EVAN H. BLACK
FRANK A. NESI
CHRISTOPHER J. CALVANO
GEOFFREY J. GLADSTONE
MARK R. LEVINE
EDITORS

BRIAN BRAZZO · RAYMOND DOUGLAS
BITA ESMAELI · JOHN HOLDS · DAVID JORDAN
ALON KAHANA · MICHAEL KAZIM · RICHARD LISMAN
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Smith and Nesi's Ophthalmic Plastic and Reconstructive Surgery

THIRD EDITION

Springer

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Christopher J. Calvano • Geoffrey J. Gladstone
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Editors

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Third Edition

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Editors
Evan H. Black, M.D., F.A.C.S.
Associate Professor of Ophthalmology
Department of Ophthalmology
Wayne State University School of Medicine
Detroit, MI, USA

Director, Ophthalmic Plastic and Orbital Surgery
Kresge Eye Institute
Detroit, MI, USA

Clinical Associate Professor of Ophthalmology
Oakland University William Beaumont
School of Medicine
Royal Oak, MI, USA

Consultants in Ophthalmic & Facial Plastic
Surgery, P.C.
Southfield, MI, USA

Christopher J. Calvano, M.D., Ph.D., F.A.C.S.
CPT, MC, US Army (Reserves)
Clinical Assistant Professor
Department of Ophthalmology
University of Central Florida
Orlando, FL, USA

Frank A. Nesi, M.D., F.A.C.S.
Clinical Professor of Ophthalmology
Director, Oculoplastic Surgery
Oakland University William Beaumont School of
Medicine
Royal Oak, MI, USA

Associate Clinical Professor of Ophthalmology
and Otolarygology
Department of Ophthalmology
Kresge Eye Institute
Wayne State University School of Medicine
Detroit, MI, USA

Consultants in Ophthalmic & Facial Plastic
Surgery, P.C.
Southfield, MI, USA

Geoffrey J. Gladstone, M.D., F.A.A.C.S.
Oakland University William Beaumont
School of Medicine, Royal Oak, MI, USA

Mark R. Levine, M.D., F.A.C.S.
Department of Ophthalmology, University
Hospitals of Cleveland, Cleveland Clinic
Foundation, Cleveland, OH, USA

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Preface to the Third Edition

It has been 13 years since the publication of the second edition of *Smith's Ophthalmic Plastic and Reconstructive Surgery*. Since that time, our specialty has continued to grow and flourish. Advancements in technology and surgical technique have allowed the creation of many new procedures, diagnostic modalities, and medical treatments for disease involving the eyelids, orbit, and lacrimal system. The scope of practice of ophthalmic plastic and reconstructive surgery has also continued its natural progression into the face, brow, and forehead, as these are the anatomic regions that directly impact the function and form of the ocular adnexae.

This third edition is now appropriately named *Smith and Nesi's Ophthalmic Plastic and Reconstructive Surgery* in honor of both Dr. Byron Smith, one of the "founding fathers" of this specialty, and Dr. Frank A. Nesi, Dr. Smith's former fellow. Dr. Nesi is one of the foremost innovators in the field of ophthalmic plastic surgery and editor of all three editions of this text. Within these pages, one will find 77 chapters written by over 70 authors. This detailed compilation of diagnostic and surgical techniques promises to demonstrate the state of the art of the specialty. Most of the material from the second edition has been completely rewritten or updated, with a few completely new chapters included.

The information contained in this textbook will be useful to practicing oculofacial plastic and orbital surgeons, fellows, and residents. Comprehensive ophthalmologists, plastic surgeons, otolaryngologists, dermatologists, and physicians in other fields should find this an invaluable resource as well. This integration of modern diagnosis and the latest techniques with the wisdom of time-honored medical and surgical practice will allow the physician to quickly locate the information needed to provide the highest quality care.

Evan H. Black, M.D.
Frank A. Nesi, M.D.
Geoffrey J. Gladstone, M.D.
Mark R. Levine, M.D.

Acknowledgments

Our first debt of gratitude goes to Dr. Byron Capleese Smith, from those of us who knew him well, those of us who only met him, and those of us who came to this field after his passing yet continue to benefit from his teachings. As a group, we have so many other mentors in ophthalmic plastic surgery and ophthalmology that it is impossible to mention them all here. It is imperative to mention the recently deceased Richard Tenzel, whose brilliance will continue to shine on all who practice this art of ophthalmic plastic surgery. Other founders and innovators in our specialty including Crowell Beard, Rocko Fasanella, Wendell Hughes, and Allston Callahan certainly must be cited here as well.

Thanks to Christopher J. Calvano, our managing editor, both for convincing us to take on this project and for keeping the wheels turning. Our section editors deserve special recognition for the exceptional effort put forth to develop each of the major units of this work. Thanks to all of our many authors who took the time and made the effort to write each outstanding chapter. In particular, several of our programs' former fellows participated as chapter authors, including Brian G. Brazzo, Steve Chen, John Siddens, Javier F. Vega, Nadia Kazim, and Francesca Nesi-Eloff. Thanks to our current fellows Dianne Schlachter, J. Javier Servat, and Karina Richani for their efforts in chapter writing and assistance with the overall production. Springer Science+Business Media, LLC deserves special recognition, with initial help from Catherine Paduani followed by the outstanding commitment of Maureen Alexander, Rebekah Amos, and Joanna Perey. Their diligence and effort made the arrangement and organization of this complex work possible.

Extraordinary thanks goes to my (Evan Black's) mentors and coeditors, Dr. Frank A. Nesi and Dr. Geoffrey J. Gladstone, for their friendship, mentorship, partnership, and too many other things to mention. Other mentors deserving of recognition are Kenneth L. Cohen, J. Richard Marion, Jack Rootman, and the recently departed Arthur C. Chandler, Jr. We also appreciate the assistance of the colleagues and staff at William Beaumont Hospital of Oakland University William Beaumont School of Medicine, Kresge Eye Institute of Wayne State University School of Medicine, Case Western Reserve University School of Medicine, and Consultants in Ophthalmic and Facial Plastic Surgery, especially the support from Margie Roth.

We forever owe the most gratitude to our wives, Nickole, Karen, Benora, and Teri for their support and patience during the long hours required for production of this text. Finally, we dedicate this book in the memory of our friend, mentor, and legend, Dr. Byron Capleese Smith, one of the most influential people in the field of ophthalmic plastic and reconstructive surgery.

From the Managing Editor

In March 2009, I approached Dr. Nesi concerning his interest in producing a third edition of *Smith's*. He responded saying "if you could find a publisher, you could do it." We were very fortunate to have a relationship with Springer from previous projects. They were not only interested but excited to secure the rights to the third edition. In many ways, the first step on a large project is the hardest step, but we had a mandate to maintain the text as a premier resource in the field. That foundation of excellence made all subsequent decisions relatively easy. Initial guidance from Catherine Paduani, followed by the absolute professionalism of Maureen Alexander, Rebekah Amos, and Joanna Perey, enabled this project to reach all targets successfully.

