Marita Eisenmann-Klein
Constance Neuhann-Lorenz
Editors

Innovations in Plastic and Aesthetic Surgery

Springer

M. Eisenmann-Klein · C. Neuhann-Lorenz (Eds.)
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With 551 Figures in 1192 Parts

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Marita Eisenmann-Klein, M.D.
General Secretary of the International Confederation for Plastic, Reconstructive and Aesthetic Surgery
Direktorin der Klinik für Plastische und Ästhetische Hand- und Wiederherstellungschirurgie am Caritas-Krankenhaus St. Josef in Regensburg
Landshuter Straße 65
93053 Regensburg
Germany

Constance Neuhann-Lorenz, M.D.
Fachärztin für Chirurgie
Fachärztin für Plastische und Ästhetische Chirurgie
President IQUAM (International Committee for Quality Assurance and Medical Devices in Plastic Surgery)
Theatinerstraße 1
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Germany

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Preface

Plastic Surgery is the most coveted field among medical students all over the world.

Cynics might conclude that this is due to the attraction of aesthetic surgery, but they are wrong.

Students realize very early, that plastic surgery has much more to offer: we treat babies and old patients, from head to toe, with a variety of sophisticated techniques, with the challenge of microsurgery topping the list. Creativity is an integral part of our daily work.

We use these techniques to make individuals regain their physical integrity, we are the quality-of-life speciality.

On our way to competence in this field we need great examples, we need heroes. And we are lucky to have so many of them.

No other field in medicine is as much internationally oriented as plastic surgery: in IPRAS 96 national plastic surgery societies are represented. One of the main objectives of IPRAS is to increase the number of training sites and subsequently the number of fully and well trained plastic surgeons worldwide.

With pride I can say, that plastic surgery is also the field with the highest number of physicians involved in humanitarian missions. These missions not only provide free treatment for patients in need, they also serve the purpose of promoting the training of young plastic surgeons in developing countries.

Most of the contributors of this book have been and still are involved in these missions. They are dedicated to teaching.

Rather than inviting them to contribute a chapter to a textbook, we asked them to share their greatest contribution to the future of plastic surgery with us. We were thrilled when we first saw their articles.

Share our enthusiasm and be up front with techniques which are likely to represent tomorrow's state-of-the-art in plastic surgery.

Marita Eisenmann-Klein

Preface

"It is now Monday and we are in the second week of creation" *Peter Sloterdijk* just recently stated in his prize award speech for innovative publication management. Nanotechnology, biotechnology and gene technology are revolutionizing our scientific world as much as our every day life – comparable only to the changes at the turning towards the industrial age at the end of the 19th century.

Plastic Surgery, one of the youngest mono-specialties in medicine, historically has been innovative to a drastic extent by introducing and adding the treatment of external appearance of mankind into medical sciences of healing patients of exclusively functional diseases. As the quality of results is more obvious in plastic surgery than in other medical fields the search for constant perfection together with lesser traumatic techniques is inherent in our daily work.

This book intends to allow an up to date overview of the latest consented techniques in Plastic and Aesthetic surgery. The inspiring spark was the 14th quadrennial International Congress of the International Confederation for Plastic, Reconstructive and Aesthetic Surgery (IPRAS) 2007 Berlin, Germany. Plastic Surgeons from all over the world exchanged their expert knowledge, innovative ideas and experience.

From all representative sections of our fascinating specialty we are grateful to have been able to include altogether 58 contributions from autografting and allografts like face transplantation to xenografts, from microsurgical techniques to laser technology, from stem cell research to bodylifting refinements. The different chapters are not separated by indication such as reconstructive or aesthetic as every single technique or therapy in Plastic Surgery by definition will never be reconstructive without respect to the aesthetic outcome and vice versa. Chapter organisation has been introduced according to different techniques or anatomical units.

Science and progress cannot exist without innovative ideas and their creators, but all innovations are based on the experience and established knowledge of our predecessors. Many promising new findings will not survive forever or be rejected after a while or even innovated by the original authors or others. Many old techniques on the other hand have never been neglected: the ever-cited Indian Flap e.g. The coexistence of both: old and new – is the secret of good science.

Johann Wolfgang v. Goethe:
„Wir ehren froh mit immer gleichem Mute
Das Altertum und jedes neue Gute."
„With the same cheerful courage we value
every good thing, both old and new"
(translated from the German)

Constance Neuhann-Lorenz

Contents

List of Contributors

Tawfeik Al-Yafi, MD
Rua Solimóes, 1175, Merces, Curitiba, Paraná, PR 80810-070, Brazil

Luiz Roberto Araujo, MD, MSc
Rua Solimóes, 1175, Merces, Curitiba, Paraná, PR 80810-070, Brazil

Andreas Arkudas, MD
Department of Plastic and Hand Surgery, University of Erlangen Medical Center, Krankenhausstrasse 12 91054 Erlangen, Germany

Alessio Baccarani, MD
Division of Plastic Reconstructive Surgery, University of Modena, Policlinico via Largo del Pozzo, Modena 71, Italy

Ricardo Baroudi, MD
Rua Itabaquara, 48, 01234.020, São Paulo, Brazil

Alfred Karl Berger, MD, PhD
Emeritus Professor of Plastic Surgery, Holbeinstr. 1 30916 Isernhagen, Germany

Patricia E. Bergey, PAC
Suite 500, 975 Johnson Ferry Rd., Atlanta, GA 30342 USA

Pietro Berrino, MD
Viale Brigata Bisagno 6, 16129 Genoa, Italy

Thomas Biggs, MD
1315 St. Joseph Pkwy., Suite 900, Houston, TX 77002 USA

Vanni Borghi, MD
HIV Metabolic Clinic, Department of Infectious and Tropical Diseases, University of Modena and Reggio Emilia, Modena, Italy

Chiara Botti, MD
Villa Bella Clinic, Viale Europa 55, 25087 Salo' (BS) Italy

Giovanni Botti MD
Villa Bella Clinic, Viale Europa 55, 25087 Salo' (BS) Italy

Håkan Brorson, MD, PhD
Lymphedema Unit, Department of Plastic and Reconstructive Surgery, Malmö University Hospital Lund University, 205 02 Malmö, Sweden

Yan-Xian Cai, MD
Department of Plastic Surgery, Shanghai First People's Hospital, Shanghai Jiao Tong University
No. 85, Wu Jin Road, Shanghai 200080, China

Antonio Cella, MD
Villa Bella Clinic, Viale Europa 55, 25087 Salo' (BS) Italy

David S. Chang, MD
Division of Plastic and Reconstructive Surgery University of California, 505 Parnassus Avenue, M593 San Francisco, CA 94143, USA

Yoon S. Chun, MD
Division of Plastic and Reconstructive Surgery Department of Surgery, Brigham and Women's Hospital/Faulkner Hospital, 1153 Centre Street Boston, MA 02130, USA

Silvia Cicchetti, MD
Plastic and Reconstructive Surgery Unit, Department of Morphological and Surgical Disciplines and Integrated Methodologies (DICMI), University of Genoa, Genoa, Italy

Bruce F. Connell, MD, FACS
College of Medicine, University of California, Irvine 2200 E. Fruit St., #101, Santa Ana, CA 92701, USA

Luis Contin, MD
Av. Ana Costa, No. 120, Vila Mathias, Santos, São Paulo, Brazil

Michel Costagliola, MD
Chirurgie Plastique, Polyclinique du Parc, 33 rue des Bûchers, 31400 Toulouse, France

Eva Csorba, Dr.
Burn and Plastic Surgical Department, St. Stephen Hospital, Budapest, XIII, Nagyvarad ter 1
1096 Hungary

Bruce Cunningham, MD
Division of Plastic and Reconstructive Surgery
Department of Surgery, University of Minnesota, 420 Delaware Street SE, Minneapolis, MN 55455, USA

Rosana Costa Damasio, MD
Rua Solimões, 1175, Merces, Curitiba, Paraná, PR 80810-070, Brazil

Fabio Rosa de Almeida, MD
Rua Joaquim Floriano, 460 – Conj. 107, 04534.002 São Paulo, Brazil

Domenico de Fazio, MD
San Raffaele Hospital, Milan, Italy; Casa di cura S. Pio X, Milan, Italy

Luis de la Cruz, MD
Clínica La Luz, Consulta 208, General Rodrigo 8 28003 Madrid, Spain

Rafael de la Plaza, MD
C. Salou, 28, 28034 Madrid, Spain

Jorge I. de la Torre, MD
University of Alabama at Birmingham
Division of Plastic Surgery, 510 20th Street South FOT – 1164, Birmingham, AL 35294-3411, USA

Ilario de Lorenzi
San Raffaele Hospital, Milan, Italy; Casa di cura S. Pio X, Milan, Italy

Sergio Ricardo Pita Pessoa de Melo, MD
"Dr. Ewaldo Bolivar de Souza Pinto" Plastic Surgery Service, Av. Ana Costa, No. 120, Vila Mathias, Santos São Paulo, Brazil

Giorgio De Santis, MD
Division of Plastic Reconstructive Surgery, University of Modena, Policlinico via Largo del Pozzo, Modena 71 Italy

Rodrigo Pessoa Martello de Souza, MD
Av. Ana Costa, No. 120, Vila Mathias, Santos São Paulo, Brazil

Ewaldo Bolivar de Souza Pinto, MD
Av. Ana Costa, No. 120, Vila Mathias, Santos São Paulo, Brazil

Giovanni Di Benedetto, MD
Department of Plastic and Reconstructive Surgery Ancona University School of Medicine, Via Conca, 71 60020 Ancona, Italy

Alberto Di Giuseppe, MD
Department of Plastic and Reconstructive Surgery Ancona University School of Medicine, Via Conca, 71 60020 Ancona, Italy

Doina Dumitrescu-Ionescu, Prof. Dr.
Plastic and Reconstructive Microsurgery Clinic University Hospital, Str. Erou Iancu Nicolae 11–19 ALFA, Sat Pipera, Ilfov, Romania

Marketa Duskova, MD
Department of Plastic Surgery, Medical School Charles University, Srobarova 50, 100 34 Prague 10 Czech Republic

Marita Eisenmann-Klein, MD
Klinik für Plastische-, Hand- und Wiederherstellungs-Chirurgie, Caritas-Krankenhaus, St. Josef, Landshuter Strasse 65, 93053 Regensburg, Germany

L. Franklyn Elliott, MD
Suite 500, 975 Johnson Ferry Rd., Atlanta, GA 30342 USA

Roberto Esposito, MD
HIV Metabolic Clinic, Department of Infectious and Tropical Diseases, University of Modena and Reggio Emilia, Modena, Italy

Rodrigo Federico, MD
"Dr. Ewaldo Bolivar de Souza Pinto" Plastic Surgery Service, Av. Ana Costa, No. 120, Vila Mathias, Santos São Paulo, Brazil

Marcus Castro Ferreira, MD, PhD
Division of Plastic Surgery, University of São Paulo School of Medicine, Rua Oscar Freire 1702, ap 78 05409-011 São Paulo, Brazil

Lucian Fodor, MD
Department of Plastic and Reconstructive Surgery Rambam Medical Center, 8 Ha'Aliya St., Haifa 35254 Israel

Tal Friedman, MD
Department of Plastic Surgery, Assaf Harofe Medical Center, Zerifin 70300, Israel

Manuel García-Velasco, MD, FRCS (C)
Vialidad de la Barranca, SN, Hospital Angeles Lomas Suite 550, Huixquilucan, Mexico City, Mexico 52763

Francesco Gargano, MD, PhD
Division of Plastic Reconstructive Surgery, University of Modena, Policlinico via Largo del Pozzo, Modena 71, Italy

Rolf Gemperli, MD, PhD
Division of Plastic Surgery, University of São Paulo School of Medicine, Rua Oscar Freire 1702, ap 78 05409-011 São Paulo, Brazil

Alain Gilbert, Prof.
Institut de la Main, 6 Square Jouvenet, 75016 Paris France

Robert M. Goldwyn, MD
Department of Surgery, Harvard Medical School, Beth Israel Deaconess Medical Center, 54 Willow Crescent Brookline, MA 02445, USA

Margarita Gonzalez Rodriguez de Azero, MD
Wound Healing Unit, Department of Plastic Surgery Cliniques Universitaires St. Luc, 1200 Brussels, Belgium

Ruth Graf, MD, PhD
Rua Solimões, 1175, Merces, Curitiba, Paraná, PR 80810-070, Brazil

Andreas Gröger, MD
Klinik für Plastische Chirurgie, Hand- und Verbrennungschirurgie, Pauwelsstr. 30, 52074 Aachen Germany

Alessandro Gualdi, MD
Villa Bella Clinic, Viale Europa 55, 25087 Salo' (BS) Italy

Giovanni Guaraldi, MD
HIV Metabolic Clinic, Department of Infectious and Tropical Diseases, University of Modena and Reggio Emilia, Via Del Pozzo n. 71, 41100 Modena, Italy

Eyal Gur, MD
Tel Aviv Souraski Medical Center, Weizmann 6 Tel Aviv 64239, Israel

Franz Maria Haas, MD
Klinische Abteilung für Plastische Chirurgie Universitätsklinik für Chirurgie, Medizinische Universität Graz, Auenbruggerplatz 29, 8010 Graz Austria

Mutaz B. Habal, MD, FRCSC, FACS
The Tampa Bay Craniofacial Center/USF Tampa 801 West M.L. King Blvd., FL 33603, USA

Elizabeth J. Hall-Findlay, MD, FRCSC
340--317 Banff Avenue, Box 2009, Banff, Alberta Canada, T1L 1B7

Ed H.M. Hartman, MD, PhD
926 Department of Plastic Surgery, Radboud University Medical Centre, Reinier Postlaan 4, PB 9101, 6500 HB Nijmegen, The Netherlands

Robert Hierner, MD, PhD
Plastic, Hand and Reconstructive Surgery, Burn Centre, Medical University of Hanover; University Hospital, Plastic, Reconstructive and Aesthetic Surgery, Center for Microsurgery, Hand Surgery and Burns, Catholic University of Leuven, University Hospital Gasthuisberg, Belgium

Ming-Zhong Hou, MD
Department of Plastic Surgery, Shanghai First People's Hospital, Shanghai Jiao Tong University
No. 85, Wu Jin Road, Shanghai 200080, China

Raymund E. Horch, MD, PhD
Department of Plastic and Hand Surgery, University of Erlangen Medical Center, Krankenhausstrasse 12 91054 Erlangen, Germany

Xie-Qing Huang, MD
Department of Plastic Surgery, Shanghai First People's Hospital, Shanghai Jiao Tong University
No. 85, Wu Jin Road, Shanghai 200080, China

Yi-Xiong Huang, MD
Department of Plastic Surgery, Shanghai First People's Hospital, Shanghai Jiao Tong University
No. 85, Wu Jin Road, Shanghai 200080, China

Mark Jewell, MD
630 East 13th Avenue, Eugene, OR 97401, USA

Wan-Xing Jia, MD
Department of Plastic Surgery, Shanghai First People's Hospital, Shanghai Jiao Tong University
No. 85, Wu Jin Road, Shanghai 200080, China

Jin Wang Kim, MD, PhD
Department of Plastic and Reconstructive Surgery Hand and Microsurgery, and Aesthetic Surgery Hallym University College of Medicine, Chun Cheon Si Kyo Dong 153, Kang Won Do, Korea; Shincheon Severance Hospital Department of Plastic and Reconstructive Surgery, Yonsei University College of Medicine, Seo Dae Moon Gu Shin Chon Dong 134 Seoul, Korea; Medical Laser Research Laboratory, Dan Kook University College of Medicine, Chung Chung Nam Do, Korea; Seoul National University College of Medicine, Seoul National University Hospital, Chong Ro Gu Yeon Kun Dong 28, Seoul, Korea

Ulrich Kneser, MD
Department of Plastic and Hand Surgery, University of Erlangen Medical Center, Krankenhausstrasse 12 91054 Erlangen, Germany

Yalcin Kulahci, MD
Department of Plastic Surgery, A60, Cleveland Clinic 9500 Euclid Avenue, Cleveland, OH 44195, USA

Hannu Kuokkanen, MD, PhD
Department of Plastic Surgery, Tampere University Hospital, Box 2000, 33521 Tampere, Finland

Donald H. Lalonde, MD
The Saint John Campus of Department of Plastic Surgery, Dalhousie University, Saint John Regional Hospital, P.O. Box 2100, Saint John, New Brunswick Canada

Joung Ok Lee, MD
Department of Dermatology, Hallym University College of Medicine, Seoul, Korea

Jörn Andreas Lohmeyer, Dr. med.
Abteilung für Plastische, Hand- und Wiederherstellungschirurgie, Intensiveinheit für Schwerbrandverletzte, Universitätsklinikum Schleswig-Holstein, Campus Lübeck, Ratzeburger Allee 160, 23538 Lübeck, Germany

Peter Mailänder, Prof. Dr. med.
Abteilung für Plastische, Hand- und Wiederherstellungschirurgie, Intensiveinheit für Schwerbrandverletzte, Universitätsklinikum Schleswig-Holstein, Campus Lübeck, Ratzeburger Allee 160, 23538 Lübeck, Germany

James W. May, Jr., MD
Division of Plastic and Reconstructive Surgery Department of Surgery, Massachusetts General Hospital, 55 Fruit Street, Boston, MA 02441, USA

Riccardo F. Mazzola, MD
Universitá degli Studi di Milano, via Marchiondi 7 20122 Milan, Italy

Marcel F. Meek, MD, PhD
Leeuwerikstraat 28, 9481 EP, Vries, The Netherlands

Bryan C. Mendelson, MD
109 Mathoura Road, Toorak, Victoria, Australia 3142

Henrik Menke, MD, PhD
Department of Plastic, Aesthetic and Hand Surgery Burn Center, Klinikum Offenbach, Starkenburgring 66, 63069 Offenbach, Germany

Paolo Mezzana, MD
Department of Plastic Reconstructive Surgery University of Rome „La Sapienza“, Viale del Policlinico, 155, 00100 Rome, Italy

Dr. Rony A. Moscona, MD
Department of Plastic and Reconstructive Surgery Rambam Medical Center, 8 Ha'Aliya St., Haifa 35254 Israel

A. Aldo Mottura, MD
Centro de Cirugía Estética, Friuli 2110, 5016 Córdoba Argentina

Alexandre Mendonça Munhoz, MD
Breast Reconstruction Group, University of São Paulo Rua da Consolação 3605 ap 91, 01416-001 Brazil

Egle Muti, MD
Department of Plastic Surgery, University of Turin Strada S. Vincenzo, 40/35, 10131 Turin, Italy

Lincoln Graça Neto, MD, PhD
Rua Solimões, 1175, Merces, Curitiba, Paraná, PR 80810-070, Brazil

Constance Neuhann-Lorenz, MD
Praxis für Plastische Chirurgie, Theatiner Str. 1 80333 Munich, Germany

Jean-Philippe A. Nicolai, MD, PhD
Department of Plastic Surgery, University Medical Center Groningen, University of Groningen Hanzeplein 1, 9700 RB Groningen, The Netherlands

Chiara Novelli, Dr.
Institut de la Main, 6 square Jouvenet, 75016 Paris France

Gabriella Orlando, MD
HIV Metabolic Clinic, Department of Infectious and Tropical Diseases, University of Modena and Reggio Emilia, Modena, Italy

Daniele Pace, MD, MSc
Rua Solimões, 1175, Merces, Curitiba, Paraná, PR 80810-070, Brazil

Norbert Pallua, MD, PhD
Klinik für Plastische Chirurgie, Hand- und Verbrennungschirurgie, Universitätsklinikum der RWTH Aachen, Pauwelsstr. 30, 52074 Aachen Germany

Gennady I. Patlazhan, MD
VIRTUS Clinic, Bunina str. 10, 65026 Odessa, Ukraine

Malcolm D. Paul, MD, FACS
Aesthetic and Plastic Surgery Institute, University of California, Irvine, USA

Antonio Pedone
HIV Metabolic Clinic, Department of Infectious and Tropical Diseases, University of Modena and Reggio Emilia, Modena, Italy

Massimo Pinelli, MD
Division of Plastic Reconstructive Surgery, University of Modena, Policlinico via Largo del Pozzo, Modena 71, Italy

Jan G. Poëll, MD
Plastisch-Rekonstruktive und Aesthetische Chirurgie FMH, Sonnenstr. 6, 9000 St. Gallen, Switzerland

Elias Polykandriotis, MD
Department of Plastic Surgery, Friedrich-Alexander University Erlangen, Krankenhausstrasse 12 91054 Erlangen, Germany

Kirill P. Pshenisnov, MD
Division of Plastic Surgery, Yaroslavl Medical Academy, 5 Revolutsionnaya St., Yaroslavl 150000 Russia

Piero Raimondi, MD, PhD
Policlinico MultiMedica, 20099 Milan, Italy

Ronald Rippel, MD, MSc
Rua Solimóes, 1175, Merces, Curitiba, Paraná, PR 80810-070, Brazil

Antonio Rottino
San Raffaele Hospital, Milan, Italy; Casa di cura S. Pio X, Milan, Italy

Maria Thereza Sarto Piccolo, MD, PhD
Scientific Department, Pronto Socorro para Queimaduras Ltda., Rua 5, 439, Setor Oeste, Goiânia Goiás, 74115 060, Brazil

Mônica Sarto Piccolo, MD
Pronto Socorro para Queimaduras Ltda., Rua 5 439 Setor Oeste, Goiânia, Goiás, 74115 060, Brazil

Nelson Sarto Piccolo, MD
Division of Plastic Surgery, Pronto Socorro para Queimaduras Ltda., Rua 5, 439, Setor Oeste, Goiânia Goiás, 74115 060, Brazil

Erwin Scharnagl, MD
Klinische Abteilung für Plastische Chirurgie Universitätsklinik für Chirurgie, Medizinische Universität Graz, Auenbruggerplatz 29, 8010 Graz Austria

Michael Scheflan, MD
Atidim Medical Center, 24 Habarzel St., Tel-Aviv 69710, Israel

Jörg Schipper, MD
Department of Oto-Rhino-Laryngology, University of Duesseldorf, Duesseldorf, Germany

Nicolò Scuderi, MD
Department of Plastic Reconstructive Surgery University of Rome „La Sapienza“, Viale del Policlinico, 155, 00100 Rome, Italy

Zun-Li Shen, MD, PhD
Department of Plastic Surgery, Shanghai First People's Hospital, Shanghai Jiao Tong University
No. 85, Wu Jin Road, Shanghai 200080, China

Ghaith F. Shubailat, MD, FRCS, FACS
28 Bin Khaldoun Street, PO Box 5180, Amman 11183 Jordan

Maria Siemionow, MD, PhD, DSc
Department of Plastic Surgery, A60, Cleveland Clinic 9500 Euclid Avenue, Cleveland, OH 44195, USA

Antonio Spaggiari
HIV Metabolic Clinic, Department of Infectious and Tropical Diseases, University of Modena and Reggio Emilia, Modena, Italy

Sinikka H.H. Suominen, MD, PhD
Department of Plastic Surgery, Helsinki University Central Hospital, Pl 266, 00029 Hyks, Finland

Bryant A. Toth, MD
Plastic and Reconstructive Surgery, 2100 Webster Street, Suite #424, San Francisco, CA 94115, USA

Carlos Oscar Uebel, MD
Vitor Hugo St. 78, 90630-070, Porto Alegre, Brazil

Philip A. Van Damme, DMD, MD, PhD
590 Department of Oral & Craniomaxillofacial Surgery, Radboud University Medical Centre, PB 9101, 6500 HB Nijmegen, The Netherlands

Romain Vanwijck MD, FRCS
Wound Healing Unit, Department of Plastic Surgery Cliniques Universitaires St Luc, 1200 Brussels Belgium

Luis O. Vasconez, MD, FACS
Division of Plastic Surgery and Aesthetic Surgery at the Kirklin Clinic, The University of Alabama at Birmingham, Birmingham, Alabama, USA

Lan Wang, MD
Department of Plastic Surgery, Shanghai First People's Hospital, Shanghai Jiao Tong University
No. 85, Wu Jin Road, Shanghai 200080, China

Maria Wiedner, Dr.
Klinische Abteilung für Plastische Chirurgie Universitätsklinik für Chirurgie, Medizinische Universität Graz, Auenbruggerplatz 29, 8010 Graz Austria

Introduction

Rediscovering the Wheel: Using the Past to Influence the Future

1

R.F. Mazzola

Very often scientific publications begin with the pompous words: "A new technique for...", or "An innovative method for...". But are these procedures really new? The French physician and philosopher Émile Littré (1801 – 1881) wrote the following in the foreword of his "*Oeuvres complètes d'Hippocrate*" ("Complete Works of Hippocrates"): "There is no development, even the most advanced of contemporary medicine, which is not found in embryo in the medicine of the past" [12]. This opinion is easy to demonstrate by doing some research in a historical library. One will discover that old books not only provide palpable contact with the medical past, but also serve to establish the precedence of an idea, a theory or a technique. Regrettably, we often realise that most of the so-called new techniques derive from ideas which were already published but then forgotten. Numerous examples exist, but we restrict our list to just a few for obvious reasons.

1.1 Nasal Surgery

Reconstructive nasal procedures using the forehead flap are countless, from the very simple to the most complicated. All aim to replace the missing parts in the best possible way.

In 1974, Ralph Millard described the so-called "flying seagull flap" outlined in the forehead and transposed to the lower half of the nose to repair a defect [14]. However, his flap reproduces almost completely the so-called "fleur de lys" design reported by the French surgeon Jacques Delpech (1777 – 1832) and published in 1828 (Fig. 1.1) [4]. The difference in shape is minimal; one has open wings, whereas the other resembles a partially opened bud, but the concept is the same; a well vascularised skin flap, drawn on the same donor site, the forehead, to repair the nose. What is surprising is the time it took to rediscover the wheel: almost 150 years!

A more recent sophisticated method for repairing a full thickness defect of the nose advocates the transposition of a prelaminated flap outlined on the forearm [17]. However, the German Carl Ferdinand von Gräfe (1787 – 1840), one of the founders of modern plastic surgery, developed a similar treatment plan in 1818, 193 years earlier [8]. The skin was prefabricated on the inner arm, shaped to match the missing part and sutured to the nasal stump according to the so-called Tagliacozzi procedure (or Italian technique) (Fig. 1.2). Von Gräfe's type of repair is a traditional, pedicled flap, separated at about day 15 after surgery, to allow good revascularisation, whereas the prelaminated fasciocutaneous flap proposed by Pribaz is lined on its undersurface and transferred microsurgically. These procedures were not available in the nineteenth century.

Modern aesthetic nasal surgery is often done using the open approach. Rhinoplasty surgeons consider this technique essential for a good visualisation and for achieving more predictable results. Evaluation and modifications of the tip are greatly improved, despite the transcolumellar scar, which is regarded as unimportant. But who introduced this method for the first time and when? We have to go back to 1934, when the Hungarian otolaryngologist Aurél Réthi (1884 – 1976) described it and demonstrated that it was possible to change the nasal tip in a very accurate way [18]. Regrettably, at the end of the operation Réthi removed a piece of columella, so as to make a long nose shorter (Fig. 1.3). The outcome was often poor and this explains why the operation fell rapidly from favour. It took almost 40 years until Goodman rediscovered and popularised the open rhinoplasty [7].

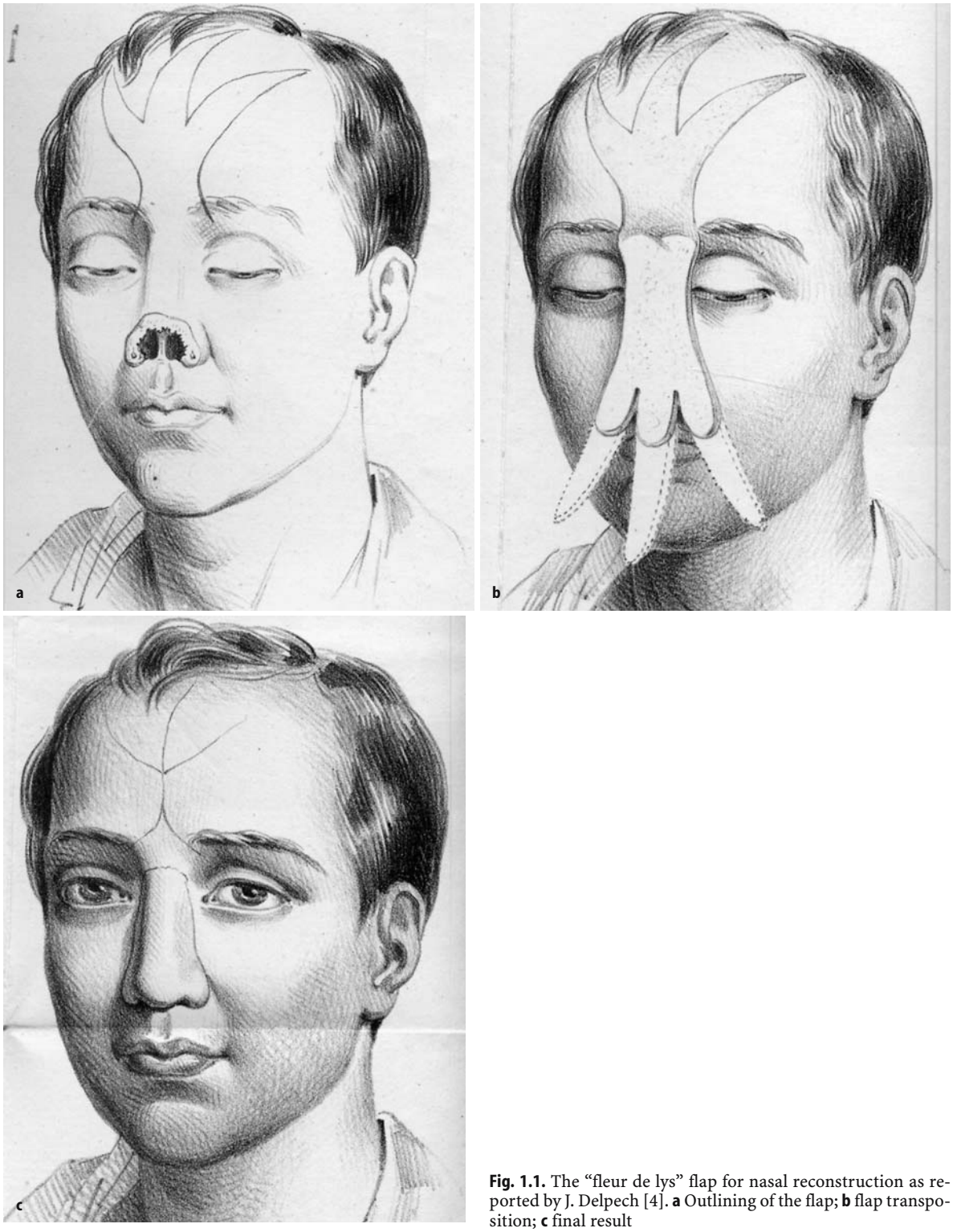


Fig. 1.1. The "fleur de lys" flap for nasal reconstruction as reported by J. Delpech [4]. **a** Outlining of the flap; **b** flap transposition; **c** final result

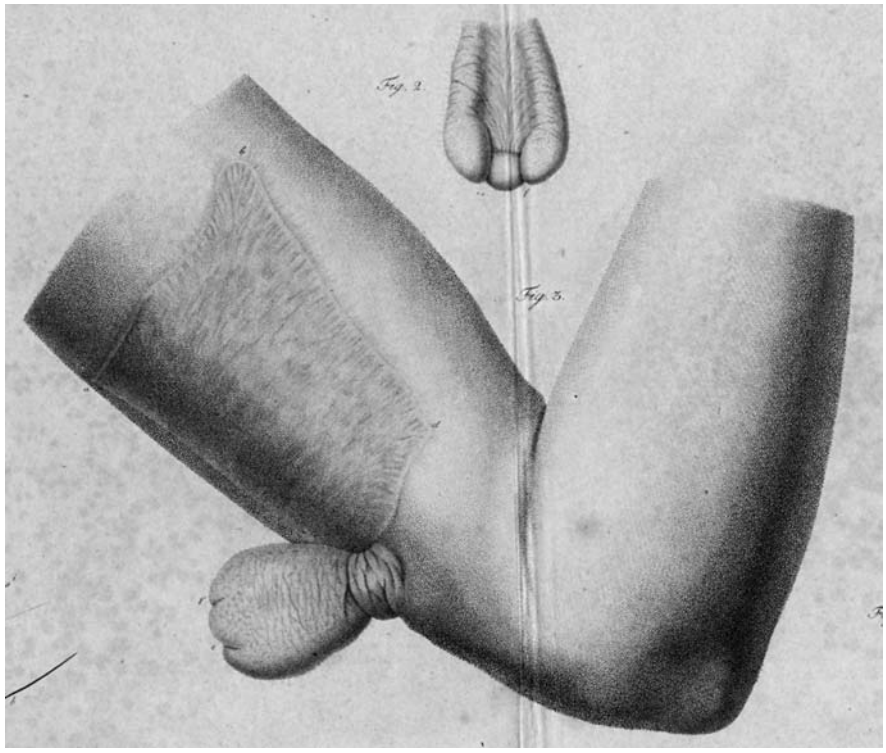


Fig. 1.2. The German method for nasal reconstruction by a prefabricated flap according to von Gräfe [6]. Outlining of the flap

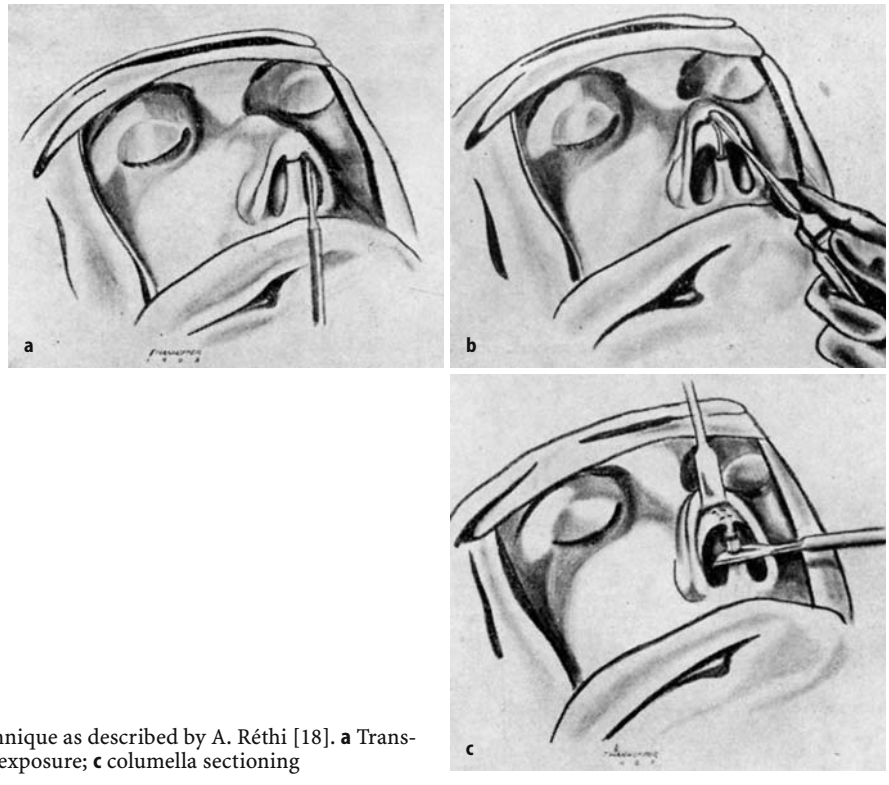


Fig. 1.3. The open approach technique as described by A. Réthi [18]. **a** Transcolumellar incision; **b** nasal tip exposure; **c** columella sectioning

1.2 Lower Eyelid

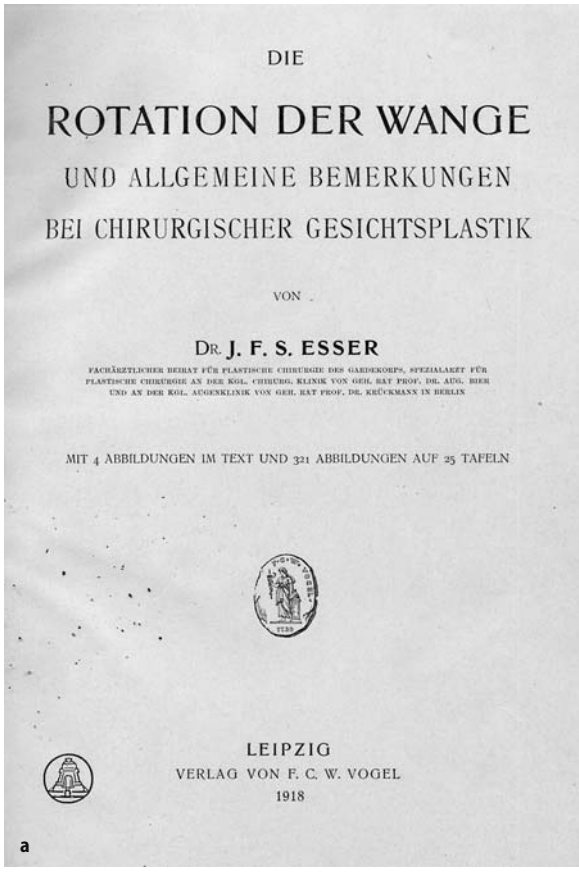
For full thickness lower eyelid repair, the rotation of the cheek constitutes one of the most common solutions. The well vascularised flap gives excellent aesthetic and functional results. It was eponymously called the Mustardé flap after the surgeon who described its use in 1966 [15]. However, the first report of the cheek rotation flap goes back to 1918, when the Dutchman J.F. Esser (1877 – 1946) published a whole book "*Die Rotation der Wange*" ("The Cheek Rotation"), devoted to this method and to its different applications for facial reconstruction [6]. Hence, this procedure should correctly be named the Esser flap (Fig. 1.4).

1.3 Lip

One of the basic principles of modern cheiloplasty is the use of lip tissue to repair a lip defect by transposing two full thickness flaps from the alar bases downward to the mentolabial groove [13]. The flaps, based at least 25 mm from the commissure, and with the same curvilinear incision, are sutured together along the midline, to re-establish the continuity of the oral sphincter. The technique, first described in 1857 by the German von Bruns (1812 – 1883) [2], was recently reintroduced by Karapandzic (1974) [11]. The only difference between the two procedures is the conservation of the neurovascular bundle that Karapandzic considers essential for the successful outcome of the operation. Thus von Bruns must be regarded as the pioneer of one of today's most frequently used procedures for lip repair, which he devised almost 130 years before Karapandzic (Fig. 1.5).

1.4 Breast

In 1932, for moderate breast hypertrophy, the Austrian surgeon Ernst Eitner advocated the periareolar suturing of the nipple without adding vertical or horizontal scars, an innovative solution in aesthetic breast surgery [5]. Reduction of the breast was achieved by mammary gland resection, according to breast size, with invagi-


DIE

ROTATION DER WANGE

UND ALLGEMEINE BEMERKUNGEN

BEI CHIRURGISCHER GESICHTSPLASTIK

VON

DR. J. F. S. ESSER

FACHÄRZTLICHER BEIRAT FÜR PLASTISCHE CHIRURGIE DES GARDEKORPS, SPEZIALARZT FÜR PLASTISCHE CHIRURGIE AN DER KGL. CHIRURG. KLINIK VON GEH. RAT PROF. DR. AUG. BIER UND AN DER KGL. AUGENKLINIK VON GEH. RAT PROF. DR. KRÜCKMANN IN BERLIN

MIT 4 ABBILDUNGEN IM TEXT UND 321 ABBILDUNGEN AUF 25 TAFELN

LEIPZIG

VERLAG VON F. C. W. VOGEL

1918

a

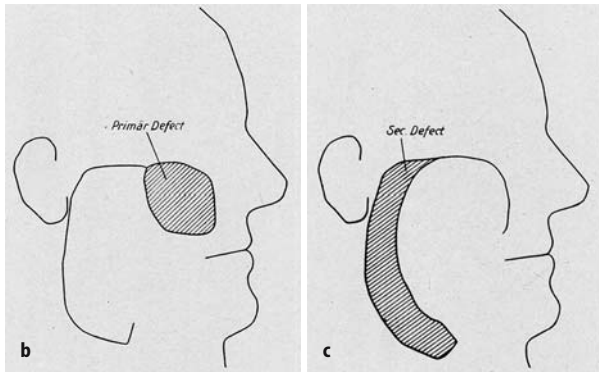


Fig. 1.4. The transposition of the cheek according to J.F.S. Esser [6]. **a** Title page of Esser's book; **b** defect of the lower eyelid; **c** closure of the defect by cheek rotation flap

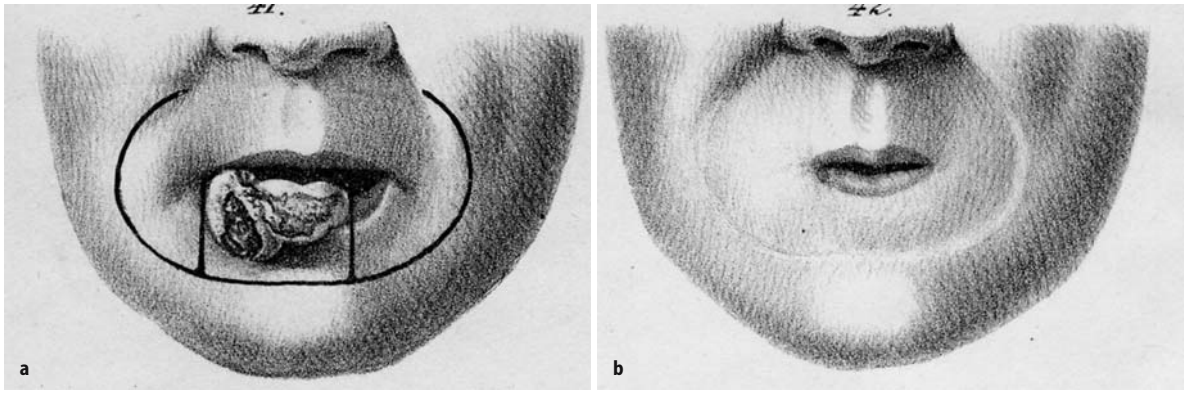


Fig. 1.5. Lower lip reconstruction following excision for cancer, according to von Bruns [2]. **a, b** Pre- and postoperative view of the patient

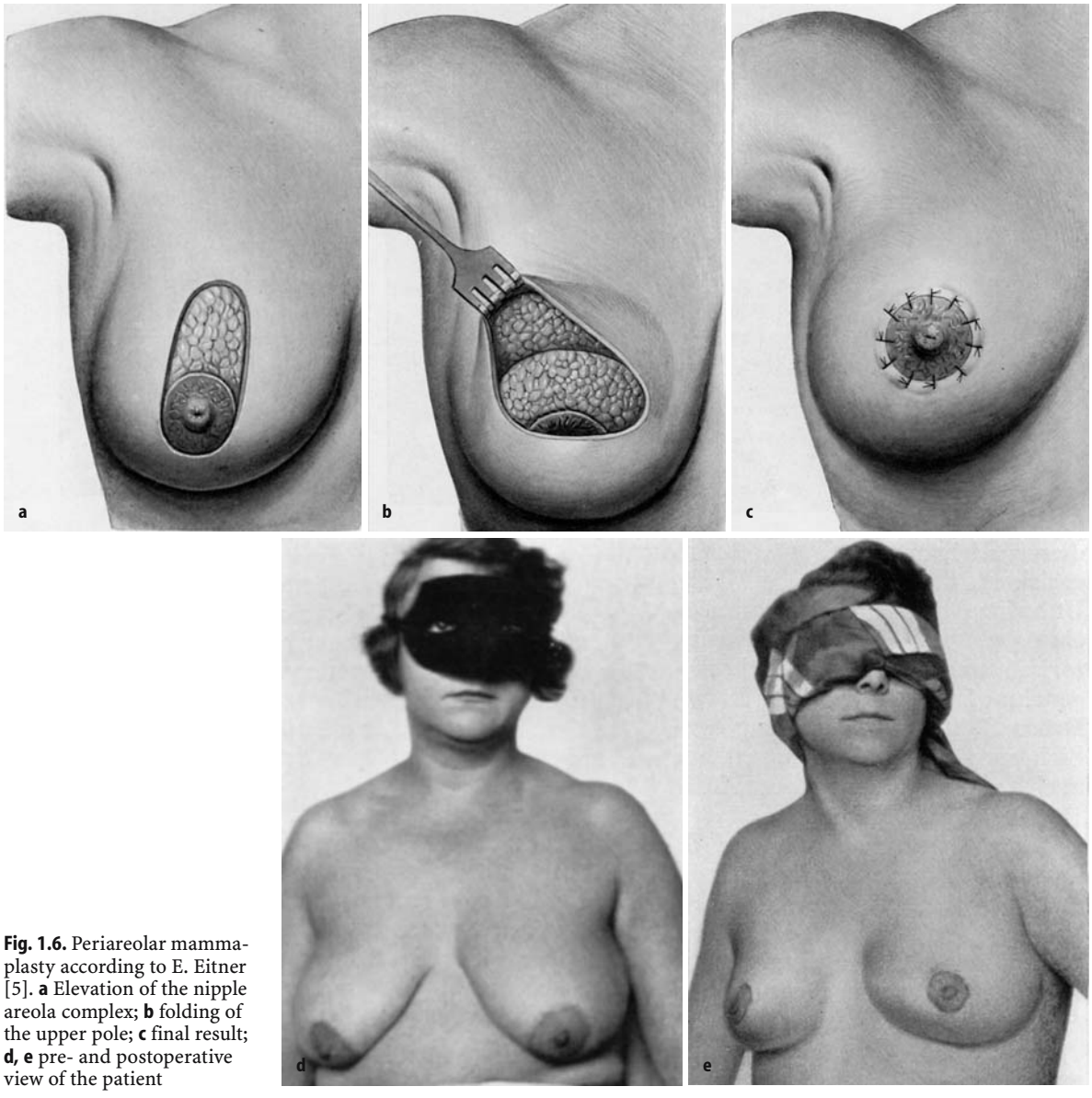


Fig. 1.6. Periareolar mammaplasty according to E. Eitner [5]. **a** Elevation of the nipple areola complex; **b** folding of the upper pole; **c** final result; **d, e** pre- and postoperative view of the patient

nation and folding of the upper pole, so as to allow elevation of the nipple-areola complex (Fig. 1.6). In 1990, almost 60 years after Eitner, the French surgeon Louis Benelli proposed a similar operation [1]. To avoid enlargement of the areola, he suggested a continuous cerclage stitch, passed as a purse string in the dermis, the so-called round block.

