006) Transient light-sensitivity syndrome after laser in situ keratomileusis with the femtosecond laser Incidence and prevention. J Cataract Refract Surg 32:2075–2079
81. Stonecipher KG, Dishler JG, Ignacio TS, Binder PS (2006) Transient light sensitivity after femtosecond laser flap creation: clinical findings and management. J Cataract Refract Surg 32:91–94
82. Recep OF, Cagil N, Hasiripi H (2000) Outcome of flap subluxation after laser in situ keratomileusis: results of 6-month follow-up. J Cataract Refract Surg 26:1158–1162
83. Aldave AJ, Hollander DA, Abbott RL (2002) Late-onset traumatic flap dislocation and diffuse lamellar inflammation after laser in situ keratomileusis. Cornea 21:604–607
84. Booth MA, Koch DD (2003) Late laser in situ keratomileusis flap dislocation caused by a thrown football. J Cataract Refract Surg 29:2032–2033
85. Tumbocon JA, Paul R, Slomovic A, Rootman DS (2003) Late traumatic displacement of laser in situ keratomileusis flaps. Cornea 22:66–69
86. Kocak I, Karabela Y, Karaman M, Kaya F (2006) Late onset diffuse lamellar keratitis as a result of the toxic effect of Ecballium elaterium herb. J Refract Surg 22:826–827
87. Lazaro C, Perea J, Arias A (2006) Surgical-glove-related diffuse lamellar keratitis after laser in situ keratomileusis: long-term outcomes. J Cataract Refract Surg 32:1702–1709
88. Shen YC, Wang CY, Fong SC, Tsai HY, Lee YF (2006) Diffuse lamellar keratitis induced by toxic chemicals after laser in situ keratomileusis. J Cataract Refract Surg 32:1146–1150

1

89. Smith RJ, Maloney RK. Diffuse lamellar keratitis (1998) A new syndrome in lamellar refractive surgery. Ophthalmology 105:1721–1726
90. Bigham M, Enns CL, Holland SP, Buxton J, Patrick D, Marion S (2005) Diffuse lamellar keratitis complicating laser in situ keratomileusis: post-marketing surveillance of an emerging disease in British Columbia, Canada, 2000–2002. J Cataract Refract Surg 31:2340–2344
91. Dada T, Pangtey MS, Sharma N, Vajpayee RB, Jhanji V, Sethi HS (2006) Hyeropic shift after LASIK induced diffuse lamellar keratitis. BMC Ophthalmol 6:19
92. Beer SM, Campos M, Lopes PT, Andre JA, Jr., Schor P (2007) Ocular wavefront aberrations in patients after diffuse lamellar keratitis. Cornea 26:6–8
93. Klein SR, Epstein RJ, Randleman JB, Stulting RD (2006) Corneal ectasia after laser in situ keratomileusis in patients without apparent preoperative risk factors. Cornea 25:388–403
94. Randleman JB, Russell B, Ward MA, Thompson KP, Stulting RD (2003) Risk factors and prognosis for corneal ectasia after LASIK. Ophthalmology 110:267–275
95. Tabbara KF, Kotb AA (2006) Risk factors for corneal ectasia after LASIK. Ophthalmology 113:1618–1622
96. Kymionis GD, Siganos CS, Kounis G, Astyrakakis N, Kalyvianaki MI, Pallikaris IG (2003) Management of post-LASIK corneal ectasia with Intacs inserts: one-year results. Arch Ophthalmol 121:322–326
97. Wollensak G, Sporl E, Seiler T (2003) [Treatment of keratoconus by collagen cross-linking]. Ophthalmologe 100:44–49
98. Kohlhaas M, Spoerl E, Speck A, Schilde T, Sandner D, Pillunat LE (2005) [A new treatment of keratectasia after LASIK by using collagen with riboflavin/UVA light cross-linking]. Klin Monatsbl Augenheilkd 222:430–436
99. Perez-Santonja JJ, Iradier MT, Sanz-Iglesias L, Serrano JM, Zato MA (1996) Endothelial changes in phakic eyes with anterior chamber intraocular lenses to correct high myopia. J Cataract Refract Surg 22:1017–1022
100 Baikoff G, Arne JL, Bokobza Y, Colin J, George JL, Lagoutte F (1998) Angle-fixated anterior chamber phakic intraocular lens for myopia of –7 to –19 diopters. J Refract Surg 14:282–293
101. Allemann N, Chamon W, Tanaka HM, Mori ES, Campos M, Schor P (2000) Myopic angle-supported intraocular lenses: two-year follow-up. Ophthalmology 107:1549–1554