Drs. Nesi, Black, Gladstone, and I reviewed the strengths and weaknesses of the second edition and decided upon a section/chapter content distribution that we believe ideally addresses the current needs of the ophthalmic plastic and reconstructive surgical community regardless of primary discipline. We were able to assemble an all-star roster of those willing to function as section editors. Their selections for chapter authors were outstanding and in keeping with the high standard of authorship set by previous editions.

It is with great personal pride that *Smith's* now includes a dedicated section for pediatric considerations. The reader will also find the orbital section significantly expanded and an updated section on aesthetic and cosmetic techniques intended to present the "state of the art" without editorializing a given procedure's merits. Some past topics were minimized or deleted as we felt these were best covered by other current resources, or that they were more appropriate for a comprehensive ophthalmic work. The other sections are all outstanding, well referenced, and the whole edition is accessible to all levels of practice. There is some intentional duplication of material between sections and often with different viewpoints; we believe this only strengthens the text without redundancy.

Production of a text mirrors the stages of one's own career and reminds us of those who helped us through that journey. Dr. Russell Mankes (Albany Medical College) was my Ph.D. mentor and developed my research skills in teratology and oncology. Dr. Derek and Gina Eisnor are the best of friends and family for over 20 years. Dr. James Mandell (now CEO and President, Children's Hospital Boston) was my clinical mentor and guided me through the beginning of a surgical career. Dr. Mark Sesto (Chief of Surgery, Cleveland Clinic, Florida) provided support and encouragement for my pursuits, including joining the Army Medical Corps. Drs. Bita Esmaeli and Dan Gombos of M.D. Anderson Cancer Center were instrumental in my ophthalmic education, inspiring pursuit of fellowship training. This was gratefully undertaken with Dr. Evan H. Black, who along with Drs. Nesi and Gladstone provided an exceptional learning environment and a long-term relationship worth far more than can be described here (and they all trace their training lineage ultimately to Dr. Byron Smith). Most important are the women in our lives, in my case Mom (Anita Calvano) and Kendra. Thank you all for your support.

Christopher J. Calvano M.D., Ph.D., F.A.C.S.

Byron Smith M.D.: Lineage of Fellows[1]

1960	Margaret Obear M.D., Arthur Schaefer M.D., Peter Rogers M.D., Richard Tenzel M.D., Orkan George Stasior M.D., David Soll M.D.
1962	Bernd Silver M.D.
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1985	Donald MacDonald M.D.
1986	Philip Silverstone M.D.
1987	Brian Arthurs M.D.
1988	Kenneth Hyde M.D.
1989	John Nassif M.D.
1990	Elizabeth Maher M.D.
1991	Nicolas Barna M.D.

[1] The American Society of Ophthalmic Plastic and Reconstructive Surgery (ASOPRS),The first 25 years: 1969–1994. editor David M. Reifler M.D., F.A.C.S., ASOPRS and Norman Publishing, San Francisco, CA 1994; page 274

Contents

Contributors

Audrey E. Ahuero, M.D. Department of Ophthalmology, Allure Facial Laser Center and Medispa, University of Washington, Kirkland, WA, USA

Adham Al-Hariri, M.D. Department of Ophthalmology, Ochsner Clinic Foundation, New Orleans, LA, USA

Richard C. Allen, M.D., Ph.D. Department of Ophthalmology & Visual Sciences, University of Iowa Hospitals & Clinics, Iowa City, IA, USA

Richard Lee Anderson, M.D. Center for Facial Appearances, Salt Lake City, UT, USA

Robert Anolik, M.D. Laser & Skin Surgery Center of New York, New York, NY, USA

Zachary Berbos, M.D. Center for Facial Appearances, Salt Lake City, UT, USA

C. Robert Bernardino, M.D., F.A.C.S. Oculoplastics and Aesthetic Surgery, Vantage Eye Center, Monterey, CA, USA

Jurij R. Bilyk, M.D. Oculoplastic and Orbital Surgery Service, Wills Eye Institute. Associate Professor of Ophthalmology, Jefferson Medical College, Philadelphia, PA, USA

Evan H. Black, M.D., F.A.C.S. Associate Professor of Ophthalmology Department of Ophthalmology, Wayne State University School of Medicine, Detroit, MI, USA

Ophthalmic Plastic and Orbital Surgery, Kresge Eye Institute, Detroit, MI, USA

Oakland University William Beaumont School of Medicine, Royal Oak, MI, USA

Consultants in Ophthalmic & Facial Plastic Surgery, P.C., Southfield, MI, USA

Brian G. Brazzo, M.D. Department of Ophthalmology, Weill Medical College of Cornell University, New York, NY, USA

Kenneth V. Cahill, M.D. The Eye Center of Columbus, The Ohio State University, Columbus, OH, USA

Michael A. Callahan, M.D. UAB, Callahan Eye Foundation Hospital, Birmingham, AL, USA

Marta Calsina, M.D. Department of Ophthalmology, Edward Harkness Eye Institute, New York Presbyterian Hospital, Columbia University, New York, NY, USA

Christopher J. Calvano, M.D., Ph.D., F.A.C.S. Department of Ophthalmology, University of Central Florida, Orlando, FL, USA

Christopher B. Chambers, M.D. Department of Ophthalmology, Feinberg School of Medicine, Northwestern University, Chicaco, IL, USA

Steven Chen, M.D., F.A.C.S. Oculoplastic Consultants of Arizona, P.C., Glendale, AZ, USA

Raymond I. Cho, M.D. Ophthalmology Service, San Antonio Military Medical Center, Fort Sam Houston, Texas, USA

Christina H. Choe, M.D. Department of Ophthalmology, University of Pennsylvania, Philadelphia, PA, USA

Adan J. Cohen, M.D., F.A.C.S. Skokie, IL, USA

Michael A. Connor, M.D. Section of Ophthalmology, Department of Head and Neck Surgery, The University of Texas M.D. Anderson Cancer Center, Houston, TX, USA

Ophthalmic Plastic and Reconstructive Surgery, Texas Oculoplastic Consultants, Austin, TX, USA

Wayne T. Cornblath, M.D. Department of Ophthalmology & Visual Sciences and Neurology, University of Michigan, Ann Arbor, MI, USA

Bryan Costin, M.D. Department of Ophthalmology, Ohio State University Eye & Ear Institute, Columbus, OH, USA

Kara Couch, M.S., C.R.N.P., C.W.S. Department of General Surgery, Walter Reed Army Medical Center, Washington, DC, USA

Steven M. Couch, M.D. Department of Ophthalmology and Visual Sciences, Washington University School of Medicine, St. Louis, MO, USA

Alison V. Crum, M.D. Department of Ophthalmology, Yale School of Medicine, Yale University, New Haven, CT, USA

Philip L. Custer, M.D., F.A.C.S. Department of Ophthalmology and Visual Sciences, Washington University School of Medicine, St. Louis, MO, USA