1.5 Anterior Chest Wall Defects

Worried by the unfavourable results obtained in covering anterior chest wall defects following excision for breast cancer, the Italian Iginio Tansini (1855–1943) reported the use of a large skin flap, with the underlying latissimus dorsi muscle, outlined on the back and transferred to fill the defect. In 1906, Tansini's anatomist, Professor Sala, demonstrated that the vascularisation of the skin was from the subscapular perforating arteries [20]. Its description constitutes the first example of a musculocutaneous flap to appear in the literature (Fig. 1.7). However, for various reasons its use was abandoned. It took 60 years for the German surgeon Neven Olivari to rediscover the wheel and to publish a paper in 1976 on the clinical application of the latissimus flap for different reconstructive purposes, mainly to cover defects of the irradiated anterior chest wall [16].

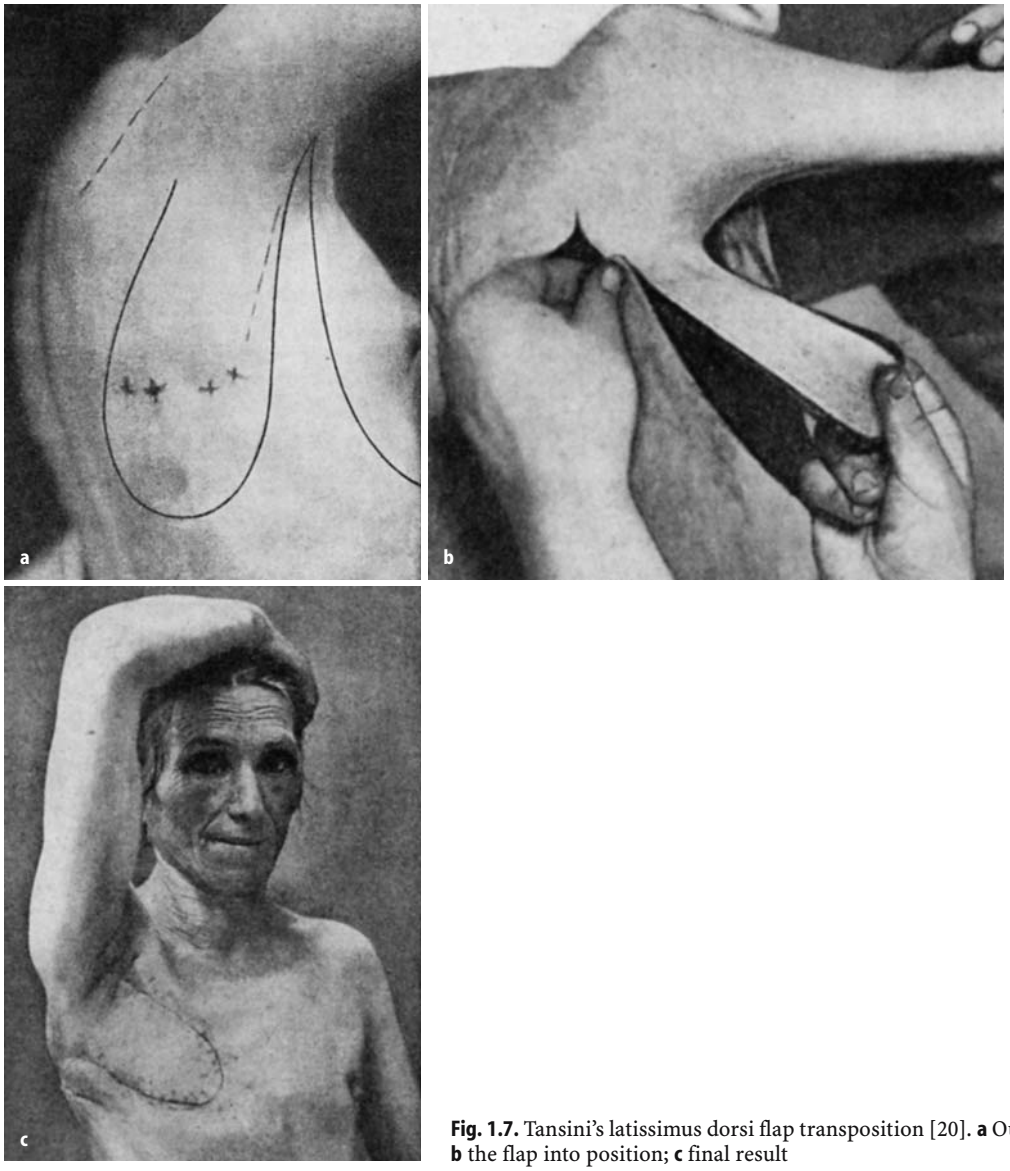


Fig. 1.7. Tansini's latissimus dorsi flap transposition [20]. **a** Outlining of the flap; **b** the flap into position; **c** final result

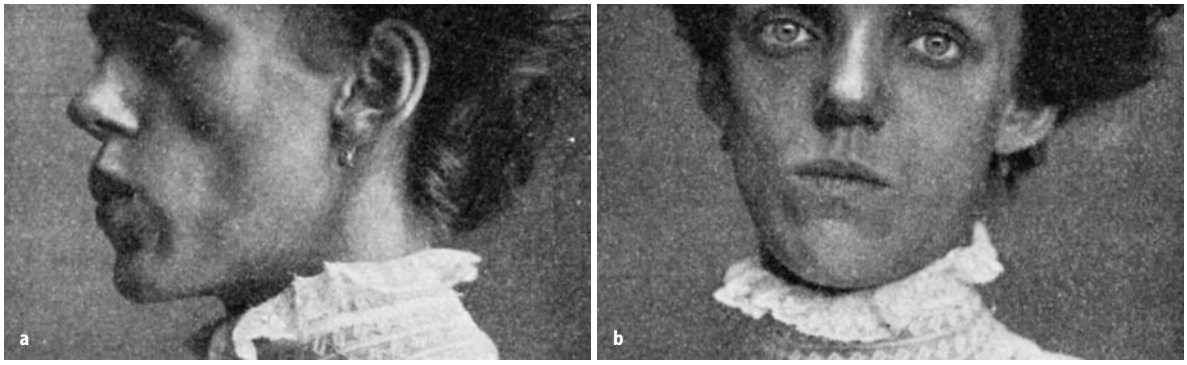


Fig. 1.8. Fat injection for management of facial atrophy by Holländer [10]. **a, b** Pre- and postoperative view of the patient

1.6 Fat Injection

One of the most recent advances in the correction of contour irregularities and for soft tissue augmentation in aesthetic and reconstructive surgery is the use of autologous fat injected locally. To avoid reabsorption and to ensure maximal cell survival, Coleman [3] systematised the procedure by means of fat centrifugation and placement of small amounts of cells in multiple tunnels so as to enhance contact between transplanted adipocytes and surrounding tissues. But who had the idea of injecting fat to correct contour irregularities? A search in the literature shows that in 1908, the Berlin surgeon Eugen Holländer (1867–1932) treated two cases of facial atrophy by injecting a blend of human and ram's fat locally. He considered this mixture the secret of success for avoiding reabsorption and for ensuring stability of the results. The pre- and postoperative photos appeared in a review paper published in 1912 in "*Handbuch der Kosmetik*" ("Handbook of Cosmetic Surgery") by Max Joseph (Fig. 1.8) [10].

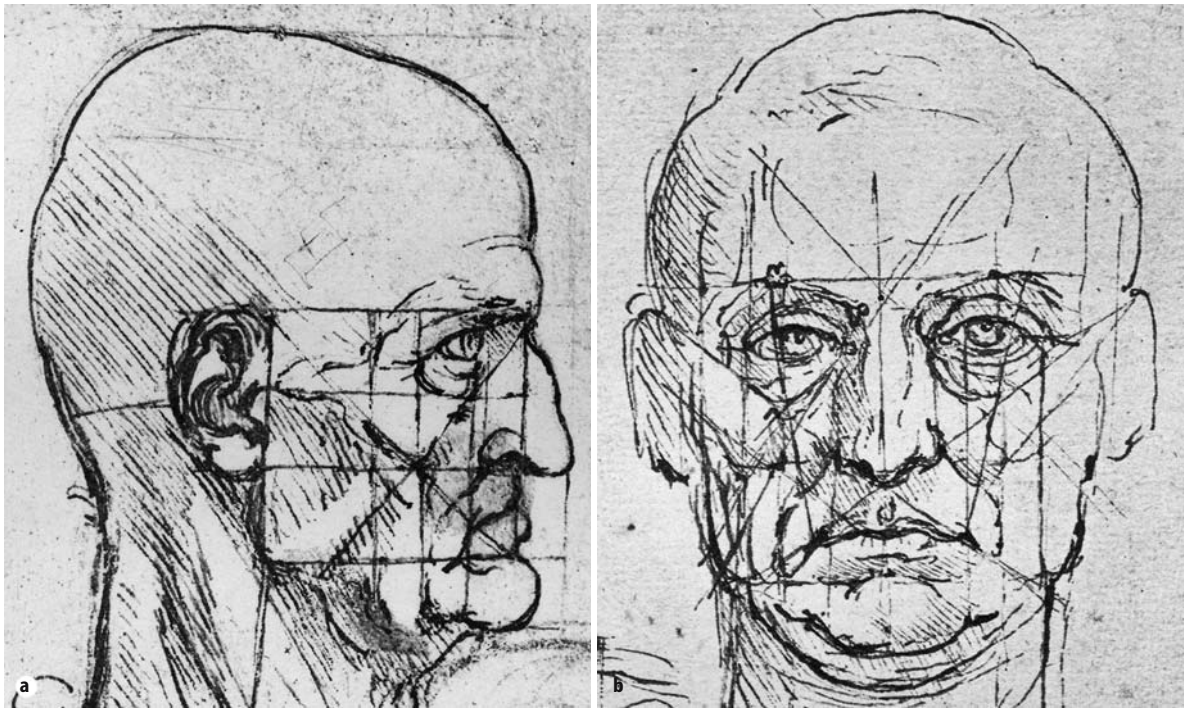


Fig. 1.9. Facial analysis according to Da Vinci (about 1495) [19]. **a** The division of the face into thirds; **b** the proportions of the face

1.7 Using the Past to Influence the Future

Surprisingly, in some instances the past may also serve to ameliorate the future. The canons of facial beauty, laid down by Leonardo Da Vinci (1452–1519), one of the most emblematic masters of the Renaissance, were used to create the ideal face in painting [21], and still represent an appropriate model for predicting results in procedures like rhinoplasty or orthognathic surgery (Fig. 1.9).

What is the purpose of facial analysis today? Its value is to analyse the proportions of the face thoroughly, to make an accurate diagnosis of the deformities and asymmetries, and to establish the surgical procedure best suited to achieve facial harmony. Da Vinci, in his Atlantic code (about 1495), stated that a well balanced face should be divided into thirds: "From the chin to the nostrils is a third part of the face. The same holds for the distance from the nostrils to the eyebrows and from the eyebrows to the hairline" [19]. The concept of the division of the face into thirds appears also in the chapter devoted to facial analysis of the recent book "Nasal Surgery by the Masters" [9] "The face is divided into thirds by horizontal lines tangential to the menton, nasal base, brows and hairline". In considering the alar base width, Da Vinci pointed out its relationship to the distance between the eyes: "Horizontally the width of the nose at its base should be approximately equal to the distance between the eyes" (Notebooks, 1495) [19]. Amazingly, a similar correlation appears in the above mentioned book: "The width of the alar base should be approximately the same as the intercanthal distance". Finally, regarding tip projection Da Vinci said: "In profile the distance from the very edge of the nostril, where it joins the cheek, to the tip of the nose will be equal to the width of the nose from one nostril to the other as seen from in front" [19], which almost corresponds to the phrase in the same book: "Another method to evaluate tip projection is to determine if tip projection equals alar base width".

1.8 Conclusions

What can we learn from old books? We can discover what our forefathers did and recognise their achievements with humility. Comparisons between old and new procedures often show that "Nothing is new under the sun".

Amazingly, knowledge of the work of past masters may influence the future positively by contributing to solutions of current problems. Facial analysis, devised in the Renaissance by Da Vinci to guide painters to a rational approach and to a better understanding of the proportions of the face, still represents an appropriate model for improving procedures such as rhinoplasty or orthognathic surgery.

In this sense the masters of modern rhinoplasty share a common bond with Da Vinci. Facial analysis, based on Da Vinci theories, assists the surgeon in the diagnosis of the asymmetries, and in designing the surgical procedure best suited to achieving facial harmony.

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Factors that Influence the Plastic Surgeon to Innovate or Accept or Reject Innovations of Others

2

R.M. Goldwyn

Unless a surgeon is implacably opposed to change, he or she will have to consider adopting a new technique in order to improve results. It is impossible to prevent changes from occurring in one's personal or professional life. Everyday, even hour by hour, events, minor or major, which demand our response are happening at home, with our family, to friends, and at work, in the office, at the hospital, in the operating room. This is true not just for doctors and those who happen to be plastic surgeons but also our patients. Everything in the universe is dynamic or, as the Greek philosopher Heraclitus (c.540–c.480 B.C.) stated: "All is flux, nothing stays still." But, as Heraclitus insisted, change or flux does not necessarily mean irreparable disarray but could be the unifying force in nature.

For every plastic surgeon change occurs and, if progressive, constitutes a kind of unity: grammar school, middle school, high school, college, medical school, postgraduate training, and finally entry into practice or another area of our specialty. The point of this prologue is to emphasize that by the time a person has become a plastic surgeon, he or she has made innumerable changes, adjustments, and adaptations. In retrospect, no period in our lives pressured us to change and to learn new skills more than did our residency. To remain in a program every trainee must labor hard to create a new professional self and to become board eligible. If not by the time the plastic surgeon has been credentialed then certainly a decade or two later, one can usually identify into which of the following categories he or she fits:

- Those who innovate
- Those who adopt an innovation
- Those who do not innovate and refuse to adopt an innovation

2.1 Those Who Innovate

The innovators among us are comparatively few. Factors of personality not just intelligence and manual skill determine whether a plastic surgeon will be an innovator. These people are willing, even enthusiastic to assume risk and to venture into the unknown. Their nature is to live on the edge in the operating room and perhaps outside it. Their personality compels them to change, to discard the security of the old for the challenge and exhilaration of the new. They have the ability to create, the stamina to persevere, and the ego strength to accept failure.

Most physicians are conservative in their personal demeanor and their professional behavior. The reality is that admission committees at medical schools would likely exclude someone who seems a flagrant non-conformist, disrespectful of authority and tradition.

Discoveries in most fields are made by the young, physics being the prototype. This is true, however, also in non-scientific areas, such as art, literature, architecture, and music.

We must remember that by the time a physician has completed training, he or she is older than many of his peers who have finished their professional schooling. The plastic surgeon is in his or her early or mid-thirties. We should not forget, however, that many monumental advances in medicine have been due to the efforts of young doctors, even students. Oliver Wendell Holmes at 34 and Ignaz Semmelweis at 29 described the cause and the prevention of puerperal sepsis. Ephraim McDowell, at 38, was the first to enter the peritoneum to perform an ovariotomy in a patient who survived. Ambroise Paré, called the Father of Surgery, who had no formal training and therefore was not blinded by false dogma, was 26 at the Battle of Turin, when his sup-

ply of boiling oil, made from elderberries, ran out. He treated wounds by applying nothing or oil of roses. To his astonishment and to the gratification of the wounded troops, their pain was less and their healing better. Remarkably Pare lived to be 80 (1510 – 1590), his biology being another defiance against his era.

Gaspare Tagliacozzi, considered the Father of Plastic Surgery, at age 31 published the first text in our specialty, describing in detail the reconstruction of the nose with a flap from the arm. Although he did not innovate this flap, which was used in the fifteenth century by the Brancas of Catania and perhaps earlier, he codified this technique so that his contemporaries and followers were able to recognize its importance and use it to benefit patients.

One need not, however, go back centuries to find a young innovator. Dr. Joseph E. Murray, a plastic surgeon in Boston, when he was 35, did the first successful organ transplant, a kidney taken from one identical twin to the other. This feat as well as his subsequent research, when he was still young, on the immunology of homotransplantation, led to his receiving the Nobel Prize.

2.2 Those Who Adopt an Innovation

Most plastic surgeons are not leaders but followers willing to change if convinced it is in the best interest of their patients and themselves. They will properly ask why they should discard a technique that has given good or better results with minimal risk. Age, training, skill, flexibility and willingness to take a risk in one's profession, especially in the operating room, are important characteristics that affect a surgeon's decision to learn and use a new technique. Some surgeons are so competitive that if they are not among the avant garde, they feel inadequate, anxious and even depressed. This type of personality is not necessarily disadvantageous since it accounts for progress.

If, when, and to what degree to change are matters that ultimately only the individual plastic surgeon can decide. There are those who always are looking for an opportunity to do something new. They read articles, attend meetings and symposia, consult colleagues in person or by correspondence, seeking advice because of the impetus to do better for their patients and themselves. While they may not be discoverers, they are the leaders of the followers. They are crucial to progress because they disseminate the new.

2.3 Those Who do not Innovate and Refuse to Adopt an Innovation

It is difficult never to change in one's profession, especially in medicine. An internist or surgeon, for example, who has not deviated for decades in the diagnosis and treatment of a condition is remindful of what Talleyrand said of the Bourbons: "They have learned nothing and forgotten nothing." Unfortunately there are plastic surgeons who devote themselves to the status quo. They may like the idea of change but dread the experience. They are unwilling to undergo what they perceive as the considerable discomfort, uncertainty and risk to themselves and possibly the patient. In my experience they exhibit the same inflexibility in their personal lives as well. Some patients feel comfortable and protected by that kind of surgeon who, they may say, is "careful" or "dependable." I heard one of my friends, a surgeon, describe another surgeon as "someone you can trust because he doesn't get any fancy ideas." Residents and colleagues may consider them out of date but they will always have loyal patients who appreciate their caution and are reassured by not worrying that they are being "experimented upon." In truth, as one studies the history of medicine and surgery, that kind of attitude would have spared many patients from the folly of becoming victims of an imprudent, statistically untested operation or treatment extolled by some physicians and surgeons and by the media without proper clinical trials. In the adopting of an innovation, two major factors must be considered: the nature of the innovation and the reputation of the innovator(s).

2.4 Nature of the Innovation

Anyone contemplating adopting an innovation will ask whether it is important to one's practice or professional life. Will the new method significantly improve results? Is it worth learning and doing or is it of minor importance even if it is an innovation?

Any sensible plastic surgeon would want to know the benefit-risk ratio.

Another extremely important consideration, seldom mentioned but always present, is the economic consequence of the innovation. Will doing it confer a fiscal advantage, or not doing it, a penalty, such as loss of patients and income?

Is the innovation relatively easy to learn by simply reading an article or obtaining a video or will it be necessary to witness it and/or dissect a cadaver? Is the learning curve so steep that the surgeon along with his or her patients may fall into disaster?

In this regard, a crucial aspect in the decision of

whether or not to embrace the innovation is the opinion of others, namely trusted, reliable colleagues. On too many occasions I have heard a new technique presented by "the professor," but his or her residents later described the results with much less enthusiasm than did their chief. This leads us to the other significant factor in addition to those mentioned: the innovator(s).

2.5 The Innovator

Who the innovator is and how he or she presents the technique also affects whether or not it will be adopted or rejected. There are some who are considered leaders yet who minimize the difficulty and the complications of what they are extolling and trying to popularize.

Is the presenter known to be truthful and reliable, or self-aggrandizing to the point of deception? Has that innovator misled us in the past? Has anyone credible seen his or her results? Some people are convincing speakers and writers but the results are less impressive.

There is a difference to me between reputation and reality. Is this person overrated by those who know his or her work? Occasionally a discrepancy exists between local reputation and national or international repute. One should remember, however, that reputation depends on whom one asks. An associate of the innovator may give a glowing evaluation, considerably different from what one might receive from a past associate or a competitor in the same town. The truth might lie between.

In our own field of plastic surgery, one should recall that the great Dieffenbach (1792–1847), the modern founder of our specialty, recommended partial glossectomy for stuttering. Because of his renown, many surgeons performed the procedure on children who, indeed, stuttered less because of their decreased ability to speak! In my time, Owen Wangensteen, a leader in American surgery and an international figure, who contributed tremendously to medicine and surgery, recommended freezing stomachs for bleeding ulcers and a "second look" with respect to intra-abdominal cancer, i.e. reoperating to find and remove residual cancer. Both these ideas were soon discarded because they were not useful and were hazardous. The point to remember is that the authority of the innovator was responsible for their initial rapid acceptance.

2.6 The Patient

The primary concern of any physician in any area of medicine or surgery is the wellbeing of the patient. My father, a neuropsychiatrist, used to say: "The practice of medicine becomes much easier if the physician never forgets to judge what is being proposed according to what is in the best interest of the patient." That determination, however, is not always easy to make. One is more willing to take a chance if the patient is facing the prospect of death. Most patients in plastic surgery, certainly those who seek aesthetic surgery, are not in that group.

Adopting a new technique in one's clinical practice is a serious undertaking. Failure may be irrevocable. Human beings are liable to suffer by undergoing the "wrong innovation." This is true of both patients and surgeons. Years may pass before the flaws of a once heralded technique become known.

One can undertake an experiment on animals in the laboratory with much less compunction than with human beings clinically. Even in the laboratory, however, respect for the animal should be a consideration.

2.7 Informing the Patient

Axiomatic is not just informing the patient but properly informing the patient who might undergo an innovation. An Internal Review Board exists in every hospital to determine whether patients should have a new treatment, medical or surgical. More often in one's practice subtle situations arise. Do we inform the patient, for example, that we have learned about a new method of performing a facelift and that he or she will be the first to have it? If the patient asks how many we have done, we must respond truthfully. The reality is that plastic surgeons, like all surgeons, may try a variation on his or her basic technique without considering it a sufficient innovation to require additional disclosure to the patient. The other possibility is that the surgeon may think that ideally the patient should be informed but does not do so because the patient may refuse and thereby deny the surgeon the opportunity of performing it.

The dilemma in the practice of plastic surgery is that we have worked hard to evolve a routine that we consider effective and reliable and one with which we are satisfied and comfortable. Soon supposed advances impinge upon us and we must face again disruption in our routine if we choose to make an effort to improve the results for our patients and, in the process, to avoid our own fossilization. This is not a trivial situation. For that reason no surgeon and consequently his or her patients should be ill informed purposely by a colleague whether it is in a presentation at a meeting or an article. It is ethically and scientifically incumbent on anyone communicating to colleagues to be scrupulous in his or her observations, results and conclusions. It is not enough to present only complications along with excellent out-

comes but also to divulge average results. This is particularly important and too often ignored in aesthetic surgery. Neither we plastic surgeons nor our patients can escape the reality of the bell-shape curve.

If we do not properly inform the patient or expose the patient to an innovation that we have insufficiently studied or mastered, then in the event of a poor result, the patient and his or her family may use the recourse of a malpractice suit. This possibility, certainly in the United States, is a deterrent either to devise a significant innovation or adopt it precipitously. Progress in medicine and surgery, however, will occur inevitably because of discoveries clinically and in the basic sciences and in technology. A pertinent question to ask oneself when considering an innovation is: "Would I want this tried on me or a member of my family?" One would hope that the surgeon asking such a question would not be self-destructive but always mindful of his or her wellbeing and that of his or her family.

Augustin Belloste (1654–1730) in his treatise, *The Hospital Surgeon*, saw the issue then more clearly than do many now:

> *"That which is New at the time, will one day be Ancient; as what is Ancient was once New. It is not Length of Time which can give Value in Things, it is only their Excellency."*

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Research

II

Tissue Engineering and Plastic Surgery 3

N. Pallua, A. Gröger

Tissue engineering found its application in plastic surgery long before technological advancements allowed the field to expand to what it is today. Both disciplines, tissue engineering and plastic and reconstructive surgery, share a common objective: to provide living tissue for the repair of congenital or acquired defects. Each new achievement in these fields is a consequence of centuries of previous investigation, observation, and insight. Viewed from a historical perspective, it is of great interest to see the development of the distinct field of tissue engineering on the basis of the tradition of plastic surgery, the beginnings of an inextricable relationship. Today, the advances of tissue engineering continue to open up new possibilities in the field of plastic surgery.

The technological innovations of the 20th century revolutionized the field of plastic surgery. Operating microscopes were developed and continuously refined, and the production of microsurgical instruments quickly moved from possibility to reality. With these advances came the advent of microsurgery, the most ambitious technique for tissue transfer yet undertaken. Amongst the breakthroughs that this form of surgery brought with it were improvements to long established surgical procedures. The replantation of severed limbs, for example, became more successful than ever before. Further, the ability to describe in minute detail the angiosomes, or the anatomical vascular supply of any given region, gave way to a variety of new procedures.

The same innovations that dramatically altered the face of plastic surgery made way for the birth of whole new fields of research. The forward movement of scientific technology brought new insights into the structural and functional relationships that prevail on a microscopic level in both physiological and pathological tissues. This foundational understanding, coupled with advances in cell culturing techniques and biomedical research, opened new doors for the old ambition of providing living material for the replacement of defective tissues. The scientific progress of the latter part of the 20th century had made the next step in tissue substitution possible: tissue engineering.

3.1 Basic Principles of Tissue Engineering

Tissue engineering, in comparison to plastic surgery, is a more modern discipline defined as being involved in the experimentation with living tissues outside of a living organism. It is a true product of interdisciplinary cooperation between a vast number of life sciences, including biotechnology, material science, cell biology, cell expansion technology and a variety of medical specialties (Fig. 3.1).

The roots of tissue engineering, however, go deeper than the contemporary definition implies. Up until recent times, the possibilities for treatment requiring tissue substitution included non-biological implants and grafts originating from the patient themselves, a live donor, or a cadaver. The development of the field of tissue engineering research might be viewed as a product of the realization that the traditional materials used for

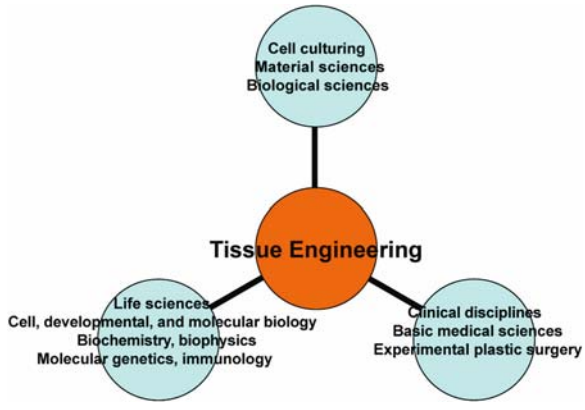

Fig. 3.1. Interdisciplinary cooperation in tissue engineering

the substitution of defective tissues were not sufficient to meet the demands placed on medicine. Solutions were sought outside of these classical therapeutic parameters.

Plastic surgery, in addressing the problem of replacing defective tissues in order to restore structure and function, achieved successes through the practices described above. Alone, however, these practices remain inadequate to meet the demand for tissue replacements needed to mend a vast range of defects. Tissue loss and organ failure are among the most frequent, devastating, and costly problems faced by the health system. Nevertheless, there are grave limitations placed on transplantation medicine, factors including a shortage of tissue and organ donations from either living or cadaver donors, as well as the high costs of transplantation, the side effects of immunosuppression, and recipient morbidity.

Another treatment option, namely the use of nonbiological implants, comes with its own set of drawbacks. While such prostheses very effectively restore structure to damaged tissues, they cannot replace all of the functions of a specialized tissue or organ. Neither can they prevent the progressive decline in the state of health of some patients, as a result of the illness that led to the need for the prosthetic implant in the first place.

The field of tissue engineering offers hope for a resolution of these difficulties. The development of biological substitutes that are intended to replace or improve the structure and function of human tissues has become a possibility. Tissue engineering is based on the knowledge gained through a wide range of scientific branches that allow an understanding of the processes and structure-function relationships within tissues at the microscopic level and beyond. It applies this information to the in vitro production of human tissues and substitutes that are biologically compatible with human tissues. Currently, the production of nearly all types of human tissue is being intensively investigated, with the intention of implementing these to restore, preserve or improve tissue structure and function in human subjects [1].

There are three aspects of tissue engineering that especially deserve attention in respect to the stated objective, the provision of living tissues for the replacement of congenital or acquired defects. First, consideration will be given to the branches of cell and tissue culture. Following this, the importance of the three-dimensional matrix for tissue engineering will be discussed. Last will be a brief account of the biological materials in the field of tissue engineering.

3.2 Cell and Tissue Culture

The first steps towards the attainment of a cell culture were taken by Rudolf Virchow, who was active in the same time period during which Reverdin, Ollier, and Billroth were making their contributions to plastic surgery. Virchow was one of the first advocates of the theory of cellular totipotency, or the ability of a single cell to divide and produce all of the differentiated cells of an organism. He postulated the independent growth of every cell under specific external circumstances, when removed from its collective cell structure, or tissue. Experiments were continuously conducted on the basis of this hypothesis, and it was a man by the name of Arnold who succeeded in verifying the postulate in 1887, when he observed the mitotic division of leukocytes in culture. This was, of course, a first step towards the maintenance and, further, the production of living human tissues outside of the living human organism. It was only 10 years later, in 1898, that Ljunggren managed to keep alive bits of skin in a fluid environment [3]. This was probably the first achievement in the creation of a milieu in which an actual tissue could be maintained external to the organism from which it came.

At about the same time that Erich Lexer was conducting the first mammoplasty, 1912, Carrel achieved the propagation of cells on a glass substrate [2]. The term "in vitro" stems from this time period as a synonym for experiments conducted outside of a living organism. From the onset of in vitro experimentation, it was clear, even without the technology known to modern-day scientists and the knowledge that this technology affords, that the composition of the medium in which cells find themselves outside of the organism is decisive for their ability to maintain life, divide, and differentiate. The goal of all cell expansion technology is to provide a suitable milieu for obtaining cell activity, function, and growth, but one that is defined and reproducible [3]. It was in the 1950s that the term "culture medium" first came to be used. It was used to define a combination of salts, nutrients, amino acids, and vitamins that allowed for the in vitro culture of living cells, which often required the addition of serum for efficacy. The first to succeed in producing a serum-free medium for mammalian cells was Ham, who accomplished this with the Ham F12 combination in 1965 [4].

Today, there is a variety of commercially available culture mediums for use with different cell types. Methods for cell and tissue culture also abound. The best known and most widely used technique for propagating human and animal cells is the monolayer culture using polystyrene dishes as the substrate. Most cell types adhere to the hydrophobic base of these dishes within 1 day, and subsequently begin to grow. The cell

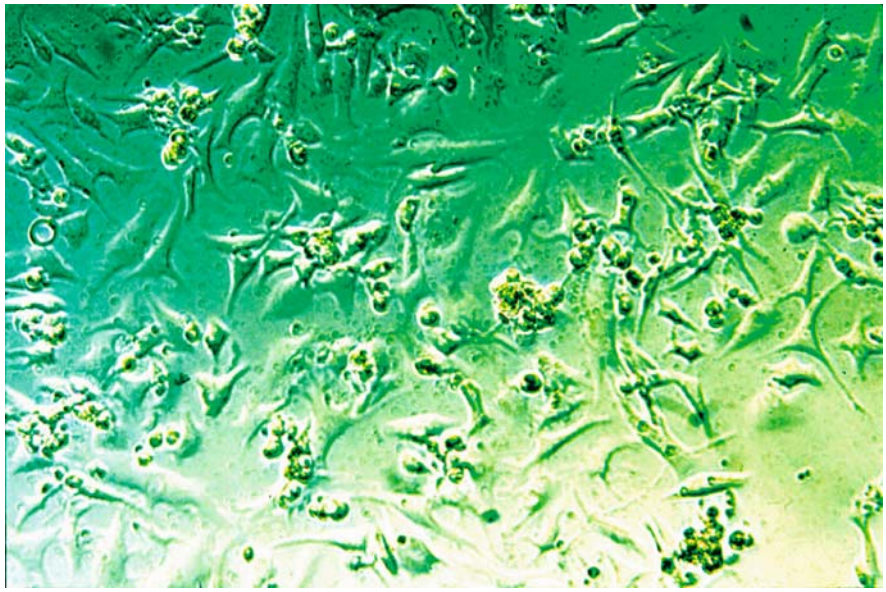

Fig. 3.2. Human chondrocytes in a monolayer culture, day 5 in vitro

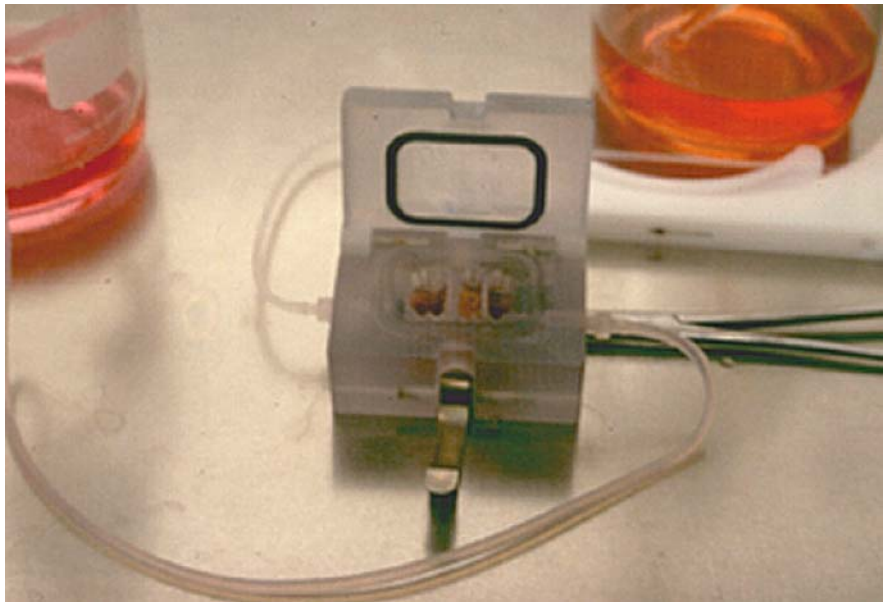

Fig. 3.3. Perfusion chamber for tissue cultivation with a variable perfusion pressure

lines attained using methods such as this are called primary cultures (Fig. 3.2).

In order to create the proper environment for cells to be cultivated, they must first be dissociated from the extracellular matrix in which they find themselves inside of their natural organisms. The association of a cell with its natural environment is complex, and freeing a cell from its matrix involves not only dispersing the matrix components, but also dissolving cell-matrix bonds and specific cell-to-cell contacts. This is most often accomplished with the help of enzymes such as collagenases and trypsin.

Following an initial period of 1 – 2 weeks, the cells, dissociated from their natural matrices, grow accustomed to the culture conditions and begin to divide. Depending on the cell type, this can continue for up to several weeks. When the number of cells has increased to a certain point, a state of confluence is achieved. If the division of the cells is to be sustained, then the cells must be distributed to new culture dishes at this point. This process is called passage. Cell division can be held at a relatively constant rate over many weeks, if the cell cultures continue to be divided and distributed at the point of confluence. The result is then the development of a large quantity of cells.

In this fashion, human diploid dermal fibroblasts can be rapidly reproduced in vitro. It is possible to acquire a primary culture of several thousand dermal fi-

broblasts from a skin biopsy a mere 1 cm2 in size. Similarly, human fibroblast cultures that are serially subjected to passage can yield a total of 1016 cells, under the proper conditions. Unfortunately, not all cells can be propagated with such success. Additionally, it has been observed that many cell lines change their biochemical properties in vitro. In this way, chondrocytes that are cultured in vitro lose the characteristic ability to produce type II collagen, and rather bind type I collagen, altering their phenotype to more closely resemble fibroblasts. This is a process that is generally referred to as dedifferentiation. Interestingly, when placed under the right culture conditions, these dedifferentiated chondrocytes can (re)-differentiate into typical chondrocytes. These are then viable for in vivo application [5].

From the first hypotheses and the subsequent achievements regarding cell and tissue cultures over a century ago, a whole series of culturing methods have been developed and are in use today. Examples of these are the suspension, organ, sponge, roller, microsubstrate, and perfusion cultures, to name a few. Each culture allows for the various nutritive, physiomechanical, and biochemical requirements of the different cell lines for whose propagation they are used [5, 6] (Fig. 3.3).

3.3 The Three-dimensional Matrix

When approaching the task of producing a substitute for human tissues that have lost their structure or function, one must consider the question of how a conglomerate of cells manages to operate as an integrated whole, as a functional tissue or organ. One must then be able to infer this organization and functionality onto the biological substitutes that are meant to replace, restore, or improve the native tissue. Put another way, in order to achieve an optimal result, the cells composing a replacement tissue must bear all of the characteristics of the cells of the original tissue in both form and function. This includes, amongst other features, the ability of the cells to divide and differentiate, to communicate with one another and other elements of their environment, and to react appropriately to the signals given by the host, as well as in certain cases to be the origin of specific signals. Years of research throughout the natural sciences, with the help of improving technology, allow a tentative response to the question of what guides these processes: a decisive role is played by the interaction of cells with the extracellular matrix that surrounds them [7].

Cells within a tissue produce components of the extracellular matrix, and have the ability to interact not only with the components that they produce, but also with the constituents originating from other cell types. This process is realized by cell surface receptors, which induce specific and variable intracellular signalling processes, depending on the matrix or cellular components with which they are presented. A wide variety of specialized surface receptors are found in nature. These include the adhesion receptors, selectins, integrins, immunoglobulins, and cadherin, and others that are known to also take part in cell-to-cell interactions. This often results in the modulation of the surface receptors of a cell, also as a result of the intracellular signalling pathways, ultimately leading to a change in the behaviour of the cell in relation to its environment [8] (Fig. 3.4) (Tables 3.1, 3.2).

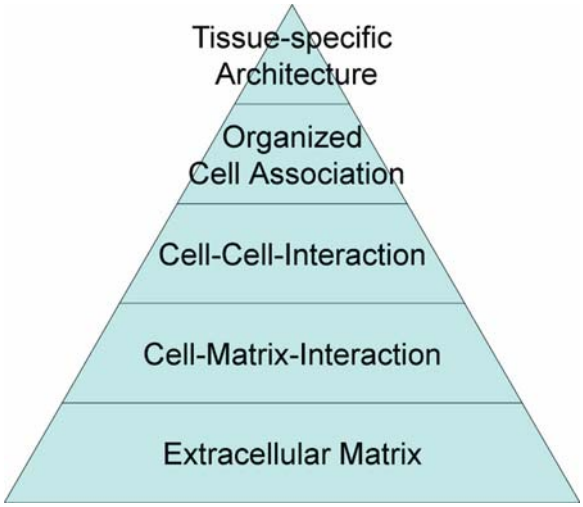

Fig. 3.4. The hierarchy of interactions, from the extracellular matrix to tissue-specific architecture

Table 3.1. Components of the extracellular matrix, and their major properties, in terms of tissue engineering

Collagen The most prevalent protein in the human body. It lends traction to the tissues, and is important for cell adhesion and differentiation	Collagen I–XII: The collagen family consists of 12 subgroups, which are defined by their supramolecular structure
Proteoglycans Important for the elasticity of the matrix. They take part in cell adhesion, migration, and proliferation	Amongst others: hyaluronic acid, chondroitin sulphate, dermatan sulphate, keratan sulphate, heparan sulphate, heparin
Glycoproteins Lend stability to tissues. Have binding sites for collagens and proteoglycans, as well as for cell surface receptors. Important for cell adhesion, migration, proliferation, and differentiation	Amongst others: fibronectin, laminin, vitronectin, thrombospondin, tenascin, chondronectin, von Willebrand factor
Elastic filaments Important for tissue flexibility	Amongst others: elastin

Table 3.2. Integrin receptors and their extracellular ligands. Integrins are composed of heterodimer transmembrane glycoproteins and play an important role in the interactions of cells amongst one another, and with the extracellular matrix

Composition of the integrin subunit	Extracellular matrix ligands
β1-family	
α1 β1	Laminin
α2 β1	Collagen
α3 β1	Fibronectin, laminin, collagen
α4 β1	Fibronectin
α5 β1	Fibronectin
α6 β1	Laminin
α7 β1	Laminin
αv β1	Fibronectin
β3-family	
αIIb β1	Fibrinogen, fibronectin, vitronectin, von Willebrand factor
αv β3	Thrombospondin, laminin, fibrinogen, fibronectin, vitronectin, von Willebrand factor
Others	
αv β5	Vitronectin
αv β6	Fibronectin
α4 β7	Fibronectin

Knowledge of the details surrounding cellular interactions is far from complete; however, the foundation is clear. Many cellular functions depend upon the interaction of a cell with its environment, and thus upon the constitution and configuration of that environment produce the appropriate signals to induce or nurture a specific function. This principle is successfully being applied in the field of tissue engineering. Just as the interaction of a cell with its matrix can affect cellular behaviours such as proliferation, differentiation, migration and communication in vivo, these activities can be influenced in vitro by providing the appropriate environment. Localized modifications to the composition and construction of the extracellular matrix result in fine-tuned adaptions in both the structure and function of a tissue, on the basis of alterations in the cell-matrix interactions [9].

Providing a milieu that mimics the natural environment within a tissue is a strategy utilized by tissue engineers to improve the ability of the tissue replacements that they produce to demonstrate desired functional characteristics and structural qualities. The isolation of native matrix molecules has helped tissue technology to more finely direct the growth of tissue substitutes that are intended to emulate the form and functions of the natural tissue. These isolates, coupled with the knowledge of their actions in vivo, can be used as a means of producing tissues that display the attributes desired for their specific use as tissue replacements. Moreover, given the provision of a proper environment, transplanted cells can be induced to actively take part in the production of components of the three-dimensional matrix in which they find themselves. The use of the extracellular matrix to control and manipulate the processes of cells produced in vitro is an invaluable tool in the field of tissue engineering.

3.4 Biological Materials in Tissue Engineering

Generally speaking, the knowledge of how to increase cells through culturing, and how to influence the qualities that these cells display by means of their extracellular matrix, does not go anywhere near explaining how these cells are to be successfully introduced into a living being in order to evolve into a tissue that functions as a well integrated part of that organism. Yet another facet of tissue engineering concerns itself with just this problem. The research area focused on biomaterials concerns itself with the production of biological and synthetic materials which can be used in association with the cells produced in culture in order to deliver these in such a manner that they can integrate themselves as a properly functioning unit of the whole in vivo.