102. Alio JL, de la Hoz F, Perez-Santonja JJ, Ruiz-Moreno JM, Quesada JA (1999) Phakic anterior chamber lenses for the correction of myopia: a 7-year cumulative analysis of complications in 263 cases. Ophthalmology 106:458–466
103. Menezo JL, Cisneros AL, Rodriguez-Salvador V (1998) Endothelial study of iris-claw phakic lens: four year follow-up. J Cataract Refract Surg 24:1039–1049
104. Saxena R, Landesz M, Noordzij B, Luyten GP (2003) Three-year follow-up of the Artisan phakic intraocular lens for hypermetropia. Ophthalmology 110:1391–1395
105. Jimenez-Alfaro I, Benitez del Castillo JM, Garcia-Feijoo J, Gil de Bernabe JG, Serrano de La Iglesia JM (2001) Safety of posterior chamber phakic intraocular lenses for the correction of high myopia: anterior segment changes after posterior chamber phakic intraocular lens implantation. Ophthalmology 108:90–99
106. Budo C, Hessloehl JC, Izak M, Luyten GP, Menezo JL, Sener BA (2000) Multicenter study of the Artisan phakic intraocular lens. J Cataract Refract Surg 26:1163–1171
107. Leccisotti A (2005) Angle-supported phakic intraocular lenses in hyperopia. J Cataract Refract Surg 31:1598–1602
108. Ardjomand N, Kolli H, Vidic B, El-Shabrawi Y, Faulborn J (2002) Pupillary block after phakic anterior chamber intraocular lens implantation. J Cataract Refract Surg 28:1080–1081
109. Smallman DS, Probst L, Rafuse PE (2004) Pupillary block glaucoma secondary to posterior chamber phakic intraocular lens implantation for high myopia. J Cataract Refract Surg 30:905–907
110. Hoyos JE, Dementiev DD, Cigales M, Hoyos-Chacon J, Hoffer KJ (2002) Phakic refractive lens experience in Spain. J Cataract Refract Surg 28:1939–1946
111. Bylsma SS, Zalta AH, Foley E, Osher RH (2002) Phakic posterior chamber intraocular lens pupillary block. J Cataract Refract Surg 28:2222–2228
112. Perez-Santonja JJ, Iradier MT, Benitez del Castillo JM, Serrano JM, Zato MA (1996) Chronic subclinical inflammation in phakic eyes with intraocular lenses to correct myopia. J Cataract Refract Surg 22:183–187
113. Menezo JL, Avino JA, Cisneros A, Rodriguez-Salvador V, Martinez-Costa R (1997) Iris claw phakic intraocular lens for high myopia. J Refract Surg 13:545–555
114. Perez-Santonja JJ, Alio JL, Jimenez-Alfaro I, Zato MA (2000) Surgical correction of severe myopia with an angle-supported phakic intraocular lens. J Cataract Refract Surg 26:1288–1302
115. Trindade F, Pereira F (1998) Cataract formation after posterior chamber phakic intraocular lens implantation. J Cataract Refract Surg 24:1661–1663
116. Fink AM, Gore C, Rosen E (1999) Cataract development after implantation of the Staar Collamer posterior chamber phakic lens. J Cataract Refract Surg 25:278–282
117. Sanchez-Galeana CA, Smith RJ, Sanders DR, Rodriguez FX, Litwak S, Montes M (2003) Lens opacities after posterior chamber phakic intraocular lens implantation. Ophthalmology 110:781–785
118. Menezo JL, Peris-Martinez C, Cisneros AL, Martinez-Costa R (2004) Phakic intraocular lenses to correct high myopia: Adatomed, Staar, and Artisan. J Cataract Refract Surg 30:33–44
119. Alio JL, de la Hoz F, Ruiz-Moreno JM, Salem TF (2000) Cataract surgery in highly myopic eyes corrected by phakic anterior chamber angle-supported lenses. J Cataract Refract Surg 26:1303–1311
120. Baikoff G, Bourgeon G, Jodai HJ, Fontaine A, Lellis FV, Trinquet L (2005) Pigment dispersion and Artisan phakic intraocular lenses: crystalline lens rise as a safety criterion. J Cataract Refract Surg 31:674–680
121. Trindade F, Pereira F, Cronemberger S (1998) Ultrasound biomicroscopic imaging of posterior chamber phakic intraocular lens. J Refract Surg 14:497–503
122. Eleftheriadis H, Amoros S, Bilbao R, Teijeiro MA (2004) Spontaneous dislocation of a phakic refractive lens into the vitreous cavity. J Cataract Refract Surg 30:2013–2016
123. Hoyos JE, Cigales M, Hoyos-Chacon J (2005) Zonular dehiscence two years after phakic refractive lens (PRL) implantation. J Refract Surg 21:13–17