Roger A. Dailey, M.D., F.A.C.S. Department of Oculofacial Plastic and Reconstructive Surgery, Oregon Health and Science University, Portland, OR, USA

Hakan Demirci, M.D. Eye Plastic and Orbital Surgery Service, Department of Ophthalmology and Visual Sciences, Kellogg Eye Center, University of Michigan, Ann Arbor, MI, USA

Mohit A. Dewan, M.D. Department of Lions Eye Institute, Albany Medical Center, Albany (Slingerlands), NY, USA

Gary R. Diamond, M.D. Division of Ophthalmology, St. Christopher's Hospital for Children, Philadelphia, PA, USA

Raymond S. Douglas, M.D., Ph.D. Department of Ophthalmology & Visual Sciences, Section of Oculoplastics, Kellogg Eye Center, University of Michigan, Ann Arbor, MI, USA

Steven C. Dresner, M.D. Eyesthetica, Los Angeles, CA, USA

Lilly Droll, M.D. Department of Head and Neck Surgery, Section of Ophthalmology, The University of Texas M.D. Anderson Cancer Center, Houston, TX, USA

Craig R. Dufresne, M.D. Chevy Chase, MD, USA

Vikram D. Durairaj, M.D., F.A.C.S. Department of Ophthalmology, University of Colorado, Aurora, CO, USA

Jonathan J. Dutton, M.D., Ph.D. Department of Ophthalmology, University of North Carolina, Chapel Hill, NC, USA

Kasra Eliasieh, M.D. Division of Ophthalmic Plastic and Reconstructive Surgery, Department of Ophthalmology, New York Eye and Ear Infirmary, New York, NY, USA

Victor M. Elner, M.D., Ph.D. Eye Plastic and Orbital Surgery Service, Department of Ophthalmology and Visual Sciences, Kellogg Eye Center, University of Michigan, Ann Arbor, MI, USA

Bita Esmaeli, M.D., F.A.C.S. Section of Ophthalmology, Department of Head and Neck Surgery, The University of Texas M.D. Anderson Cancer Center, Houston, TX, USA

Jill A. Foster, M.D., F.A.C.S. Department of Ophthalmology, The Ohio State University, Columbus, OH, USA

Lindell R. Gentry, M.D. Department of Radiology – Section of Neuroradiology, University of Wisconsin School of Medicine and Public Health, Madison, WI, USA

Dan Georgescu, M.D., Ph.D. Wilmer Eye Institute, Baltimore, MD, USA

Roy G. Geronemus, M.D. Laser & Skin Surgery Center of New York, New York, NY, USA

Geoffrey J. Gladstone, M.D., F.A.A.C.S. Oakland University William Beaumont School of Medicine, Royal Oak, MI, USA

Mithra O. Gonzalez, M.D. Department of Ophthalmology, University of Colorado, Aurora, CO, USA

Shivani Gupta, M.D., M.P.H. Eye Plastic and Orbital Surgery Service, Department of Ophthalmology and Visual Sciences, Kellogg Eye Center, University of Michigan, Ann Arbor, MI, USA

John B. Holds, M.D., F.A.C.S. Department of Ophthalmology and Otolaryngology/Head and Neck Surgery, Ophthalmic Plastic and Cosmetic Surgery, Inc., Saint Louis University, St. Louis, MO, USA

Srinivas S. Iyengar, M.D. Eyesthetica, Los Angeles, CA, USA

Glenn W. Jelks, M.D., F.A.C.S. Department of Plastic Surgery, New York University Langone Medical Center, New York, NY, USA

David R. Jordan, M.D., F.A.C.S., F.R.C.S.(C.) University of Ottawa Eye Institute, Ottawa, ON, Canada

Alon Kahana, M.D., Ph.D. Eye Plastic and Orbital Surgery Service, Department of Ophthalmology and Visual Sciences, Kellogg Eye Center, Comprehensive Cancer Center, C.S. Mott Children's Hospital, University of Michigan, Ann Arbor, MI, USA

Amir M. Karam, M.D. Department of Surgery, Clinical Instructor, UC San Diego, San Diego, CA, USA

James A. Katowitz, M.D. Department of Ophthalmology, The Children's Hospital of Philadelphia, University of Pennsylvania Medical Center, Philadelphia, PA, USA

William R. Katowitz, M.D. Department of Ophthalmology, The Children's Hospital of Philadelphia, University of Pennsylvania Medical Center, Philadelphia, PA, USA

Steven E. Katz, M.D. Department of Ophthalmology, Ohio State University Eye & Ear Institute, Columbus, OH, USA

Michael Kazim, M.D. Department of Ophthalmology, Edward S. Harkness Eye Institute, NY Presbyterian Hospital, Columbia University Medical Center, New York, NY, USA

Department of Ophthalmology and Surgery, Columbia University College of Physicians and Surgeons, New York, NY, USA

Nadia Kazim, M.D., F.A.C.S. Bonita Springs, FL, USA

Tabassum A. Kennedy, M.D. Department of Radiology – Section of Neuroradiology, University of Wisconsin School of Medicine and Public Health, Madison, WI, USA

Tiffany Kent, M.D., Ph.D. Department of Ophthalmology, Barnes-Jewish Hospital, Washington University, St. Louis, MO, USA

Robert C. Kersten, M.D. Department of Ophthalmology, University of California – San Francisco Medical Center, San Francisco, CA, USA

Don O. Kikkawa, M.D. Division of Oculofacial Plastic and Reconstructive Surgery, UCSD Department of Ophthalmology, Shiley Eye Center, La Jolla, CA, USA

H. Jane Kim, M.D. Department of Ocular Oncology Service, Wills Eye Institute, Thomas Jefferson University, Philadelphia, PA, USA

Stephen R. Klapper, M.D., F.A.C.S. Klapper Eyelid and Facial Plastic Surgery, Carmel, IN, USA

Irina V. Koreen, M.D., Ph.D. Department of Ophthalmology, Wake Forest University School of Medicine, Medical Center Boulevard, Winston-Salem, NC, USA

Bobby S. Korn, M.D., Ph.D., F.A.C.S. Division of Oculofacial Plastic and Reconstructive Surgery, UCSD Department of Ophthalmology, Shiley Eye Center, La Jolla, CA, USA

Dwight R. Kulwin, M.D. Department of Ophthalmology, Cincinnati Eye Institute, Cincinnati, OH, USA

Paul D. Langer, M.D., F.A.C.S. New Jersey Medical School, Newark, NJ, USA

Wayne F. Larrabee Jr., M.D. Larrabee Surgical Center, University of Washington, Seattle, WA, USA

H.B. Harold Lee, M.D. Department of Ophthalmology, Indiana University, Indianapolis, IN, USA

Brian J. Lee, M.D. Eye Plastic and Orbital Surgery Service, Department of Ophthalmology and Visual Sciences, Kellogg Eye Center, University of Michigan, Ann Arbor, MI, USA