Again, the successes in this field today could not have been achieved without the efforts of several scientists and physicians in times past. The mention of a few whose research has made contributions to the field of biomaterials could begin with Erich Lexer. Starting in 1908, Lexer reported the implementation of donations taken from freshly amputated subjects or cadavers for the reconstruction of joints [10]. Several decades later, in the early 1970s, W.T. Green experimented with the implantation of chondrocytes into animal models using bone as the carrier [11]. While Green's experiments failed, he had the insight to predict the direction that the field of biomaterials would take, namely the production of synthetic substrates. He correctly postulated that the development of biologically compatible materials would allow for cells to be placed in a synthetic framework that would produce functional tissue following transplantation.

Following this route and the research that Jannas and Burke had also undertaken in the 1970s, Vacanti et al. developed polymer complexes whose form and composition were variable, but into which cells could be integrated [12]. These complexes of cells and synthetic, biologically compatible polymers were implanted into laboratory animals to successfully yield a new functional tissue. The experiments of Vacanti et al. judiciously took into consideration the fact that the transplantation of large areas of tissue requires all regions of that tissue to have sufficient connection to the blood supply of the host. The polymer constructs used could be variably fashioned to optimize the surface area and exposure of the transplanted cells, and were able

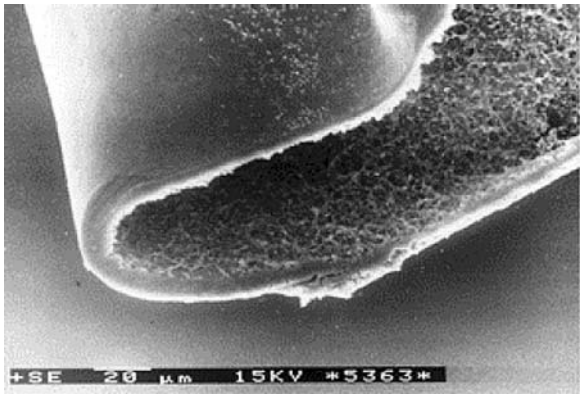

Fig. 3.5. Scanning electron microscope images of an immune-protective, semi-permeable microcapsule. These can be used for encapsulating cells, for example in the allogeneic transplantation of islets of Langerhans cells

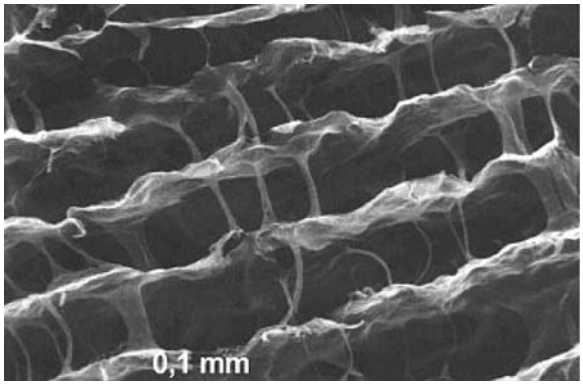

Fig. 3.6. Scanning electron microscope image of a porous collagen carrier. The pore size can be adjusted to conform to the requirements of specific cell lines

to function as an anchor and external structure for the cells to proliferate within the native tissue.

The field of biological materials research following the original accomplishments of Vacanti et al. has since produced substrates that can generally be divided into two groups. The first are products devised in such a way that they are intended to be immune-resistant. These immune-resistant devices consist of semipermeable membranes, which are supposed to prevent elements from the immune system of the host from infiltrating the protected graft. The other group, on the other hand, are constructs whose main functions are structurally oriented. These are biological materials with large pores, which offer support and anchoring within the intrinsic tissues of the host (Figs. 3.5, 3.6).

In the spirit of Green, the fundamental question remains for both of the substrates described above, of whether a synthetic or natural material should be used for transplantation of tissue replacements. In support of synthetic materials, which consist of organic polymers, it must be considered that these can easily be produced in a variety of forms, and are additionally inexpensive and reproducible. Further, their properties, such as mechanical strength and hydrophobicity, can be manipulated to suit the circumstances. In contrast to this, natural materials such as collagen occasionally demonstrate limited mechanical characteristics, can be difficult to isolate, and have a certain biological activity. In exchange, natural materials, for the most part, do not provoke an immune reaction, which is why many are viewed as being biologically compatible. In contrast to this, some synthetic materials, over a longer period, cause inflammatory reactions in intrinsic tissues. The challenge facing tissue engineering today is to find either a natural biological material that can be produced in large quantities and with consistent quality, or to develop a synthetic material that shows biologically compatible characteristics [9].

Table 3.3. Selection of biomaterial features for tissue engineering

Biological features	Biocompatibility, cell adhesiveness, immune response of the host against the biomaterial, risk of disease transfer, possible bioactive properties, e.g. binding of growth factors
Mechanical features	Tension and pressure characteristics, pore size, surface-pore ratio, pore patency
Chemical features	Surface chemistry, e.g. modification with adhesion factors, degeneration rate, hydrophobic/hydrophilic properties
Production features	Cost, technical effort, reproducibility, sterility

The aim of present research is the further optimization of natural and synthetic polymers on the micro- and nanoscale, in order to facilitate specific material-cell interactions. It is now possible, thanks to novel biomaterial array systems, to test and evaluate various modified biological materials, for example monomeric polymers, on many cell lines simultaneously, in great quantities, and under standardized conditions. By this means, it is possible to find the optimal biological material for a specific cell line within a short time, without the need for extensive animal trials. With the help of computer-supported production on the nanoscale, modern biomaterials can be developed in such a way that they are reproducible [13] (Table 3.3).

3.5 Conclusions

The fields of tissue engineering and plastic surgery have developed into interdependent and interdisciplinary fields with a common goal of providing living tissue replacements that can re-establish, preserve, or improve the structure and function of tissues possessing either congenital or acquired defects. The accomplish-

ments and insights throughout the history of both investigation and application in these fields have brought the research to the point at which it is today. Through the development of cell and tissue culturing techniques, it has become possible to propagate cells in quantities that can be applied therapeutically. It is also now possible to influence the properties of these cells on the basis of an understanding of the importance and mechanisms of cell-matrix interactions. Lastly, the area of biological material production is making advances in transplanting these cells into a living being in such a way that they might evolve into a tissue that functions as a well integrated part of that organism.

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4 The Bioengineered Organoid Skin in Plastic and Reconstructive Surgery

N. Scuderi, P. Mezzana

4.1 Introduction

The development of tissue engineering has given us the possibility of treating organic pathologies, whether congenital or acquired. Langer and Vacanti, in their article titled "Tissue Engineering" in 1993, defined tissue engineering as "an interdisciplinary field that applies the principles of engineering and sciences of life in order to develop biological substitutes that restore, maintain or improve the function of a tissue or an organ" [10].

Tissue engineering can be considered one of the most promising fields in the new chapter of modern surgery, so-called regenerative surgery or inductive surgery.

Tissue engineering uses two principal methods:

- *In vivo:* stimulating self cells to regenerate as a reaction to the appropriate biomaterials or growth factors; or restoring a proper function using gene therapy.
- *Ex vivo:* using cells able to grow in cultures, seeded in a scaffold (a three-dimensional matrix of support made up of hyaluronic acid, collagen, chitosan or synthetic materials, in the case of culture of fibroblasts or keratinocytes), which can later be implanted in the host.

This is the most widely used and promising approach, generally called "tissue engineering." It therefore includes the use of biomaterials such as scaffold (support matrix) and living cells. Moreover, biologically active molecules can be added such as growth factors in order to facilitate the growth and/or the differentiation of the cellular components.

In this way it is possible to take advantage of the structural and mechanical characteristics of the biomaterials and of the biological characteristics of the cells and/or bioactive molecules in order to obtain substitutes able to interact with the host organism to compensate for a lack of function or to modulate biological phenomena (e.g., growth and tissue reactivity).

A choice can be made between heterologous type cells that are from various species, allogeneic type cells that are from the same species but taken from different organisms, or autologous type cells that are from the same organism. Autologous cells are preferred because they do not cause an immune reaction from the host against the implant, avoiding the use of immunosuppressive agents, which are known always to have many adverse effects, often of a serious nature [8].

Different maturative stage cells can be used, such as differentiated tissue specific cells, isolated progenitor cells isolated from specific tissues such as the stem cells of the bony marrow or at least the embryonic stem cell derivatives from the blastomere [2, 5]. Autologous cellular cultures have found a remarkable use in the field of reconstructive plastic surgery, and particularly the culture of autologous fibroblasts and keratinocytes for the repair and reconstruction of widespread loss of cutaneous substance. In our department we have developed a clinical method for the application in vivo of a scaffold in which both fibroblasts and autologous keratinocytes are present and arranged to form an organotypical co-culture that could simulate the architecture of the normal skin, so as to reduce convalescence and surgical times in patients affected by widespread loss of substance, particularly in those affected by giant congenital nevi.

4.2 Indications

The bioengineered skin can be used in all cases in which a widespread loss of cutaneous substance is present. These can be classified, based on their etiology, into wounds caused by: burns, trauma, surgery, and vascular causes.

4.3 Biomaterials

Tissue engineering cannot considered without also including the development of biomaterials. These are indispensable for the culture of the cells in a three-dimensional environment, so that they produce a geometrical organization similar to that existing in the tissue of origin. The esters of hyaluronic acid (HYAFF®) are examples of the latest generation of biomaterials. These are semisynthetic biomaterials produced by the chemical modification of natural polymers with the purpose of improving their mechanical characteristics, manageability and degradation times. This type of modification is generally made in polymers of saccaridic origin because of their elevated hydrophilicity, which renders them suitable for the production of scaffolds for cell culture. Their development has been carried on to the production of reabsorbable sheets used like matrices of support for cellular growth and differentiation in vitro, like a substrate for the transport and delivery of cell cultures and for three-dimensional tissue reconstruction (three-dimensional sheets that simulate the normal structure of the extracellular matrix of the tissues).

4.4 Cellular Bioengineered Cutaneous Substitutes

The idea of recreating the skin in vitro has always fascinated the bioengineers, who have been engaging in this difficult enterprise for some considerable time. There is an urgent clinical requirement for such methods: annually 6,000 persons in Europe are hospitalized for third degree burns. Similarly, every year approximately 800,000 diabetic patients in the same geographic area consult doctors for ulcers of the foot that are difficult to heal; approximately 1,500,000 patients suffer from chronic ulcers of another nature; and more than 3,000,000 patients suffer from decubitus sores.

In 1989 Gallico et al. were the first to propose a technique they already used in the treatment of burns patients, based on the use of keratinocyte autografts cultivated in vitro, for the treatment of giant congenital hyperpigmented nevi [6]. The removal of the nevi was performed by excising deep to the fascial plane and an area corresponding to 6.9 % of the body surface was removed at each procedure. The grafted areas underwent a contraction, which was greater in the softest regions, so the method was not used on flexor surfaces; moreover, in many cases the epithelialization was only partial. In 1990 Matsuda and Suzuki used artificial dermis to treat giant congenital nevi and obtained good results [14].

In 1999 Carsin et al. obtained pleasing results utilizing autologous epithelial culture for the treatment of 30 patients affected by widespread acute burns [3].

Some Italian authors such as Uccioli et al. (in 2002) and Travia et al. (in 2003) have obtained good results with the treatment of patients affected by acute burns, chronic ulcers from pressure or diabetes, and with the treatment of extended lack of substance provoked by trauma, using cultures of fibroblasts and autologous keratinocytes [15, 16].

Organotypical co-culture of keratinocytes and fibroblasts, containing collagen hydrogel, have been used in vitro to study several aspects of the epithelial-mesenchymal interactions in epidermal regeneration and morphogenesis. These conventional systems have shown, however, some defects such as a limited survival, an insufficient resistance to the contraction and an anchorage deficit of the epidermis to the matrix of collagen [12]. In addition, for clinical applications, it is preferable to avoid a matrix of xenogeneic collagen because of the imminent danger of infective or immunological complications.

In 2004 Paul Ehrlich published results on the implantation of sheets of a co-culture of fibroblasts and keratinocytes expanded on a scaffold composed of native collagen in rats, showing a remarkable performance in the acceleration of wound healing through the liberation of numerous growth factors [1].

Recently, Judith Hohlfeld (in August 2005) published in an authoritative international review the results of a clinical trial based on the use of a scaffold of collagen repopulated with fetal cutaneous cells from a donor for the treatment of young burns patients, obtaining encouraging results but with too small a number (only eight) of patients examined [9].

4.4.1 Bioengineered Autologous Organotypical Skin (Figs. 4.1 – 4.3)

The production of autologous organotypical co-culture we have utilized is based on a non-complex method [12]. The patient is seen at the day hospital for blood and instrumental preoperative tests. At the same time, a skin biopsy of about 6 cm^2 is taken from the right groin and sent to the laboratory [Fidia Advanced Biopolymers (FAB), s.r.l., Italy] specializing in the production of skin substitutes.

The technique for preparing organotypical cultures is based on this method: briefly, skin specimens are enzymatically digested to separate epidermis from dermis. The fibroblasts and keratinocytes obtained are propagated for subsequent passaging, after which the cells are seeded to produce the skin substitute [11].

The skin equivalent is produced starting with a scaffold (a non-woven pad measuring 64 cm^2) constituting a benzyl ester of esterified hyaluronic acid (HYAFF 11), especially a partial ester of hyaluronic acid [3]. A quantity of 2×10^5 fibroblasts/cm^2 was seeded on the HYAFF

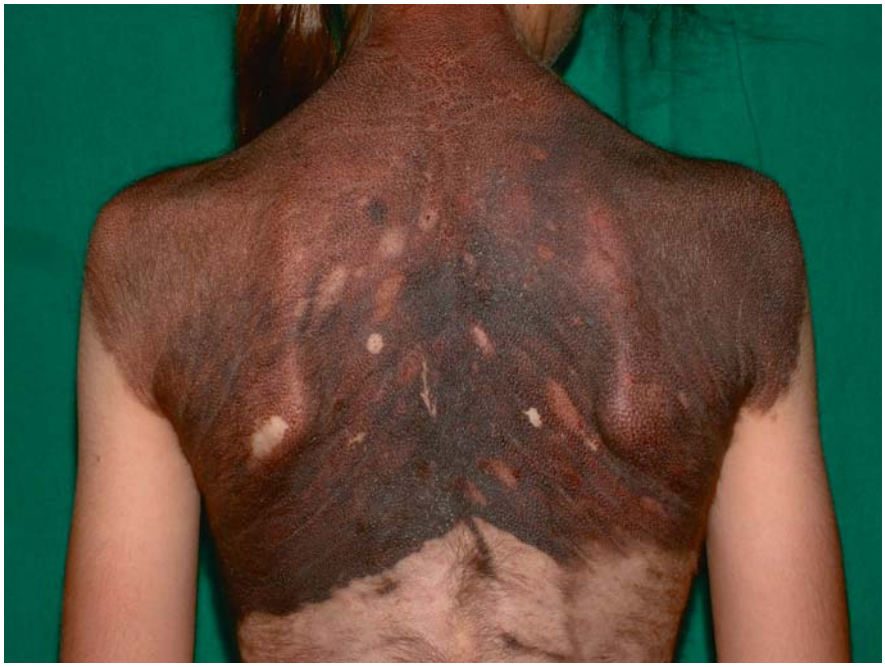

Fig. 4.1. Seven-year-old girl with giant congenital nevus (preoperative view)

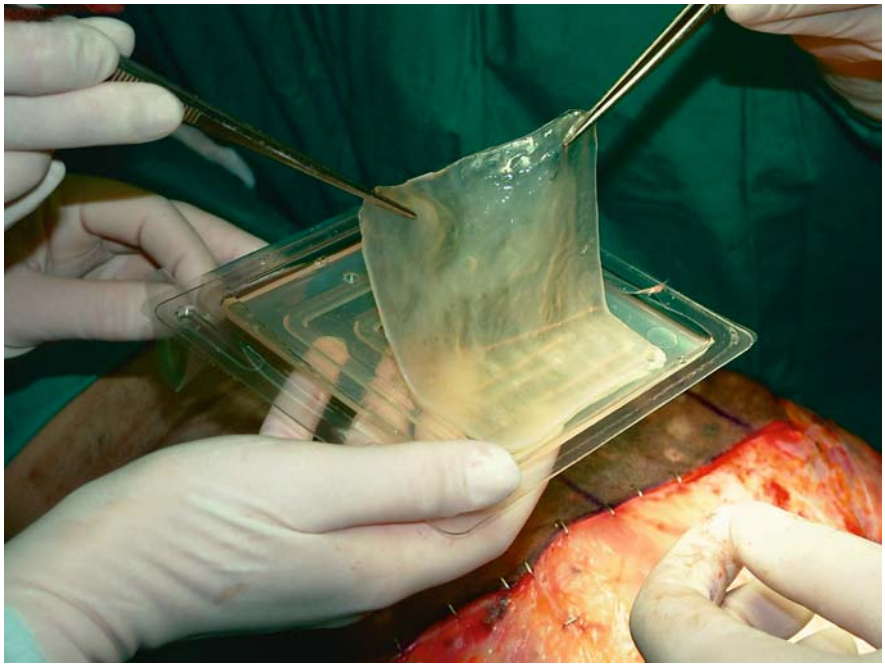

Fig. 4.2. A sheet of autologous organotypical skin substitute based on HYAFF

11 scaffold, resuspended in fibrin gel (Tissucol Baxter). Subsequently, 2×10^5 keratinocytes/cm^2 resuspended in culture medium were seeded on the surface of the skin equivalent. After about 4 days incubation, during which time the cells were kept submerged in the culture medium, the level of the latter was lowered so as to expose the surface of the cells to the air. Incubation at the air-liquid interface promoted development in vitro of a keratinized epidermal surface with a stratum corneum analogue [7].

The applications were performed in ten patients affected by widespread post-traumatic and iatrogenic loss of substance and were extended on a variable surface area of from a minimum of 64 cm^2 to a maximum of approximately 400 cm^2, with a degree of integration of between 40 % and 90 % of the grafted area. At the follow-up, carried out at time intervals of from 6 months to 2 years, a perfect stabilization of the new skin, with a progressive improvement of the scars and the absence

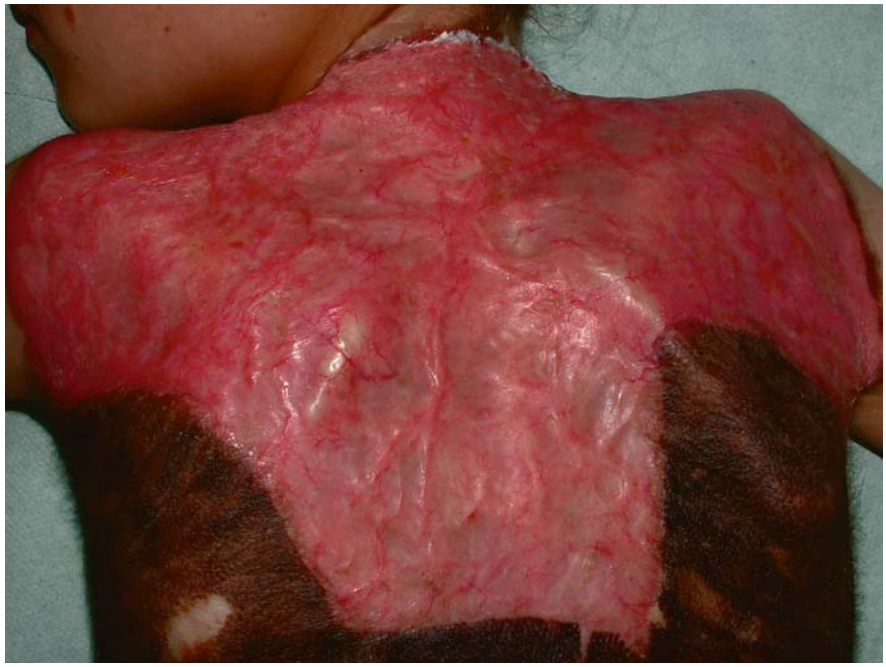

Fig. 4.3. Seven-year-old girl with giant congenital nevus after the application of autologous organotypical skin substitute based on HYAFF (postoperative view, 6 months follow-up)

of alterations of the cellular turnover of the more superficial layers, was observed.

4.5 Conclusions

The results obtained from in vivo experimentation of organotypical co-culture of fibroblasts and keratinocytes on a scaffold of HYAFF 11 demonstrate the possibility of using complex structures in human patients, produced in the laboratory and composed of an artificial part ("scaffold") and a cellular mixed autologous component. The reduction of the hospitalization times and the possibility of carrying out only one surgical procedure are the elements that encourage and stimulate us to persevere in overcoming the technical difficulties. An important next step in tissue bioengineering will be the production of a cutaneous substitute with combined dermis and epidermis arranged with other cellular components such as the endothelial vessel cells, to produce a capillary vessel net that will ensure adequate nourishment to the new tissue. The vascularization is very important in the complete integration of cutaneous substitutes as well as for all types of grafts [13].

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Matrix Flaps – New Approaches to Flap Prefabrication: Experimental Data and First Clinical Applications

5

R.E. Horch, E. Polykandriotis, A. Arkudas, J. Schipper, U. Kneser

5.1 Introduction: Flaps, Cells, Matrices, and Modulation

Reconstruction of large soft tissue defects caused by tumors or trauma remains a surgical challenge. Flap prefabrication of customized tissue components has been one of the recent advances in reconstructive surgery [1, 2], and the technique has fulfilled the need for flaps with multiple surfaces or functional properties, such as long-term stability.

Major technical breakthroughs have been made with recently developed surgical and non-surgical tools, such as continuous vacuum therapy [3–7] and techniques learned from tissue engineering (i.e., cell cultures, matrix composition, cytokines, etc.) [8–10]. Combining traditional knowledge of flap creation with the insights from clinical and experimental findings from these new techniques has been the basis for the customized prefabrication of three-dimensional autologous flaps for functional tissue defect reconstruction.

It has been shown by our group that application of topical negative pressure during the time of prefabrication may help to reduce the incidence of infection and tissue necrosis [11–13]. However, while the blood flow in flaps may be improved, the prefabrication process may be less timely. The integration of autogenous and alloplastic materials, for example titanium or resorbable polylactide scaffolds, offers another prospect in this context [14, 15].

On the other hand, our experimental findings with the induction of axial vascularization in tissue-engineered three-dimensional constructs give rise to the hope that further advances toward an optimization of customized flaps and minimizing donor site effects can be achieved in the future [8, 16–18].

Clinical experience of the use of prefabricated free and pedicled flaps for partial laryngeal reconstruction in ten patients with various defects in the head and neck region has followed our experimental results with vascular axialization by means of arteriovenous loops in an animal model [2, 12, 16] (Figs. 5.1, 5.2).

Due to advances in cell culture techniques, virtually all types of single tissue elements can now be expanded in vitro with tissue specific cells [10, 19–21]. Furthermore, efforts have focussed on pluripotent cells able to produce tissues of different kinds. A particular subset of these progenitor cells has attracted special interest, i.e., the so-called mesenchymal stem cells (hMSCs). Although adult mesenchymal stem cells were first isolated in 1975, it was not until 1994 that a better understanding was achieved of their role as protagonists in homeostasis and regeneration of all tissues [22, 23].

During the past decade, there has also been an explosive growth in the field of biomaterials. It was recognized at an early stage that the key element of success for a scaffold was its interaction with the surrounding tissue at the cellular level. Scaffold technology has provided a vast variety of materials for all applications, with an emphasis on tissue engineering of bone [8, 15].

Surface chemistry as well as geometry and porosity was found to have a large influence on cellular differentiation and growth. The addition of growth factors enhanced the recruitment and differentiation of host cells, e.g., the use of bone morphogenetic proteins (BMPs) to promote osteogenesis. Surface properties and chemistry were altered to boost specific adhesion of cells or to hinder it. An example is bioartificial vessels with enhancement of endothelial growth and concomitant inhibition of platelet adhesion. Geometry and porosity were modified for optimal growth of cells, with optimal pore size found to be in the range 200–900 µm [15].

For the favorable modulation of these interactions, biomolecular research has focussed on tissue engineering for the advanced application of growth factors and

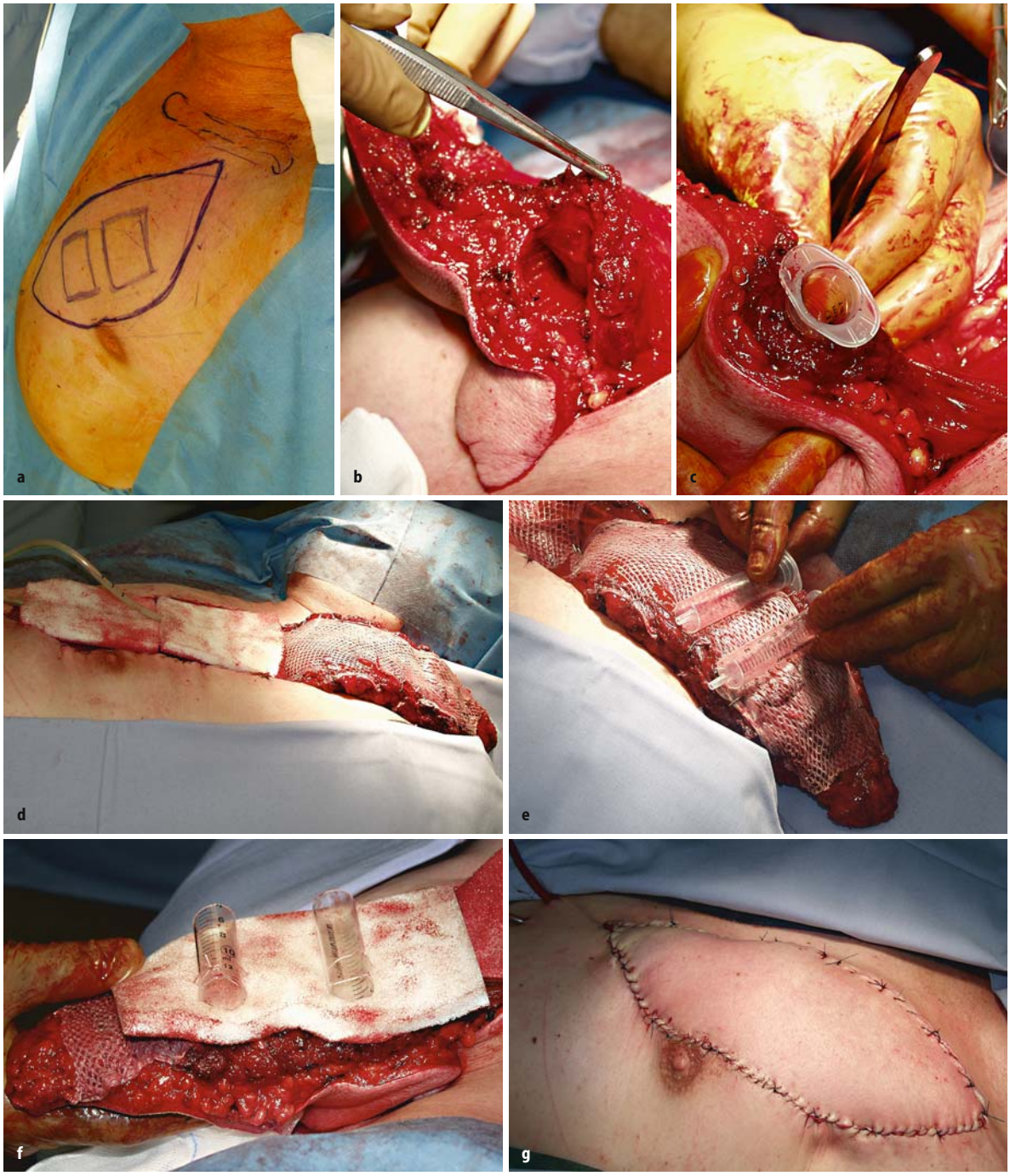

Fig. 5.1. a Schematic drawing of a planned double half pipe construct with integration of an alloplastic biomaterial scaffold into a pectoralis major muscle flap for tracheal reconstruction. **b** Implantation of a half pipe shaped bioresorbable scaffold into the pectoralis muscle. **c** Stabilization and shaping into the desired shape with a plastic syringe. **d** Closure of the donor site at the chest with a meshed split thickness skin graft and fixation of the graft with vacuum polyvinyl (PV) foam. **e** Demonstration of the creation of half pipe shapes of corresponding muscle parts plus creation of a new flap undersurface for inner lining of later tracheal replacement. **f** Placement of PV foam upon the split thickness skin graft on the undersurface of the flap. Syringes serve as spacers. **g** The prefabricated flap is left in situ utilizing vacuum closure for the securing of grafts and allografts until integration of tissue and materials allows for flap transfer

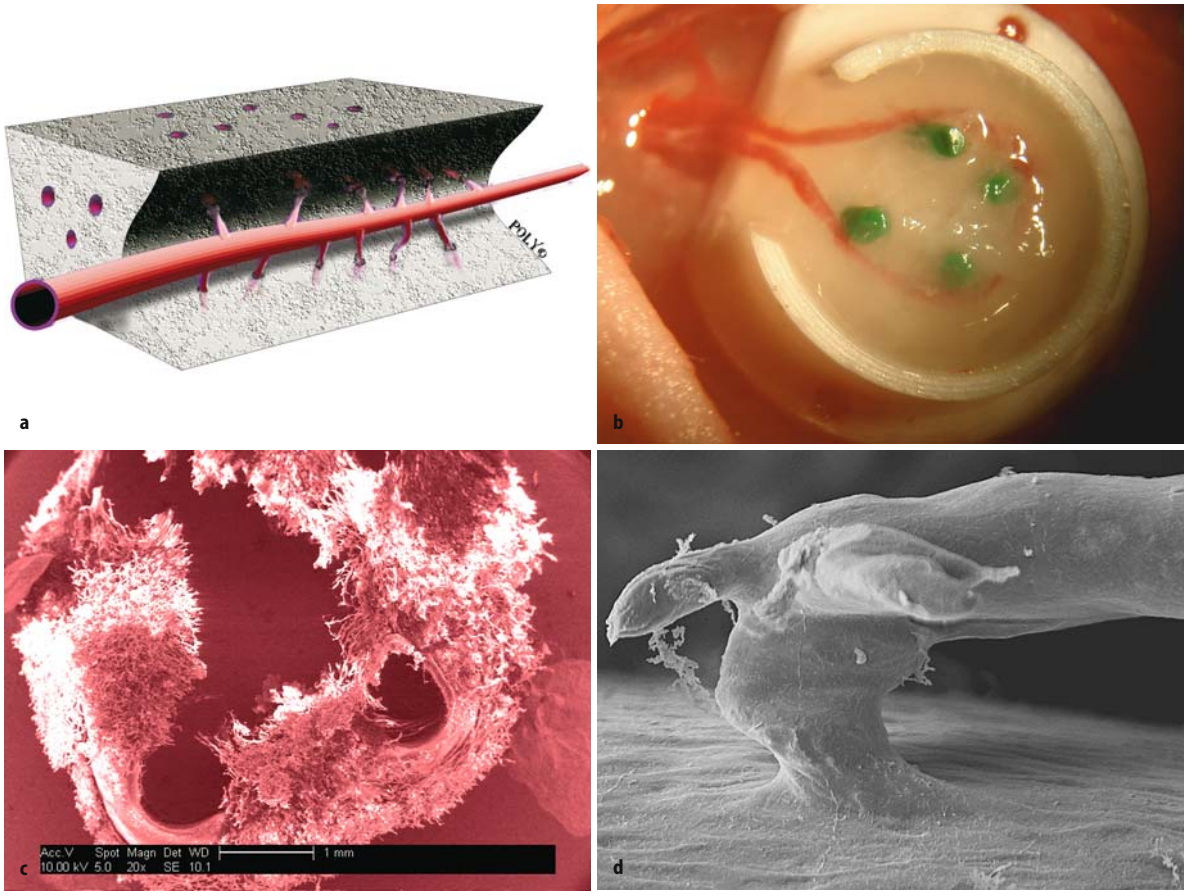

Fig. 5.2. a Schematic representation of the "matrix flap." An alloplastic or allogenous matrix is placed in the vicinity of a vascular axis. The organism serves as bioreactor and vascularization of the matrix is achieved prior to microsurgical or pedicled transfer. **b** The surgical field upon experimental implantation of an arteriovenous loop in a gel matrix. The construct is encased in an isolation chamber. The perforations at the base of the matrix are used for fixation of the assembly on the medial thigh of the rat. **c** The loop will induce a vivid angiogenic response in the fibrin matrix. Here a microvascular replica of the neocapillary network 14 days after implantation is shown. The vascular replica was constructed by means of corrosion casting with a low viscosity resin. Scanning electron microscopy was used, ×20. **d** The nuclei of the endothelial cells are imprinted on the vascular replica of the venous portion of the arteriovenous loop. A new vessel by means of direct luminal sprouting is visible. The impression on the basis of this new vessel might be signs of blood flow controlling structures such as a sphincter or a valve. The illustration was produced by means of corrosion casting and scanning electron microscopy, ×1,000

bioactive proteins. At the high end of these technologies, cells and scaffolds have been designed to release growth factors of their own [24–27].

These ex vivo technologies were transferred to the in vivo environment with promising results [28]. However, in most cell seeded biomaterial constructs, the volume-to-surface-ratio of the constructs was kept low and successful implantation took place in a site of rich perfusion; in other words, small constructs in healthy recipients. The matrices were rapidly invaded by capillaries from the local vascular network, which, in turn, ensured functional interaction and biointegration of the constructs [9, 29, 30].

5.2 Tissue Engineering in Plastic Surgery

The clinical situation requiring tissue substitution differs completely from the ideal laboratory setting, however. Tissue defects can be the result of radical tumor excision [31, 32], fulminant infection [33, 34] or compound tissue trauma [35, 36]. In such cases there is either ongoing inflammation with exhausted immune resources or marked fibrosis with virtually zero local angiogenic capacity [37]. The absence of sufficient perfusion represents a further high risk factor for bacterial inoculation. Any means of tissue substitution would have to introduce vascularization to the site so as to promote healing and restore functionality. The standard treatment nowadays is microsurgical plastic re-

construction by means of free flaps [36] or vascularized bone grafts [38].

These therapies perform quite well, but there is always a cost for autologous microsurgical transplantation in terms of donor site morbidity and remaining functional. Furthermore there is limited availability in the size and form of tissue to be spared, this holding true for all tissues and bone grafts in particular. Therefore plastic reconstructive surgeons have been forced to come up with new ideas; modern approaches include perforator flaps and flap prefabrication.

Prefabricated free flaps represent a method of staged microvascular transfer where a graft is introduced in form and implanted ectopically into a site of rich vascularity and adjacent to a vascular axis. During a second step, the construct is harvested as a compound free flap including the vascularized graft and the surrounding tissue, with the vessel serving as pedicle. This method has been further refined in a hybrid strategy incorporating tissue engineering concepts into flap prefabrication [2, 12].

Experimentally we investigated the implantation of tissue specific cells in a suitable matrix which permitted interaction with the environment [9, 39]. In vivo experiments with various materials when implanted after loading with expanded hepatocytes [29] and osteoblasts [9] clearly demonstrated the problem of low transplantation efficiency. Histological findings were complemented by labeling studies to track down the fate of the cells in vivo and confirmed a high cell-death ratio especially in the central portions of the construct [17, 40]. The single most important factor leading to cell loss after in vivo transplantation was thought to be the lack of vascularization. Nutrient supply and metabolite evacuation were ensured in vitro by frequent changes of culture medium. After implantation of the cell-loaded matrices in vivo, local diffusion was insufficient, especially for cell populations residing in the central portions of the matrix. The importance of vascularity for cell survival therefore is considered to be a core issue in improving tissue engineering concepts clinically. The necessary step to linking the in vitro findings with in vivo application was rendering the matrix vascularized, prior to cell transplantation.

5.3 Materials and Methods

In a preliminary study we developed a device consisting of an isolation chamber and a matrix in the form of a disc. The cylindrical Teflon chamber was constructed by the Institute of Materials Research (Professor Dr. P. Greil, Division of Glass and Ceramics, University of Erlangen). The chamber comprised a base plate (diameter: 15 mm), under a cylindrical shell (height 6 mm × diameter 12 mm) and an upper cup (height: 2 mm × diameter: 14 mm). The basal plate had two peripheral perforations for stabilization on the fascia of the medial musculature of the thigh.

The matrix consisted of processed bovine cancellous bone (Tutogen Medical AG, Neunkirchen, Germany). The pore size of the matrix was 300 – 500 µm with a porosity of 65 – 80 % rendered acellular and non-antigenic by a standardized procedure. Canals for future injection of gel-immobilized osteoblasts were included in the matrix design. The matrix was a disc 9 mm in diameter with a groove (1.5 × 2.0 mm) around the periphery of the disc allowing for optimal accommodation of the arteriovenous loop.

The vascularization of the matrix itself was to be effected by implantation of a vascular axis. The femoral artery and vein were used as donor vessels. During the same study, microsurgical techniques were established for construction of the vascular configuration to drive angiogenesis within the construct [41].

Several patterns for the vascular axis were tested. The arteriovenous loop model performed best in terms of vascularization potential and rate of thrombosis.

This vascularization pattern was based on a model introduced by Erol and Spira in 1979 and augmented by Morrisson and coworkers in the 1990s [42, 43].

In this model an arteriovenous loop is created by interposition of a venous graft between the femoral artery and vein in the medial thigh of the rat in the following manner. The femoral neurovascular bundle is exposed through a 4-cm-long incision at the medial thigh. Dissection of the vessels extends from the pelvic artery in the groin to the popliteal artery in the knee. After dissection of the artery and vein, a femoral venous graft is harvested from the contralateral side and interposed between the femoral vessels by anastomoses using an 11-0 nylon suture (Ethilon, Ethicon, Norderstedt, Germany). The processed bovine cancellous bone (PBCB) disc is placed in the arteriovenous loop and the vascular axis is positioned in the peripheral groove. The construct is placed in the Teflon chamber with the artery and vein exiting through an opening at the proximal pole.

For control purposes, different configurations for the vascular carrier were also tested. An arteriovenous fistula between the femoral artery and vein without the use of a venous graft did not provide a sufficient loop radius to accommodate the matrix. An arteriovenous bundle constructed by en bloc dissection of the femoral vessels and distal ligation was also used. Furthermore, matrices void of vascular carrier encased in the isolation chamber as well as a processed bovine cancellous bone (PBCB) disc implanted subcutaneously without the use of an isolation chamber were evaluated.

5.3.1 Methods of Assessment

5.3.1.1 Experimental Design and Groups

Four different groups of animals were incorporated in the studies. Animals with a PBCB matrix containing an arteriovenous loop were included in group A. Animals bearing a construct with an arteriovenous bundle as a vascular carrier were incorporated in group B. Group C included animals with constructs encased in an isolation chamber and implanted without a vascular carrier at all, whereas group D comprised animals with a construct implanted subcutaneously without the use of an isolation chamber. Each group contained 15 animals. The explantation intervals were 2, 4 and 8 weeks after the initial operation for all groups.

Explantations with India ink injection, corrosion casting, and histology were performed as described by previous publications, and morphometric analysis was performed according to our established protocols [8, 16, 18].

Magnetic resonance angiography was performed using a 4.7-T Bruker Biospec scanner, and MRIan software (www.biocom-online.de) was used for evaluation of volume datasets. Amira software (www.mc.com/tgs) was used for visualization.

5.4 Results and Discussion

The clinical results of flap prefabrication have been published elsewhere [2, 12]. The principle of three-dimensional flap generation is demonstrated in Fig. 5.1.

Experimental data of the microsurgical prevascularization of constructs showed that all animals tolerated the implantation operations well. There was no loss of weight or cyanosis of the extremity, indicating that there was no circulatory compromise of either the animal or the isolated extremity as a result of the artificial arteriovenous shunt. The capacity of the AV loop to fully vascularize the matrices was evident upon explantation; well vascularized constructs displayed a distinct dark coloration due to perfusion with India ink. In those constructs perfused with methylmethacrylate, patency of the arteriovenous loop was confirmed by the rigid pedicle exiting the chamber due to polymerization of the resin. The incidence of abscess formation in the chamber was significantly lower in the AV loop group. Histology and morphology confirmed the macroscopic findings. Quantitative evaluation of vascularization displayed a clear advantage of the arteriovenous loop as a means of vascularizing the PBCB disc. However, there were also several morphological landmarks in favor of the method. In subcutaneous implantation, the angiogenetic front propagated from the periphery toward the center, representing a fibrovascular "ingrowth." In this setting perfusion derives per se from the outer side of the construct; hence the term "extrinsic vascularization" coined by Cassell [44].

In contrast, in the AV loop constructs vascularization radiated from the center toward the periphery: representing an "outgrowth" from within; hence the term "intrinsic vascularization." Furthermore, in the subcutaneously implanted matrices there was a significant amount of inflammatory reaction and scarring.

That was not the case in the AV loop group. The dominating generated tissue here was loose vascularized connective tissue as opposed to a marked fibrosis with abundant polymorphonuclear infiltration in the subcutaneously implanted discs [17].

Finally, although from a quantitative point of view results between subcutaneous and axial vascularization were comparable, the capillary tree in the latter displayed a higher degree of variability in luminal diameter, implying a higher degree of differentiation and more advanced arborization.

In the constructs harboring an arteriovenous bundle, there was frequently a thrombosis of the vessels, mostly the artery. Neovascularization propagated even distally to the point of thrombosis. The level of thrombosis was variable, ranging from complete thrombosis of both the vein and the artery to distal thrombosis of the artery alone. However, the more proximal the occlusion the more inflammatory the character of the neovascularization and the less the extent and volume of the newly formed fibrovascular tissue. At none of the constructs could any osteogenesis be witnessed.

Scanning electron microscopy of the vascular replicas, after corrosion of the matrix and the fibrovascular tissue, confirmed these results. In the proximal-arterial part of the loop the neovascular beds were oriented parallel to the vascular axis, as an adaptation to higher pulsatile pressure. On the venous side, the new vessels assumed a rather cavernous form.

New vessels emerged from the remaining perivascular tissue and the vasa vasorum as well as the main loop elements themselves (femoral artery, venous graft, femoral vein). Luminal sprouting was a sign of a very vivid angiogenic response. Not only the venous segment participated in this phenomenon but the arterial and the graft parts too. Direct luminal sprouting from the arterial and especially the graft portions of a vascular axis have not previously been documented in the literature.

Propagating angiogenesis seemed to occur at "hot spots." In these areas, clusters of neovascular sprouts revealed a higher occurrence of angiogenetic activity.

Independently of these processes and concomitant to them, the so-called "non-sprouting" or "intussusceptive" form of angiogenesis has been observed as

well. However, the incidence of this form of new vessel formation was significantly higher in the constructs implanted subcutaneously and bearing an AV bundle.

The axial character of the newly formed vascular tree in the AV loop constructs was conserved even in the 8-week groups. By this time the venous graft was showing signs of arterialization as indicated by spindle like impressions of the nuclei of the endothelial cells on the cast, oriented along the long axis of the vessel.

The axial pattern of perfusion even at advanced stages of vascularization was confirmed by micro-MRI angiography. Inflow through the artery and outflow through the vein could be visualized at the entrance of the vascular axis into the chamber. However, the shunt pattern changed over the weeks from a strictly serial mode exclusively through the venous bypass during the first weeks, to a more diffuse mode throughout the experiment, indicating ever increasing participation of the newly formed capillary network in the arteriovenous exchange. In other words, the construct assumed with time the perfusion pattern of a distinct organoid with a rise in intrinsic impedance. This is an example of self-regulation as in the embryonic organogenesis.

Numerous studies with implications regarding the importance of vascularization for cell survival have been conducted since the beginning of the twentieth century [45, 46].

As early as 1961, Greene showed that tiny tumors implanted for more than a year in the anterior chamber of the guinea pig eye would not exceed 1 mm in diameter because they could not become vascularized. When these tumors were reimplanted in the muscle of a rabbit where they could become vascularized, they grew to a large size [47].

However, even in the case when a cell loaded construct is slim enough to allow for rapid vascularization and the site of implantation offers conditions favorable for angiogenesis, the cells are still in peril. An intense inflammatory response at the site of implantation of a cell loaded matrix hinders cellular growth of the tissue specific cells immobilized in the biomaterial. The cells were overrun by the inflammatory cells and the subsequent fibrosis [48].