Gary J. Lelli Jr., M.D. Division of Ophthalmic Plastic, Reconstructive, and Orbital Surgery, Department of Ophthalmology, Weill Cornell Medical College, New York-Presbyterian Hospital, New York, NY, USA

Bradley N. Lemke, M.D. University of Wisconsin School of Medicine and Public Health, Madison, WI, USA

Alex V. Levin, M.D., M.H.Sc. Department of Ophthalmology, Wills Eye Institute, Thomas Jefferson University Hospital, Philadelphia, PA, USA

Pediatric Ophthalmology & Ocular Genetics, Wills Eye Institute, Philadelphia, PA, USA

Mark R. Levine, M.D., F.A.C.S. Department of Ophthalmology, University Hospitals of Cleveland, Cleveland Clinic Foundation, Cleveland, OH, USA

Ilya Leyngold, M.D. Center for Facial Appearances, Salt Lake City, UT, USA

Richard D. Lisman, M.D., F.A.C.S. Department of Ophthalmology, Division of Ophthalmic Plastic and Reconstructive Surgery, New York University School of Medicine, New York, NY, USA

Mark J. Lucarelli, M.D., F.A.C.S. Department of Oculoplastics Service, Ophthalmology & Visual Sciences, University of Wisconsin Hosptial and Clinics, Madison, WI, USA

Harry Marshak, M.D., F.A.C.S. Department of Ophthalmic Plastic and Facial Surgery, Eisenhower Medical Center, Rancho Mirage, CA, USA

Douglas P. Marx, M.D. Department of Oculofacial Plastic and Reconstructive Surgery, Oregon Health and Science University, Portland, OR, USA

Amanda E. Matthews, M.D. Department of Ophthalmology, Wills Eye Institute at Thomas Jefferson University, Philadelphia, PA, USA

Louise Mawn, M.D., F.A.C.S. Vanderbilt University Medical Center, Nashville, TN, USA

Alan A. McNab, M.B., B.S., F.R.A.N.Z.C.O. Department of Orbital Plastic and Lacrimal Clinic, Royal Victorian Eye and Ear Hospital, East Melbourne, VIC, Australia

Jill Melicher, M.D. Department of Ophthalmic Plastics, Orbit and Reconstructive Surgery, Management of Zygomaticomaxillary Complex Fractures, Minnesota Eye Consultants, P.A., Minneapolis, MN, USA

Murray A. Meltzer, M.D. Department of Ophthalmology, Mount Sinai School of Medicine, New York, NY, USA

Dale R. Meyer, M.D., F.A.C.S. Department of Lions Eye Institute, Albany Medical Center, Albany (Slingerlands), NY, USA

Michael R. Migden, M.D. Departments of Dermatology and Plastic Surgery, Mohs and Dermasurgery Unit, The University of Texas M.D. Anderson Cancer Center, Houston, TX, USA

Department of Dermatology, University of Texas Medical School at Houston, Houston, TX, USA

Sonya D. Mitchell, M.D. Bassin Center for Facial Plastic Surgery, Melbourne, FL, USA

Ann P. Murchison, M.D., M.P.H. Oculoplastic and Orbital Surgery Service, Wills Eye Institute. Assistant Professor of Ophthalmology, Jefferson Medical College, Philadelphia, PA, USA

John C. Mustardé, O.B.E., M.D., F.R.C.S. (deceased) West of Scotland Plastic Surgery Service, Glasgow University, Glasgow, Scotland, UK

Christine C. Nelson, M.D. Department of Ophthalmology, University of Michigan Kellogg Eye Center, Ann Arbor, MI, USA

Jeffrey A. Nerad, M.D. Department of Ophthalmic Plastics, Orbit and Reconstructive Surgery, Cincinnati Eye Institute, Cincinnati, OH, USA

Frank A. Nesi, M.D., F.A.C.S. Oculoplastic Surgery, Oakland University William Beaumont School of Medicine, Royal Oak, MI, USA

Department of Ophthalmology, Kresge Eye Institute, Wayne State University School of Medicine, Detroit, MI, USA

Consultants in Ophthalmic & Facial Plastic Surgery, P.C., Southfield, MI, USA

Francesca Nesi-Eloff, M.D. Consultants in Ophthalmic and Facial Plastic Surgery, P.C., Southfield, MI, USA

Oculoplastic Surgery, Oakland University William Beaumont School of Medicine, Royal Oak, MI, USA

William R. Nunery, M.D. Department of Ophthalmology, Methodist Hospital, Indianapolis, IN, USA

Sang-Rog Oh, M.D. Division of Oculofacial Plastic and Reconstructive Surgery, UCSD Department of Ophthalmology, Shiley Eye Center, La Jolla, CA, USA

Ann Ostrovsky, M.S., M.D. Department of Ophthalmology, Mount Sinai School of Medicine, New York, NY, USA

Kristina Yi-Hwa Pao, M.D. Department of Ophthalmology, Wills Eye Institute. Thomas Jefferson University Hospital, Philadelphia, PA, USA

Rakesh M. Patel, M.D. Department of Ophthalmology, Montefiore Medical Center, Bronx, NY, USA

Ayelet Priel, M.D. Division of Oculofacial Plastic and Reconstructive Surgery, UCSD Department of Ophthalmology, Shiley Eye Center, La Jolla, CA, USA

Ginger Henson Rattan, M.D. Fellow in Ophthalmic Plastic and Reconstructive Surgery, Cincinnati Eye Institute, Cincinnati, OH, USA

Karina Richani-Reverol, M.D. Consultants in Ophthalmic and Facial Plastic Surgery, P.C., Southfield, MI, USA

Gina M. Rogers, M.D. Department of Ophthalmology & Visual Sciences, University of Iowa Hospitals & Clinics, Iowa City, IA, USA

Javier Fernandez-Vega Sanz, M.D. Instituto Oftalmologico Fernandez-Vega, Oviedo, Asturias, Spain

Khami Satchi, M.B., B.Chir, F.R.C.O phth. Department of Orbital Plastic and Lacrimal Clinic, Royal Victorian Eye and Ear Hospital, East Melbourne, VIC, Australia

Aaron Savar, M.D. Section of Ophthalmology, Department of Head and Neck Surgery, The University of Texas M.D. Anderson Cancer Center, Houston, TX, USA

Peter J. Savino, M.D. Department of Ophthalmology, University of California, San Diego, La Jolla, CA, USA

Daniel P. Schaefer, M.D., F.A.C.S. School of Medicine and Biomedical Sciences, State University of New York at Buffalo, Buffalo, NY, USA

Dianne M. Schlachter, M.D. Department of Ophthalmology, Kresge Eye Institute, Detroit, MI, USA

Jaime S. Schwartz, M.D. Department of Plastic Surgery and Aesthetic Medicine, Bright Health Physicians, Whittier, CA, USA

Robert M. Schwarcz, M.D., F.A.C.S. Department of Ophthalmology, Division of Oculofacial Plastic & Reconstructive Surgery, Assistant Professor, Chief, Division of Oculofacial Plastic & Reconstructive Surgery, Montefiore Medical Center/Albert Einstein College of Medicine, New York, NY, USA