5.5 The Future

There are preliminary results indicating that prevascularization of a matrix by means of the arteriovenous loop largely increases survival of secondary transplanted cells. Further, angiogenetic growth factors such as vascular endothelial growth factor (VEGF) and basic fibroblast growth factor (bFGF) greatly enhance and accelerate angiogenic response. Transfer of the model into large animals and upscaling the size of tissue defects to be replaced by prevascularized constructs will provide further insight into how well prevascularization strategies are applicable in the clinical setting. The combination of our clinical experience with flap prefabrication using the vacuum technique and the initial results from our promising axially vascularized tissue engineered constructs will offer new perspectives for customized tissue replacement.

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6 Low Level Laser Therapy and Phototherapy Assisted Hydrogel Dressing in Burn Wound Healing: Light Guided Epithelial Stem Cell Biomodulation

Jin Wang Kim, Joung Ok Lee

6.1 Introduction

As a result of the influence of fetal wound healing, recent trends in wound dressing have been toward a focus on the wet condition. The other current focus is on energy transmission for wounds such as electromagnetic energy and negative pressure therapy to the wound for the purpose of rapid healing. In many countries basic hydrogel dressing material is used such as Comfeel gel (Coloplast, Denmark) with foam or Opsite (Smith and Nephew), etc. Therefore wound dressing transillumination is performed by a combination of transparent dressing, low level laser, LED light source (Omnilux PDT lamp, FDA approved NASA space LED for wound healing) and polarized light (Bioptron, FDA approved) [1, 2, 8]. For the treatment of various wounds including burns and pressure sores, laser assisted aquaphoresis and several other techniques such as modulation of granulation tissue, epithelialization and wound contraction are used. Low level laser therapy (LLLT) (Cho Yang, Korean Medical Laser Laboratory – Kim's Mochida Diode and Erchonia, FDA approved Lasers) and phototherapy for early skin rehabilitation are very useful for functional recovery as well as for cosmetic skin problems such as erythema, hyperpigmentation, psoriasis, keloid and hypertrophic scar formation. For rapid healing, one purpose of light targeting is pilosebaceous unit stimulation and biomodulation [2, 8].

6.2 Materials and Methods

We followed the progress of 45 patients who were treated with Purilon gel, and whose wound surface area was less than 15%. Two hundred and fifty of the patients had deep second degree burns and 50 had third degree burns. Fifty patients were admitted while the others received outpatient treatment. The face was the most common wound site and the hand was the other. Sixty percent of the patients were children. Eschar had formed in about 80% of the patients. The average dressing and change interval was 48 h and laser lighting was performed every day.

As autolytic debridement progressed and granulation tissue formed, we used hydrocolloid dressings and calcium alginate to promote effective epithelialization.

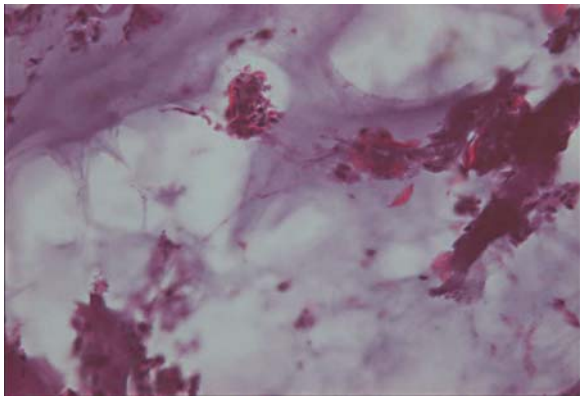


Fig. 6.1. Osmotic potential of the gel. LLLT causes an increase in blood circulation by angiogenesis. Laser light penetration into deep tissue causes softening and debridement of necrotic tissue, which lacks a vascular supply, and propagation of healthy granulation tissue by combined hydrogel dressing. Note the ascending daughter keratinocyte

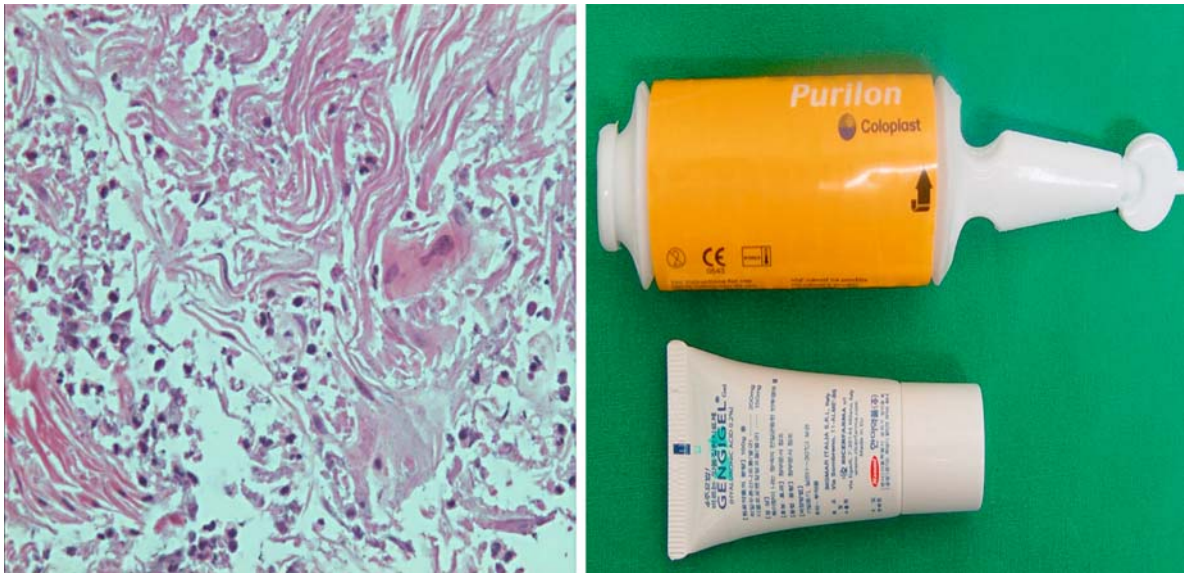
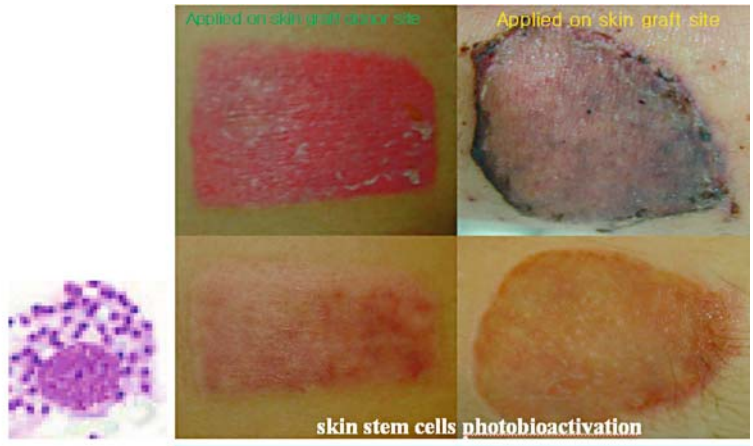


Fig. 6.2. *Left* Epidermal stem cell islands, β_1-integrin expression in basal cells but none in the spinous or granular area, regenerating epidermis during wound healing – shaving biopsy findings. *Right* Hydrogel dressing material: orange color for external wounds, white color for intraoral use



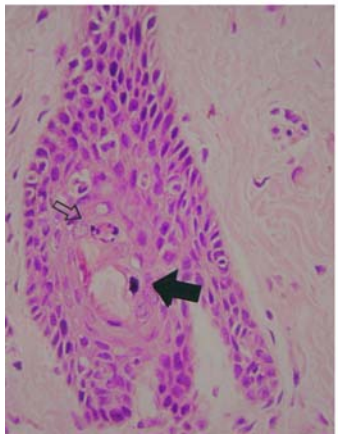


Fig. 6.3. *Left upper* Macrophages with light interaction: FGF-mediated fibroblast proliferation and angiogenesis. *Right upper* Applied quasimonochromatic light source to the skin graft wound as well as donor site showing a lot of hair growth due to the stimulation of skin stem cells. *Left lower* Stem cells in hair follicle and skin basal layer. *Right lower* LED system: large treatment area for hands-off application which is quasimonochromatic compared to other light sources such as IPL or LLLT and other RF light laser sources. Another Bioptron light source polarized the light [2]

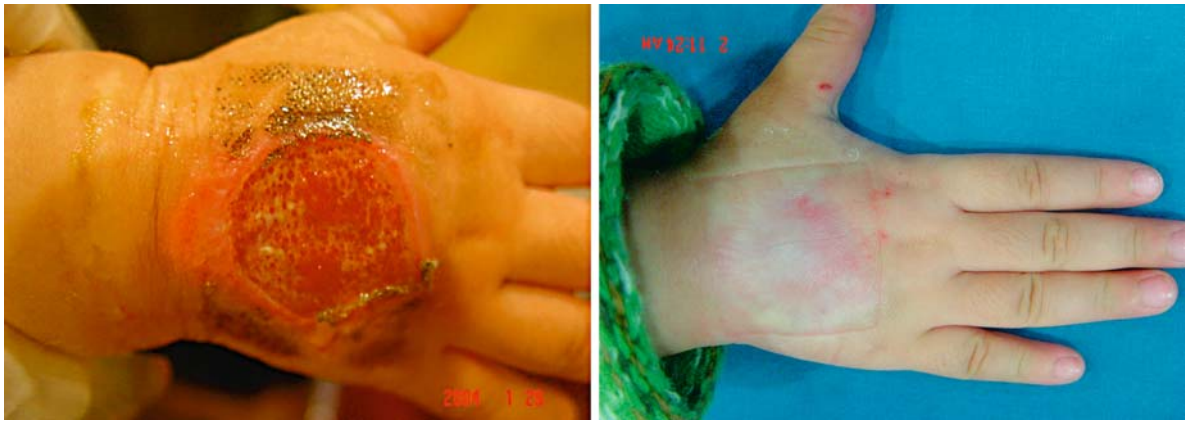


Fig. 6.4. *Left* Application of new innovative dressing on an approx. 3-cm-diameter skin defect on the dorsum of the hand from running machine injury. *Right* Combination light and laser therapy with Comfeel gel plus mupirocin ointment aseptic occlusive dressing, 14 days after the result, and showing a remarkable decrease in wound pain and itching (visual analog scale point 4)

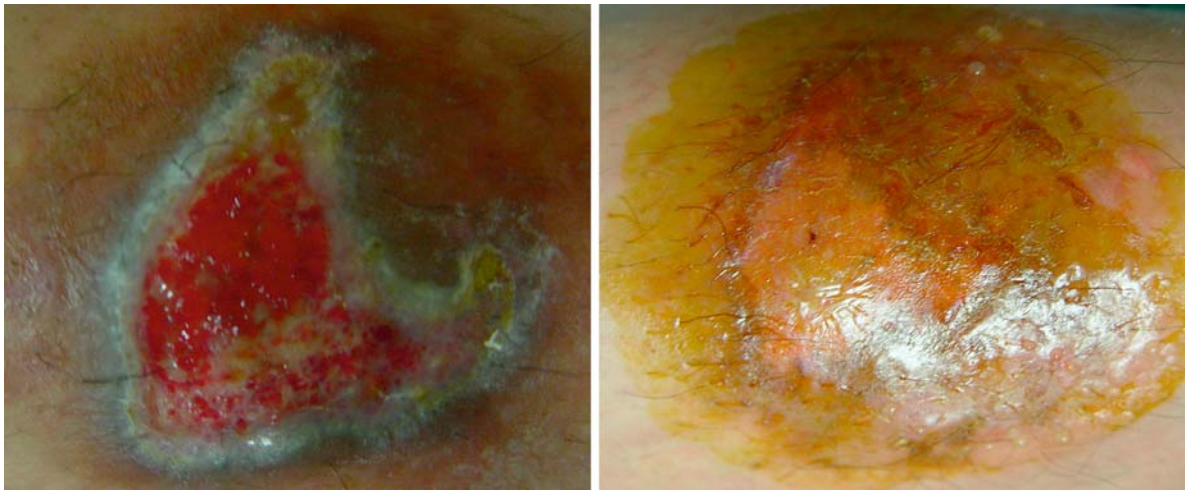


Fig. 6.5. Treatment parameters: diode laser, wavelength 830 nm; 905 nm with He-Ne laser, power density 0.5 J/cm^2. Treatments were given once a day, 6 days a week, for a total of 4 weeks [8, 10]

6.3 Patients

Between 2003 and May 2007, we treated 300 burn and trauma patients with hydrogel and LLLT transparent aseptic occlusive dressing. Gels used were Comfeel gel and Intrasite gel. The lasers used were He-Ne and IR laser and the light source used was the Omnilux LED system. The general health status was good, and some patients had diabetes mellitis (DM) and chronic nephropathy.

6.4 Results

The mean healing period for deep second degree burns was 10 days and for the third degree burns it was 17 days. So the hospitalization required for these patients was reduced. Autolytic debridement occurred and extra moisturization with aquaphoresis was performed. The wound dressing method was very simple and uses LLLT for 10 min. The wound area was photographed before and after. Compared to comfeel gel this combined dressing produced more natural and healthy tissue without psoriasis and dyschromia [2, 10].

6.5 Discussion

Many dressing techniques are in use throughout the world. In the past, e.g., in the Roman period, many people used baths and heliotherapy for wound healing. The recently developed low level laser has assisted aseptic occlusive dressing. This combination method is now approved safe, effective and cost-effective.

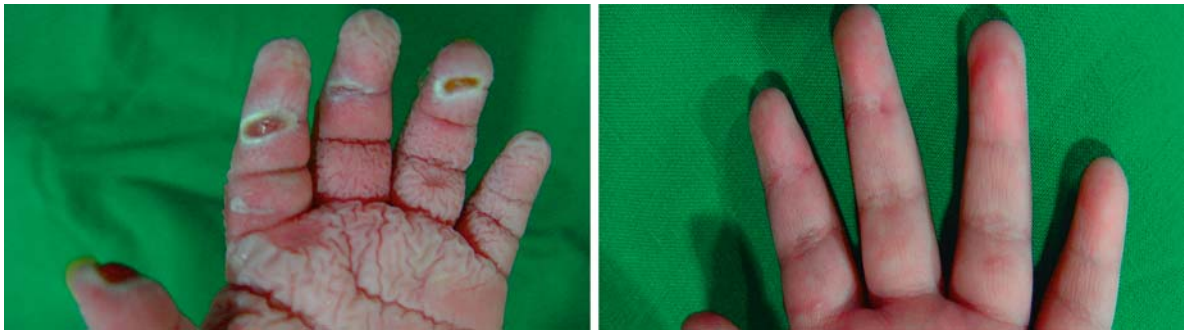


Fig. 6.6. *Left* 220-V electrical burn injury after chopstick insertion in electrical socket. Three-year-old patient develops multiple skin defect on left palm and fingers. *Right* Treated with LLLT and Comfeel gel dressing for 1 month, cosmetically and functionally acceptable

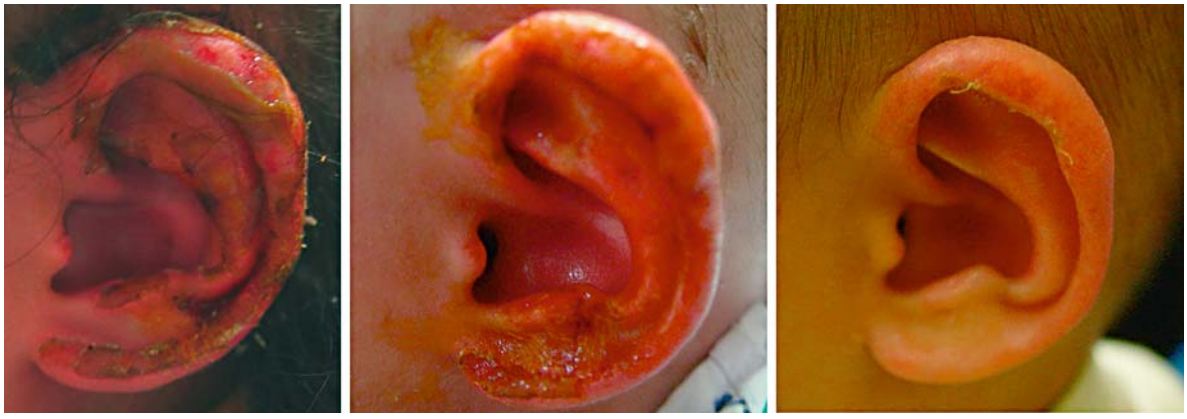


Fig. 6.7. *Left* Ear cartilage exposure with infection in 3-year-old female patient postburn day 14. After Physol burn soap cleansing, hydrogel dressing was applied with Bioptron phototherapy and LLLT. *Middle* Daily dressing 5 days after the result. *Right* Ten days after treatment [10]

It is believed that gels promote autolytic debridement by increasing the moisture content of sloughing and necrotic tissue, thereby facilitating enzymatic activity. At the same time amorphous hydrogels are able to absorb fluid from the exudating lesion, and the low level laser simultaneously enables drug to penetrate into the tissue more easily by the mechanism of aquaphoresis [2–4].

All patients were washed with Physol (aseptic soap) with saline washing, and all wounds were managed with the atraumatic technique. We used the Comfeel gel treatment for pressure sores, DM foot, failed flap operations and trauma as well as burn wounds and found that this combination treatment overcame the limitations of hydrogel treatment. And it is suitable for patients who do not want the operation for various reasons [5, 6].

6.6 Summary of Phototherapy in Wound Healing

Light therapy can increase vascularity (circulation) by increasing the formation of new capillaries, which are additional blood vessels that replace damaged ones. New capillaries speed up the healing process by carrying more oxygen as well as more nutrients needed for healing and they can also carry more waste products away. They also stimulate the production of collagen, which is the most common protein found in the body [7]. Collagen is the essential protein used to repair damaged tissue and to replace old tissue. It is the substance that holds cells together and has a high degree of elasticity. Enhancement of macrophage acts to help fibroblast action, and by increasing collagen production less scar tissue is formed at the damaged site. It also stimulates the release of ATP, which is the major carrier of energy to all cells. Increases in ATP allow cells to accept nutrients more rapidly and to get rid of waste products more rapidly by increasing the energy level in the cell. All food turns into ATP before it is utilized by the cells. ATP provides the chemical energy that drives the chemical reaction of the cell. An increase in lymphatic system activity leads to edema, which is the swelling or natural splinting process of the body, and which has two basic components. The first is a liquid part which can be evacuated by the blood system and the second comprises the proteins which have to be evacuated by the lymphatic system. Research has

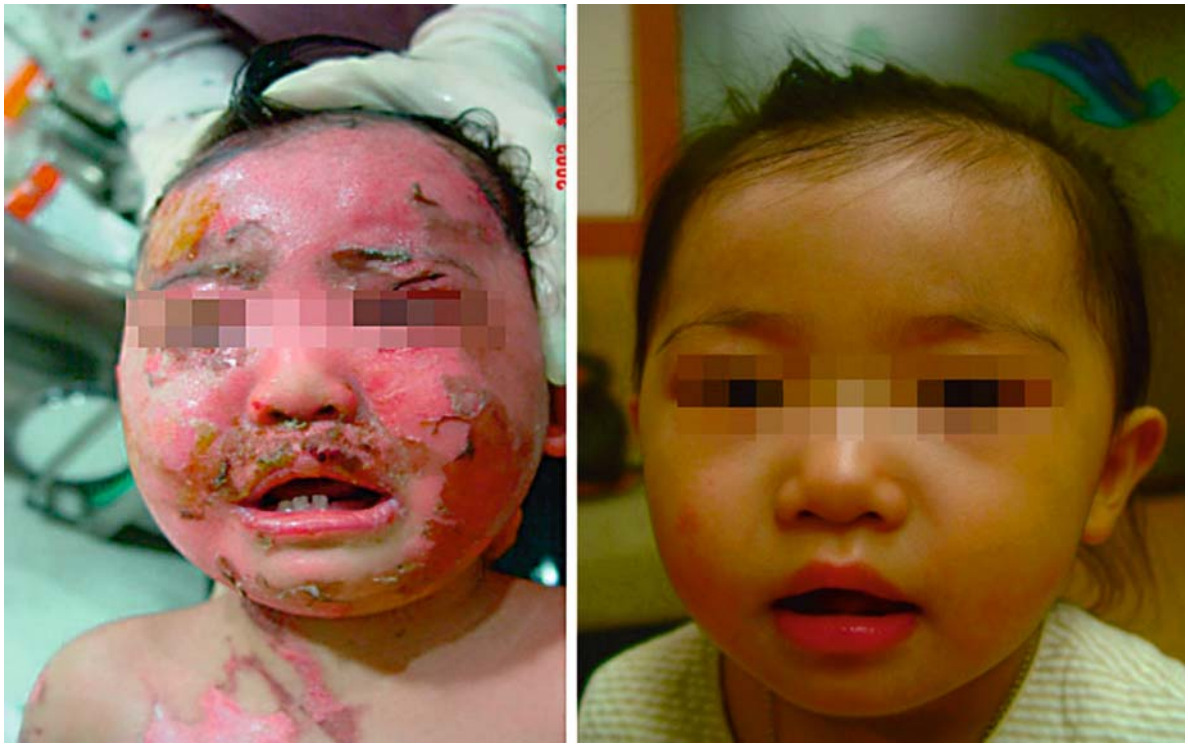


Fig. 6.8. *Left* Three-year-old female patient with deep second degree and partial third degree scalding to face with severe *Pseudomonas* and MRSA infection. *Right* Daily cleansing with Physol soap and combined light therapy and Comfeel gel dressing for 2 weeks. Markedly improved dyschromia and skin tone

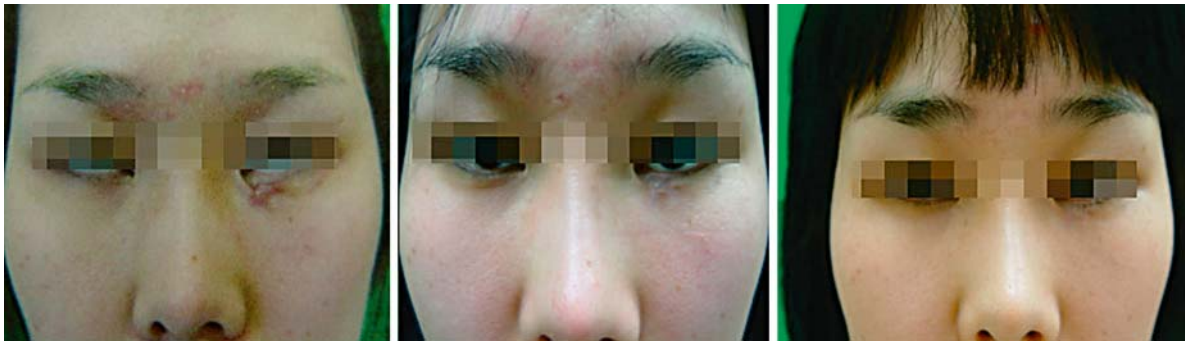


Fig. 6.9. *Left* Twenty-five-year-old female patient with traumatic ectropion in left lower eyelid 4 months previously. *Middle* One month later the treatment gel with laser act as a Silastic sheet dressing. *Right* Two months later treatment is functionally and cosmetically acceptable (1,600 LEDs, 50 – 96 J/cm^2, 80 mW/cm^2, three times a week for 2 months) [8]

shown that the lymph vessel diameter and the flow of the lymph system can be doubled with the use of light therapy. The venous diameter and the arterial diameters can also be increased. This means that both parts of edema (liquid and protein) can be evacuated at a much faster rate to relieve swelling. The increased RNA and DNA synthesis helps damaged cells to be replaced more promptly. The excitability of nervous tissue is reduced. The photons of light energy enter the body as negative ions. This calls upon the body to send positive ions such as calcium to go to the area being treated. These ions assist in firing the nerves, thereby relieving pain. Fibroblastic activity is stimulated which aids in the repair process. Fibroblasts are present in connective tissue and are capable of forming collagen fibers. Phagocytosis is increased, which is the process of scavenging for and ingesting dead or degenerated cells by phagocyte cells for the purpose of cleaning up. This is an important part of the infection fighting process. Destruction of the infection and cleaning up must occur before the healing process can take place. Tissue granulation and connective tissue projections are stimulated, which are part of the healing process of wounds, ulcers or inflamed tissue. Dedifferentiation and epithelization

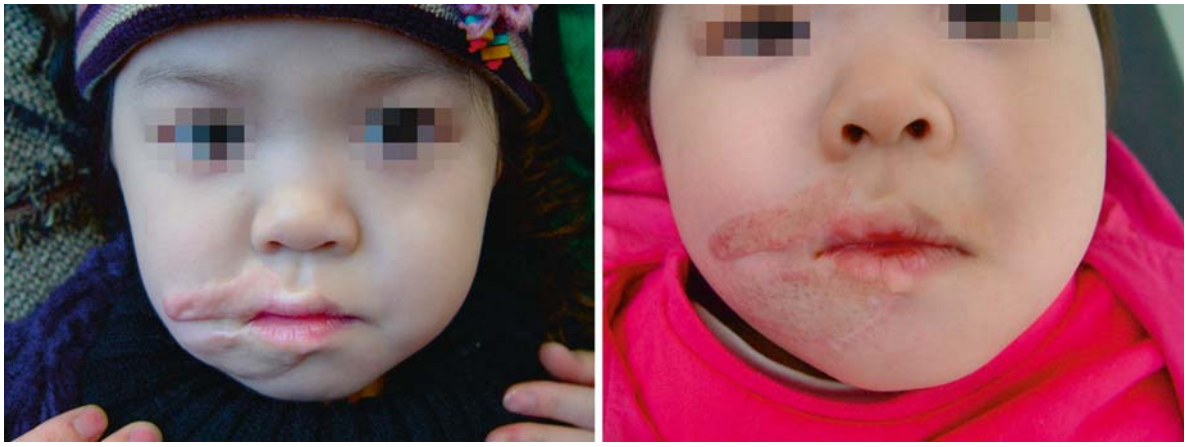


Fig. 6.10. *Left* Combination laser and light therapy modulation in a 4-year-old female patient; grafting had been done 2 years previously in another hospital. *Right* Markedly decreased hypertrophic scar on perioral area, 6 months after result. By aid of recent developed laser scanner, ultrasonography and optical CT and patient's symptom and sign, we can predict the prognosis of the wound. So prevention or reduced the incidence of hypertrophic scar and keloid by light & laser is possible now by modulation of each period of wound healing [9, 10]

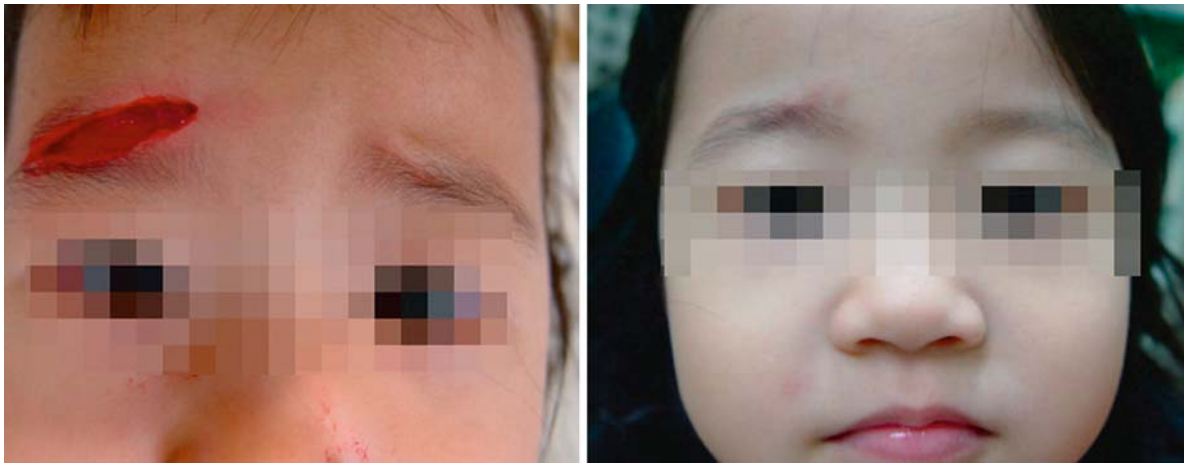


Fig. 6.11. Two-year-old female patient with deep muscle laceration on upper eyebrow after trauma. After secure repair of the tissue, LED and laser combination light therapy were performed for 2 months [8, 10]

are controlled, which prevent psoriasis, and normal keratinization function is controlled [1, 2].

6.7 Conclusions

The combination dressings described seem to have many advantages for Asian patients, who are more apt to have complications such as scarring, hyperpigmentation and hypopigmentation compared to Western patients. A combination of various kinds of laser or light sources and a wet hydrogel dressing is very effective in children and unmarried young women to reduce the donor site morbidity and operation risk. And in skin graft patients they provide a more natural skin color appearance as well as hair function and skin tonicity.

When humans sustain injury from heat, trauma, or infection, the body reacts quickly to overcome the injury, and healing mechanisms begin because from ancient times every creature evolved by the energy of light. Wound dressing transillumination is a good friend to the plastic surgeon and is still the modus vivendi for the photobiomodulation of the wound.

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Artificial Nerve Conduits and the Role of Autologous Hair Follicle Stem Cell Derived Schwann Cells for Repair of Large Peripheral Nerve Gaps

7

M.F. Meek, J.-P.A. Nicolai

7.1 Scientific Background

Peripheral nerve injury produces a cascade of cellular and humoral events especially at the distal extent of the nerve. The process involves several stages at which the distal portions of all affected axons degenerate. Complete nerve transections should be restored in order to restore nerve function. If tension on the suture line and gap formation is absent, nerve stumps can be repaired end-to-end. Short nerve gaps of up to a few centimetres can be bridged by resorbable nerve conduits (Fig. 7.1) [2–4].

Extended peripheral nerve defects, including facial paralysis (cross-face nerve grafts) and brachial plexus injuries, are routinely repaired using autologous nerve grafts (e.g. sural nerve) of more than 10 cm. Nerve grafts offer a microenvironment that provides the most appropriate facilitation of axonal regeneration. Schwann cells (SCs) in the nerve grafts are a source for nerve growth stimulatory and adhesion factors, thus promoting axonal recovery, guidance and remyelination. However, this technique can only be applied at the cost of a healthy nerve taken from the donor site. Other drawbacks include neuroma formation, sensory disturbances, scars and wound healing disturbances in the donor area. Only a limited number of donor nerves is available.

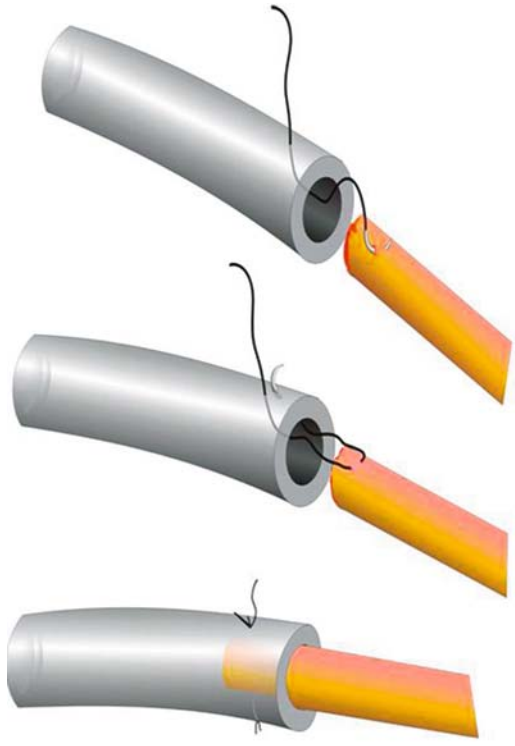

Fig. 7.1. Technique of nerve repair using a nerve conduit

With extended nerve defects, in the absence of Schwann cells, the distal nerve stump is unable to produce sufficient trophic factors to reach the proximal stump, and consequently nerve regeneration fails through nerve guides. Moreover, most guides also lack the support provided by the axonal basal lamina, which is crucial for successful regeneration. Therefore, large nerve defects are still bridged by autologous nerve grafts.

Large nerve gaps require additional axon growth-promoting factors. Nerve guides coated with exogenous Schwann cells, producing growth factors and appropriate adhesion factors, have been proposed as a promising option in bridging peripheral nerve gaps of

more than 3 cm. Creation of a favourable microenvironment for nerve regeneration is a must for this technique.

The yield of SCs from biopsies is generally low and is difficult to use for therapeutic purposes. Recent development in stem cell research, in particular the use of pluripotent stem cells, has provided promising alternative, accessible, and autologous sources for SCs. Here we describe a new source for functional autologous SCs: hair follicle stem cells. Furthermore, the use of a new and high-tech evaluation method for the viability of the stem cell coated nerve guides in intact living animals, bioluminescence imaging, is presented.

7.2 Schwann Cells and Nerve Injury

In a healthy peripheral nerve, SCs form the myelin insulation around the axons, which is crucial for the rapid, saltatory transduction of action potentials. The main tasks of adult SCs are the maintenance of the myelin sheath and the proper functioning of the ensheathed axon by the expression of neurotrophic factors [e.g. ciliary neurotrophic factor (CNTF) and neurotrophin-3 (NT-3)]. SCs produce a dramatic response following a peripheral nerve injury, aimed at cleaning up axonal and myelin debris and restoring axonal connections. The SCs transform into an immature precursor-type cell and stop the production of myelin components. Instead, they start to synthesise various cytokines [e.g. interleukin (IL)-1β, IL-6 and IL-8] and chemokines [monocyte chemoattractant protein-1 (MCP-1), macrophage inflammatory protein-1α (MIP-1α)], inducing macrophage migration and activation. After debris has been removed, SCs provide optimal conditions for axonal regrowth. By rapid proliferation, they form a framework along which axons can regrow. Moreover, they start to produce adhesion factors [neural cell adhesion molecules (N-CAM, NgCAM/L1), N-cadherin, L2/HNK-1] and extracellular matrix components (laminin, fibronectin, HSP, tenascin), creating an optimal substrate for axonal growth cone activity. They also express a number of neurotrophic factors [e.g. nerve growth factor (NGF), brain-derived neurotrophic factor (BDNF) and glial cell-line-derived neurotrophic factor (GDNF)] which exert a retrograde supportive effect on the injured neurones and so, indirectly, enable growth cone activity. Subsequently, de novo axonal contact with SCs induces myelin formation, contributes to the generation of nodes of Ranvier and mediates revascularisation. Finally, the SCs switch again into their quiescent state, maintaining axonal function and proper myelin conditions.

The properties of SCs make them useful in approaches to repairing extended peripheral nerve gaps. For such an approach an abundant, accessible source of SCs is required. Obviously, to prevent graft-versus-host reactions, these SCs have to be autologous as the use of immunosuppressants in the treatment of peripheral nerve injury is considered to be deleterious and the cause of many side-effects. Primary autologous human SCs, however, are difficult to obtain and to expand to the numbers required for optimal coating of the nerve guides. The time required to culture appropriate numbers can amount to 10 weeks. Such a delay would be deleterious; the longer the time lag between injury and repair, the greater the extent of neuronal cell death and consequently the lower the growth potential of the injured axons. Recent progress in stem cell research, in particular the use of pluripotent stem cells, has provided promising alternative, autologous sources for SCs. Since SCs are neural crest-derived cells, hair follicles which have been shown to contain pluripotent neural crest stem cells must be considered as the most favourable accessible, autologous source for using these inside a long artificial nerve guide.

7.3 Differentiation of Hair Follicle Stem Cells into Mature Functional Schwann Cells

Hair growth is a unique, cyclic regeneration phenomenon and the hair follicle undergoes repeated cycles of growth, regression and rest throughout life. The follicle bulge region (Fig. 7.2a) contains true neural crest stem cells, giving rise to a great number of different cell types. Sieber-Blum et al. have shown their in vitro differentiation into neurons, smooth muscle cells, melanocytes and SCs [5, 6]. Furthermore, when adding specific (combinations of) morphogenetic signals and differentiation-induction factors [e.g. bone morphogenetic protein-2 (BMP-2), sonic hedgehog (Shh), fibroblast growth factor (FGF)] the differentiation direction can be manipulated. Thus β-neuregulin-1, in combination with forskolin, appears to be a crucial factor in inducing selective differentiation of neural crest stem cells into SCs. Recently, Amoh et al. have confirmed the exciting potential of hair follicle stem cell-derived SCs for peripheral nerve repair [1]. However, they implanted hair follicle cells without in-vitro predifferentiation directly into a very small sciatic nerve gap, thus leaving the differentiation into SCs to unknown factors at the transplantation site. A few SCs did indeed differentiate and their beneficial effect on nerve repair could be demonstrated. Obviously this approach is not suitable for using nerve conduits filled with SCs from differentiation of hair follicle stem cells. In preliminary in-vitro experiments we have established the feasibility of culturing of neural crest stem cells of neonatal rat dorsal root ganglia and their in-vitro differentiation into functional SCs (Fig. 7.2).

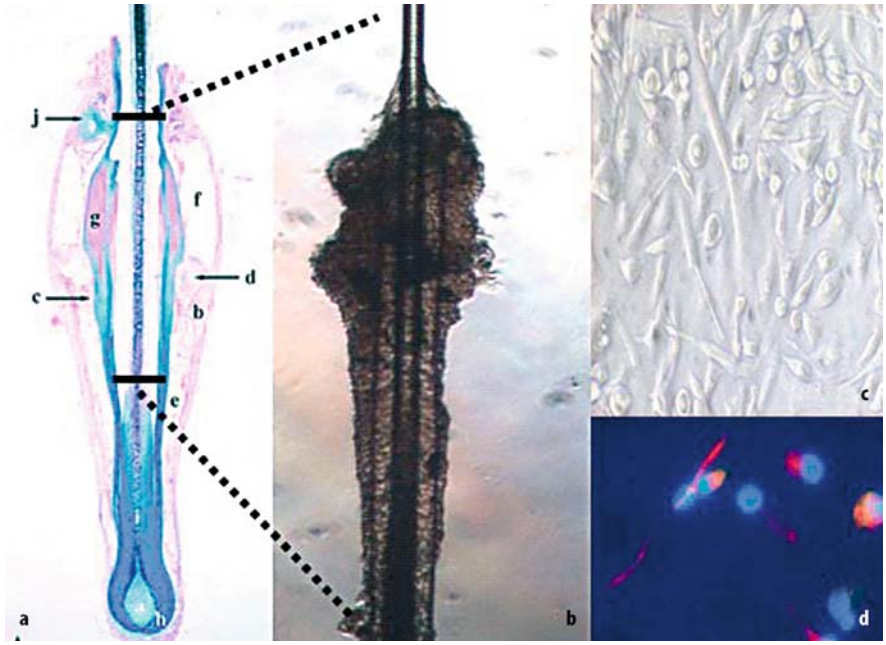

Fig. 7.2. a Histological section depicting a rat hair follicle; *g* indicates the bulge region with pluripotent neural crest stem cells. We have explanted this region (size 1 mm) as shown in **b**. **c** shows the neural crest stem cells after 7 days of culture of the bulge region and after migration, proliferation and spontaneous differentiation into various cell types. Among these cells, various developing Schwann cells can be detected by their immunostaining for Oct6 (*red*) in **d** (*blue* nuclear staining)

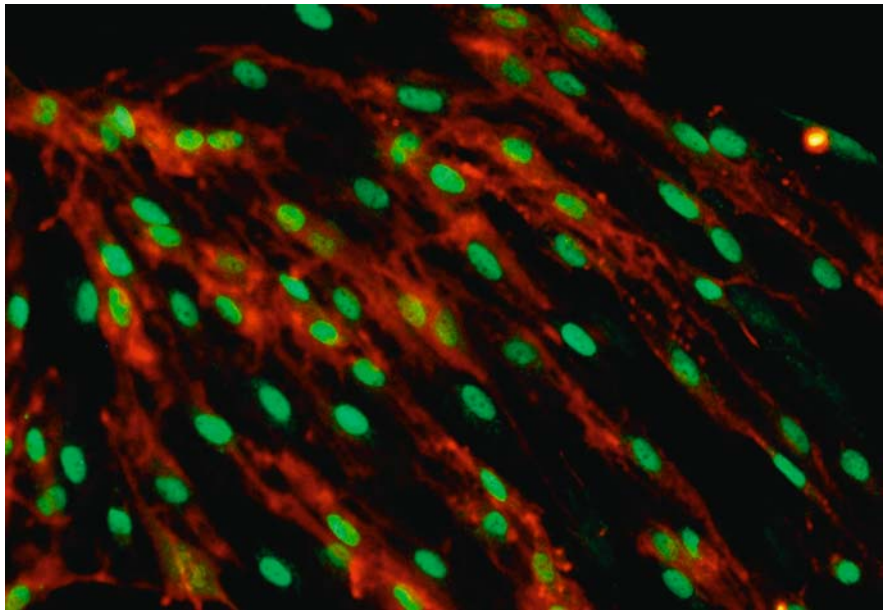

Fig. 7.3. An almost pure Schwann cell population is obtained after differentiating DRG neural crest stem cells in medium containing neuregulin-1 and forskolin; Schwann cells are immunostained for p75 (*red*) and Oct6 (*green*), the transcription factor located in the nucleus

Currently, we are applying the same culturing procedure with rat hair follicle cells. It is now possible to isolate hair follicle stem cells and multiply and pre-differentiate them in vitro towards SCs at the inner side of nerve guides before implantation. The pluripotent neural crest stem cells in the hair follicle are located in the bulge area of the hair follicle structure (indicated by "g" in Fig. 7.2). Selective differentiation towards SCs of neural crest stem cells can be induced in medium containing neuregulin-1 (10 nM) in combination with raising the intracellular cAMP levels, for instance with forskolin (Fig. 7.3).

For the recognition of the various cell types before and after differentiation of rat hair follicle stem cells, different antibodies were used in immunohistochemical staining procedures directed against glial fibrillary acidic protein (GFAP), S100, p75, Oct6, Sox1&2, and nestin, among others. Since the p75 receptor is a main characteristic of cultured mature SCs, the presence of this receptor is used for cell sorting purposes using the magnetic-activated cell sorting (MACS) technology, and a pure population of differentiated SCs is obtained. Besides immunohistochemistry, polymerase chain reaction (PCR) and Western blot are used to further cha-

racterise and identify the neural crest stem cell derived Schwann cells by checking their expression of NGF, BDNF and GDNF, various chemokines (MCP-1, MIP-1α), cytokines (IL-1β, IL-6 and IL-8) and adhesion factors (N-CAM, NgCAM/L1, N-cadherin, L2/HNK-1, laminin) besides the above mentioned protein markers such as S100, GFAP, and Oct6.

7.4 Nerve Conduits Coated with Stem Cell Derived Schwann Cells: Evaluation of Nerve Function and Longitudinal Monitoring Survival and Axonal Growth Promoting Capacity After Transplantation

In previous in vitro experiments we have shown that SCs require a coating of laminin and fibronectin on a (polymer) surface for proper adhesion, growth and differentiation (Fig. 7.4).

In further studies we intend to apply long resorbable nerve guides in peripheral nerve gaps in the rat. These nerve guides are coated with extracellular matrix proteins. Mature functional SCs, after differentiation from hair follicle stem cells, are sown onto the coating. In order to obtain a sufficient postoperative assessment the following are of importance:

- Evaluation of nerve regrowth from the proximal nerve stump
- Presence and viability of mature SCs
- Proliferation of the SCs
- Influence of the foreign body reaction and of the nerve guide's degradation on the quality of SCs
- Determination of motor and sensory nerve function

One of the major challenges in clinical application of stem cells in peripheral nerve repair is to obtain confirmation of the long-term survival, the proper location, the maintenance of the differentiated state (i.e. no de-differentiation with possibly subsequent proliferation leading to tumor formation) and the proper functioning of the stem cell-derived SCs.

Thus far, in experimental animals, we followed the fate of implanted SCs by extensive histological analyses in relatively large numbers of laboratory animals. Further detailed studies would require the use of considerably more animals. We have therefore developed an alternative approach for longitudinal monitoring of the survival and functionality of (stem cell derived) SCs by using a noninvasive bioluminescence imaging technique.