Javier Servat, M.D. Beaumont Eye Institute, Royal Oak, MI, USA

Consultants in Ophthalmic and Facial Plastic Surgery, P.C., Southfield, MI, USA

James Banks Shepherd III, M.D. Department of Ophthalmology, Barnes-Jewish Hospital, Washington University, St. Louis, MO, USA

Carol L. Shields, M.D. Department of Ocular Oncology Service, Wills Eye Institute, Thomas Jefferson University, Philadelphia, PA, USA

Roman Shinder, M.D. Department of Ophthalmology, SUNY Downstate Medical Center, Brooklyn, NY, USA

Section of Ophthalmology, Department of Head and Neck Surgery, The University of Texas M.D. Anderson Cancer Center, Houston, TX, USA

John D. Siddens, D.O. UMG Plastic Surgery, Greenville Hospital System, Greenville, SC, USA

Sirunya Silapunt, M.D., F.A.A.D. Department o Dermatology, University of Texas Medical School at Houston, Houston, TX, USA

Daniel T. Sines, M.D. Department of Ophthalmology, University of North Carolina, Chapel Hill, NC, USA

Bryan S. Sires, M.D., Ph.D. Department of Ophthalmic Plastic Surgery, Allure Cosmetic Surgery, University of Washington, Kirkland, WA, USA

Terry J. Smith, M.D. Department of Ophthalmology & Visual Sciences, Kellogg Eye Center, University of Michigan, Ann Arbor, MI, USA

Michael B. Starr, M.D. Department of Ophthalmology, Mount Sinai School of Medicine, New York, NY, USA

Peter J. Timoney, M.B.B.Ch., M.R.C.O phth. Department of Ophthalmology, Indiana University, Indianapolis, IN, USA

Essam El Toukhy, M.D., F.R.C.O ph. Cairo University, Dokki, Cairo, Egypt

Kirsten Trotter, M.D. University Dermatologists Inc., Cleveland, OH, USA

David T. Tse, M.D., F.A.C.S. Department of Ophthalmology, University of Miami Miller School of Medicine, Miami, FL, USA

Gregory P. Van Stavern, M.D. Department of Ophthalmology and Visual Sciences and Neurology, Barnes-Jewish Hospital, Washington University School of Medicine, St. Louis, MO, USA

David A. Weinberg, M.D., F.A.C.S. Dartmouth Medical School, Concord Eye Care, Concord, NH, USA

Jeff White, M.D. Department of Ophthalmology, Moore Regional Hospital, Carolina Eye Associates, Southern Pines, NC, USA

Michael K. Yoon, M.D. Department of Ophthalmology, University of California – San Francisco Medical Center, San Francisco, CA, USA

Christopher I. Zoumalan, M.D. Department of Ophthalmology, Division of Ophthalmic Plastic and Reconstructive Surgery, Keck School of Medicine of USC, Los Angeles, CA, USA

Richard A. Zoumalan, M.D. Facial Plastic & Reconstructive Surgery, Ledors Sunai Medical Center, Los Angeles, CA, USA

Section 1

Anatomy

Anatomy of the Ocular Adnexa, Orbit, and Related Facial Structures

1

Bradley N. Lemke and Mark J. Lucarelli

Understanding the structural abnormalities and the corrective surgical procedures described in this volume is predicated on a familiarity with normal anatomy. This chapter is designed to discuss this anatomy in sufficient detail and to provide key past and current references so as to be useful to the physician and surgeon working in this area.

Osteology

Orbital Shape and Development

The confines and the relationships of the orbits are best understood by examining a skull (Fig. 1.1). Early in human development, the optic vesicles point in opposite directions. As facial development occurs, the angle between the optic stalks decreases as the eyes become situated more anteriorly. In the adult, the exact angle of the divergent optic nerves is determined in part by the placement of the optic chiasm on the sphenoid body, but it is usually about 68° [1].

The adult lateral orbital walls are approximately 90° from each other, or 45° from anteroposterior. The medial orbital walls are nearly straight anteroposterior, angling slightly medial anteriorly. The divergent axis of each orbit thus becomes half of 45°, or about 23° (Fig. 1.2). The eyes tend to diverge in accordance with their bony surroundings, as is seen in individuals with acquired visual loss, under general anesthesia, or in death. It is not surprising to find the medial rectus, the thickest of the rectus muscles, because of the constant demand on it for torsion of the globe away from the orbital axis.

Facial development occurs from processes evident in the third week of development. The mandibular swellings are the most caudal and initially are separated by a midline depression. The frontonasal process is rostral with symmetric halves and is separated from the former by the median stomodeum, or primitive mouth, and laterally by the paired maxillary processes (Fig. 1.3). The frontonasal and mandibular processes form the central face and mandible, respectively, while the maxillary processes later approach the midline to form the malar eminences.

The lateral nasal process lies medial to the eye and fuses with the maxillary process situated beneath and lateral to the eye, thus forming the medial, inferior, and lateral orbital walls. The orbital roof is formed by the capsule of the developing forebrain. The enlarging globe stretches the surrounding connective tissue making it fairly dense and a relative restraint to further embryologic modeling in this area [2]. Within these condensed fibrous plates, numerous ossification centers first appear around the seventh week. Ossification of the orbital walls is completed by birth except at the orbital apex. The lesser wing of the sphenoid is initially cartilaginous, unlike the greater sphenoid wing and the other membranous orbital bones. The orbital walls are derived from cranial neural crest cells, which expand to form the frontonasal and maxillary processes.

The orbit most closely resembles a four-sided pyramid that becomes three-sided near the apex. The side lost is the floor, which is cut off by the inferior orbital fissure at two-thirds the orbital depth. The widest portion is 1 cm behind the orbital rim corresponding to the equator of the globe. The relative narrowing of the orbital rim is minimal at birth but proceeds with facial growth, especially with expansion of the frontal and maxillary sinuses. The depth of the orbit measured from the apex to the center of the orbital margin is approximately 45 mm, with substantial variation between individuals and slight differences between sides of an individual.