7.5 Bioluminescence Imaging to Determine the Viability of Stem Cell Coated Nerve Guides in Intact Living Rats

Bioluminescence imaging enables the detection of luciferase-positive cells in intact animals. The hair follicle-derived SCs can be stably transfected using a lentiviral vector with a gene encoding for the firefly luciferase (*LUC*) gene. Because bioluminescence imaging has minimal background activity, this technology is very sensitive for the detection of photons emitted from luciferases. Stem-cell derived luciferase imaging of implanted LUC-neural stem cells can be performed using a bioluminescence imaging device in anaesthetised animals, 5 – 20 min after intraperitoneal injection with D-luciferin. Image acquisition and analysis is performed using special software.

Gene constructs in which the *LUC* gene is coupled to promoters of genes encoding proteins present in functional SCs, including NGF, MIP-1α, N-CAM and laminin, are used. Preliminary experiments with a resorbable nerve guide coated with a few SCs transient-

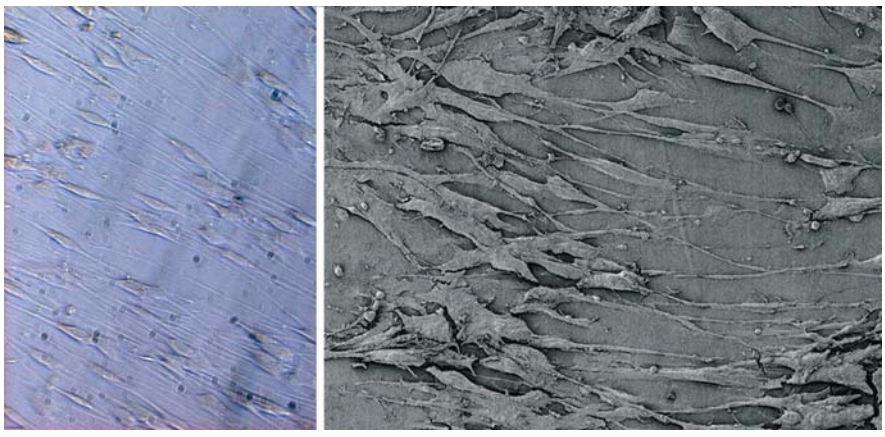

Fig. 7.4. Phase contrast microscopy (*left*) and scanning electron microscopy (*right*) pictures show the perfect coating and lining of a biodegradable nerve conduit with pure Schwann cells after plating these cells in the tubes in culture

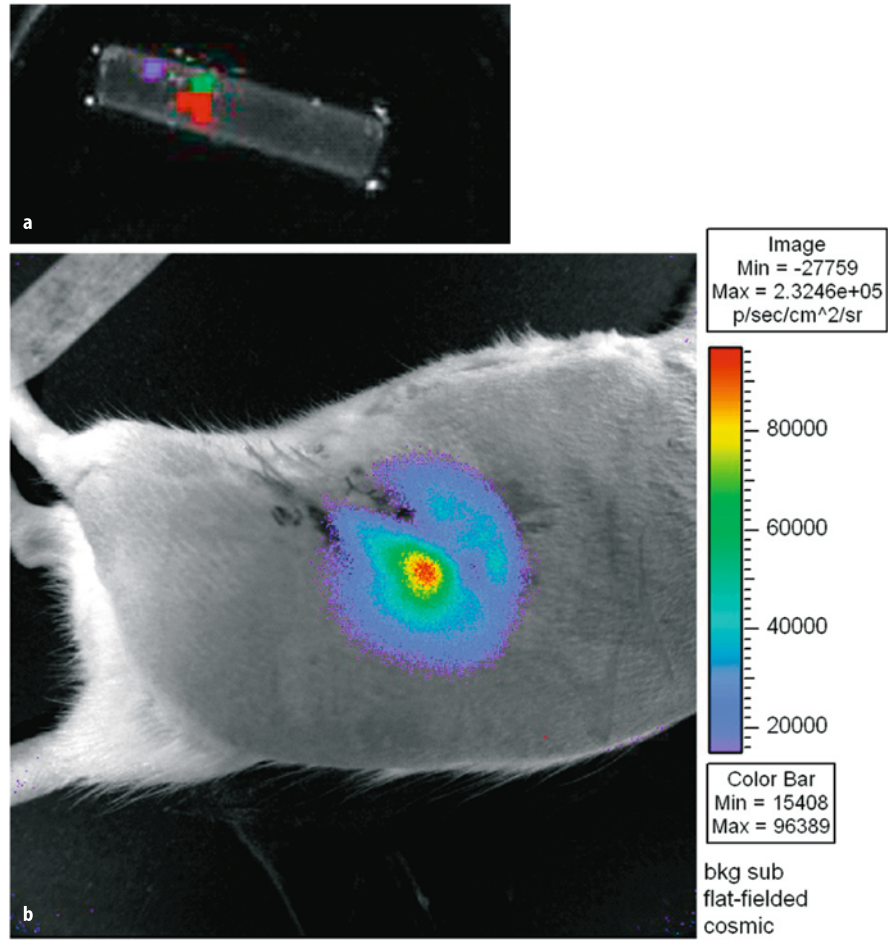

Fig. 7.5. IVIS imaging system 100 recording of a biodegradable nerve guide with several luciferase-labeled Schwann cells (**a**), and a transcutaneous bioluminescent image of the conduit after implantation (**b**). Two millilitres luciferin 15 mg/ml in 0.9 % NaCl was injected subcutaneously and 2 ml was injected intraperitoneally. After 1 h a second time 2 ml was injected i.p. The intensity of emitted light is represented as a pseudocolour ranging from *violet* (least intense) to *red* (most intense)

ly expressing luciferase (gene transfection shows the feasibility of our approach; Fig. 7.5) prove that this is feasible without sacrificing the animals.

7.6 Conclusions

Implantation of SCs for nerve repair has been used by several researchers. Clinically this procedure is difficult to apply because healthy nerves have to be sacrificed. Furthermore, the time required to culture a sufficient number of cells exceeds the time frame of successful surgery. The use of SCs derived from pluripotent stem cells from hair follicles is innovative.

Also the technology for monitoring stem cells longitudinally is novel. Bioluminescence imaging enables the detection of luciferase-positive cells in living animals. Using Schwann cell-specific luciferase reporter constructs, it is possible to monitor SC physiology in live animals. This technique will strongly reduce the number of experimental animals required for in vivo evaluation of the stem cell-coated nerve guides.

In conclusion, autologous Schwann cells derived from hair follicle stem cells can be sown as coatings inside artificial nerve conduits, which can then bridge large peripheral nerve gaps. Longitudinal monitoring using bioluminescence imaging reduces the necessary number of laboratory animals. These are promising and innovative techniques which are expected to change peripheral nerve surgery fundamentally in the near future, both experimentally and clinically.

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Therapeutic Healing of Radiolesions by Autologous Lipoaspirate Transplant: A Process Mediated by Adipose-Derived Adult Stem Cells

8

G. Rigotti, A. Marchi, M. Galiè, G. Baroni, D. Benati, M. Krampera, A. Pasini, A. Sbarbati

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8.1 Introduction

An increasing amount of clinical evidence strongly supports the therapeutic potential of mesenchymal stem cells for ischemic tissue revascularization and restoration of function. Significant clinical results have been obtained by autologous transplantation of bone marrow-derived endothelial and hematopoietic stem cells in ischemic lesions in limbs [1].

Myocardium [2] and retina [3] have been supported by in vitro studies and in animals, providing elucidation on stem cell-mediated mechanisms underlying neoangiogenesis. These appear to be based on the release of angiogenetic and antiapoptotic growth factors, which ultimately facilitates the recruitment of endothelial progenitor cells into newly sprouting vessels [4]. Recent studies have demonstrated that the stromal-vascular cell fraction of adipose tissue represents a rich reservoir of regenerative precursor cells with proangiogenic capabilities comparable to those of bone marrow-derived stem cells [5 – 7]. In mice, adipose stromal cells have been proven to secrete angiogenic and antiapoptotic factors [8], to differentiate into endothelial cells and to incorporate into vessels [9], thus promoting neovascularization in ischemic tissues.

We tested the therapeutic potential of adipose-derived adult stem cells within the framework of a clinical pilot study focused on the treatment of irradiation-induced lesions. These are well-known side effects of external oncologic radiation therapy, which affect irradiated healthy tissues and exhibit a several-year progression in a sort of self-maintaining pathologic condition [10]. The most frequent presentation is radiodermatitis with erythema, desquamation, and edema, which evolve over time in subcutaneous fibrosis and, in the most critical cases, toward radionecrosis. Hypotheses on the cause of radiolesions focused on vessel hyperpermeability and altered blood flow [11] were confirmed in this work by ultrastructural analysis, which revealed clear signs of ischemia, with capillary vessels reduced in number and exhibiting duplication of the basal membrane, ectatic lumen, and cytoplasmic activation of endothelial cells.

The chronic ischemic status of the irradiated tissue represented the rationale for the applicability of adi-

pose-derived adult stem cell therapy, which was based on computer-assisted transplant of purified autologous lipoaspirates. In vitro establishment and cytofluorimetric analysis were used to assess a priori presence and density of mesenchymal stem cell fraction in the transplanted tissue and to evaluate their differentiation potentialities. Ultrastructural analysis enlightened adipose-derived adult stem cell-mediated mechanisms of tissue neovascularization and regeneration during patient follow-up, in support of the observed and objectively assessed long-term clinical improvements.

8.2 Patients and Methods

8.2.1 Study Population

At the II Division of Plastic and Reconstructive Surgery, Ospedale Civile Maggiore (Verona, Italy), patients suffering from progressive lesions after radiation therapy are screened and objectively assessed according to the LENT-SOMA scale [12, 13]. Starting in 2002, the therapeutic option based on autologous transplantation of purified lipoaspirate was explained to all patients, none of whom had a medical history of connective, metabolic, or skin disease. Until now, a total of 207 patients have given their informed consent and have been treated accordingly. Among this patient population, the first 20 consecutive patients with LENT-SOMA grade 3 (severe symptoms) or grade 4 (irreversible functional damage) were selected for this specific pilot study, which required ultrastructural and cytofluorimetric characterization of the lipoaspirate and repeated ultrastructural analysis of tissue samples from the treated area during patient follow-up. The rationale and aims of these additional procedures were clearly explained, and all patients gave their informed consent. The mean age of this patient subgroup was 50.9 years, ranging from 37 to 71 years. Targeted areas included the supraclavicular region, the anterior chest wall after mastectomy with or without breast prosthesis [14], and breast after quadrantectomy. Patients had undergone radiotherapy treatment with a prescribed total dose ranging from 45 and 55 Gy administered in 20 – 25 irradiations (2.00 – 2.25 Gy per session). The prescribed radiation dose for breast cancer patients ranged between 45 and 55 Gy and was administered in 20 – 25 sessions delivering 2.00 – 2.25 Gy each. The supraclavicular area received 40 Gy, administered in 20 sessions of 2.0 Gy. Table 8.1 gives the patient classification based on objective clinical evaluation of the severity of symptoms caused by radiolesions.

8.2.2 Surgical Technique and Tissue Purification Protocol

The areas eligible to be adipose tissue donor sites were the medial area of the knee, the abdominal region, and the trochanteric region. The selected region was infiltrated with a cold saline solution with the addition of 15 cc of adrenaline and 20 – 30 cc of 0.5 % lidocaine per 500 cc. Adipose tissue was removed using a 2-mm-diameter cannula and a 2-cc syringe. The lipoaspirate purification procedure was designed to remove a large part of the triglyceride stored in the tissue and to cause

Number of patients	LENT-SOMA grade	Area involved	Symptoms	Notes
4	4	Chest wall (mastectomy), no prosthetic implant	Fibrosis, atrophy, retraction, ulcers, teleangiectasia	Osteoradionecrotic rib exposure (one case)
4	4	Chest wall (mastectomy) with prosthetic implant	Fibrosis, atrophy, retraction, ulcers with implant exposure	Extended teleangiectasia ($< 4\ cm^2$) (one case)
2	4	Breast (quadrantectomy)	Fibrosis, atrophy, retraction, ulcers	
1	4	Supraclavicular region	Fibrosis, atrophy, retraction, teleangiectasia, itching, hypersensitivity	
4	3	Chest wall (mastectomy), no prosthetic implant	Fibrosis, atrophy, retraction	Pain (grade 3)
4	3	Chest wall (mastectomy) with prosthetic implant	Fibrosis, atrophy, retraction	Teleangiectasia (grade 2)
1	3	Breast (quadrantectomy)	Fibrosis, atrophy, retraction	

Table 8.1. Summary of patient clinical assessment before treatment

lesion in the thin cytoplasmic sheets of the mature adipocytes, as a way to favor their rapid clearance after injection. Purification was obtained by centrifuging the syringes (IEC Medispin-6) at 2,700 rpm for 15 min to separate the tissue from its water content and from the oil produced by the destruction of damaged adipocytes. The layer of oil and residual liquid was discarded. The lack of cell culture ensured the reduction of the risk of microorganism contamination. In addition, stem cells were not isolated but maintained in their natural three-dimensional scaffold, which was described to favor the reconstruction of a microvascular bed [15]. The number of cell therapy fractions was established as a function of the initial clinical picture. Radiation injuries had been present within a time span ranging from 1 to 30 years (median ± quartile, 4.5±8). The number of procedures was one in five patients, two in eight patients, three in six patients, and six in one patient. The average quantity of injected purified lipoaspirate varied between 60 and 80 cc at each fraction. All patients underwent the routine surgical and pharmacologic procedures designed for necrotic ulcers. Clinical results after treatment with lipoaspirates were assessed by means of LENT-SOMA scoring. The nonparametric *t*-test equivalent sign test for dependent samples was applied for statistical evaluation.

8.2.3 In Vitro Characterization of Adipose-Derived Adult Stem Cells

8.2.3.1 Isolation of Stromal-Vascular Fraction

To assess the presence of mesenchymal stem cells in human lipoaspirates and to evaluate their multilineage properties, we cultured and characterized by flow cytometry the stromal-vascular fraction derived from adipose tissue. The harvesting was performed on the first five patients. Consistent results suggested that we avoid continuing the cytofluorimetric characterization on the entire patient population. According to the current methodologies, the isolation of the stromal-vascular fraction was performed on 40 cc of lipoaspirates, which were extensively washed with sterile Hank's balanced salt solution. Extracellular matrix was digested at 37 °C in Hank's balanced salt solution with 1 mg/ml collagenase type I and 2 % bovine serum albumin. After incubation, digestion enzyme activity was neutralized with Dulbecco's modified Eagle's medium (DMEM) containing 10 % fetal bovine serum and centrifuged at 1,200 *g* for 10 min to obtain high-density stromal-vascular fraction pellets. This was then resuspended in 160 mM ammonium chloride and incubated at room temperature for 10 min to lyse contaminating red blood cells. The stromal-vascular fraction was collected by centrifugation and filtered through a 70-μm nylon mesh to remove cell debris.

8.2.4 Mesenchymal Stem Cell Expansion

Stromal-vascular fractions were cultured in 25-cc flasks (BD Falcon; Becton Dickinson, Milan, Italy) at a concentration of 1×10^5 cells/cm^2 using DMEM with high glucose concentration, GLUTAMAX I, 15 % heat-inactivated fetal calf serum, 100 U/ml penicillin, and 100 μg/ml streptomycin (all from Gibco BRL/Life Technologies, Milan, Italy). Cultures were incubated at 37 °C in a 5 % carbon dioxide atmosphere. After 72 h, nonadherent cells were removed. When 70 – 80 % confluent, adherent cells were trypsinized (0.05 % trypsin at 37 °C for 5 min; Gibco BRL/Life Technologies), harvested and washed with medium to remove trypsin, and expanded in larger flasks. A homogeneous cell population was obtained after 2 – 3 weeks of culture.

8.2.5 Clonogenic Assay

Colony-forming units–fibroblast (CFU-F) assay was used to evaluate the frequency of mesenchymal stem cells in the stromal-vascular fraction, by culturing with the same medium 104 cells in a 10-cm Petri dish and then counting the number of fibroblastic colonies with more than 50 cells 10 days later.

8.2.6 Mesenchymal Stem Cell Immunophenotype

Mesenchymal stem cells were recognized by immunophenotype using monoclonal antibodies specific for CD105 (endoglin), CD73, CD106 (VCAM-1), CD29, CD44, and CD90. In addition, we assessed the lack of endothelial cell (with anti-CD31 antibodies) and hematopoietic (with anti-CD45, anti-CD14, anti-CD11c, and anti-CD34 antibodies) marker expression. All antibodies were purchased from Pharmingen/Becton Dikkinson (Milan, Italy). For immunophenotypic analysis, mesenchymal stem cells were detached using trypsin/ethylenediamine tetraacetic acid for 5 min, immediately washed with phosphate-buffered saline to remove trypsin, and resuspended at 106 cells/ml. One hundred microliters of cell suspension was incubated at 4 °C for 10 min with 15 % fetal calf serum, followed by incubation with the specific antibody at 4 °C for 30 min. Cells were washed with phosphate-buffered saline. At least 10,000 events were analyzed by flow cytometry (FACScalibur; Becton Dickinson) using Cell Quest software. In addition, the enumeration of CD105+ cells with mesenchymal stem cell physical properties (high fetal calf serum and saline sodium citrate values) was carried out in the collected stromal-vascular fraction to compare the results obtained by the CFU-F assay.

8.2.7
Mesenchymal Stem Cell Differentiation Assay

Mesenchymal stem cells were tested for their ability to differentiate into adipocytes, osteoblasts and chondrocytes, as previously described [16–18].

Adipocyte differentiation was achieved after 2 weeks' culture of mesenchymal stem cells with adipogenic medium, containing 10^{-6} M dexamethasone, 10 µg/ml insulin, and 100 µg/ml 3-isobutyl-1-methylxanthine (all from Sigma Immunochemicals, Milan, Italy). Osteoblast differentiation was achieved after 2 weeks' culture with osteogenic medium containing 10^{-7} M dexamethasone, 50 µg/ml ascorbic acid, and 10 mM β-glycerophosphate (Sigma Immunochemicals). Chondrocyte differentiation was achieved after 2 weeks' culture with chondrogenic medium containing 10^{-7} M dexamethasone and 10 ng/ml transforming growth factor-β (Sigma Immunochemicals). Oil Red O, von Kossa, and toluidine blue dyes were used to identify adipocytes, osteoblasts, and chondrocytes, respectively. More than 90% of the cells differentiated, depending on the time left in culture with the differentiating agent. Four different trials of mesenchymal stem cell differentiation were performed. Results are reported as mean ± SD.

8.2.8
Computerized Model for Injection

The adipose tissue was implanted in single tunnels using an injection cannula 1 mm in diameter. Entry points and direction of tissue injection tunnels were planned on the computer by means of a multidimensional, unconstrained, nonlinear minimization [19] based on multiple two-dimensional representations of the patient-specific area of intervention. The goal was to provide the surgeon with an interactive intraoperative guidance, to achieve maximum uniformity of distribution and to limit significant overlaps and gaps in tissue deposition. The starting point is represented by the acquisition of a set of photographs of the patient by means of a calibrated digital camera. On the most representative images (typically frontal and sagittal planes), the numbers and initial position of entry points and tunnels, and peak angular values of feasible insertion pathways and possible inaccessible or untreatable areas are manually defined and represent the boundaries of the optimization procedure. The iterative algorithm was based on a constrained objective function designed to minimize dimension and variability of the areas generated by the intersection of tissue deposition pathways associated with each set of entry points and tunnel directions. The optimization procedure takes a few seconds (depending on the number of entry points) to produce as output a composite representation of the optimized entry point position and direction of insertion pathways, superimposed onto the selected patient images. This is used for intraoperative guidance by the surgeon for the highest uniformity of adipose tissue deposition under the predefined set of boundaries.

8.2.9
Ultrastructural Study

For transmission electron microscopy, the specimens were fixed in 2.5% glutaraldehyde, postfixed in 1% osmium tetroxide, dehydrated, and embedded in Epon-Araldite. Ultrathin sections were stained with lead citrate and observed under an EM10 electron microscope (Zeiss, Oberkochen, Germany). Ultrastructural analyses were performed on purified lipoaspirates after centrifugation as above to describe the outcomes of the purification procedure and detail the cellular state of the transplanted medium, and on radiodamaged subcutaneous tissue of all patients before and after cell therapy. After treatment, ultrastructural examinations were carried out 1, 2, 4–6, and 12 months after the last surgical procedure; four patients had their last analysis after 18 months and one after 31 months.

8.3
Results

8.3.1
Purified Lipoaspirate Ultrastructural Characterization

For all lipoaspirate undergoing ultrastructural analysis, structurally normal adipose tissue was found. However, adipocytes showed interruptions of the cytoplasmic membrane and exhibited various degees of degeneration ranging up to cellular necrosis. Well-preserved adipocytes were so rare as to be virtually absent. In contrast, the stromal-vascular cell fraction (Fig. 8.1) appeared to be well preserved, with minimal loss.

8.3.2
Purified Lipoaspirate Cytologic Characterization

The immunophenotype of adipose tissue-derived and in vitro-expanded mesenchymal stem cells corresponded to that of bone marrow-derived mesenchymal stem cells [16–18], as they were positive for surface CD105, CD73, CD29, CD44, and CD90, with the exception of CD106, which was not expressed; similarly, they were negative for hemopoietic (CD45, CD14,and CD34) and endothelial markers (CD31) (Fig. 8.2, above and center). They showed multilineage differentiation potential into adipocytes, osteocytes, and chondrocytes, as assessed by the specific staining (Fig. 8.2, below). CD105+ cells with mesenchymal stem cell physical

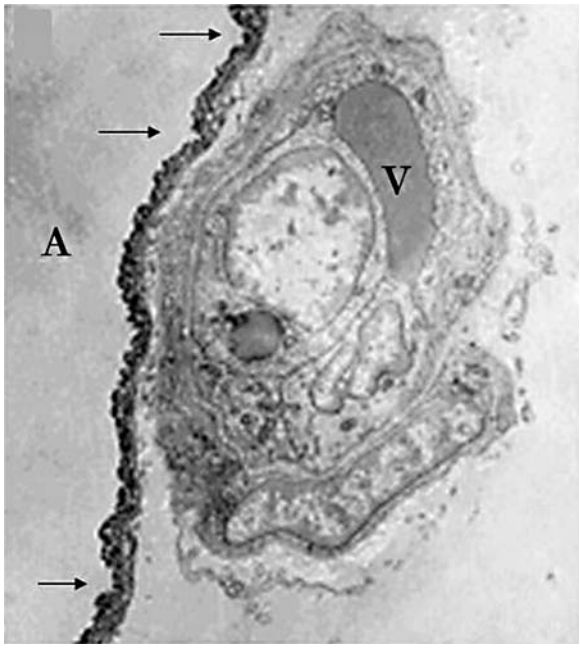

Fig. 8.1. Ultrastructural analysis revealed a well-preserved stromal-vascular component of purified lipoaspirate (original magnification, ×4,000) (*V* vessel, *A* adipocyte). Adipocyte shows signs of cytoplasmic alterations (*arrows*)

properties (high fetal calf serum and saline sodium citrate values) in the stromal-vascular fraction cell suspension ($7.4\pm3.6\times10^5$ cells/lipoaspirate; range $3.86–11.1\times10^5$) were $1.07\pm0.5\%$ ($n=4$). However, CFU-F number at 10 days was $13.9\times4.3/10^4$ cells (0.139%), thus suggesting that not all the CD105+ cells in the stromal-vascular fraction are clonogenic, and that at least 1.02×10^3 CFU-F could be obtained with a single lipoaspirate.

8.3.3 Clinical Results

Generalized dramatic improvement of symptoms was observed in all the patients (except one) belonging to

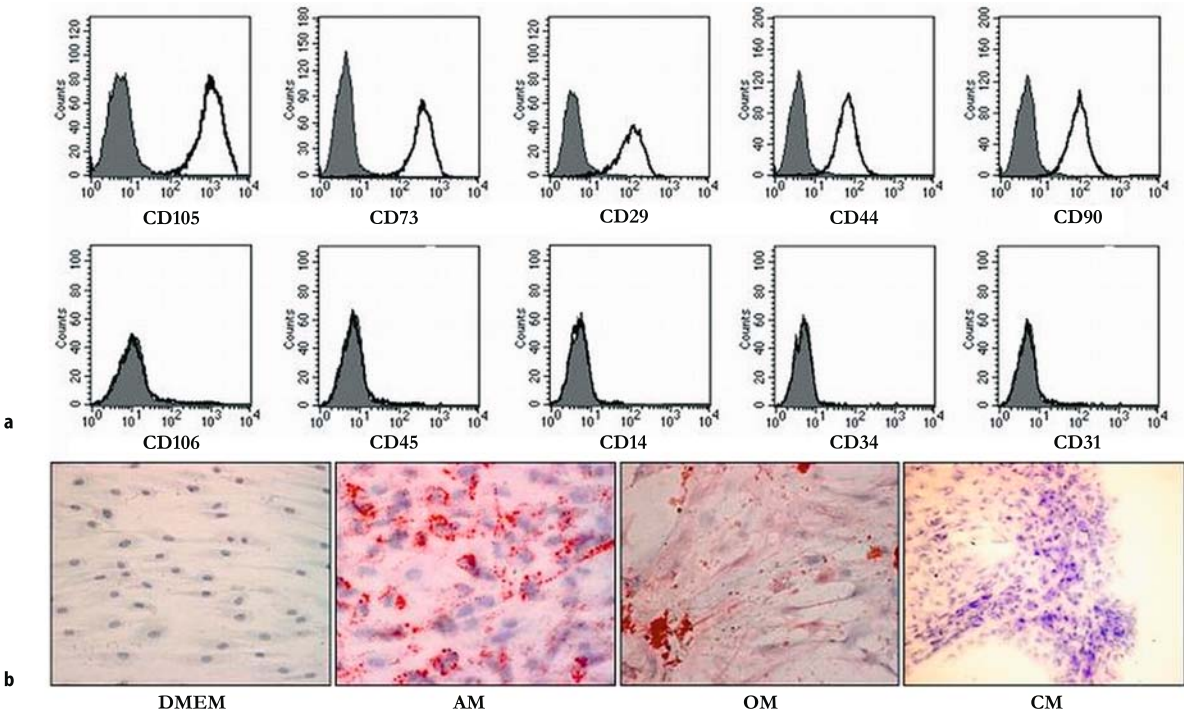

Fig. 8.2. a Immunophenotype of adipose tissue-derived mesenchymal stem cells. In vitro-expanded mesenchymal stem cells were analyzed by flow cytometry for the expression of CD105, CD73, CD29, CD44, CD90, CD106, CD45, CD14, CD34, and CD31 biomarkers. The graphs report the entity of positivity for each specific biomarker versus the frequency of positive cells. The *shaded curves* represent the negative controls and the *open curves* represent the stem cell sample. When the curves are overlapped, the sample is negative. The shifting of the open curve with respect to the control curve indicates positivity of the sample for the specific biomarker under consideration. **b** Multilineage differentiation potential of adipose tissue-derived mesenchymal stem cells. As detailed in the "Patients and Methods" section, mesenchymal stem cells were cultured for 2 weeks with simple medium (DMEM) or with adipogenic, osteogenic, and chondrogenic medium, and then the cells were stained with Oil Red O, von Kossa, and toluidine blue dyes, respectively. In adipogenic medium, adipogenesis was indicated by the accumulation of neutral lipid vacuoles that stain with Oil Red O. In chondrogenic medium, chondrogenesis was indicated by the deposition of sulfated proteoglycan-rich matrix that stained with toluidine blue. In osteogenic medium, osteogenesis was indicated by von Kossa staining of extracellular matrix calcification

the initial examined population (20 patients) (Table 8.2), with a statistically significant decrease of LENT-SOMA scores before and after cell therapy ($Z(19) = 4.13$, $p < 10^{-5}$). The clinical follow-up varied between 18 and 33 months (mean follow-up 30 months). The 11 patients initially classified as LENT-SOMA grade 4 (irreversible functional damage) progressed to grade 0 (no symptoms), grade 1, and grade 2 in four, five, and one cases, respectively; in one case, no improvements were observed. In the four mastectomized patients carrying breast prostheses and exhibiting initial areas of skin necrosis, necrosis showed complete remission. Remaining wounds were sutured at the same time of lipoaspirate injection and healed, allowing prosthesis conservation in two cases. In one case, the wound healed only with two injections without any suture. In the latest case, the severity of the initial clinical picture did not allow conservation of the implant. In the grade 4 patient without a breast implant who was suffering from a 10×15-cm ulceration in the chest region, osteoradionecrosis, exposure of the ribs, and grade 4 pain, the therapy supported the formation of an excellent granulation tissue, which was later covered by a skin graft (Fig. 8.3). The lack of recurrence of rib exposure, the stability of the skin graft with no complications, and the disappearance of pain after 2 years since the last lipoaspirate injection suggest that the osteoradionecrotic process is in remission. In the entire group of nine patients classified as LENT-SOMA grade 3, fibrosis, atrophy, and retraction progressed to grade 0 and grade 1 in five and four cases, respectively. In patients with telangiectasia and pain, complete healing and symptom remission was obtained (Table 8.2). Substantially equally striking clinical results were assessed on the overall 207-patient population, who underwent lipoaspirate transplant for the treatment of radiation induced lesions: Location of the treated lesion was not limited to the breast but generally included upper thorax (Fig. 8.4) and limbs.

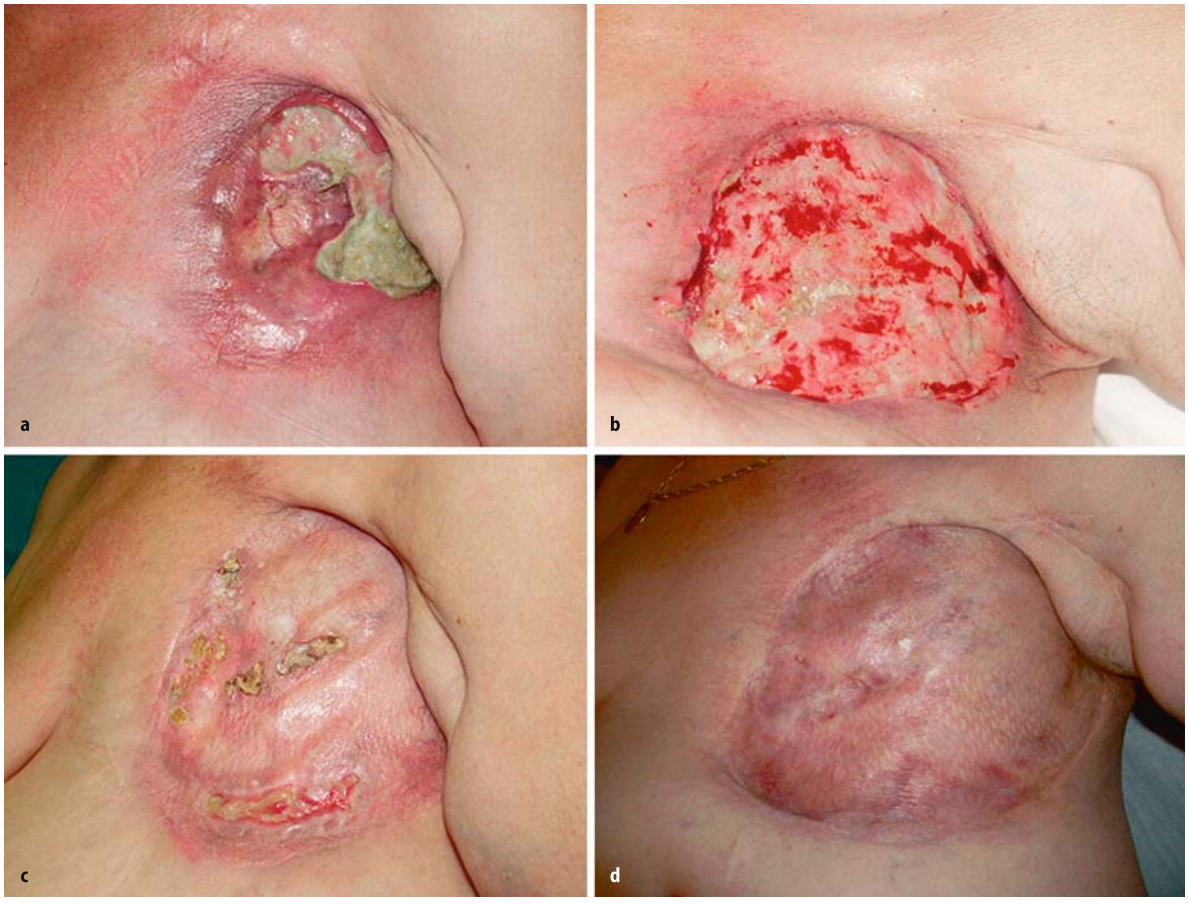

Fig. 8.3. a Grade 4 patient 2: ulcerative phase with osteoradionecrosis of the ribs. **b** First result after one treatment with adipose-derived adult stem cells showing good granulation tissue. **c** Result after skin grafting with three residual ulcers and osteoradionecrosis. **d** Note the healing of the residual ulcers and osteoradionecrosis after three more adipose-derived adult stem cell injections

Table 8.2. Summary of patient clinical assessment after cell therapy. Evaluation was performed within the follow-up time frame varying between 18 and 33 months after the last procedure

Number of patients	Pre-treatment LENT-SOMA grade	Area involved	Post-treatment LENT-SOMA grade	Post-treatment evaluation	Notes
7	4	Chest wall, breast (no breast prosthesis), supraclavicular	LS 0 1 pt. LS 1 5 pts. LS 2 1 pt.	Ulcers healed, no pain	Osteoradionecrosis (one case) in remission
4	4	Chest wall (with prosthetic implant)	LS 0 3 pts. LS 4 1 pt.	Ulcers healed; prosthetic implants conserved (Fig. 8.3)	Breast prosthesis extruded (one case)
9	3	Chest wall, breast	LS 0 5 pts. LS 1 4 pts.	Total remission of fibrosis atrophy and retraction	Teleangiectasia (one case) and pain (one case) remissed

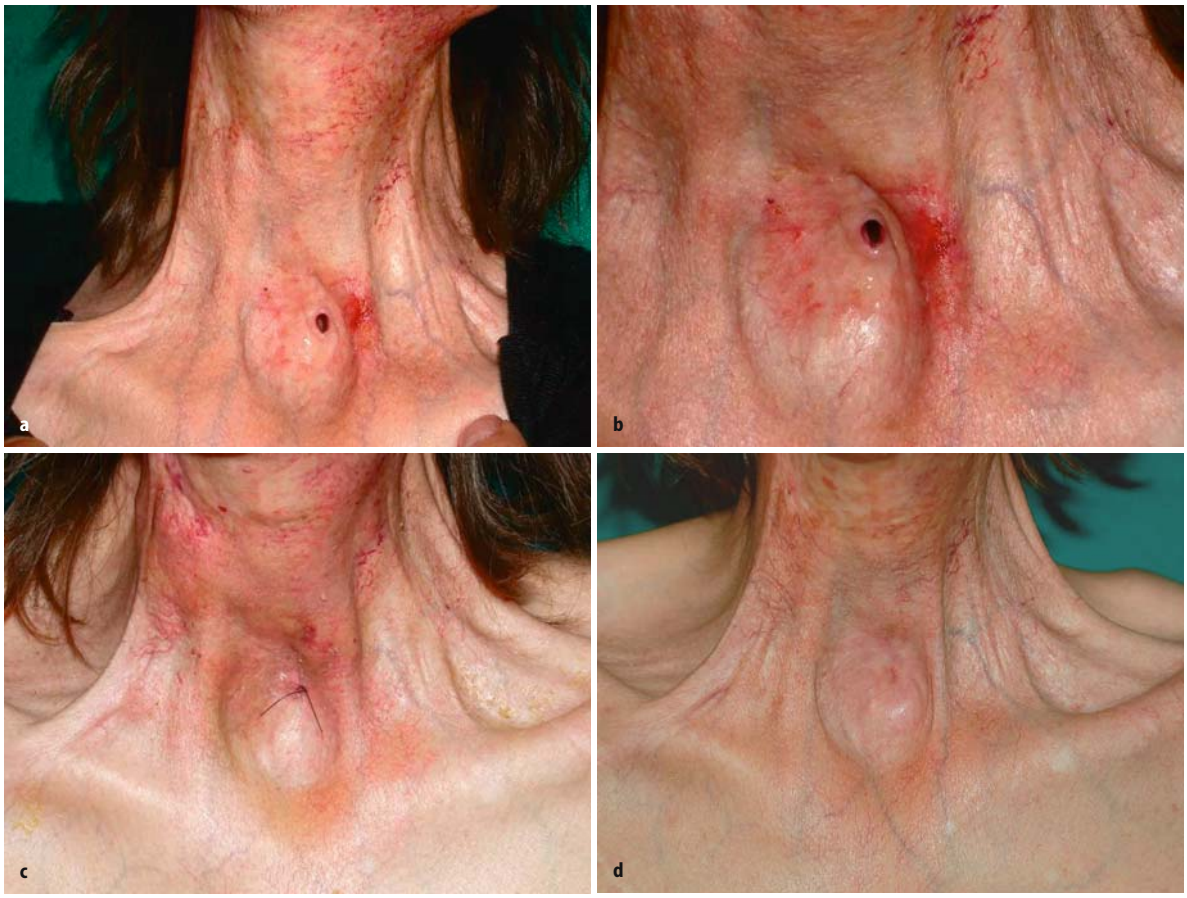

Fig. 8.4. a Patient treated with external radiotherapy for pharynx cancer (7 Gy administered) and suffering from pharynx-stoma as side effect (**b**). **c** After administration of lipoaspirates in two sessions with 3-month interval, the improvement of tissue conditions allowed the surgical closure of the lesion with simple stitching (**d**)

8.3.4 Ultrastructural Analyses

8.3.4.1 Before Treatment

An example of the fibrotic and microangiopathic initial aspect of radiodamaged tissue, which was systematically observed in all patients, is depicted in Fig. 8.5. The capillary vessels showed duplication of the basal membrane; their lumen was usually ectatic and the endothelial cells showed abundant cytoplasm, micropinocytotic vesicles, and numerous Weibel-Palade bodies. A space was often visible between endothelial cells and pericytes. The adipocytes showed lysosomes or clusters of mitochondria. In the connective tissue, collagen accumulation and cell debris were visible, composed of membrane with fragments of external lamina, thus suggesting an origin from disrupted adipocytes. This suggests an ischemic cause of radiolesions, with similar patterns of scleroderma.

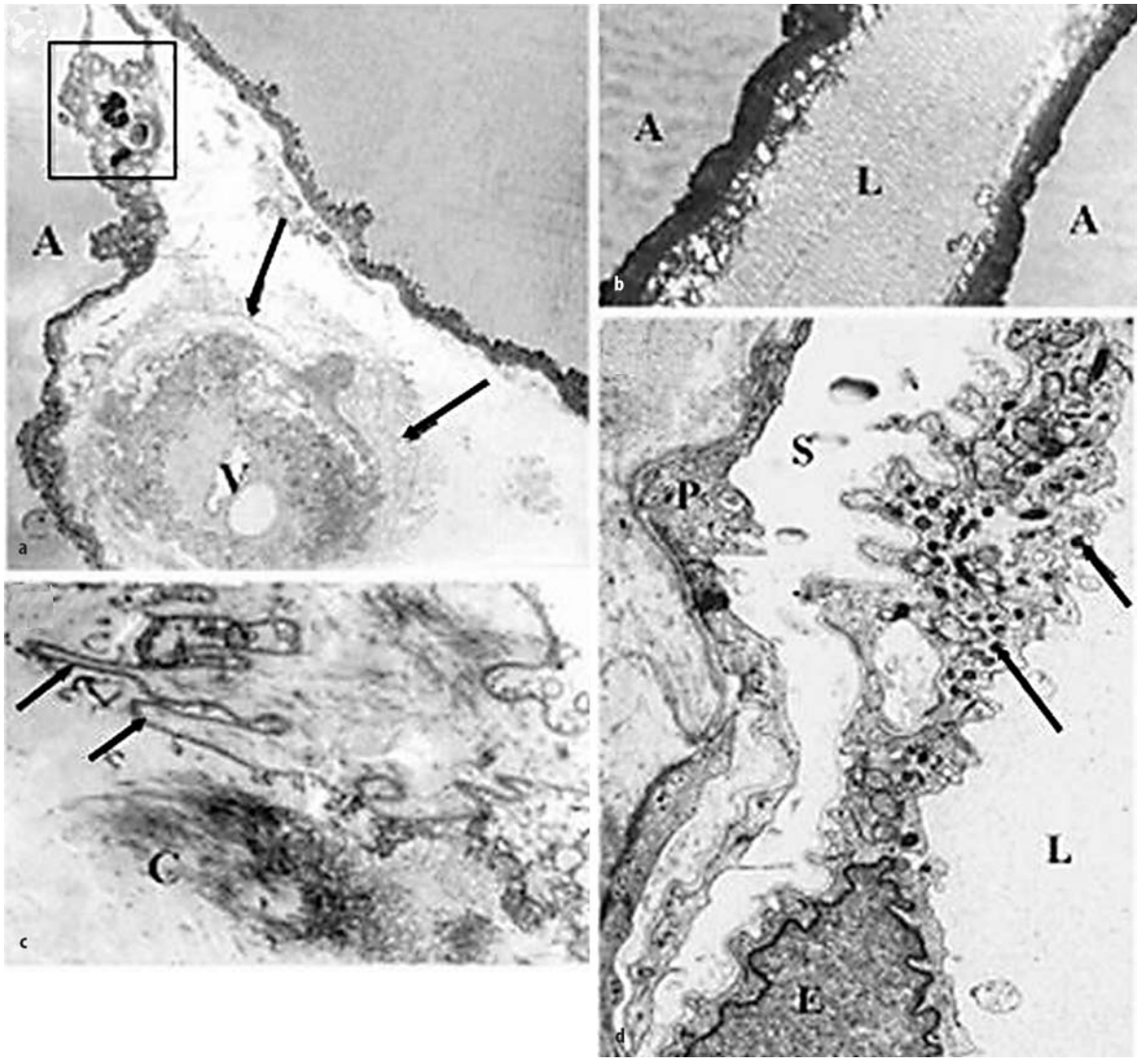

Fig. 8.5. Ultrastructure of subcutaneous tissue after irradiation. **a** A capillary vessel shows duplication of the basal lamina (*arrows*). An adipocyte shows lysosomes (*inset*) (original magnification, ×2,500) (*A* adipocytes, *V* vessels). **b** A thick layer of collagen is visible between two adipocytes (original magnification, ×5,000). **c** In the connective tissue, collagen accumulation and cell debris were visible, composed of membrane with fragments of external lamina (*arrows*) (original magnification, ×7,000). **d** An endothelial cell (*E*) shows numerous Weibel-Palade bodies (*arrows*). A space (*S*) was often visible between the endothelial cell and a pericyte (*P*) (original magnification, ×8,000)

8.3.4.2 One Month After Treatment

The subcutaneous tissue was of normal morphology and the adipocytes generally appeared well conserved (Fig. 8.6, left). An evident advanced process of injected material removal was observed, and isolated lipid droplets were found in the fibrous connective tissue, where removal is probably slower. Macrophages or lymphatic cells were occasionally found and tissue appeared well hydrated. The spaces between adipocytes were large and had little collagen. There were elements with the characteristics of maturing preadipocytes (i.e., elongated or rounded, relatively poorly differentiated cells, with an abundance of polyribosomes and lipid droplets), which were never observed in the radiodamaged tissue before cell therapy. The presence of a basal membrane proved that they belonged to the adipocyte line. Capillaries were observed and exhibited a lack of basal membrane reduplication and their normal appearance, in contrast to what was observed in irradiated areas before treatment (Fig. 8.5). The overall picture was characterized by signs of removal of the injected material along with signs of regeneration. Phenomena indicating regeneration were the maturation of stem cells into both adipocytes and vascular cells. The preadipocytes seemed more mature 1 month after treatment than the preadipocytes found in the tissue ready for injection. The pattern was suggestive of an old microcirculation, recognizable from lesions caused by radiotherapy, coexisting in the same tissue with a newly formed microcirculation.

8.3.4.3 Two Months After Treatment

The process of injected material removal was found to be well advanced, with an almost complete absence of cell debris (Fig. 8.6, above right). The tissue appeared hydrated, although areas of fibrosis were occasionally found. The spaces between adipocytes were large with little collagen. The adipocytes appeared well conserved. Blood vessels showed only occasional signs of hyperpermeability or reduplication of the basal membrane. The overall picture showed that regenerative phenomena were at an advanced stage, as shown by the presence of almost mature multilocular adipocytes, which testifies to their progress toward complete maturity. The absence of reduplicated blood vessels can be interpreted as a sign of a newly formed microcirculation.

8.3.4.4 Four to 6 Months After Treatment

The process of removal of injected material was almost finished. Very few cells were found in the connective tissue, which appeared well hydrated, with very little collagen. The adipocytes were normal. Maturing adipocytes were no longer evident. The microvessels exhibited a normal ultrastructure, with a very low percentage of vessels showing reduplication of the basal membrane. Areas of fibrosis were found in a single case. The tissue was well hydrated and the newly formed microcirculation showed no lesions.

8.3.4.5 One Year or More After Treatment

The picture was substantially unchanged, apart from a tendency toward shrinkage of the extracellular spaces. The adipocytes were large and the overall appearance was of mature adipose tissue with a well-formed microcirculation (Fig. 8.6, below right).

8.4 Discussion

We have shown here that the transplant of lipoaspirates containing adipose-derived adult stem cells is a highly effective therapeutic approach for the treatment of degenerative, chronic lesions induced as late effects by oncologic radiation treatments (Figs. 8.7 – 8.10). We have also provided evidence supporting the hypothesis that the reported clinical results could be associated with the observed signs of neovascularization of the targeted tissue, which initially exhibited microvascular alterations similar to several chronic ischemic diseases. The reported regenerative potential of autologous adipose tissue was related to the observed presence of multipotent mesenchymal stem cells, which have been recently reported to secrete multiple potentially synergistic proangiogenic growth factors [8] and, despite the loss of CD34 after long-term culture, maintain the capability of differentiating into endothelial cells in vitro and improving postnatal neovascularization in vivo [9]. The results of the ultrastructural analysis before transplant revealed that radiodamaged tissue significantly featured reduction of the capillary bed. The considerable presence of damaged adipocytes and the duplication of vessel basal membranes (Fig. 8.5) are put forward to represent signs of suboptimal perfusion, chronic damage, and subsequent repair. In subcutaneous fibrosis, the perfusion was supported mainly by a small number of vessels with morphology suggesting increased transendothelial transport. One possible interpretation of the provided ultrastructural evidence is

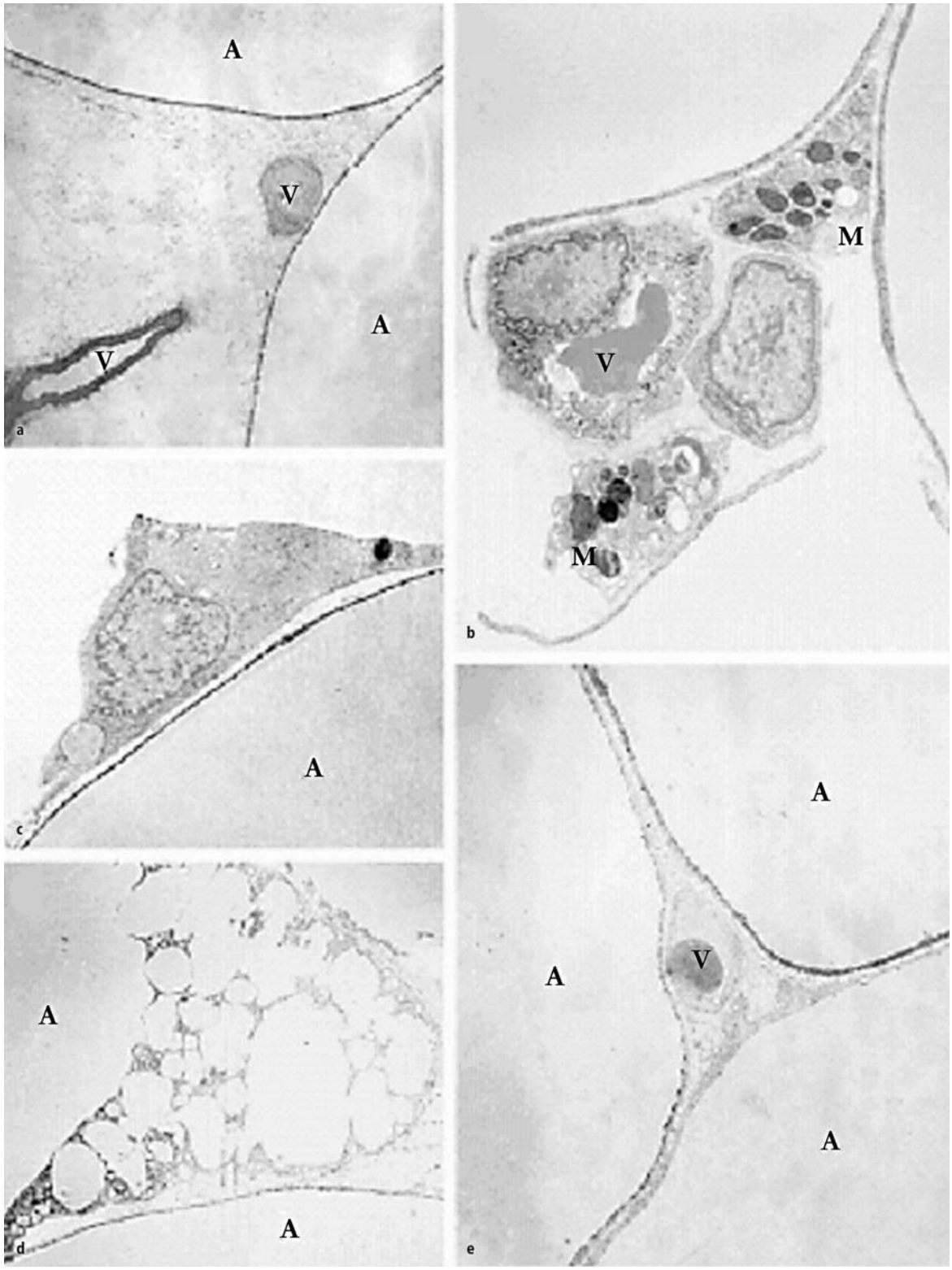

Fig. 8.6. Ultrastructure of subcutaneous tissue after cell therapy (*A* adipocytes, *V* vessels, *M* macrophages). *Left* Photomicrographs obtained at 1 month. **a** The adipocytes are well conserved and separated by large spaces with little collagen. Vessels do not show reduplication of the basal lamina (original magnification, ×2,500). **c** Macrophages (original magnification, ×4,000). **d** Maturing preadipocyte (original magnification, ×2,500). *Right* Photomicrographs obtained at 2 months. **b** Multilocular adipocyte (original magnification, ×2,500). **e** Mature adipocytes with thin extracellular spaces (original magnification, ×2,500)

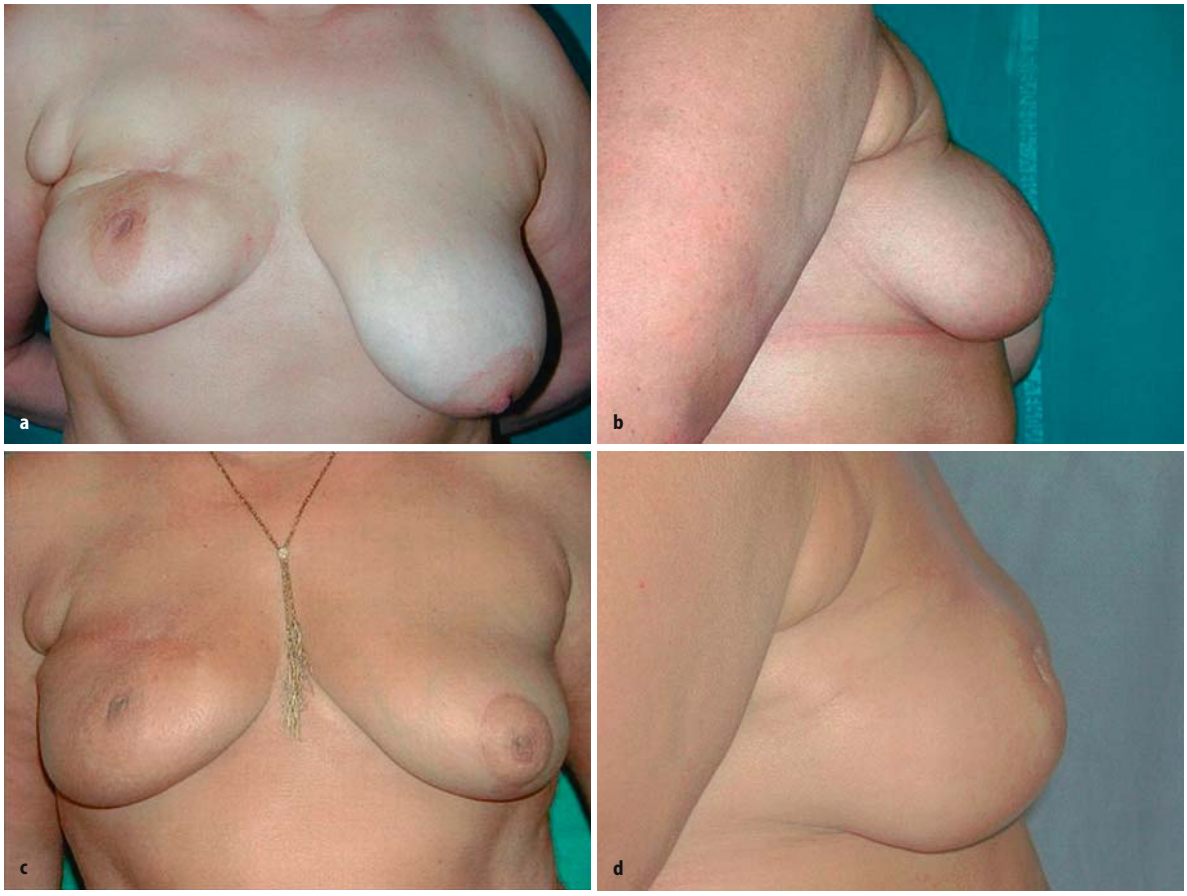

Fig. 8.7. One case following stem cell therapy after a severe outcome of quadrantectomy irradiation. Stiffness and scarring were improved enormously. This follow-up is 1 year after the last treatment

hat the capillary leakage was not caused by interruptions of the endothelial layer but by an increase in transendothelial transport. This aspect can still be found years after radiotherapy. The concentric layers of the basal membrane are generated during phases of repair and are visible in several chronic microvascular diseases. As a whole, the clinical picture was quite similar to the one described in some forms of connectivitis, particularly in systemic sclerosis [20]. Megavoltage irradiation might therefore share similar patterns of microvascular lesions with systemic sclerosis. This is supported by the fact that in patients suffering from scleroderma and other connective diseases, postirradiation complications are frequent and severe, as if irradiation would act as a triggering factor in patients exhibiting a predisposition to microangiopathies. The objective clinical evaluation of the patient population [13] led to the conclusion that severe radiation-induced lesions do not improve spontaneously but potentially evolve toward severe fibrosis and ultimately to ulceration [21]. For this reason, the reported pilot study was organized without including a control group of patients not receiving a manifestly effective therapy for their chronic and progressive injuries. According to the proposed interpretation of the reported clinical results and ultrastructural analysis, the therapeutic approach has to be designed aiming at breaking the vicious circle (i.e., vascular lesion, ischemia, hyperpermeability, fibrosis, and increased ischemia) and at favoring the growth of a microvascular bed with a correct ratio of adipocytes to capillaries. Our interpretation is that this might be obtained by exploiting the recently described proangiogenic capabilities of adipose-derived mesenchymal stem cells [8]. Previous studies have already demonstrated that adipose tissue contains a clonogenic pool of stromal cells with the same immunophenotypic and functional properties of bone marrow-derived mesenchymal stem cells [16–18]. On the basis of this evidence, we characterized and quantified the mesenchymal stem cell potential of small samples of adipose tissue collected by lipoaspiration as a way to support the use of adipose tissue to regenerate damaged subcutaneous tissues. We have found that the lipoaspirate-derived stromal-vascular fraction contains a mesenchymal stem cell pool with multilineage differentiation potential that may be responsible for the clinical improve-

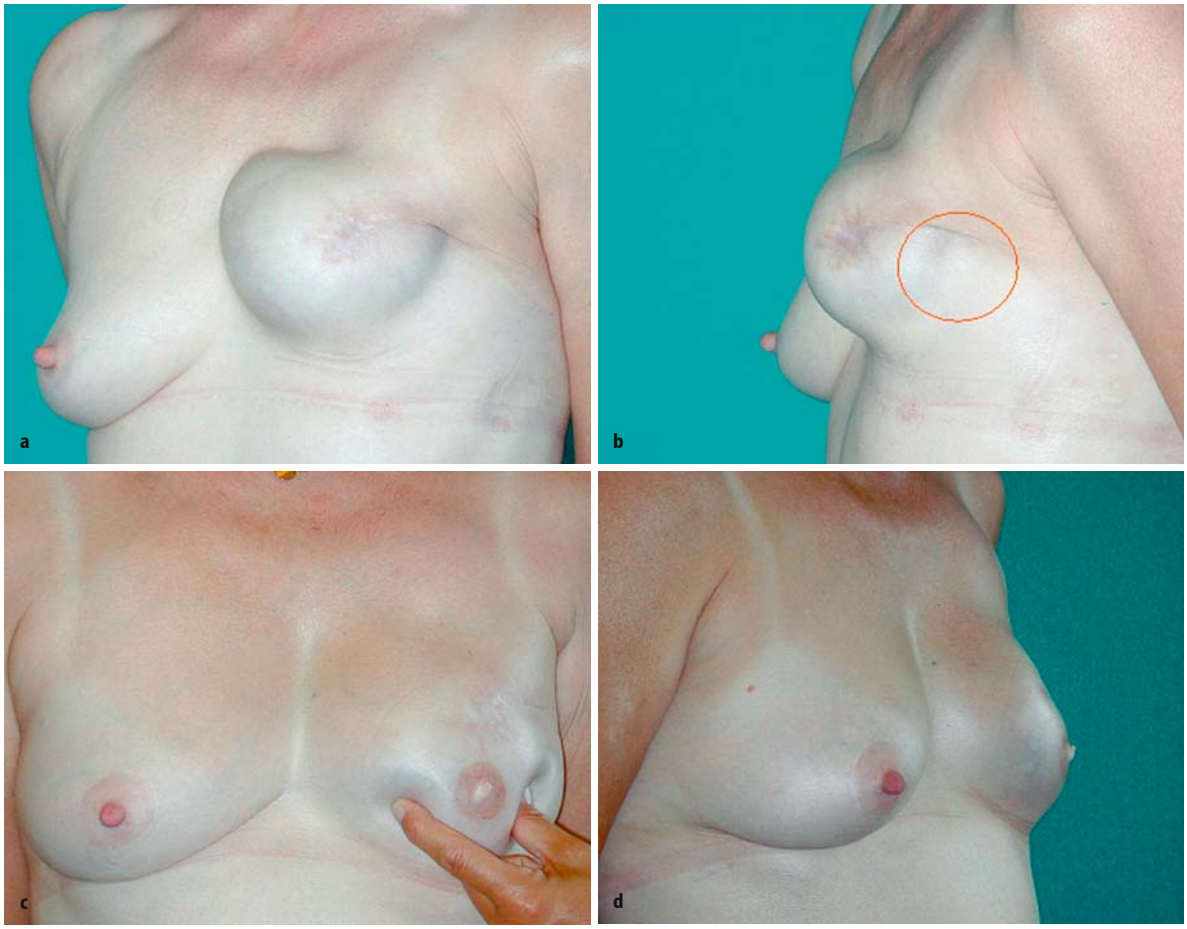

Fig. 8.8. Severe irradiation performed after expander insertion with dramatic capsular contracture (**a**) with a high risk of exposure laterally (**b**). **c, d** At 18 months after three treatments followed by expander substitution with a prosthesis, no capsular contracture is visible

ment observed in the treated patients. According to the ultrastructural analysis results, in the early stages after adipose-derived stem cell transplant, signs of tissue "mesenchymalization" were found to occur. Tissue appeared well hydrated and with large extracellular spaces, resembling fetal connective tissue. Later on, tissue matured and showed aspects similar to those of normal mature adipose tissue. According to the outcomes of recent studies [8, 9], the administration of the stromal-vascular component of normal adipose issue, which has been documented to be rich in stem cells, would elicit the excretion of angiogenic factors. This would lead to the production of new microvessels, which ultimately would ameliorate the circulation. In light of the reported results, we advanced the idea that the chain of events leading to mesenchymalization of the tissue would be the following: (1) targeting of damaged areas by stem cells (favored by their direct injection into the damaged areas), (2) release of angiogenic factors, (3) formation of new vessels, and (4) ossigenation. This process would favor the development of stem cells in mature adipocytes and in a newly formed microcirculation replacing the existing, seriously damaged one. Damaged vessels could still be found in persisting areas of fibrosis late after treatment (Fig. 8.6). This emphasizes the importance of repeated computer-assisted injections to obtain homogeneous improvement throughout the entire radiodamaged area. Indeed, we noticed a linear relationship between clinical improvements and the number of transplants. The reason is probably because the healing of tissue microangiopathic status increased as a function of the total number of stem cells introduced. We are aware of the fact that, in light of the data provided, alternative interpretations of the reported results are feasible. Concerning the microangiopathic cause of radiation ulcers, Rudolph et al. [22] proposed an alternative hypothesis not dependent on decreased blood supply. According to their study, the dominant radiation effect would act intrinsically on fibroblasts or cause a selective ablation of a faster growing fibroblast subpopulation. In addition, a potential role of the inflammatory response inherent

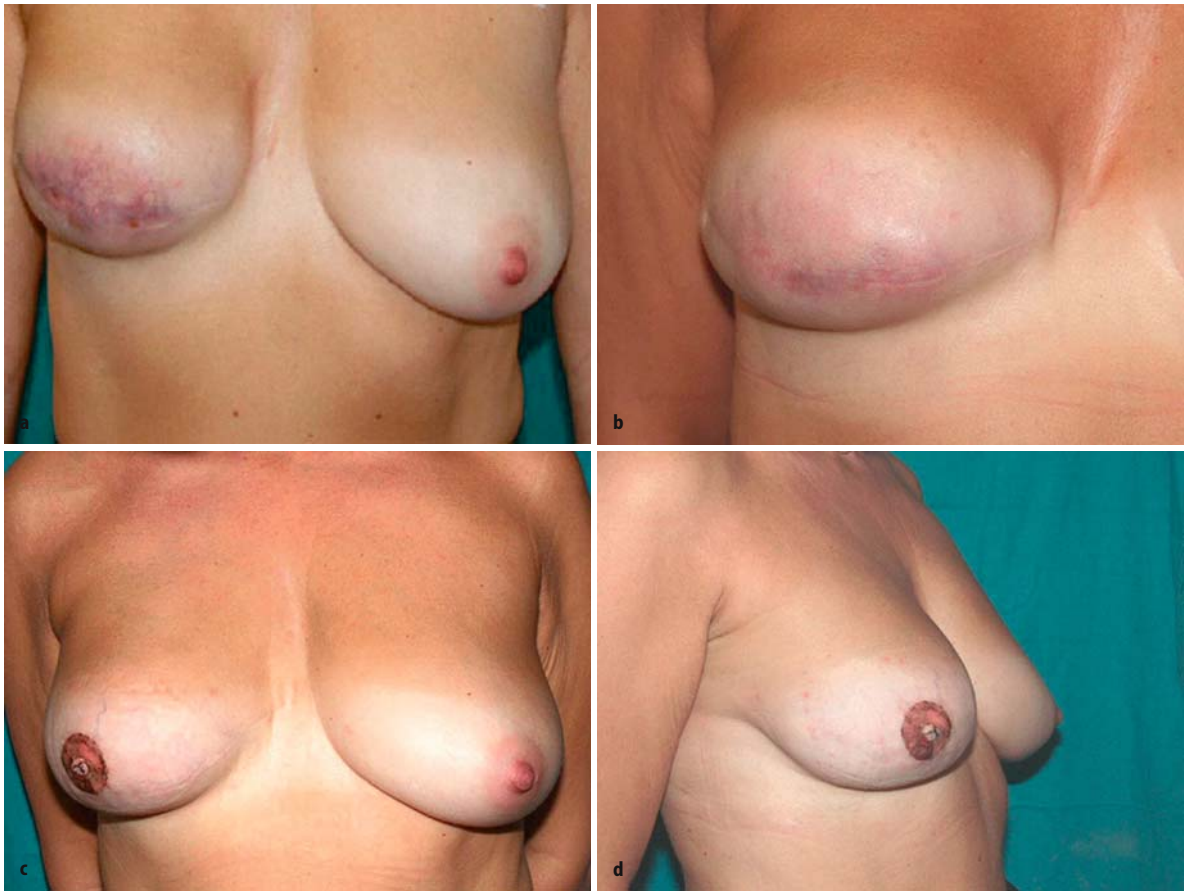

Fig. 8.9. An implant covered only by undamaged periprosthetic capsula and skin with initial radionecrosis (**a, b**). Lipoaspirate was injected between the two layers four times. Notice the newly formed adipose tissue exactly in the treated area that allowed nipple reconstruction with local flaps and reduction of the capsular contracture (**c, d**). No additional surgery was performed

in any surgical trauma should also be considered, even if the timing of the response to the lipoaspirate injection procedures and the provided ultrastructural data suggest a marginal role of inflammatory processes. From the clinical point of view, if one considers the clearly significant results, which we obtained on a large population of patients and supported by a long-term follow-up, a radical change in the therapeutic approach of radiodamaged tissues might be taking place. Tissue damage is usually considered a matter for surgical removal followed by replacement with distant flaps. In our approach, damaged tissues were conserved rather than eliminated: stem cell therapy led to their radical structural change, transforming them into normal tissue. The beneficial effects turned out to be particularly evident in patients with cutaneous ulcers and even more complicated by osteoradionecrosis. In light of the reported outcomes of this pilot study, the current approach to autologous adipose tissue transplants for tissue regeneration seems to hold sway. Although most authors focus on lipoaspirate transplantation procedures aiming at preserving mature adipocytes as a way to maximize the survival rate within the treated area [23, 24], we showed that mature adipocytes were already seriously damaged during the adipose tissue sampling procedure and therefore could not survive in the host tissue. Only the adipose stem cell fraction seems to be the regenerative active component in the transplanted tissue. With respect to traditional fat grafting for aesthetic/filling purposes, the surgical technique is no different, due to the therapeutic rationale for the treatment of late radiotherapy injuries and the innovative aspect of the reported approach. Regarding clinical complications of the described procedure, no case of infection, postinjection necrosis, or any other complication forcing suspension of therapy was experienced.

The significant presence of stem cells in the adipose tissue with multilineage capacity and therapeutic neovascularization potential, and the ease and minimal invasiveness of procurement, make autologous adipose tissue transplantation a recommended therapy for the treatment of radiation induced injuries.

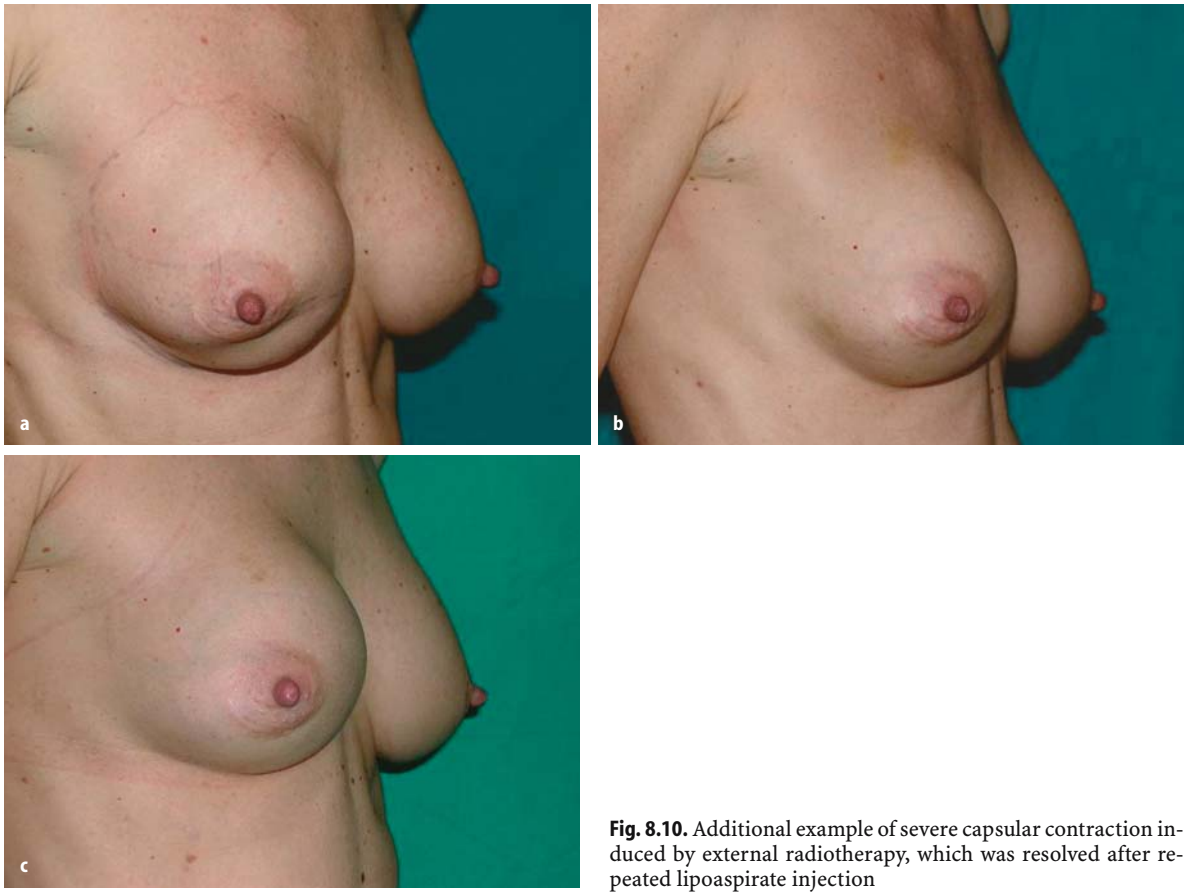

Fig. 8.10. Additional example of severe capsular contraction induced by external radiotherapy, which was resolved after repeated lipoaspirate injection

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Reconstruction

III

Neurotizations in Brachial Plexus Injuries: New Approaches

9

C. Novelli, A. Gilbert, P. Raimondi

Restoration of extremity function after nerve injury is often unpredictable. If management is based on a thorough knowledge of nerve physiology and the basic principles of nerve regeneration, however, excellent function is achievable.

Nerve transfer has been developed and refined to attain the best possible results, and the technique offers reconstructive possibilities limited only by our imagination.

9.1 Principle of Nerve Transfer

The procedure, while considered innovative, dates from the turn of the century, as Harrys and Low proposed it in 1903, followed by Tuttle, who in 1913 proposed the use of the spinal accessory nerve. The first work existing in the literature was published by Tsuyama in 1972 [36], who analysed the concept of neurotization of intercostal nerves. Almost at the same time, in 1971 Kotani [16] proposed the possibility of taking the spinal accessory nerve to reinnervate the biceps, and this was repeated by Allieu in 1982 [2].

The theoretical basis for nerve transfers is similar to that for tendon transfer: it is possible to sacrifice a redundant motor unit, as is done with muscular units, to restore a critical lost function, not reparable by direct suture or by interposed graft. In cases of neurotization sensitive recovery is also possible.

The indications for this kind of procedure include severe lesions of the brachial plexus, with root avulsion, and elderly nerve lesions with considerable nerve tissue defect.

It is evident that these situations are quite rare, fortunately, in current daily practice, but when encountered generally present many reconstructive problems for the surgeon.

The control mechanisms that allow reprogramming of previously antagonistic actions into complex smoothly integrated extremity movements are unknown, but they are evident in each patient and presumably involve cerebral plasticity.

The technical aim of this treatment is evidently to recover a nerve function which is otherwise not possible, while also introducing the concept of converting a high level nerve injury into a low level one. In fact the problem with high level nerve injuries is that generally after 15 – 18 months of denervation, skeletal muscles become refractory to reinnervation. That is why motor nerves are transected as distally as possible so as to be connected as closely as feasible to the denervated muscle. The prerequisite for a neurotization is to have a muscle still alive. This is not easy to determine and in long-standing paralysis the only objective EMG test is the presence of **spontaneous fibrillations**, which is an acceptable indication (of denervation but also of the vitality of the muscle fibres).

Neurotization has been described as the transfer of a functional but less important nerve to a denervated more important nerve.

Evidently it is not that easy. The transfer of a nerve to the distal part of a denervated nerve stump requires some characteristics that often reduce the indication or render the procedure more complex, and ultimately reduce the possible option of nerve transfer.

At first the most important factor is the **number of fibres** in the donor nerve compared with the receiving one. Unfortunately brachial plexus primary, secondary and terminal branches have many nerve fibres (see Ta-

Table 9.1. Average number of nerve fibres in roots of brachial plexus, terminal branches, and nerves utilized for transfers

C5	16,472	Suprascapular nerve	3,500	Intercostal nerves	1,200
C6	27,421	Axillary nerve	6,500	Cervical plexus	7,000
C7	23,781	Musculocutaneous nerve	6,000	Spinal accessory nerve	1,600
C8	30,626	Median nerve	18,000	Charles Bell nerve	1,600
T1	19,747	Ulnar nerve Radial nerve	16,000 19,000	Nerve to latissimus dorsi	500

ble 9.1) on their inside. On the contrary close nerves which could act as donor present a really low number of fibres, which reduce their restoring potential. That is why, as we see below, some authors suggest, especially for the restoration of critical function (such as elbow flexion), to utilize at least two donor nerves, to be sure that the number of fibres can at least be sufficient to restore a valid function (considered as M3 or M3+, on the modified scale).

One more thing to remember, if it is evident, is to try to restore a motor unit with an **agonist nerve**, which would facilitate the cortical recovery, and eventually would not create co-contraction. In any case this condition is considered preferable, but not necessary [23]. Another condition to consider is the **sensitive motor composition** of the donor nerve compared to the receiving one. Normally the aim is to restore motor function, due to the fact that generally this procedure is used in really dramatic cases in which the arm control and its basic motion are the primary achievable aim; in any case sometimes also sensibility can be restored, as we see below. So it is important to utilize a pure motor nerve. For the receiving nerve the problem is similar; it is advisable to go a little further distally to identify the precise motor branch, to neurotize only that, minimizing the donor nerve drop into sensitive distal fibre. Sometimes the surgeon is faced with the problem of having to do a pure motor neurotization, but which requires a graft interposition, or having to do a neurotization by direct suture, in which an imprecise amount of fibres could be lost.

Finally it is important to make a wise **choice of the donor nerve or of a specific part of it**, as we see there are not many usable nerves. In some cases it would be possible to take an entire nerve denervating the original target to reinnervate another muscle. In other cases, it would not be feasible, so an option is to choose the distal component of the donor nerve, which has already reached a portion of its target muscle, and to reroute only the distal part, reducing the normal innervation only partially. Another alternative is to take only a fascicle of the donor nerve (usually a fifth or a quarter part of it) taking care to outline, by intraoperative electrical stimulation, the specific action of the rerouted fascicle, and not to remove a relevant part of the entire nerve.

9.2 Technique

When considering a brachial plexus reconstruction, the surgeon must identify the entity of the lesion and immediately afterwards the possible reconstructive strategy depending on the available donor nerves.

Normally even in the better cases there is a discrepancy between the donor nerve and the function to be restored. Therefore the surgeon must prioritize the function that he aims to restore in the injured limb, as considered essential, when compared to the rest.

In complete brachial plexus palsy the first aim, evidently, is elbow flexion, followed by or at the same level as shoulder stability and abduction. Wrist extension-finger flexion and wrist flexion-finger extension follow next. Intrinsic hand function, due to the large distance from the denervated muscle to the possible donor nerve, is the last priority. Recent advances even offer some concrete hope for this distal target.

The possible donor nerve could come from the plexus itself (and is then called intraplexal neurotization) or from elsewhere (then called extraplexal neurotization).

Evidently when available the most suitable donor nerves for distal branch repair are the plexus roots themselves, and clearly this is not a neurotization but a direct reconstruction.

Obviously when we speak about intraplexal neurotization we are dealing with incomplete brachial plexus palsies, where a branch or a fascicule of a nerve could be used to reanimate another function.

When direct reconstruction is not possible and we are faced with a complete paralysis, we must look for a neighbouring expendable nerve to reconstruct lost function.

Next we present the technical alternatives for reconstruction based on the possible donor nerve.

9.3 Extraplexal Donor Nerve

9.3.1 Spinal Accessory Nerve

The use of this nerve as a donor nerve was first described by Kotani in 1972 and was later introduced in Europe by Allieu in 1982 [2]. This is the XI cranial nerve, which innervates the sternocleidomastoid and the trapezius muscles. Due to its intracranial course,

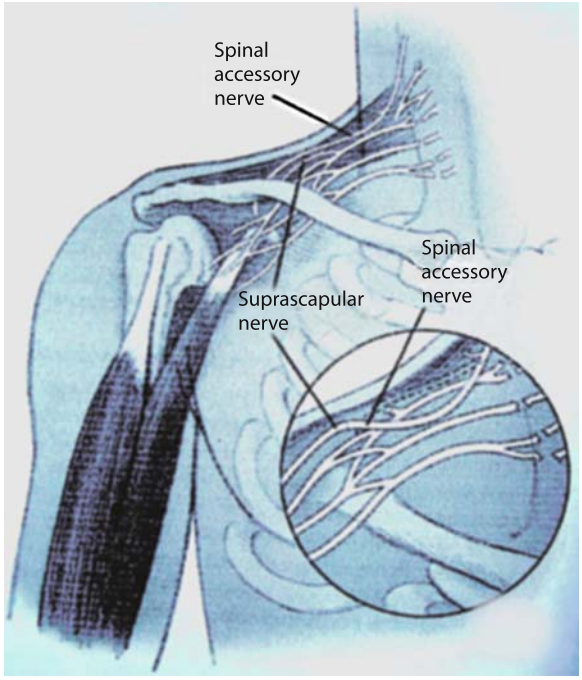

Fig. 9.1. Neurotization of spinal accessory nerve on suprascapular nerve

the spinal nerve is usually protected during traumatic stretching of the brachial plexus, and so it is usually available to perform neurotization. Moreover, it is a pure motor nerve, and it contains approximately 1,700 myelinated motor fibres. This makes this nerve even more suitable for pure muscular neurotization.

Harvesting this donor nerve, we encounter the advantage that it lies in the operative fields, so it is not necessary to use another surgical approach to obtain the nerve. The precise anatomy of the nerve has been studied to a large extent, in order to reduce the damage at the denervated trapezius muscle. Moreover, accurate anatomical study could also provide precise landmarks to reduce the frequent iatrogenic nerve lesions associated with several lymph node related procedures.

The spinal accessory nerve supplies the sternocleidomastoid and trapezius muscles. In the posterior triangle of the neck, this gives off two to three branches for the upper trapezius muscle, and then passes under and supplies the middle and lower portion of the muscle [9].

Anatomical study [9] shows that the outcome of neurotization procedures and their consequences on the trapezius and sternocleidomastoid function depend on the level of division of the spinal accessory nerve. Preservation of function of the primary target muscle (sternocleidomastoid and the upper trapezius) is possible when the spinal accessory nerve is used as a donor nerve and divided in the posterior triangle, just distal to the point where the branches for the upper trapezius are given off.

This nerve is generally used for suprascapular nerve reconstruction (Fig. 9.1), usually in cases when one root judged as being of good quality is found and the direct reconstruction is performed to prioritize musculocutaneous reconstruction with the aim of elbow flexion recovery. In this case it is advisable to try to achieve some shoulder abduction and extrarotation by restoring the supraspinatus and infraspinatus muscles, through suprascapular neurotization. Normally, due to the similar size of the two nerves and due to their proximity, no interposed nerve graft is needed. For this reason, which reduces recovery time and reduces the axonal sprout lost at the suture line, this procedure is considered somewhat safe. A recent literature review reported that 98 % of patients recover < M3 strength in shoulder abduction [20], while another series reported an 80 % rate of success (muscle strength < M3) after this procedure [30].

Some authors [35] consider this procedure even more infallible and successful than suprascapular direct reconstruction by the C5 or C6 roots. This could be explained by the absence of an interposed nerve graft in the proposed neurotization and by the fact that the plexus roots are defined as "in the sphere of lesion" and so they could be somehow compromised.

In other cases the spinal accessory nerve could also be transferred to the musculocutaneous biceps branches, or to the axillary nerve by a sural nerve graft.

New possibilities for using this assured donor nerve include the free functioning muscle flaps that are transferred to restore elbow function or other function (such as wrist extension or finger flexion) [5, 8]. In this situation, if the spinal accessory has not been used in primary reconstruction, it is possible to use it in a "one time free functioning muscular flap" neurotizing the branch of the obturator nerve in a free gracilis muscle transfer.

9.3.2 Intercostal Nerves

The use of these nerves was first described by Seddon in 1963 [37] to restore musculocutaneous nerve by the interposition of an ulnar nerve graft. The technique was later modified by Hara and Tsuyama by elimination of the interposed nerve graft [36].

Since these first descriptions many other utilities for this nerve transfer have been described, but elbow flexion remains the most achievable goal.

Intercostal nerves are the ventral primary rami of the spinal nerves. The ventral primary ramus of the T12 spinal nerve is the subcostal nerve. T1 contributes to the brachial plexus, and T12 does not actually occupy an intercostal space. Therefore ten thoracic nerves (T2–T11) make up the anterior branch of the intercos-

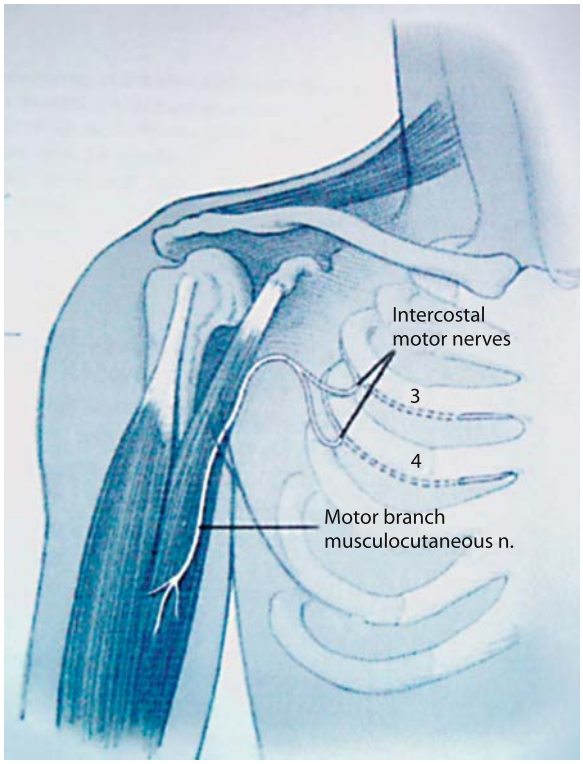

Fig. 9.2. Neurotization of intercostal nerves to motor branch of musculocutaneous nerve

tal nerves. The second intercostal nerve, due to its high location, is not accessible for neurotization.

Intercostal nerves provide segmental cutaneous sensation as well as motor power for intercostal subcostal, serratus posterior superior and transversus thoracic muscles. The nerves are located on the caudal undersurface of each rib. Generally three or four intercostal nerves are harvested and used for neurotization, and commonly these are the third, fourth, fifth and sixth intercostal nerves. Both the lateral cutaneous branch and the anterior motor branch are of use. Due to their small calibre, and reduced number of nerve fibres (about 1,200), at least two intercostal nerves are used for each nerve transfer.

Contraindications for the use of these nerves include, evidently, important chest trauma, associated with rib fractures. In women patients it is correct to consider the use of these donor nerves. In fact, due to the scar for the surgical approach, if there are other feasible solutions, maybe these could be more cosmetically appealing. It is important, regardless of the sex of the patient, to spare, whenever possible, the cutaneous branch of the fourth intercostal nerve, which possesses substantial sensory components which supply the nipple areolar complex.

As already mentioned the primary goal of intercostal reconstruction is elbow flexion by direct musculocutaneous neurotization (Figs. 9.2, 9.3). Recent studies have shown the evident superiority of results in direct intercostal nerve neurotization, when compared to interposed graft repair. That is also why the 3rd to the 6th intercostal nerves are chosen, due to their proximity to the recipient nerve, as the pivot point is at the axilla.

Nevertheless the decision is between a direct neurotization, without graft nerve interposition, from the intercostal nerves to the entire musculocutaneous nerve, versus a punctual neurotization connecting the donor nerves directly to the bicipital rami of the musculocutaneous nerve.

Intercostal nerves have also been used with an interposed nerve graft to restore triceps function and to neurotize the axillary nerve [22]; other authors [35] referred to the use of the 6th, 7th and 8th intercostals to perform a direct neurotization to the axillary nerve.

A recent series of elbow flexion repair by the intercostal nerve [4] showed that 67 % of patients recovered a biceps flexion of M4 or more. The same authors outlined the most important factors of success as early exploration, use of at least three intercostal nerves, nerve repair without graft and under no tension and of course shoulder stability.

New proposals of use of the intercostal nerve include the mixed-to-mixed transfer, in which the intercostal nerves are transferred as the main motor branch and its sensitive accessory branch together to the musculocutaneous nerve, in an attempt to orient the branches of the donor nerve to the fascicle of the recipient nerve, to improve the sensibility.

Another innovative use of the intercostal nerve is the transfer to the free muscular transfer, as already seen for the spinal accessory nerve. A recently proposed technique [15] used in adults and also anticipated in children with non-obstetrical brachial plexus palsy, suggests the use of a double free muscle transfer, to restore the elbow flexion and finger flexion, by using both the spinal nerve and the intercostal nerve as donor nerves for the transferred functioning muscle (the technique and detail are explained below).

9.3.3 Phrenic Nerve

The use of the phrenic nerve was first proposed by Gu [12]. It originates from the C4 cervical nerve root with some contribution also from C3 and C5. It can easily be identified in the same surgical field, as it lies on the anterior surface of the scalenus anterior muscle.

Despite its proven clinical consistency, some authors are still in doubt about its use due to the functional pulmonary compromise resulting from its section for transfer. Several studies [13, 32] have shown that unilateral phrenic nerve sacrifice in patients with an adequate reserve is safe and well tolerated.