B.N. Lemke, M.D. (✉)
University of Wisconsin School of Medicine
and Public Health, Madison, WI 53717, USA

M.J. Lucarelli, M.D., F.A.C.S.
Department of Oculoplastics Service,
Ophthalmology & Visual Sciences, University of Wisconsin
Hospital and Clinics, 600 Highland Avenue, F4/348 CSC,
Madison, WI 53792, USA
e-mail: mlucarel@wisc.edu

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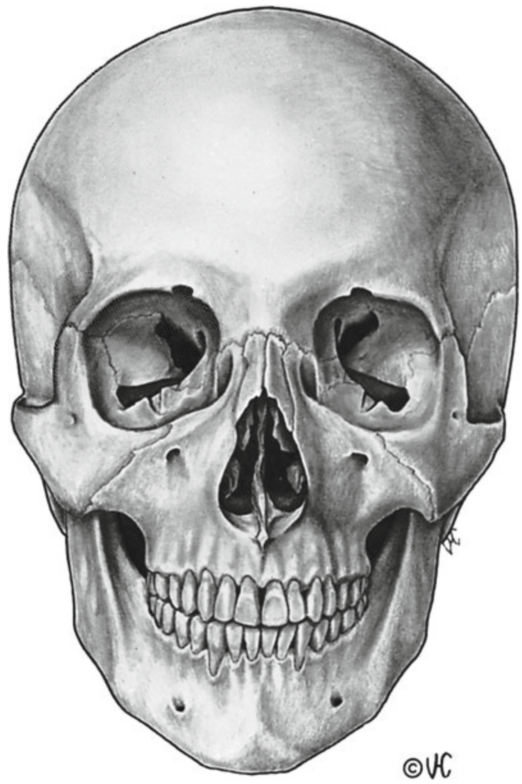

Fig. 1.1 Anteroposterior view of adult skull

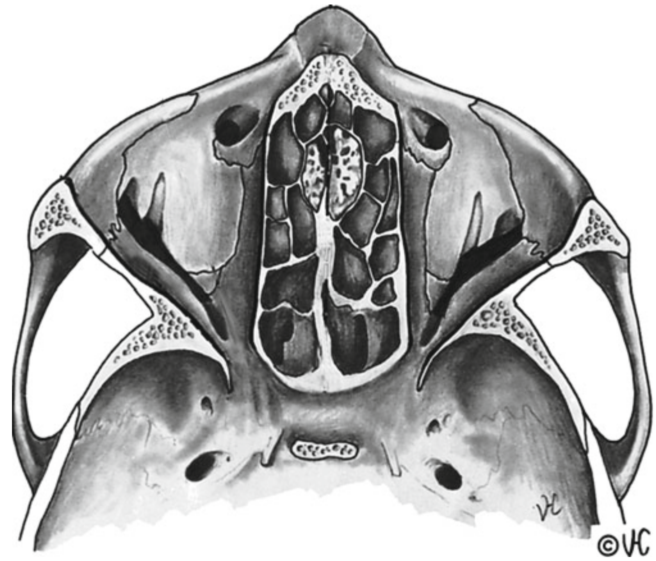

Fig. 1.2 Horizontal section through orbits. Medial walls are nearly parallel and lateral walls diverge 45° from midline

Orbital Margin

The adult orbital rim is a discontinuous spiral. It is roughly rectangular with a horizontal dimension of 40 mm and a vertical dimension of 32 mm. The zygomatic bone forms most of the lateral margin and the lateral half of the inferior rim (see Figs. 1.1 and 1.4). This orbital protector or "facial buttress" can withstand severe trauma before fracture which usually occurs along the suture lines. Steps may then be felt inferiorly at the zygomaticomaxillary suture and superolaterally at the zygomaticofrontal suture. The frontal bone encompasses the superior orbital margin and extends laterally and medially to form portions of these borders. The newborn superior orbital rim is sharp. It remains so in the female but becomes rounded with development in the male. Medially between the superior orbits is the smooth glabellar area below which the nasal bones arise. In most skulls, the medial superior rim is indented by a supraorbital notch formed by the supraorbital nerve and artery rising to the forehead. In some skulls, the bone covers these structures, forming a foramen.

The medial orbital margin is formed anteriorly by the maxillary bone rising to meet the maxillary process of the frontal bone. The lacrimal excretory sac complicates the medial rim by indenting the bone and forming anterior (maxillary bone) and posterior (lacrimal bone) crests (see the Sect. Lacrimal Excretory Osteology). Thus, the orbital rim was described by Whitnall as a single coil of an undulating spira1 [3].

The infraorbital nerve and attendant artery exit 4 mm or more below the inferior rim medially. In two thirds of skulls, a supraorbital notch can be found along the superomedial rim [4]. A foramen is seen instead of a notch in other skulls. The possibility of this variation should be considered during coronal or endoscopic brow lifting. The supraorbital ridge lies above the medial one half of the orbit.

Orbital Walls

The triangular orbital roof is formed primarily by the orbital plate of the frontal bone (Figs. 1.4 and 1.5). Its progressive convexity with growth reflects molding about the globe. The roof is usually strong and only rarely will blunt ocular trauma explode it, vis-a-vis the common orbital floor fracture. Small dehiscences, however, are not uncommon in the orbital roof. An incidence of approximately 15% has been reported [3, 5].

Posteriorly, the roof remains flat and receives a 1.5-cm contribution from the lesser wing of the sphenoid bone. Near the suture between the frontal and sphenoid bones, approximately 30 mm posterior to the orbital rim, a menin-golacrimal foramen may be found. In roughly 30% of individuals, this foramen conducts an anastomosis between the middle meningeal artery (external carotid system) and the root of the lacrimal artery [6]. The optic nerve pierces the roof at an angle of about 35° from midline to form the optic foramen (see later). Anteromedially, the small trochlear fossa is found while the large lacrimal gland fossa is seen laterally.