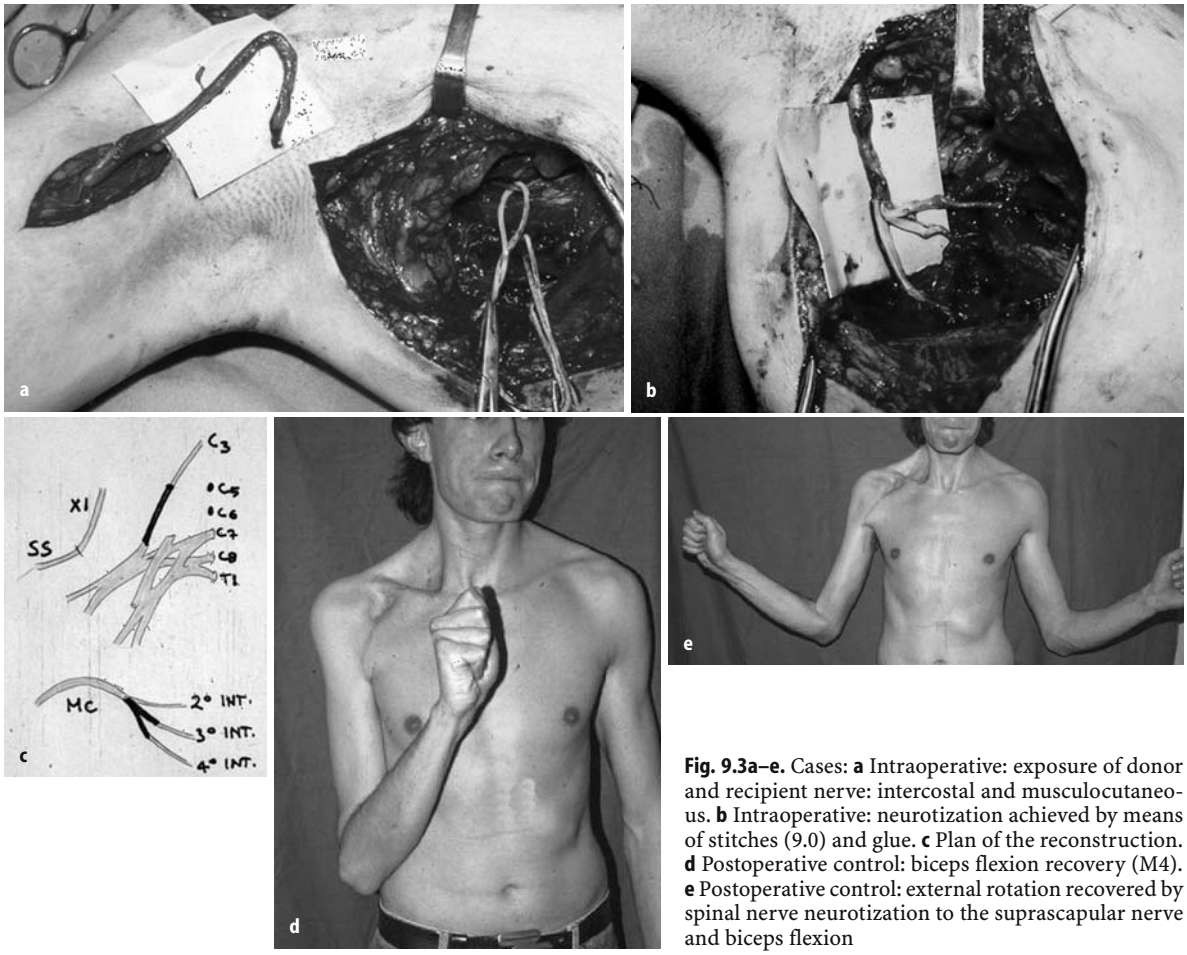

Fig. 9.3a–e. Cases: **a** Intraoperative: exposure of donor and recipient nerve: intercostal and musculocutaneous. **b** Intraoperative: neurotization achieved by means of stitches (9.0) and glue. **c** Plan of the reconstruction. **d** Postoperative control: biceps flexion recovery (M4). **e** Postoperative control: external rotation recovered by spinal nerve neurotization to the suprascapular nerve and biceps flexion

Nevertheless its use is contraindicated in patients with pulmonary compromise; additionally it should not be harvested in patients in whom the intercostal nerves have also been used for reconstruction. In similar cases an end-to-side coaptation could be carried out with the phrenic nerve, without complete transection. When a rupture of the phrenic nerve is encountered, based on clinical and instrumental evidence, and in the case of the impossibility of direct phrenic repair, it could then be used entirely for neurotization.

With regard to children its use has unanimously been ruled out. Nevertheless it has been shown [38] that in children younger than 3 years phrenic transfer has some consequences regarding the respiratory system, thorax, and digestive system, and the younger the patients, the more severe the cost is. In children older than 3 years this kind of procedure could be better tolerated.

The phrenic nerve contains about 1,000 – 1,500 myelinated fibres. Before its use diaphragmatic and pulmonary function must be tested clinically preoperatively, and documented by X-ray, which shows a normally mobile diaphragm at the affected side. Intraoperative electrical stimulation is also advised. The phrenic nerve, due to its size and location, could be a suitable match with the suprascapular nerve as well the axillary. Better results are obtained when it is used for neurotization of the suprascapular nerve, and some authors [6] have reported an increase of up to 40° of shoulder abduction, while others [30] have reported 75% of patients with more than M3 recovery in the shoulder muscle.

9.3.4 Cervical Plexus Motor Donor

There are four motor branches available lying in the same surgical fields, despite the fact that they do not offer a really large number of myelinated nerve fibres.

These are the accessory branches of motor nerves for the sternocleidomastoid, trapezius, levator scapulae and rhomboid muscles. They are located between the C5 spinal nerve and the spinal accessory nerve. These must be considered in cases of multiple root avulsion, even if outcomes are controversial. Brunelli [3] popularized their use with satisfactory results for

suprascapular neurotization. Other authors still regard this solution as being unreliable [6, 30]. Nevertheless it is important to remember to consider carefully the association of cervical plexus donor nerve with accessory spinal nerve, due to the possibility of developing shoulder instability as a result of the complete denervation of the scapulothoracic muscle.

9.3.5 Contralateral C7

In the years 1986–1989 Gu [10] developed this new technique of extraplexal neurotization, distressing the brachial healthy side roots to provide a new donor nerve in patients affected by complete brachial plexus lesion. Since then many authors have supported this technique and have recorded little if any donor site morbidity.

The advantages of the use of this donor nerve are evident: first of all the large number of myelinated fibres it contains (~27,000), which makes it possible to achieve a target, until then regarded as unachievable, such as hand function. All the muscles which have a C7 contribution do not have the C7 root as the only source of fibres, but, on the contrary, they receive cross innervation mainly from C6 and C8. This anatomical data forms the basis for the possibility of sectioning a portion or the whole of C7 healthy roots, without a significant loss of specific muscle function. The specific documented outcomes after this kind of surgery are a temporary paresthesia of the first three fingers, or of the palm, or of the anterolateral arm. These sensory findings were or were not associated with weakness of the triceps or of the extensor digitorum communis. All the series reported a spontaneous recovery of the temporary sensory abnormalities within 3 months, and a normalization of the muscular strength at long-term follow-up. Other studies have also assessed the limited donor morbidity with clinical [7] and electrophysiological study [11].

There are several proposed techniques such as complete or partial C7 transfer, generally using a vascularized ulnar nerve graft. Partial C7 transfer has been proposed [31] due to the already huge amount of fibre available, in order to minimize the risk at the uninjured arm. When only half of the healthy C7 is used, intraoperative stimulation must identify the C7 component which predominantly stimulates for the pectoralis major, and this would be chosen. In cases of each half of the nerve producing wrist and finger contraction, some authors [29] suggested abandoning the procedure because of the considerable risk of jeopardizing the hand.

In cases of complete root avulsion, the use of the contralateral C7 rather has the aim of restoring the **median** nerve, while dedicating the other available motor nerve sources (such as spinal accessory and intercostal) to elbow and shoulder.

Despite the low rate of donor site morbidity associated with the satisfactory sensitive results encouraging the use of this new technique, motor outcomes are far from optimal. With regard to sensibility recovery in Songcharoen's [31] series, 48 % of the patients obtained S3 function and 33 % obtained S2 function. On the contrary regarding wrist and finger flexion only 29 % of the patients obtained good finger flexion; the same mediocre results are documented in all the large series. Gu [14] reported slightly better results in 63 % of his patients, using the whole contralateral C7.

The author concluded that even though the results of contralateral C7 to median nerve are better if compared to other donor nerves, the success rate of this procedure is still far too low. The best outcomes are seen in individuals younger than 18 years.

New Proposal. Other authors [15] suggested the use of contralateral C7 in a complex double free muscle transfer technique. They use the whole contralateral C7 to reconstruct shoulder and elbow extension in primary surgery: subdividing the ulnar nerve graft and directing it to the radial and to the suprascapular nerve. And more recently they have reconstructed elbow flexion with a free gracilis muscle transfer, neurotized to the spinal accessory; the third operatory procedure was directed to finger flexion recovery by a second free gracilis muscle transfer neurotized to the intercostal nerves. In their series, also including children with non-obstetrical brachial plexus palsies, they reported encouraging results.

Other uses of contralateral C7 include the reanimation of a single free muscle transfer to restore elbow flexion, as already described for the spinal accessory nerve and intercostal nerve.

9.4 Intraplexal Donor Nerve

In cases of incomplete brachial plexus palsy it could be possible to utilize a healthy expendable nerve or part of one to restore function.

9.4.1 Triceps Branch of Radial Nerve

Lesion of the upper roots of the brachial plexus results in loss of shoulder abduction and external rotation due to the paralysis of the supraspinatus and infraspinatus muscles and of the deltoid and teres minor muscles. The normal procedure usually prioritizes the suprascapular direct or selective reconstruction, rather than the axillary. Nevertheless it is known that all the muscles of the glenohumeral joint contribute to shoulder abduction and external rotation. Finally the reinnerva-

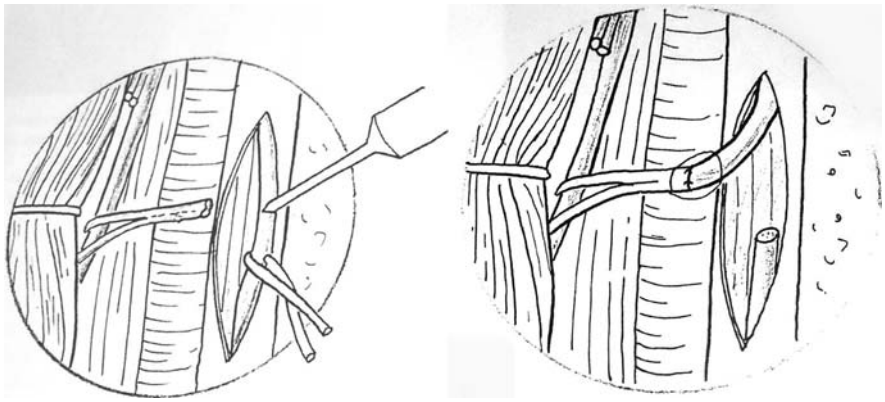

Fig. 9.4. Oberlin's procedure of biceps branches of musculocutaneous nerve neurotized by a fascicle of ulnar nerve

tion of both axillary and suprascapular nerves provides the best possible functional results in terms of shoulder abduction and external rotation.

We have already seen the possibility of neurotization of the suprascapular nerve, outlining that the gold standard procedure appears to be the use of the spinal accessory nerve as source of neurotization.

With regard always for the same principle of at the same time reducing the pathway the nerve has to run in recovery and the number of sutures it has to cross, a new kind of neurotization has been studied and proposed for reanimation of the axillary nerve.

Commonly the axillary nerve has been neurotized by the available roots of the plexus, through nerve graft, or by extraplexal donor nerve such as the phrenic nerve or the intercostal nerve. Recently some authors [37] have studied the anatomy of the long head of the triceps nerve to the axillary injured nerve. This *new procedure* uses a posterior approach centred over the quadrilateral space, which allows the exposure of both the radial nerve, with its branch to the long head of the triceps, and the axillary nerve; the nerves are then matched together directly.

This procedure offers the advantage of having the nerve in the same operative fields that are also far away from the original lesion, so dissection could be easier and faster. Moreover the proximity of the two nerves renders this procedure appealing for its shorter time of recovery, because it does not require a nerve graft.

Other studies [39] have been directed at the macroscopic and interfascicular anatomy of the axillary nerve, to render the neurotization even more efficient by focusing the reparation only on the deltoid branches.

9.4.2 Ulnar Nerve

We have already seen that the ulnar nerve has been used in cases of complete brachial plexus palsy, as a vascularized nerve graft, when the only possible donor was the contralateral C7, which lies far away from the receiving nerve target.

The ulnar nerve could also be a valuable donor nerve in cases of upper plexus palsy (C5, C6–C7 palsy).

This technique, first proposed by Oberlin in 1994 [25], explains completely what is meant by the use of the expendable nerve or part of it. He used a consumable part of the healthy ulnar nerve to restore the paralyzed elbow flexion, by a direct neurotization (Figs. 9.4, 9.5). In this way he transformed the high level lesion of the biceps branches of the musculocutaneous nerve into a low level injury, increasing the rate of success of the recovery and reducing the time of reinnervation, due to the proximity of the donor and the recipient nerve.

In his procedure the ulnar nerve is identified and dissected at the arm level; an intrafascicular dissection associated with an intraoperatory stimulation allows a fascicle to be identified, with a size of 15–20% of the entire nerve, which stimulates mostly the wrist flexor rather than the intrinsic function. That fascicle is chosen for neurotization; so it would be freed proximally and divided distally. In the same operative field the musculocutaneous nerve is identified, in the belly of the biceps muscle; the muscular branches for the biceps are identified and divided proximally. So the donor ulnar fascicle and the recipient biceps branches are glued together, without any graft.

This technique provides a really high rate of success in elbow flexion recovery, such as 93% of < M3 recovery in elbow flexion in the series of Leechavengvongs [17], and the results were similar in the series of Sungpet [32].

No donor morbidity was recorded.

Other authors [34] proposed a slight modification of the technique using a fascicle of the median nerve, instead of the ulnar nerve, to neurotize the biceps branch of the musculocutaneous nerve, likewise reporting satisfactory results, without morbidity at the donor site.

Recently reanalysing the different series of the original procedure, Liverneaux [18] outlined some incomplete recovery or weakness of elbow flexion, in cases of

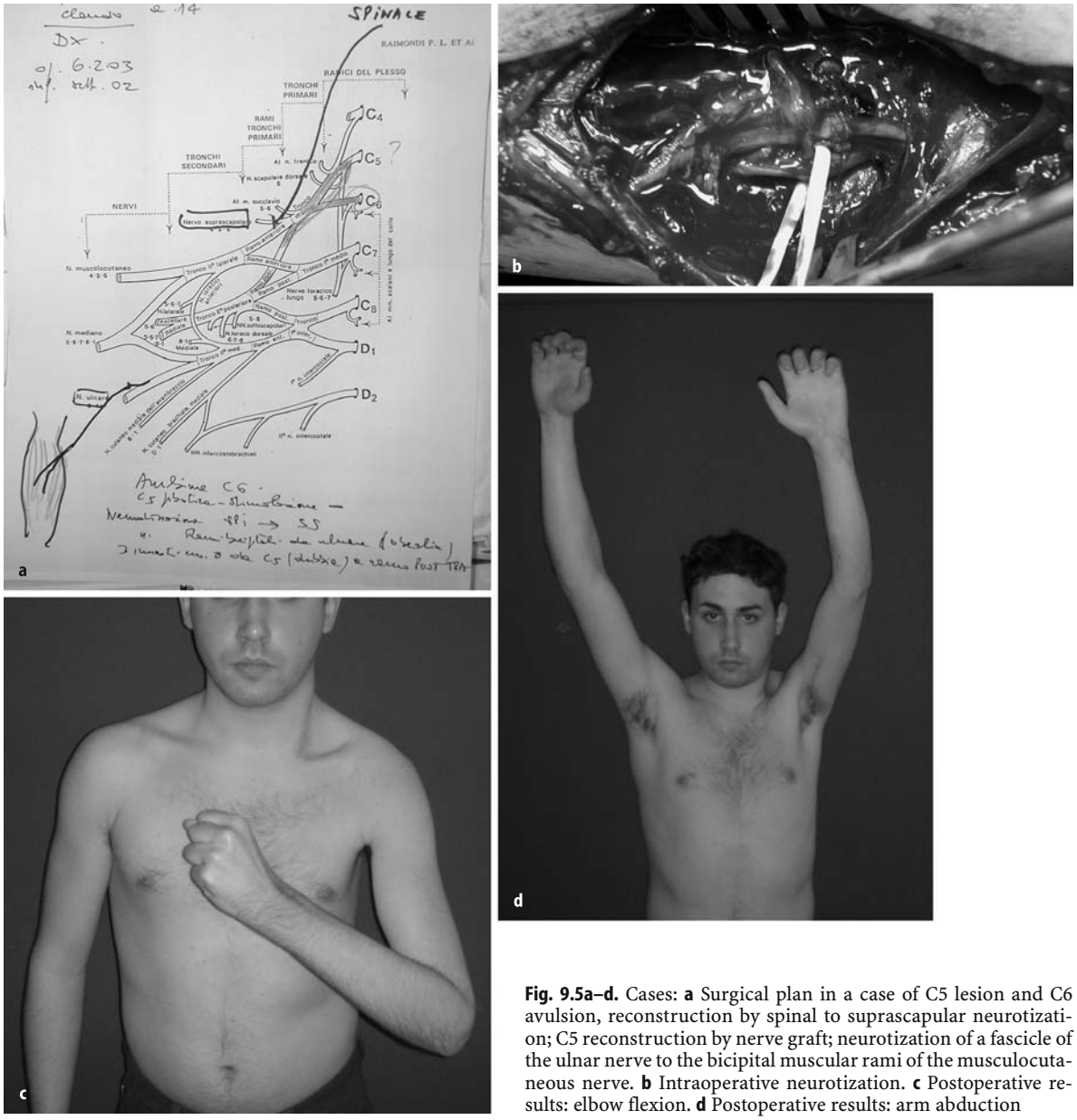

Fig. 9.5a–d. Cases: **a** Surgical plan in a case of C5 lesion and C6 avulsion, reconstruction by spinal to suprascapular neurotization; C5 reconstruction by nerve graft; neurotization of a fascicle of the ulnar nerve to the bicipital muscular rami of the musculocutaneous nerve. **b** Intraoperative neurotization. **c** Postoperative results: elbow flexion. **d** Postoperative results: arm abduction

Fig. 9.6. Intraoperative: double neurotization with one fascicle of the ulnar nerve directed to the bicipital rami of the musculocutaneous nerve, and a fascicle of the median nerve directed to the muscular rami of the brachial muscle

elderly patients and in those with long preoperative delays. So he proposed a new technique, to maximize the result of elbow flexion. The new procedure bases its rationale on the fact that the biceps is originally a forearm supinator, while the brachialis is the primary elbow flexor muscle. The new scheme associates the previous ulnar fascicle transfer with an additional transfer of a fascicle of the median nerve, chosen as a wrist flexor fascicle, to neurotize the brachialis branches of the musculocutaneous nerve, increasing the motors for elbow flexion (Fig. 9.6).

This technique, already shared by several authors [19], shows really encouraging results.

9.4.3 Median Nerve

Some authors [34] proposed a slight modification of the technique suggested by Oberlin, using a fascicle of the median nerve, instead of the ulnar nerve. They suggest using a small fascicle of the median nerve to neurotize the biceps branch of the musculocutaneous nerve and they likewise report satisfactory results. Moreover, the study shows that grip strength, pinch strength, moving two-point discrimination, and strength of wrist volar flexion on the unaffected side are not worse than before the operation in any patient. Other authors [19] use the median nerve as a donor site, but outline the possibility of using both the donor nerve, and median and ulnar nerves to revitalize two different targets, the biceps and the brachialis, to reach the strongest elbow flexion.

9.4.4 Brachialis Muscle Motor Nerve

Another recently described procedure refers to the rare cases of lower root avulsion with intact upper roots, the so-called Klumpke paralysis. These types of lesions involve C8–T1 ± C7 avulsion, and are somewhat rare: in the published series they range from 2 % in the Narakas and Oberlin series [21, 24] to 10 % in Seddon's [28] series.

This kind of lesion is characterized by a severely compromised hand which could be compared to some tetraplegic hands or cases of combined median and ulnar palsy. Commonly there is a complete absence of all the finger flexors, of the thumb flexor and of all the thenar and hypothenar intrinsic musculature. Recently Palazzi reevaluated the work of Accioli [1], who first described a technique of reanimation of the finger flexor by the use of an intraplexal donor, and particularly the brachialis motor branch.

The proposed technique [26] was developed in three different possible schemas, which share the common use of the brachialis motor branch as donor nerve, to neurotize different target muscles secndary to the paralyzed distal muscle.

The first schema foresees the use of the brachialis to reanimate the epitrochlear branch of the median nerve, with a direct suture due to the proximity of the donor and recipient nerve. The second option is exploited in cases of conserved epitrochlear muscle innervation, and utilizes the donor brachialis nerve in an end-to-side neurotization with the median nerve distally to the site of emergence of the epitrochlear branch, in order to reinnervate the finger and thumb flexor.

The third possibility is used for more complex lesions with avulsion of the C7, C8 and T1. In such cases most of the radial extensor function is lost. The reconstruction is conducted by an end-to-end suture from the donor motor branch of the brachialis to the posterior interosseous nerve with an interposed nerve graft; the aim evidently is to restore wrist and finger extension.

Even if conducted in a small series (due also to the fact that the original lesion is quite rare), results are quite encouraging, with motor and sensory recovery, and without any donor morbidity recorded.

9.5 Our Strategy in Using Nerve Transfers

The strategy depends on several factors: complete or incomplete palsy, adult or child, and duration of the paralysis.

9.5.1 Complete Paralysis

A maximum number of neurotizations is necessary, usually spinal accessory to suprascapular, intercostals on musculocutaneous. The use of phrenic nerve or contralateral C7 has been discussed. However, it may be possible after 1 year to use the contralateral pectoralis nerve with a long graft, to reinnervate a gracilis transplant.

Another possibility would be to reinnervate with one intercostal nerve the thoracodorsal nerve with the aim of restoring a latissimus dorsi which can be secondarily utilized for transfer.

9.5.2 Partial Paralysis

During the primary repair, if the upper roots are slightly scarred or one is avulsed, or there is a lack of grafts, a spinal accessory to suprascapular suture is done immediately and at the same time the upper trunk is grafted from the remaining root. If there is an avulsion of C5–C6, the double neurotization spinal accessory on suprascapular and ulnar to musculocutaneous is done immediately. It can be refined by a triceps to axillary nerve transfer. If C7 is also avulsed, the three branches to the triceps are neurotized with the median nerve. In non-operated patients (mostly children but even sometimes adults after a failed repair) who have not recovered external rotation, or a good biceps, or triceps, but have a reasonable recovery of the other muscles, an isolated nerve transfer can be of great help.

This use of isolated, on demand, neurotization, targeting one missing function is a recent and very useful development of this surgery.

As briefly seen, neurotization considerably changes the panorama of possible reconstruction in severe bra-

chial plexus palsy, and allows us to imagine reconstructive options that were previously completely unachievable.

The strongest points of this innovative "way of thinking" include firstly the significant number of available donor nerves, secondly the possibility of precisely addressing the chosen target, and ultimately the advantage of transforming a high level nerve lesion into a lower level one, reducing the time of nerve recovery.

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10 Nerve Reconstruction by Means of Tubulization

J.A. Lohmeyer, P. Mailänder

10.1 Clinical Background

Injuries of peripheral nerves are regularly seen in trauma and hand surgery. The impact of the loss of motion and sensitivity often puts the treatment of nerve injury at the center of interest. Incomplete nerve regeneration could lead to permanent severe impairment of hand function. This and the microsurgical techniques needed for reconstruction place high demands on the attending surgeon.

Direct, tensionless suture is the method of choice for the treatment of partially or completely disrupted nerves. However, if tensionless approximation of both nerve stumps cannot be achieved, direct suture is not acceptable because tension on the suture line severely impairs nerve regeneration [19]. Nerve gaps can originate either from trauma, from nerve retraction at the time of secondary reconstruction or from nerve resection. The gold standard for the reconstruction of peripheral nerve gaps is the nerve autograft. Usually, sensitive skin nerves such as the sural nerve or the medial cutaneous nerve of the forearm are used for grafting.

However, nerve harvesting inevitably leads to donor site morbidity, which can include loss of sensitivity, scarring and neuroma formation.

In injuries of small, solely sensitive nerves such as the digital nerves, the risks and benefits of nerve grafting have to be considered thoroughly. Artificial nerve tubes could help avoid donor site morbidity. The tubes are inserted between the proximal and distal nerve stump and act as a growth chamber for the regenerating nerve. The longitudinal direction of growth is determined and scarring from the surrounding tissue can be eliminated from the lumen.

Nerve reconstruction by means of tubulization was first mentioned in the late 19th century. Since then, numerous materials in various shapes have been tested for efficiency [8, 12, 17]. Experiments on animals have increasingly concentrated on the use of growth factors, modifications of the intrinsic framework and the incorporation of living cells [9, 13].

Simple, mostly hollow tubes have already crossed the barrier into clinical practice [14, 15]. Today, several conduits made of synthetic, biodegradable materials are approved for clinical application. Various results on the effectiveness of these conduits have been published by different studies in the literature [1, 2, 4, 6, 7, 10, 11, 15, 21, 24, 28].

10.2 Tubulization as an Alternative to Nerve Grafting

Since nerve grafting is limited in terms of donor site morbidity and the available amount of donor nerves, the search for alternatives continues [17].

The underlying idea of tubulization is to secure a growth chamber where neurotropic and neurotrophic substances of both nerve stumps can promote and direct nerve regeneration [14, 28]. The use of hollow conduits is limited to gap lengths of up to 30 mm in humans. The aim of animal and clinical research is the improvement of the growth-promoting abilities of the artificial nerve graft [8, 17].

Synthetic tubes help to avoid donor site morbidity and are available in random amounts at the primary surgery. Non-resorbable tubes show the drawback of secondary nerve compression and frequently have to be removed in a second operation [14]. Thus, biodegradable materials such as collagen or polyglactin have become accepted in clinical practice.

The use of conduits of biologic origin is still controversial. Muscle grafts and vein conduits have been used in the first instance [5, 22, 27]. Results are partly promising, but the methods also require donor sites. In addition, hollow vein conduits could collapse and thus fail to secure an open lumen.

Commercially available conduits made of synthetic

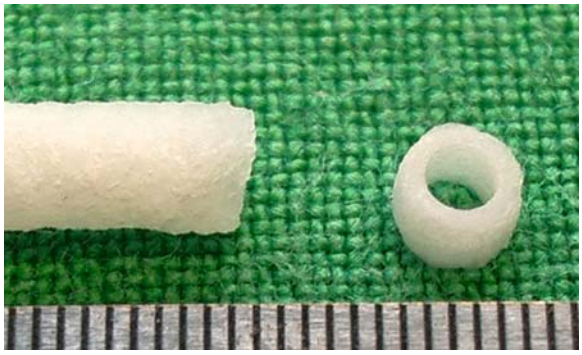

Fig. 10.1. Collagen I conduit (NeuraGen, Integra Lifesciences). Internal diameter 1.5 mm, smallest size available

polymers or collagen seemed to yield comparable results, but a direct comparison has not yet been performed. Several authors have gained good results by reconstructing nerve gaps of up to 30 mm by means of tubulization [2, 6, 11, 15, 21, 28]. Individual cases of successfully bridged distances of 40 mm have also been reported [1, 4, 10]. On the European market, nerve tubes up to 40 mm in length can be purchased. Their use should be limited to gaps of less than 30 mm. The internal diameter ranges from 1.5 to 10 mm.

10.3 Surgical Procedure

Surgery on the peripheral nerve requires microsurgical techniques. Following debridement and neurolysis if applicable, the nerve stumps are located with one or two u-sutures of 10/0 nylon and inserted into the moistened tube with an overlap of 2 – 3 mm. Tubulization has to be performed after release of the tourniquet to prevent bleeding into the conduit. After finishing each coaptation, the lumen has to be rinsed with normal saline or electrolyte solution using a small cannula to remove any remaining blood clots.

Antibiotic treatment is partially described in the literature [28]. We chose the single shot intravenous treatment with 1.5 g cefuroxime. Immobilization of the adjacent joints is advisable for at least 14 days. Massaging the scar should be avoided due to the risk of dislocation of the tube in the first weeks following the operation.

10.4 Clinical Experience

Tubulization seems equally appropriate for primary and secondary nerve reconstructions, as well as for reconstruction after neuroma resection [1, 10, 11]. Although the capacity for nerve regeneration diminishes in the elderly [16], good results are possible in patients older than 65 years [1, 2, 28]. Increasing the length of defect diminishes the prognosis of regeneration. Crushing or avulsion injury can have the same impact on outcome, compared to a clean cut of the nerve [28]. Cases of rejection or allergic responses have not been reported so far. However, scar sensitivity or palpability of the conduit has been mentioned in some trials [24]. In general, nerve reconstruction even with an excellent surgical technique could lead to significant failure in nerve regeneration. After direct suture or nerve grafting, a detectable 2-point discrimination was achieved only in about 80 % of cases [16, 23, 26]. It is likely that favorable results following tubulization are also highly dependent on the experience of the surgeons in carrying out end-to-end nerve repair [16, 18].

In our clinical experience of 13 reconstructed digital and palmar nerves using collagen conduits (Fig. 10.1),

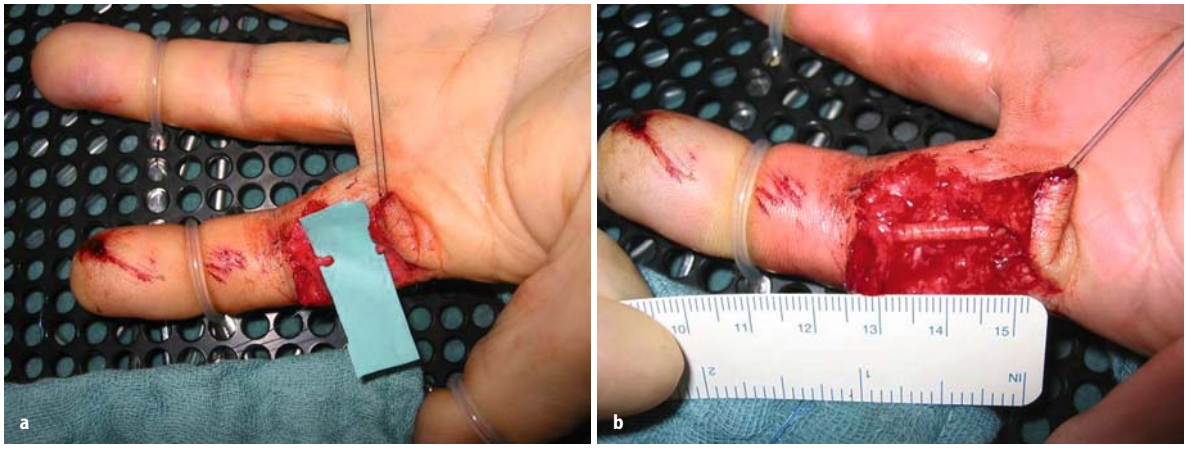

Fig. 10.2a, b. Reconstruction of the radial nerve of the index finger in a 66-year-old patient using a collagen I nerve conduit (internal diameter 2 mm, gap length 10 mm)

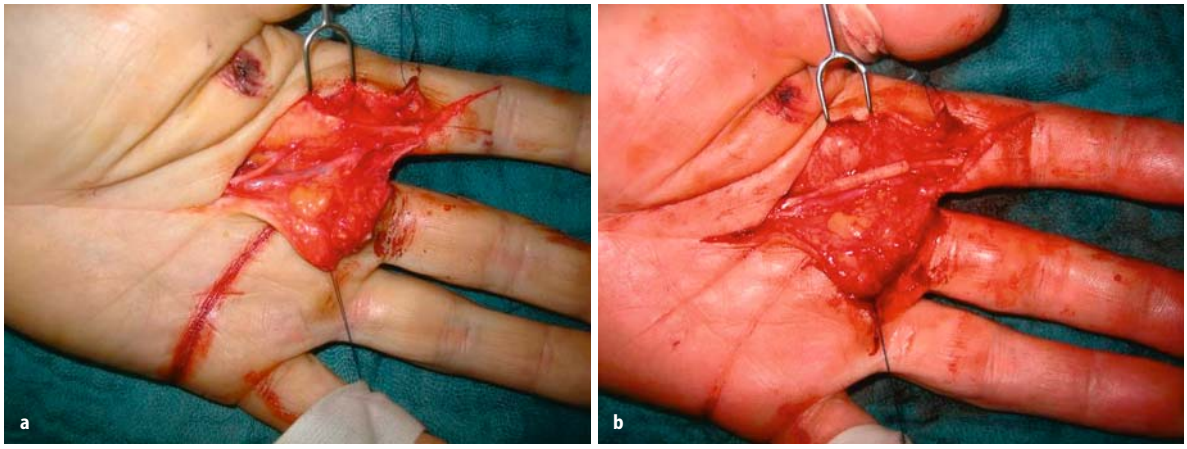

Fig. 10.3a, b. Reconstruction of the ulnar nerve of the index finger at the palmar level in a 19-year-old patient using a collagen I nerve conduit (internal diameter 2 mm, gap length 18 mm)

we saw different degrees of nerve regeneration. We applied a fixed aftercare schedule. All patients were assessed 3, 6 and 12 months postoperatively based on their scores of restored sensitivity by static and dynamic two-point discrimination (s/d2PD) and Semmes-Weinstein monofilament testing. So far, four out of six patients with a follow-up exceeding 12 months have achieved a s2PD of 4 – 7 mm (Highet S4). One regained minimal sensitivity (s2PD 15 mm, Highet S3) and one patient failed to regain any sensitivity (Figs. 10.2, 10.3).

The use of conduits allows shorter narcosis and primary nerve reconstruction by avoiding nerve harvesting and grafting. We saw the priority indication for nerve reconstruction by means of tubulization in these cases, in which the advantage of nerve reconstruction was outweighed by the disadvantage of donor site morbidity. In defects longer than 30 mm, an alternative to nerve grafting still does not exist.

Continuous aftercare is obligatory to detect inefficient nerve regeneration and to allow early secondary nerve reconstruction if needed.

10.5 Aspects of Tissue Engineering

Following transection of the peripheral axons, the distal part of the nerve undergoes wallerian degeneration. Debris is phagocytosed and Schwann cells reorganize and align to form axon growth-promoting bands of Büngner [3]. These bands function as internal guiding cues by direct interaction with outgrowing axons [20]. Proliferating Schwann cells and recruited myelomonocytic cells secrete neurotrophic and neurotropic substances, creating a growth-promoting environment [9]. Scientific approaches to create an optimized artificial nerve graft include providing a longitudinally oriented internal framework and incorporating living cells [13]. A positive supporting effect on nerve regeneration has been shown, e.g., for Schwann cells, mesenchymal and neuronal stem cells [25]. A plethora of experiments worked with different growth factors or a combination of the above [9]. Nerve regeneration over prolonged gap lengths could be achieved but the distance to be successfully bridged still lay far behind the expectations and the gold standard, the nerve autograft [8, 17].

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11 Recent Conclusions Regarding the Reconstructive Microsurgery of Peripheral Nerves

D. Dumitrescu-Ionescu

The introduction of reconstructive microsurgery has meant not only the addition of microsurgical microscopes and instruments, but a change, an advance, towards a new idea, the concept of the microsurgical reconstruction of tissues. The microscope and the instruments themselves are only a means of utilizing to good effect this new concept since the mere use of the microscope and of the instruments according to the old concept of the reconstruction of tissues cannot be considered to be reconstructive microsurgery.

From December 1979 through December 2005, more than 3,000 patients with peripheral nerve lesions were operated on by the same microsurgeon, the author, Doina Ionescu-Dumitrescu.

The conclusions are based on the following:

- A huge amount of work involved in carrying out microsurgical reconstructions of over 7,500 peripheral nerves in over 3,000 patients, 1,800 of which were nerve transplants for defects of peripheral nerves of the extremities, for post-traumatic brachial plexus paralyses (89), for replantations and/or revascularizations following partial or complete amputations of the extremities (24, of which 23 were successful) or for free transfers of functional composite tissues (53). For a more accurate picture of such an effort one should consider the operation time that these types of reconstruction involve: between 3 and 12 h for each patient under general anesthesia and for both the anesthetist and the microsurgeon
- Experimental microsurgery on rabbit ears
- The results of the histopathological examination of 500 postoperative neuromas of peripheral nerves repaired traditionally
- The Moberg test
- Pre-, intra- and postoperative monthly observations of the patients until their full recovery according to the criteria set by the International Reconstructive Microsurgery Society (postoperative intervals of 6 – 12–24 months)
- Taking pictures and recording pre-, intra- and postoperative stages
- The patients' professional, social and familial reintegration
- The patients' state of mind; level of cooperation
- Comparing results with those of classic and palliative repairs
- Comparing the data resulting from this experience with the information provided by the specialist literature of the world
- Completing the internationally defined reconstructive procedures with the personal ones, to produce a new concept

The conclusions drawn from my own experience can be summed up as follows:

1. The fact that for hundreds of years post-traumatic paralyses of the spinal and partly cranial peripheral nerves have been considered insurmountable obstacles is largely justified by a very limited concept of the restoration of neural "connections." This implies:
   a) Little knowledge of the functional mechanism of the peripheral nerves and even less knowledge of the behavior of the traumatized peripheral nerves
   b) Little or no consideration of the importance of the extensive cerebral area assigned to the hand
   c) No conceptionalization of peripheral nerve reconstruction methods
   d) Too frequent recourse to mechanical devices and operation procedures employing the muscles for some existing movement in a paralyzed territory so that the achieved movements have always been mistaken for recovery; no comprehension of the fact that the purpose should not be to simulate or train purely mechanical movements
   e) Although the research carried out throughout the world has been highly sophisticated over the past 2 decades, it has optimistically been interested in "a single cell," organelle or growth factor and most often such efforts are focused on other methods than the "natural" ones of peripheral nerve reconstruction
   f) Faith in the evasive doctrines of degeneration-regeneration of the injured and reconstructed peripheral nerve has been tolerated for too long; conformity and passiveness have rendered the

doubts cast on them unable to gain the strength and momentum required to change the reconstructive concept
   g) The general principles of the reconstruction of extremity soft parts have been widely developed and extended over the past 30 years
   h) Late division of surgery into distinct surgical specialties
   i) Slow development of magnifying devices and, consequently, tissue manipulation equipment
   j) Even 40 years after magnifying devices were first used there is still confusion over what should be reconstructed, procedures are eagerly and carelessly applied and "planning" is limited to the microsurgical technique

2. Reconstructive microsurgery (RM) is a new concept. Although the vision of reconstruction by neural transplant belongs to Philipeaux and Vulpian (1870), while Langhley and Hashimoto (1917) were the first to consider fascicular reconstruction, the new surgical procedures were actually introduced as late as 1968, when Bora and Millesi made that giant leap forward by creating worldwide receptivity to the idea of soft part structure microsurgical reconstruction.

3. Thirty years of the dissemination and improvement of the concept of microsurgical reconstruction and reconstructive microsurgical practice have led to feedback that changed a series of precepts but also raised many questions. Such developments are inevitable within and after real experience. The peripheral nerve microsurgical reconstruction concept is closely connected to the mechanism of the recovery of severed and microsurgically reconstructed peripheral nerves.

4. Reconstructive microsurgery is a new concept, the concept of microsurgical reconstruction of tissues using specific means:
   a) The operating microscope
   b) Microsurgical instruments; bipolar coagulator
   c) Special microsurgical suture material
   d) Microsurgical techniques specific to the types of tissue to be reconstructed
   e) Specialized surgeons equipped for reconstructive microsurgery specific to that specialty
   f) Special general anesthesia conditions
   g) Special operating room conditions
   h) Special intra- and postoperative care conditions and a team trained and put together for this purpose

5. Significant changes to peripheral nerve surgery were made primarily by the emergence of a new concept of nervous system repair. Introducing the microsurgical concept, surgeons have tried to improve the operating conditions, visualization and manipulation of the delicate neural elements, to overcome the great obstacle in the way of successful peripheral nerve repair by introducing a new operating technique – the microsurgical reconstructive one.

6. Classic epineural sutures are gradually being abandoned in favor of fascicular sutures.

7. Of all the microsurgical peripheral nerve suture techniques, the fascicular group suture is currently the most appropriate for maximal recovery. Naturally, in adequate technical conditions and when "there is no alternative" the epiperineurial suture and especially the circumferential fascicular suture can prove useful.

8. In 1982, associated anastomosis of the main artery of the nerve (0.2 – 1 mm in diameter) proved that in 70 % of cases recovery was faster and better. The most difficult thing about this anastomosis is not the technical skill but finding the artery to which anastomosis can be performed.
   Considering the major defect created by strokes as well as the data provided by the specialist literature describing a vascular system that is in excellent condition from an epiendoneural point of view, and the importance of this artery in embryonic life, in 1982 I decided to associate fascicular group reconstruction of the peripheral nerve with the anastomosis of the main artery of the peripheral nerve, i.e., the median nerve. There were two striking conclusions: (1) the recovery period was reduced to half and its quality doubled; (2) there was concern for the safety of the anastomosis carried out on a vessel 0.2 – 1 mm in diameter and the surrounding compressive fibrosis.

9. How old the lesion is, the patient's age and the microsurgical concept are the key factors on which the level of recovery depends after a peripheral nerve lesion. Obviously, the shorter the post-traumatic period, the better the results. However, in young and very young patients, the age of the lesion does not represent a contraindication for grafting provided it is done for the purpose of gaining at least the tactile sensitivity.
   There are several key reasons why I will not recommend laborious reconstruction during the emergency operation:
   a) The injury is more or less contaminated, so, at this point, it is more exposed to infection than at the moment of the secondary operation.
   b) The emergency procedures are basically meant to provide first aid treatment. In general, one has to be extremely lucky to come across a highly skilled reconstructive plastic surgeon who happens to be on regular duty. Iatrogenic damage (something that apparently can never be checked retrospectively), added to the initial injury, will

complicate and diminish the actual chance of recovery.

c) For the time being, the emergency exploration cannot detect the extent of damage to the neural tissue of the peripheral nerve; while at the next stage, 3 weeks later, the length of the neuroma is clearly "outlined" and the microsurgeon alone has to perform appropriate, highly specialized surgery.

d) Provided I had the authority to do so, I would set up special regulations to be followed when performing emergency operations.

e) There are exceptions: when, from the very beginning, the patient is taken care of by a specialized unit or if replantation is involved, an operation that can be successfully carried out (i.e., with optimal motor and sensory results) only by a highly skilled and experienced specialist; of course, emergency reconstruction must have clearly defined goals: bone alignment, blood vessel (arteries and veins) repair, fixing the flexor and extensor tendons when this is possible without compromising reconstructed vessels and nerve anchoring, tegument suturing and immobilization will certainly be part of the program.

This may seem a simple enumeration of reconstruction stages and this may actually be the case when the surgeons involved understand what they are doing, the purpose of what they are doing and that they did not learn their job from "hearsay," or "watching." Reconstruction involves solid knowledge and time-consuming study.

10. As for the level of the lesion, I could not notice any difference in the quality of the postoperative evolution of the peripheral nerves operated on within 6 months of the accident, regardless of the level of injury (hand, forearm, arm, foot, calf, thigh).

11. The "surgical bed," the associated lesions as well as the number of surgical reinterventions (for example, the cases in which two nerves have been affected or major arteries have been severed) are matters that I find more important. In such cases the recovery period increases and the quality of the recovery is poorer. When the patient is young, no more than 6 months have passed since the accident and there were no previous surgical interventions, the quality of the repair can be as good as that in the case of only one severed nerve.

12. The most difficult moment is the adequate coaptation according to the corresponding sensory and motor groups. The only conclusion at this point is that a rapid and safe intraoperative identification method would be really helpful; until then relying on the "common sense" of sight and orientation under the operating microscope remains the only available option.

13. As for the length of the nerve defect, the longest nerve defects covered by grafts measured 28 cm. I am not in the least convinced of the point held by many specialized studies that the longer a defect the poorer the postoperative results. To my surprise, the sensitivity level tests carried out on different lengths of defects within the first 30 days after the operation proved the presence of hypoesthesia, then of tactile sensitivity in 80 % of the grafted median and posterior tibial nerves within a period of 7 – 30 days after the operation, as well as some degree of finger flexion in the high median nerve lesions or finger extension in external popliteal sciatic nerve lesions.

I will not question the tendency of the peripheral nerve to "grow" through its axonal buds especially if the proximal stump meets optimal requirements: clean section after delimiting the neuroma through excision. But the problem of the distal stump, of leading the nervous impulse from the proximal to the distal and vice versa plays, in my opinion, a major role in the quality of the restored fiber continuity. Under the present circumstances a good fascicular reconstruction is the most we can hope to achieve. When the peripheral nerve fiber becomes as important as the fascicle is now for reconstruction, I contend that the recovery will be almost "instantaneous," taking no longer than a current neuropraxis. The fact that proximal regeneration is better than the distal one is due to the multiplication of the nerve fascicles and, moreover, of nerve fibers, a multiplication that is greater distally, resulting in the higher stakes of coaptation and a greater difficulty in properly and technically carrying it out according to the standards of the year 2005. The problem of coaptation in fewer and "coarser" structures such as the ones at brachial plexus or arm level has been largely solved, but in the matter of "perfect" distal coaptation we are still some way behind. The special means (operating microscope, instruments, suture materials) permitting recovery will be, figuratively speaking, "instantaneous," as it happens in neuropraxis.

This is how I explain why in a higher lesion, where there are one to two or very few fascicles, the result is, "say," equivalent to 8 mm a day. In reality things are much more "serious"; there may be many more millimeters a day, something I have observed all too often.