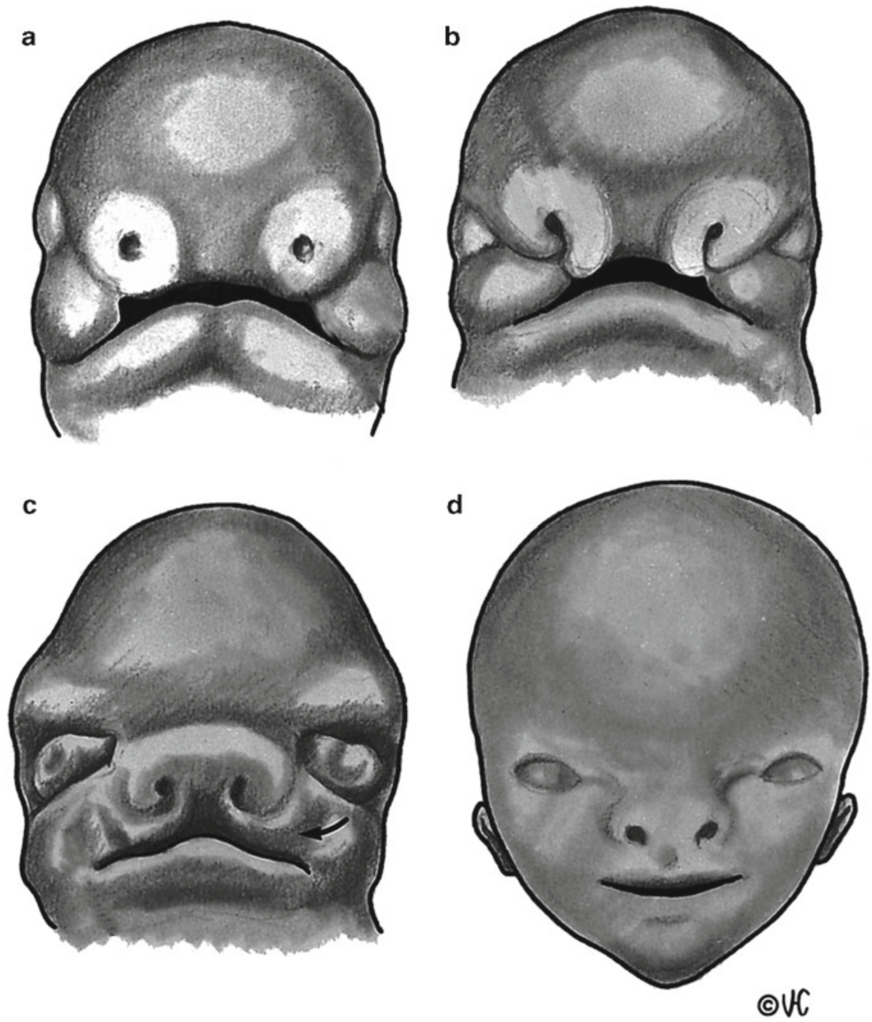

Fig. 1.3 Facial development. (**a**) Frontonasal and mandibular processes separated by maxillary processes and mouth. (**b**) Lacrimal groove develops between lateral nasal and maxillary processes. (**c**) Medial expansion of maxillary processes forming lateral wall and floor of orbit. Medial wall is formed by lateral nasal process and roof by frontal process. (**d**) Medial nasal processes fuse, forming upper lip and hard palate

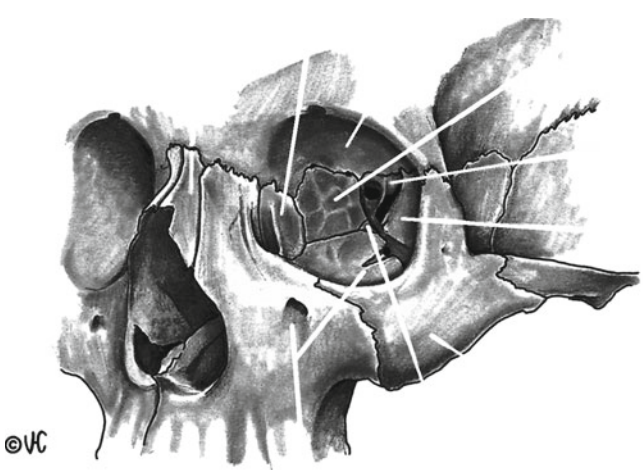

Fig. 1.4 Bones of orbit

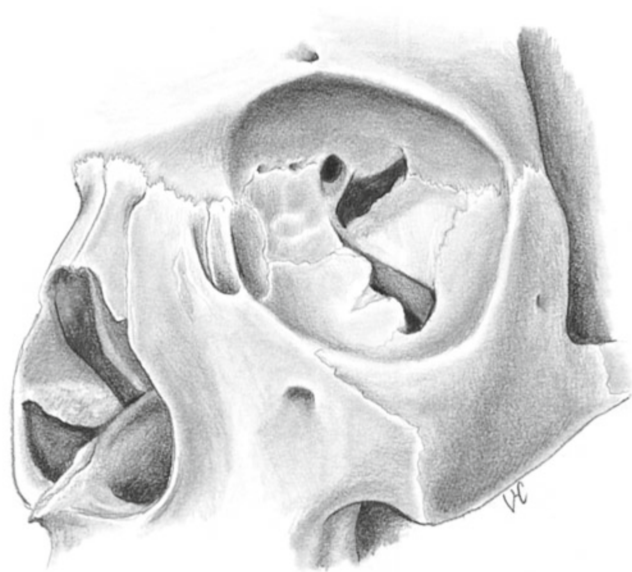

Fig. 1.5 Osteology of orbital apex

The lateral orbital wall is bounded by the superior and inferior orbital fissures. These borders are carried anteriorly roughly by the frontosphenoidal and the zygomaticomaxillary sutures. Posteriorly, the greater wing of the sphenoid forms the lateral wall. Anteriorly, the zygoma and the lateral angular (zygomatic) process of the frontal bone each contribute to the lateral orbital wall. The vertical zygomaticosphenoid suture marks the thinnest part of the lateral orbital wall and forms a convenient breaking point for bone removal during orbitotomy. Posterior and lateral to the lateral rim lies the firmly adherent temporalis muscle. The muscle has a dense superficial fascia easily harvested through a skin and superficial muscle plane incision.

Just within the lateral orbital margin about 11 mm below the frontozygomatic suture the lateral orbital tubercle of Whitnall is found [7]. At this important site, the lateral canthal ligament, lateral rectos check ligament, lateral horn of the levator, suspensory ligament of the eye (Lockwood's ligament), and orbital septum all attach. The zygomaticotemporal and zygomaticofacial foramina perforate the anterior lateral orbital wall and transmit neurovascular bundles.

The shortest of the orbital walls is the floor. It is shaped like an equilateral triangle. A line passing through the axis of the inferior orbital fissure forms the lateral border. The medial border can be defined with anterior and posterior extensions of the maxilloethmoidal suture. The orbital floor does not continue to the orbital apex. It ends approximately 35–40 mm posterior to the rim at the pterygopalatine fossa. This fact must be kept in mind during surgery on the orbital floor because more posterior dissection could lead to extensive hemorrhage from the internal maxillary artery located in the pterygopalatine fossa.

The orbital plate of the maxillary bone comprises nearly the entire floor, with small contributions from the palatine bone posteriorly and from the zygoma anterolaterally. The floor remains strong lateral to the infraorbital nerve but becomes thin medially with maxillary sinus expansion. This thin, unsupported dome of the maxillary sinus is where the floor usually fractures with trauma. In static loading studies, the orbital floor shows the greatest degree of deformation [8]. This location is also a convenient site for entry into the maxillary sinus during orbital decompression surgery.

The infraorbital groove is found posteriorly and centrally in the orbital floor. It carries the maxillary division of the trigeminal nerve. This groove or sulcus is converted into a canal, which ends anteriorly as the infraorbital foramen. In the embryo, the infraorbital nerve lies freely along the orbital floor, but by birth, it has been encompassed by the more rapidly growing maxillary bone. In the child, the infraorbital foramen is situated immediately below the orbital margin. In the adult, the infraorbital nerve exits approximately 6 mm inferior to the orbital rim.

The medial wall is the smallest and the thinnest of the orbital walls. It extends roughly 4.5–5 cm posterior to the anterior lacrimal crest. The ethmoid bone makes the major contribution, with extensions of its frontoethmoidal and maxilloethmoidal sutures defining the superior and inferior medial borders. The lacrimal, maxillary, and sphenoid bones also contribute to the medial wall. The medial wall becomes thicker posteriorly at the body of the sphenoid and anteriorly at both the posterior lacrimal crest of the lacrimal bone and at the anterior lacrimal crest of the maxillary bone. The many bullae of the ethmoid pneumatization can be seen as a honeycomb pattern beneath the lamina papyracea. This supportive structure in part explains why the medial wall fractures less often than the thicker orbital floor.

Congenital dehiscences sometimes are seen at the ethmoidal suture lines, whereas age atrophy is seen centrally in the ethmoid plate. Important to the orbital surgeon are the anterior and posterior ethmoidal foramina conveying branches of the ophthalmic artery and the nasociliary nerve. They are located at the frontoethmoidal suture approximately 24 and 36 mm posterior to the anterior lacrimal crest, respectively. Additionally, the frontoethmoidal suture serves as an important guide during orbital surgery approximating the level of the floor of the anterior cranial fossa.

The position of the cribriform plate relative to the medial orbital wall is variable. At the posterior lacrimal crest, the vertical distance from medial canthal ligament to the anterior cranial fossa ranges between 0 and 19 mm (mean = 6.5 mm). This distance may be 3 mm or less in 20% of individuals [9]. This variability in anatomy should be considered during dacryocystorhinostomy.

Orbital Apex

Because of its many important neural and vascular structures, the orbital apex is especially worthy of study. The orbital apex is an extremely busy area because of the narrowing of the walls associated with the exit of venous blood, the entrance of arterial blood and a large number of nerves, and the origin of six extraocular muscles.

The superior orbital fissure [10] is a transverse notch 22 mm in length between the greater and lesser wings of the sphenoid bone, which descends medially (see Fig. 1.5). There is much individual variation in the shape of the superior orbital fissure, but usually the fissure is more narrow superotemporally. This fissure transmits most of the critical neurovascular structures entering the orbit. Important exceptions are the optic nerve and ophthalmic artery, which traverse the optic canal as well as the maxillary division of the trigeminal nerve, and the inferior ophthalmic vein, which course through the inferior orbital fissure.

The lacrimal, frontal, and trochlear nerves and the superior ophthalmic vein pass through the superolateral portion of the fissure outside the annulus of Zinn. The middle meningeal artery anastomosis with the ophthalmic artery may enter here, if not through its own foramen more anteriorly in the roof. The annulus of Zinn is a fibrous ring formed by the common origin of the rectus muscles. This ring encircles the central portion of the superior orbital fissure, the oculomotor foramen, giving access to the intraconal space. Structures passing through this portion of the superior orbital fissure include the superior and inferior divisions of the third cranial nerve, the sixth cranial nerve, the nasociliary branch of the ophthalmic trigeminal nerve, and sympathetic nerve fibers. Additionally, the optic nerve and the ophthalmic artery pass through the annulus of Zinn from the optic canal.

Radiologic enlargement of the superior orbital fissure may accompany aneurysm, meningioma, chordoma, pituitary adenoma, or tumors of the orbital apex. Pathologic entities involving this region may result in superior orbital fissure syndrome manifested by total or partial ophthalmoplegia, V, anesthesia, and venous congestion.

Medial to the superior orbital fissure lies the optic foramen, which conveys the optic nerve, the ophthalmic artery, and sympathetic nerve fibers. This canal is formed by the lesser wing of the sphenoid superolaterally, the optic strut inferolaterally, and the body of the sphenoid medially. The inferior root of the lesser wing of the sphenoid, the optic strut, joins the body of the sphenoid to its lesser wing and separates the optic foramen from the superior orbital fissure (see Figs. 1.5 and 1.15). In approximately 50% of cases, the posterior ethmoid air cells are in contact with the medial aspect of the optic canal [11]. The axis of the foramen is directed downward and outward toward the lateral inferior orbital rim. Deviation away from the sagittal plane is about 35°, and descent below the horizontal plane is about 38° [12]. The optic canals measure approximately 8–10 mm in length and course posteromedially and superiorly, ending just medial and anterior to the anterior clinoid processes. This relationship is useful in differentiating the optic canals from the superior orbital fissures on neuroimaging studies. Microcryoplaning with computerized reconstruction has been performed to illustrate the anatomic relationships [13] at the orbital apex.

The optic canal normally measures 5–6 mm in diameter. Because of a shift in the position of the ophthalmic artery relative to the optic nerve, the canal is horizontally oval posteriorly and more vertically oval anteriorly. The optic canal attains adult dimensions by age 3 years and usually exhibits symmetry within the individual. A diameter greater than 6.5 mm or a difference of more than 1 mm between sides is generally considered abnormal. Deformation of the optic canal has been demonstrated in dried skulls by direct forehead pressure [14]. The thin optic strut forming the lateral and inferior borders of the optic canal is subject to deformation in optic nerve gliomas and infraclinoid aneurysms [15].

At the orbital apex and just inferior to the optic canal lies the inferior orbital fissure. This fissure is a bony defect 20 mm in length separating the orbital floor and the lateral wall in the posterior half of the orbit (see Fig. 1.5). Laterally, the fissure is bounded by the greater wing of the sphenoid and medially by the palatine and maxillary bones. The axis of the fissure is an anterior projection of the optic foramen. The inferior fissure extends more anteriorly than the superior fissure, ending about 20 mm from the orbital rim. This structure serves as the posterolateral limit of subperiosteal dissection along the orbital floor. Immediately beneath the fissure lies the pterygopalatine fossa, with the infratemporal fossa positioned more laterally. Blunt trauma to the temporalis muscle can thus result in orbital hemorrhage via the inferior orbital fissure.

The inferior orbital fissure allows passage of the inferior ophthalmic veins to the pterygoid venous plexus. The maxillary division (V2) of the trigeminal nerve leaves the foramen rotundum to enter the orbit at the extreme superoposterior aspect of the fissure. Arriving with the maxillary nerve is a terminal branch of the internal maxillary artery, which becomes the infraorbital artery. The fissure also transmits the zygomatic nerve and accompanying postganglionic parasympathetic branches from the pterygopalatine ganglion. These parasympathetic fibers pass from the zygomaticotemporal nerve to the lacrimal nerve en route to the lacrimal gland. The inferior orbital fissure is covered by the vestigial smooth orbital muscle of Muller.

The cavernous sinus, located immediately posterior to the orbital apex, is discussed later.

Nasal and Paranasal Sinuses

The orbital roof, floor, and medial wall are intimately related to the nasal cavity. These bones are pneumatized by paranasal sinuses arising from and maintaining communication with the nasal cavity. Because of this intimate relationship, the orbital surgeon must have a solid understanding of paranasal sinus anatomy. Pathologic processes of these sinuses often create orbital effects. In addition, the lacrimal excretory system must be studied in light of these same surrounding structures.

Regional anatomy often can best be understood in terms of function. The nose, for example, filters, warms, and moistens air and collects secretions from the sinuses and nasolacrimal duct. The paranasal sinuses, however, do not enjoy a function that has been universally accepted as reason for their development. Leading theories are as follows: (1) impart resonance to the voice, (2) humidify and warm inspired air, (3) increase the area of the olfactory membrane, (4) absorb shock applied to the head for protection of sensory organs, (5) secrete mucus for keeping the nasal chambers moist, (6) thermally insulate the nervous centers, (7) aid facial growth, (8) exist as evolutionary remnants or unwanted air