It has been a long time since I first made the same remark concerning the length of grafted nerve defects as well as the level of such defects: at the plexus, brachial, or antebrachial plexus the

nerve defects quite often reach over 20–25 cm in length. Bearing this in mind, what kind of explanation for regeneration can we produce for the current use of the truncal ulnar nerve as a nerve graft in older than 6 months – 1 year, in serious brachial plexus lesions (i.e., involving all the components), and in adults over 40–55, resulting in regaining flexion 8–12–21 days after the operation?

14. With respect to the location of the lesion and the length of the nerve defect, any time there is tension "to the limit" upon the future suture line, one must choose between under tension suture and nerve grafting. The specialist literature maintains that in 3- to 4-cm-long defects the nerve graft should be taken into consideration. In reality, in median nerve lesions, the 2- to 3-cm-long defects can be "compensated" by proximal and distal mobilization of the nerve. Things are different in the case of ulnar nerve defects in the proximal or median third of the forearm, where 1-cm-long defects definitely need grafting.
    In small 1- to 2.5-cm-long ulnar nerve defects, I obtained better results after using the dorsal sensory branch of the ulnar nerve rather than a sural nerve segment as a donor nerve.

15. Drawing from Millesi's understanding of the epinerve conjunctive tissue, since 1981 I have regarded the excision of the graft epinerve (at the graft extremities) as a reasonable and useful decision. It increased the chance of comfortable and high quality fascicular alignment during the operation and the postoperative reinnervation.

16. Nerve graft harvesting requires special attention and therefore all the grafts were harvested "by sight," through an incision covering the whole length to be excised, without any traction–stretching (knowing that a 15% stretching compromises the nerve), so that the only conjunctive tissue surrounding the nerve would be the inner layer of the epinerve.

17. The 41 patients who underwent vascularized sural nerve graft and microvascular anastomosis are not enough to enable us to draw certain conclusions. That is why the fact that 38 patients with vascularized grafts recovered exceptionally well may be purely coincidental. Nevertheless, the results achieved in such a short period of time are exceptional when compared with those obtained by common microsurgical grafting.
    In 1985 I resorted to international experience in using vascularized nerve grafts, being persuaded by the importance of adding vascularization to peripheral nerve reconstruction.

18. I do not believe in the usefulness of the anterior ulnar nerve transposition in the cases indicated by the specialist literature. Higher lesions have less chance of perfect recovery of the intrinsic musculature, but the big deep flexors can still recover. If transposition is carried out, the motor fascicles for the deep flexors are most often severed or stretched; in other words they are pointlessly sacrificed. A nerve graft is therefore indicated and preferred.

19. In case of "continuity lesions" or peripheral nerve lesion of the 6th degree, the diagnosis during the operation is necessary although it is very difficult to accurately identify the site of the lesion, the number of affected fascicles and the margins of the lesion. These data can be obtained as a result of a painstaking, irreproachable internal neurolysis, and thus reconstructive surgical intervention can proceed. The annoying, "endless" continuity lesions can however be carefully delimited. The absence of vascularization on a portion of the nerve affected by this kind of lesion, and the conjunctive tissue of the epinerve with its interfascicular extensions, become a valuable guide for identifying the "limits" of this type of lesion. By feeling the nerve segment and permanently comparing it with the rest of the peripheral nerve, the surgeon may find signs of empty tube, more fibrous, more sclerotic content. Most frequently, if not always, the "continuity lesions" need healthy tissue excision and grafting of the initial nerve defect. The neurolysis alone is not able to sustain recovery of the injured peripheral nerve territory.

20. In cases of median and/or ulnar nerve paralyses, severe sequelas such as a neglected Volkmann, or severe, prolonged nerve ischemia, spectacular results can be achieved following fasciotomy and the restoring of nervous continuity even by using nerve grafts, but only if the deep flexor muscular mass still has "survival" chances.

21. In lesions due to nerve stretching, we believe that neurolysis "alone" is useless, the only real opportunity to recover being provided by healthy tissue excision and covering the defect by nerve graft.

22. Daily monitoring of the operated patient up to the 12th day for direct coaptation and the 21st day for indirect coaptation (nerve transplants) proved the presence of hypoesthesia and tactile sensitivity on the 3rd, 7th and 14th days after the operation, on previously inert areas. They are clearly outlined on the 21st day following the operation. Timid flexion or extension movements and even incomplete and inaccurate flexions and extensions were evidenced during the same interval. Peripheral and less than peripheral movements were also evidenced in the

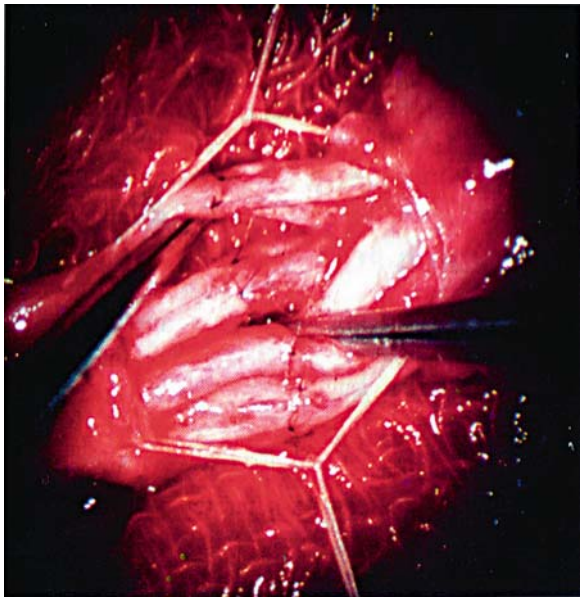


Fig. 11.1. Peripheral nerve microsurgical fascicular suture in fascicular groups. Note the removal of the nerve sheath, the epineurium, as well as the aligned, already sutured (coapted) fascicular groups

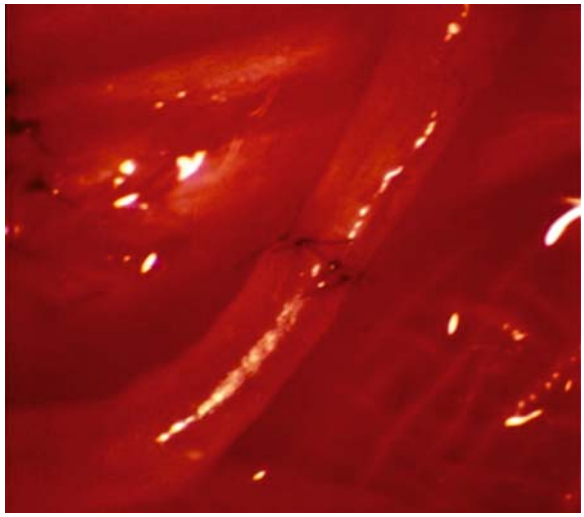


Fig. 11.2. Anastomosis of the main artery of the nerve, magnified 25 times

15- to 30-day interval following microsurgical reconstruction by long nerve transplants in complete brachial plexus paralyses and therefore reconstructions of "four out of five nerves." These observations do not confirm the current physiopathological explanations provided by the international specialist literature on nerve recovery. I am certain that new theories on the recovery or so-called " regeneration" of the operated post-traumatic peripheral nerve will soon become available.

In 1980 – 1981, I observed the presence of the Tinel sign in the distal finger extremity after fascicular group reconstruction of the peripheral nerve 3 – 5-7 days after the operation. In 1982 – 1983, anxious that I could not find the Tinel sign in the same location within the same time lapse, at the patients' insistence that they "could feel" the previously insensitive part, I started to closely monitor them for I could not believe them, since the peripheral nerve degeneration–regeneration theory said otherwise. After 1 year, I was positive that in 3 – 4–7 days, several disparaged hypoesthesia areas did appear on the initially denervated area and that by the 21st day they had extended over the entire previously denervated surface. In the absence of an objective factor I began to require the patient to very carefully attempt some basic movements that had been abolished before the operation. I thus realized that the movements frequently appeared 6 – 8–21 days following the operation. As I gained microsurgical experience, such movements began to appear as a matter of course in patients who met the essential conditions for good recovery: time lapse since the accident, younger than 45, fascicular group reconstruction.

23. I think somehow the post-traumatic peripheral nerve degeneration-regeneration theory has blocked our minds and we ignore one simple fact: any major trauma produces disorder of which the conjunctive tissue takes advantage, at the expense of noble tissues. When the skin is cut and no reconstruction succeeds, when our organs are badly traumatized and injured and there is no reconstruction afterwards or if the natural tissue order is not restored, is there anything to prevent cell destruction and to help the body part resume its function? The same happens when a neuroma is formed proximally and distally by means of an edema, disorientation, stupor, loss of direction and continuity, to which the conjunctive tissue is added to drive the last nail into the coffin, increasing the reaction to trauma of the peripheral nerve fascicles-fibers.

The neuroma is not the result of degeneration, degeneration being the result of trauma and conjunctive tissue invasion. This mechanism reduces the fascicle and endoneurial tube diameters, resulting in the lack of normal supply of nutrients, by deficit to the proximal stump, and by absence to the distal one. Why is it that following secondary coaptation in due time, i.e., after continuity was resumed, degeneration and regeneration phenomena fail to follow the same pattern? Were they not severed and then sutured?! Deeper understanding of the phenomena and more adequate surgical means to suit the new level of understanding will create the opportunity for more rapid and higher quality recovery. Undoubtedly, in

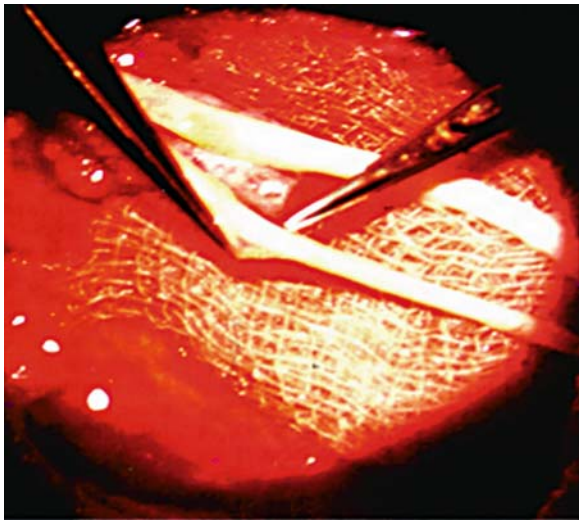


Fig. 11.3. Image exemplifies epineurial delimitation at the level of nerve graft segment extremities, and its excision

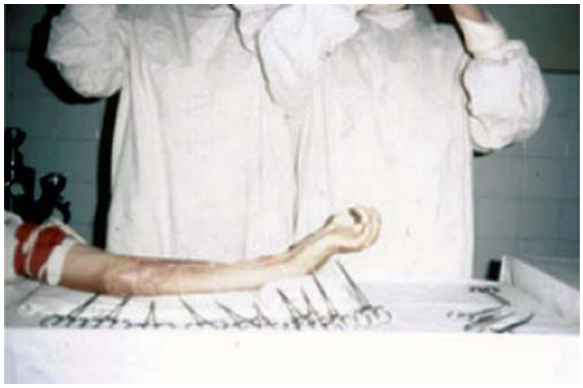


Fig. 11.4. The Volkmann syndrome: extensive fibroses of muscles in two children. Surgery consisted of forearm fasciotomy, lengthening of deep flexor tendons, excision of musculus pronator teres, and microsurgical reconstructions in two stages, at 2 and/or 3 months, of the median, ulnar nerves with nerve graft

the future, when the peripheral nerve fiber suture becomes possible or genetic engineering takes over, the results will no longer have to be improved. Why cling on to the 8 mm/day regeneration? Twenty years ago, when I completely believed in the 1 – 3 mm/day of peripheral nerve regeneration, I realized that this rate was not at all real.

As long as a peripheral nerve can recover 90 % following microsurgical reconstruction with or without nerve grafting, if the time lapse since the accident was optimal, if the patient is of the right age, if the reconstructive indication is adequate and if the microsurgeon does his/her best, why believe that a much better reconstruction, at the fiber level for example, or maybe with more accurate means, must fall under the "theory" instead of changing the theory by updating it to suit the needs of today and, especially, those of the future?

24. None of the patients who underwent peripheral nerve microsurgical transplant on peripheral nerve defects needed palliative surgery.

25. None of the more than 3,000 patients with microsurgically operated on peripheral nerves displayed any suppurating complication. During the operation or within the first 3 h after the operation, four patients suffered ruptures along the suture line of the peripheral nerve; the suture was redone 24 h later.

26. Limb replantations have a special status; there is a very strict "order" of carrying out the surgical intervention, an order set forth by the most outstanding microsurgeons in the world, which proves reasonable and relatively "simple." Yet, I would make one observation: I only performed a small number of replantations (24, 23 of which were successful) and I may not be entitled to such a remark, but my experience with peripheral nerve surgery leads me to believe that in the case of replantation operations the emergency intervention should be restricted to the simple nerve anchoring. Nerve continuity should be restored in a secondary intervention, quietly, under less pressure.

    Although the solution does not follow the recommendations of the specialist literature, which maintains that peripheral nerve continuity be restored during the emergency intervention, I recommend anchoring as the most effective solution for the time being.

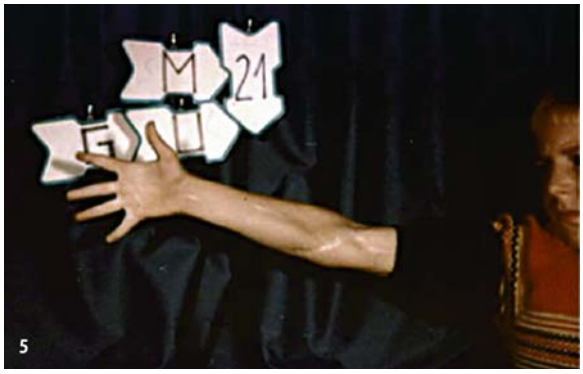
    Here are the arguments in favor of this option:

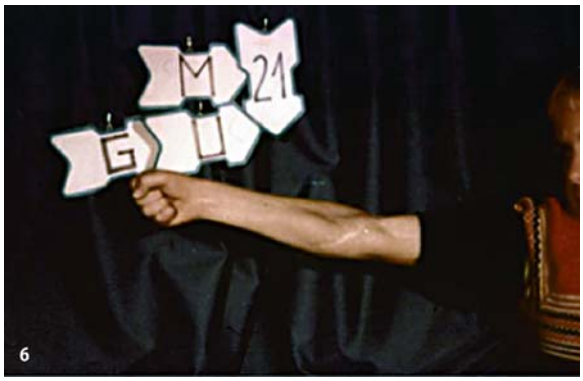
    a) It is impossible to determine the total length of the peripheral nerve lesion, the essential condition for a maximal result.
    b) Prolonged exposure of the fresh arterial and venous anastomoses can compromise replantation.
    c) The already long duration of general anesthesia – usually from 6 to 12 h – may lead to vital, unforeseen complications; such cases usually refer to patients with an unknown medical history.

    Replantation is out of the question in a room without adequate personnel and equipment (microsurgeon, operating microscope, microsurgical instruments, proper conditions for longer general anesthesia: 6 – 8 – 10 – 12 h).

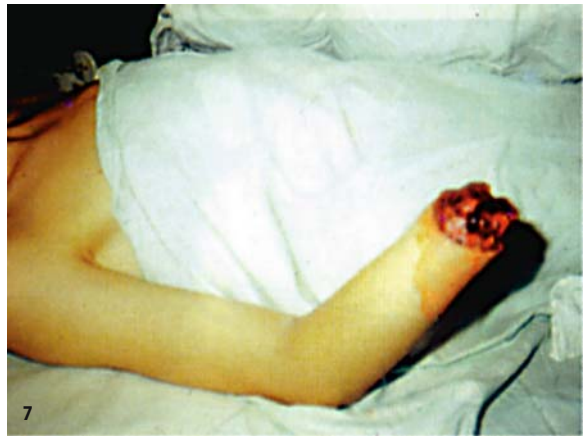
27. Concerning brachial plexus reconstructions of post-traumatic paralyses, I have reached the following additional conclusions:

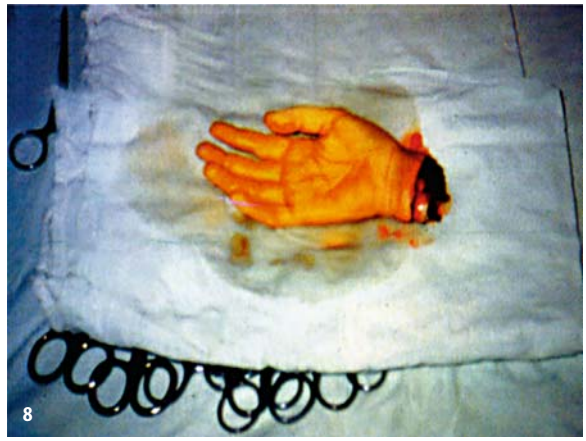
    The need to bypass the fibrosclerotic formation to avoid accidental rupture of the vessels with ex-





Figs. 11.5, 11.6. Result at 21 months in the first child





Figs. 11.7 – 11.9. Replantation case

tremely fragile walls traumatized during the accident.

The length of defects along the root-trunk-fascicle-nerve pathway is not relevant as long as there are adequate nerve graft sources.

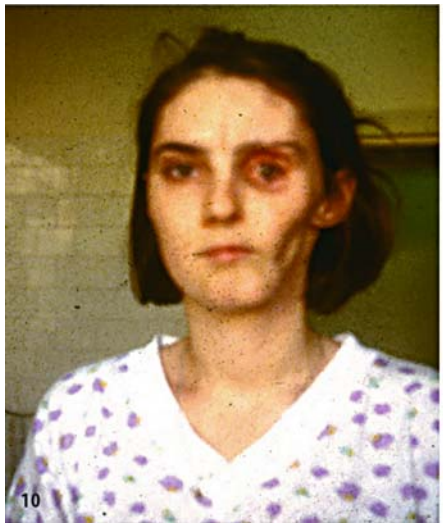
It is preferable to use the truncal nerve grafts at least for connections with the nerves that have priority.

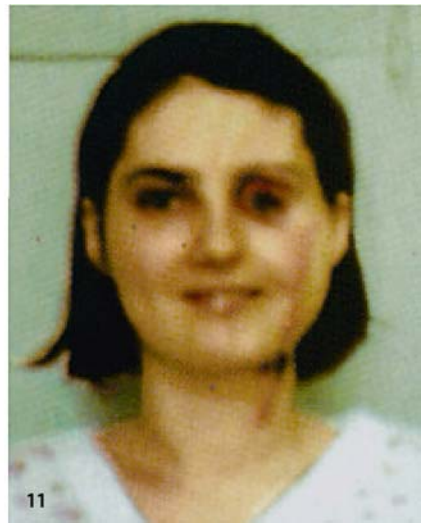
No matter how dim their prospects appear to be, the remaining roots should never be left out.

In most cases of brachial plexus paralyses due to avulsion-pulling outstretching vascular damage is equally severe; therefore, I believe it is extremely useful and advisable to perform routine antebrachial fasciotomy during plexus reconstruction.

28. Special conclusions on functional free flap transfer: Free microsurgical muscular transfer for the purpose of hand motor function recovery can only be carried out if certain requirements concerning the host area are met, such as:
    a) Very good sensitivity on the territory of the palmar and digital median nerve
    b) Absence of any contractile muscles at the level of the forearm
    c) Existence of free joints at the metacarpophalangeal and interphalangeal levels
    d) The patient has the will

Old facial paralysis treatment. To select the optimal donor nerve that can be used in the host area is often difficult in very old facial paralyses. In the best cases, such as facial paralyses after the excision of tumors, the free transfer of muscle together with nerves often makes the remaining facial nerve stump reusable. The function of the transferred muscle innervated by a former facial nerve is always superior to that of the muscle innervated by a hypoglossal or trigeminal nerve even if a nerve graft is inserted.





Figs. 11.10, 11.11. Progressive facial hemiatrophia. Reconstruction of face contour: the vessels of the latissimus dorsi free flap were anastomosed to the facialis vessels. One year later, the aesthetic free flap modeling was performed

Combination with "cross-face" type nerve grafts for the purpose of facial reanimation: the reconstructive operation described by the international specialist literature consists of two stages separated by 6 – 10 months: The first stage involves the transportation of the cross-face nerve graft, the second one focuses on providing its connection with the muscle nerve that is subject to free vascularized transfer.

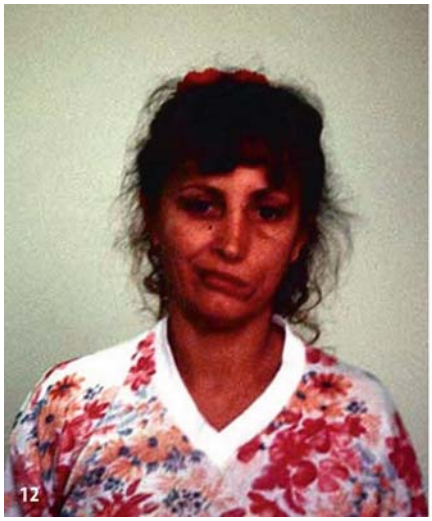
The following considerations influenced my decision to join the two stages into one and the same operation:

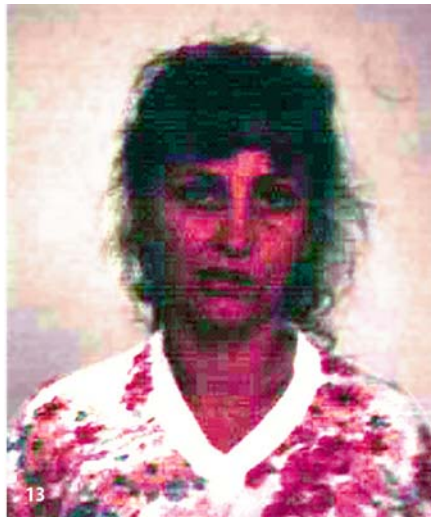
a) My experience and observations concerning peripheral nerves.
b) When the gracilis muscle is subject to a free transfer for covering an antebrachial muscular defect, there is no need for postponing nerve repair.
c) "The size" of the host nerve (mandible, zygomatic branch). It is hard to believe that in such delicate facial dissections, upon delimitation of the neural and vascular elements, fibroses will not appear around them, thus compromising at least part of these valuable elements. Why then have a second stage and inevitably further produce fibrosis since element delimitation becomes even more difficult? It is a pity that, once delimited, the nerve fibers, which are invisible to the naked eye, be deprived of continuity before postoperative fibrosis starts to affect them.
d) The local conditions of the face, with its entire vascularization, determine the rapid destruction of the non-innervated nerve graft. In this case, the motor plate cannot act as a stimulus to innervation recovery as the nerve graft lives through its function or the beginning of its impulse leading function.
e) If in cases of replantation or revascularization I am in favor of a secondary nerve repair operation, in this case, I believe that primary repair is crucial for the quality of the free muscular transfer; without it the free transfer is useless. I am thinking of the delicate function of the facial expressiveness, control of the mouth commissure and the opening-closing of eyelids.

The one stage surgery that I propose consists of the following operation steps:

aa) Delimiting the mandible branch and, if possible, the zygomatic component of the unaffected facial nerve.
bb) Harvesting the sural nerve graft without pulling it out.
cc) Indirect coaptation of the nerve graft to the unaffected end to the mandible branch of the facial nerve (and, possibly, to the zygomatic component) as well as nerve tunneling strictly beneath the skin, usually on the upper and/or lower lip and bringing the remaining free end of the graft to the affected side of the face.
dd) Harvesting the anterior serratus muscle (the last three branches) with the corresponding neurovascular pedicle.
ee) Free transfer and positioning of the anterior serratus digitations at the level of the affected side of the face, "spreading" and fixing the muscular digitations to the mouth commissure, the upper and lower eyelids.

29. My microsurgical experimental studies on the reconstruction of the rabbit ear nerves proved the existence of fiber continuity in all the histopathological examinations performed. The rabbit's ear contains extremely fine nerves, with no more than two to four fibers.





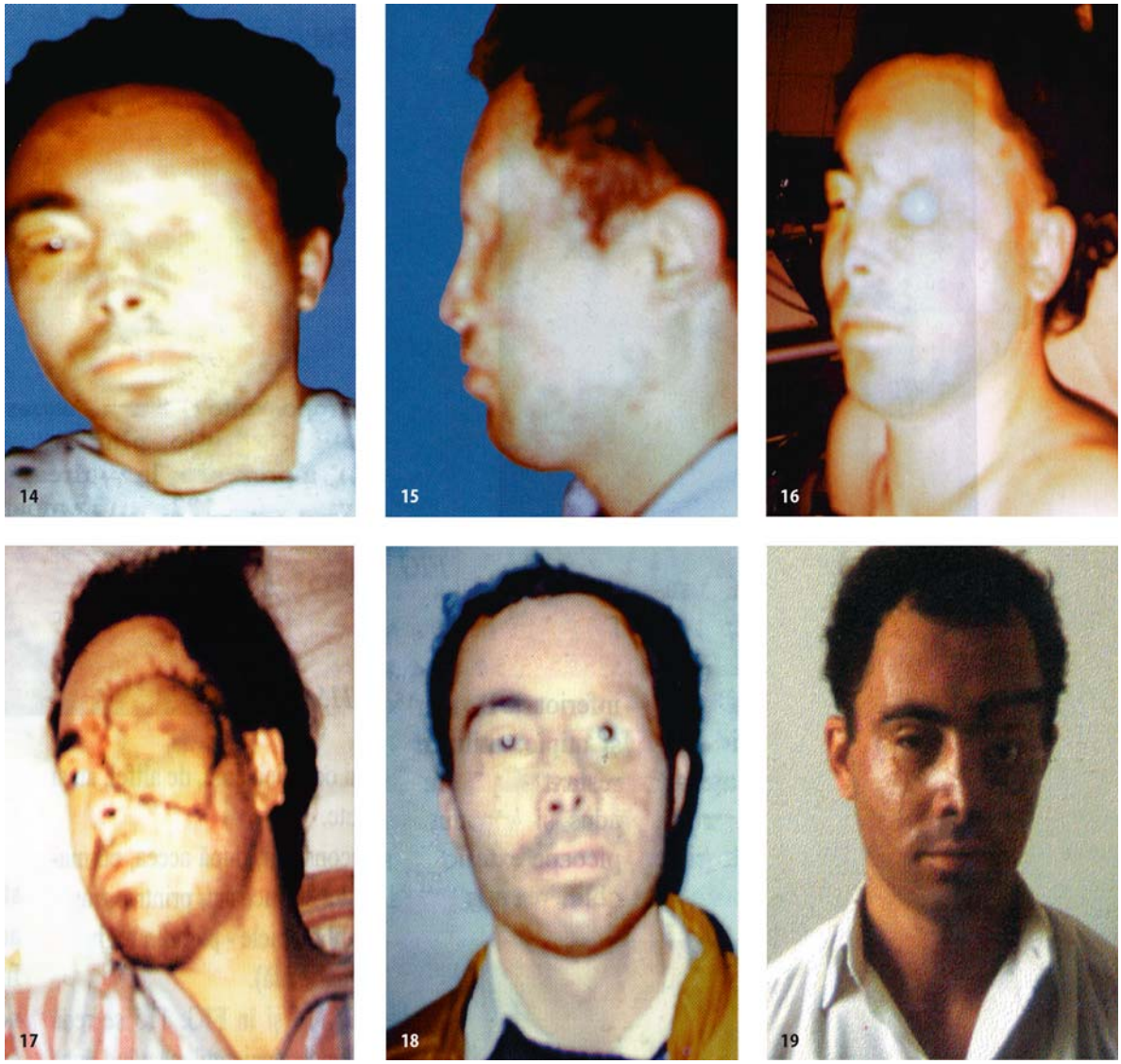
Figs. 11.12, 11.13. Old facial nerve paralysis: One stage surgery, free flap transfer of serratus anterior muscle innervated with sural nerve graft 12 – 22 days after the operation; the patient displayed obvious contractions of the affected mouth commissure and upper eyelid

30. The histopathological examinations performed on the 500 neuromas of the classic sutures on large nerves such as the median, ulnar and radial ones constantly revealed the absence of fascicular continuity. Only a tiny fraction of neuromas displayed some partial level of fiber continuity, the rest of the section being filled with classic suture threads and granulomas within the conjunctive tissue.

31. The histopathological examinations carried out on the experimental vascular anastomoses of the rabbit's ear (over 100 arteries and veins 0.2 – 1 mm in diameter) between 1980 and 1985 revealed a 90.2 % success rate.

32. Reconstructive microsurgery cannot be successfully performed in haste. Any seemingly minor mistake will compromise the entire 3 – 6–12 h work.

33. Peripheral nerve reconstructive microsurgery complementary treatment:
    The limb segment that underwent operation for reconstruction purposes is maintained in an elevated resting position. This means that:
    A peripheral nerve reconstruction of the direct coaptation type at the hand-forearm level needs segment resting and immobilization in plaster splints over a 22-day period, then immobilization ends but another 30 days for one nerve and 45 days for two reconstructed nerves are needed before starting practicing passive and active movements; for 6 months physical effort is not recommended, and that includes lifting weights over 1 – 2 kg.
    A peripheral nerve reconstruction of the indirect coaptation type located in the same region follows the same indication but the patient needs additional sick leave days and cannot start practicing hand/forearm movement within 45 days of the operation. It also involves special care for the donor area to ensure physiological healing.
    A brachial peripheral nerve or nerve reconstruction by direct or indirect coaptation needs a 30-day period of bed rest immobilization in order to avoid the weight of the limb segment; the same recommendations apply here.
    Cranial-facial peripheral nerve reconstructions usually need a 14 – 21–day period of "immobilization," which is actually meant to avoid tension and edema in the region; the patient can return to work if the operated area is protected from cold or maneuvering, but the doctor may recommend an additional 14-day sick leave.
    Pelvic extremity peripheral nerve reconstructions require total bed rest in the recommended position so as not to produce tension on the reconstruction line or lines; this compulsory 30-day immobilization period is followed by another 2 months (which are part of the sick leave) when, for 6 weeks, the patient is allowed to walk without touching the ground with the operated limb and then to walk with a cane for the remaining 2 weeks.
    Brachial plexus reconstructions involve bed rest immobilization in a pseudo-Dessault, horizontal position, avoiding tensions between the neck-cervical region and the operated area, preventing the thoracic extremity from exerting pressure through its weight, without the least amount of tension on the usually multiple reconstruction lines; movement from the logical positions is forbidden in order to preserve the chances for the best possible results. If the patient's job provides little guarantee for the safety of joint mobilization to maintain the allowed amplitude, it is safer and more advisable to immobilize the patient for a month than risk coping with an important deficit throughout the pa-



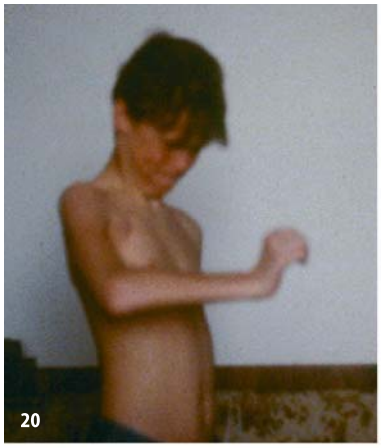
Figs. 11.14 – 11.19. Eye-socket reconstruction, mobile upper eyelid, lower eyelid, eyebrow

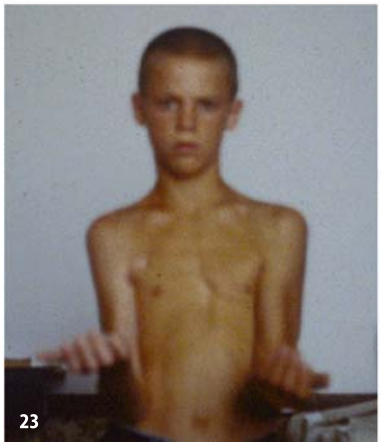
tient's life. Usually, after such reconstructions, patients need a 6- to 12-month sick leave to gather strength and energy and to concentrate on the exercises and workouts they need to do.

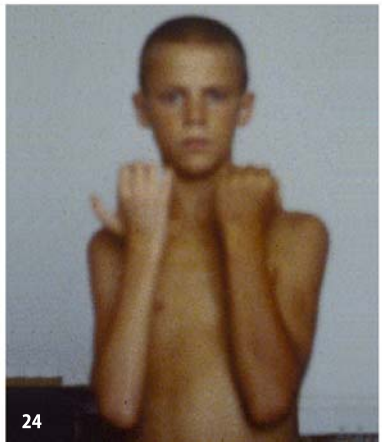
All the recommendations in the case of hand-forearm grafting apply to peripheral nerve reconstruction upon replantation.

After the end of the compulsory immobilization periods, i.e., the intervals following the 22 days – 1 month period after the operation, the passive and active gradual mobilization of the reconstructed segment components must begin. The idea is that this mobilization must be performed by the patient from the very beginning, even if the patient is a child, since the patient's mental cooperation is indispensable after this type of reconstruction, in order to regain the kind of movement any patient wants, that is to regain the normal movement abilities before the accident, with the obvious limitations in each patient's case, but always comparing it with the function of the healthy, non-traumatized opposite limb segment. Cooperation and results will completely depend on such "details."

34. Diapulse-therapy associated with surgery facilitates axonal growing and breaking of the barrier at the suture level. This is proved by the presence of the Tinel sign between the metacarpophalangeal joint (MPJ) and the third phalanx (F3) during the first 3 days following the operation in all the patients who underwent fascicular suture associated with diapulse therapy (DPT).







Figs. 11.20 – 11.24. Complete brachial plexus palsy reconstruction of the brachial plexus, completely paralyzed, is performed by sural nerve grafts, 6 – 12 cm long, between the medial, lateral fascicles to the median, musculocutaneous, ulnar nerves as well as the neurolysis of the posterior fascicle (radial and axillary nerves). Two months after reconstruction useful extension of fingers and hand can be performed (Fig. 10.20). Six months after surgery, complete extension of fingers and hand (Fig. 10.21); efficient flexion of the fingers (Fig. 10.22); flexion of the forearm to the arm (Fig. 10.23); and supination (Fig. 10.24) can be performed

In the 1980s, in the Plastic Surgery Clinic, Professor Agrippa Ionescu gained a lot of experience concerning the role of the electromagnetic field in treating burns. His conclusions, i.e., reduction of the edema, cell membrane repolarization, became arguments in favor of using diapulse therapy as a complementary treatment to be employed immediately after microsurgical reconstruction. The ultimate conclusion was that every time DPT treatment was associated with fascicular group reconstructions for 12 – 21 days, the period in which the Tinel sign emerged dropped from 3 – 7 days to 2 – 3 days.

We started from the following assumptions:

a) DPT increases blood flow, enhances circulation and, therefore, raises the oxygen level in the tissues.
b) In case of circulatory disorder, which is always present in the post-traumatic–postoperative period, by restoring the electric potential of cells, DPT also restores their function, reduces circulatory disorder, and causes the edema to shrink or disappear along with all its negative consequences, such as distension, pain, and the emergence of scar tissue.

35. It is vital that the results be assessed for groups of patients operated on by one and the same surgeon-microsurgeon. Apparently the same technique, applied to apparently the same category of patients, can yield opposite results or just a minimal improvement in comparison with results following conventional surgery. At present, as a result of microsurgical interventions, in the best of cases (within a 6-month period after the accident in patients younger than 45 years), recovery can reach 75 – 90 %. These are the real parameters of authentic reconstructive microsurgery. We should never encourage microsurgeons to achieve results that only show some improvement in comparison with the results yielded by classic techniques and be content with the patient's satisfaction with such minimal improvements. Patients may be happy even with a 10 – 20 % improvement, but they are not in a position to estimate their real chance of "maximal" recovery. The surgeon alone can justly appreciate what was achieved and what might have been achieved. Therefore high quality microsurgery can only be performed by doctors with a high level of professional conscience.

36. It is important that these microsurgical procedures be constantly evaluated and openly compared with conventional methods not only from a functional and aesthetic point of view, but also taking their actual cost into account. Microsurgery has the potential to reduce the number of hospital days, the period of functional handicap and, more importantly, it provides good prospects for total, or almost total, functional recovery. It is clear that over the next decade microsurgeons must include social considerations alongside medical ones when they evaluate their work.

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Long-term Results After Vascularized Joint Transfer for Finger Joint Reconstruction

12

A.K. Berger, R. Hierner

12.1 Definition

Vascularized joint transfer is defined as a partial or complete joint transplant with preserved (pedicled transposition) [1, 2] or immediately restored (free microvascular) [3] blood supply.

A further subclassification can be made, with the clinically most relevant categories being: source of transplant, type of transplant, and donor site of transplant (Table 12.1).

Depending on the source, autologous (from the same patient), allogenic (from another human) or heterogenic (from another species) transplants can be distinguished. Allogenic joint transfer offers the possibility of an unlimited amount of tissue and the absence of donor site defects. Experimental studies on vascularized allogenic joint transfer reveal that these transplants show identical functional results compared to autologous vascularized joint transplants, provided there is adequate systemic immunosuppressive treatment [4], without which these transplants undergo rapid cartilage destruction and lose their function 6 – 8 months after transplantation [5]. Their clinical use is limited because of possible patient impairment (infections, late malignancies, etc.) from the lifelong systemic immunosuppression in the scope of missing vital threat. Under these circumstances such allogenic joint transplantations are ethically not justified in our opinion [6].

With regard to the type of transplantation, partial [7] or complete transplants can be distinguished. In a complete joint transfer, the whole functional joint capsule/joint cartilage/bone unit is transferred completely.

Table 12.1. Clinically most relevant subclassifications of vascularized joint grafts

1. Source of transplant
Autologous vs. allogenic and heterogenic
2. Donor site of transplant
Hand
Homodigital joint transfer
DIP–PIP
(PIP–MP)
Heterodigital joint transfer
DIP–PIP
PIP–PIP
PIP–MP
MP–MP
Foot (2nd and 3rd toe)
PIP (toe)–PIP (finger)
MTP (toe)–MCP (finger)
MTP/PIP (toe)–MCP/MCP (finger)
PIP/PIP (toe)–PIP/PIP (finger)
MTP/MTP (toe)–MP/MP (finger)
MTP (toe)–CMC I (thumb)
3. Type of transplant
Complete joint transplant
Partial joint transplant
Monoarticular replacement
Biarticular replacement

The joint capsule is not opened, and therefore the internal "milieu" is not altered. Joint surfaces stay congruent to each other. In a partial joint transfer, there is significant impairment of the functional joint capsule/joint cartilage/bone unit. As the joint capsule is opened, there are significant changes in the internal milieu, subsequent scarring of the synovia and incongruent joint surfaces will face each other after transfer. Because P1 (basic phalanx) and P2 (middle phalanx) have two joint surfaces, there is the possibility that one (monoarticular replacement) or two (biarticular replacement) joint surfaces will have to be reconstructed.

Depending on the donor site, vascularized joint grafts can be harvested from the hand or the foot. Vascularized joint grafts from the hand [1, 2, 8 – 10] can be further differentiated into homodigital (from the same finger) [5, 11 – 13] and heterodigital (from another finger) [2, 3, 5, 14] joint grafts. This donor site offers the best joint grafts available although with the highest donor site morbidity.

Because of the high donor site morbidity, joint grafts from the hand are only taken following the so-called "tissue bank principle" according to Chase, i.e., from a finger that cannot be reconstructed, but which can be used as a graft donor for different tissues [2, 8, 12–16]. Vascularized joint grafts from the foot show similar anatomical features to finger joints but much less donor site morbidity when harvested. Therefore the foot has become of interest as a donor site for reconstruction of finger joints [5, 12, 13, 17]. The following techniques have been described in the literature: (1) vascularized proximal interphalangeal (PIP) (toe) joint transplantation for replacement of finger-PIP joint [5, 7, 12, 18]; (2) vascularized metatarsophalangeal (MTP) joint transplantation for replacement of finger-metacarpophalangeal (MP) joint [5, 19]; (3) combined vascularized transplantation of the MTP and PIP joint of the 2nd toe for replacement of two adjacent MP joints of the hand [5]; (4) combined vascularized transplantation of two MTP joints for the replacement of two adjacent MP joints of the hand [20]; (5) combined vascularized transplantation of PIP joint of the 2nd and 3rd toes for replacement of two adjacent PIP joints [5]; and (6) vascularized MTP joint transplantation for replacement of the carpometacarpal (CMC) joint of the thumb (Table 12.1).

12.2 Patients and Methods

In a retrospective clinical study, 16 vascularized joint transfers to the hand with an average follow-up of 8.2 (3–15) years were evaluated. The finger joint defect was caused by trauma in 12 patients, tumor in 2 patients and infection in 1 patient, as well as 1 patient presenting a congenital deformity. There were 14 men and 2 women. The mean age was 26 (2–42) years. In six cases a partial vascularized joint transfer was carried out, with the transplant being harvested in four cases from a non-replantable finger following the "tissue bank concept" according to Chase and in the other two cases from the PIP joint of the second toe. In ten patients a complete vascularized joint transfer was carried out, the joint being harvested from the hand in six cases and from the second toe in four cases (Table 12.2). The following criteria were evaluated: (1) active range of motion (Neutral-0 method), (2) postoperative arthritis, (3) growth, and (4) complications.

12.3 Results

The active range of motion of the transplanted joint for partial PIP joint transfer was Ex/Flex 0/20°/65° and for partial MP joint transfer it was 0/20°/30°. After distal interphalangeal (DIP)-to-PIP joint transposition, the active range of motion was measured to be Ex/Flex 0/20°/60°, after PIP-to-PIP transposition it was 0/30°/60° (Fig. 12.1a–f), after PIP-to-MP transposition it was 0/20°/80° and after MP-to-MP transposition 0/20°/57°. The results after microvascular PIP joint transfer from the second toe for PIP joint reconstruction were 0/25°/58° for PIP joint reconstruction and 0/15°/70° for MP joint reconstruction (Fig. 12.2a–k). Arthritic changes could be seen in three out of four patients with partial vascularized joint transfer. In all complete joint transfers there was no clinical and radiological evidence of arthrosis even after 15 years. In the two skeletal immature patients at the time of transfer, a normal growth compared to the contralateral donor site could be seen. Complications occurred in 8 out of 14 patients. In 4 cases tendolysis of the extensor tendon was necessary. In four patients skeletal malalignment (×3 sagittal plane, ×1 rotation) was diagnosed. In one patient flexor pulley reconstruction was necessary in order to correct a bowstring deformity.

12.4 Discussion

12.4.1 Partial Vascularized Joint Transfer

Transplantation of only one joint component is technically possible and is practised clinically [12, 21–26]. The main disadvantages of this technique are incongruent joint surfaces, lesions of the synovial sheath and postoperatively scarring with subsequent joint stiffness and joint malalignment. Because of the reduced mobility and the early onset of degenerative arthritis, partial vascularized joint grafts are a technically demanding operation with no significant advantage when compared to non-vascularized autologous partial joint grafts [12, 27, 28]. As only one joint component is denervated and postoperative degenerative changes occur, secondary pain at the reconstructed joint is possible. Nowadays indications for partial joint transplantation are exceptional; in an emergency situation after hand trauma one should always bear in mind the possibility of a vascularized partial joint graft from the hand in the context of "spare part surgery" or the "tissue bank concept". If adequate joint material is available without creating a donor site defect, one should try to reconstruct even one-half of a joint if there is a good chance of functional improvement with additional joint movement and a low risk of impairment of global function. There are rare indications for partial vascularized joint transfer from the foot. Reconstruction of the thumb after transarticular amputation at the MP joint using a great toe transplant offers additional mobility at the thumb with acceptable onor site morbidity at the

Table 12.2. Personal experience

	Diagnosis	Age (years)	Gender	Type of transplantation	Active range of motion	Complications	Postoperative arthritis	Growth
1	Trauma	21	M	Partial PIP (P1) DV–DIV (heterodigital transposition)	0/20°/70°	Extensor tendon adhesion = tendolysis	+	–
2	Trauma	32	M	Partial PIP (P1) DII–DIV (heterodigital transposition)	0/20°/60°	–	+	–
3	Trauma	29	M	Partial PIP (P1) D IV–D III (heterologous transposition)	0/20/40	–	–	–
4	Congenital	2	F	Partial MP MT/D(f)II–MC I (free microvascular transplantation)	0/20°/35°	(Opponens transfer)	–	+
5	Trauma	21	M	Partial PIP (P1) D(f)II–MP I (free microvascular transplantation)	0/20°/25°	MP joint instability with axial malalignment = capsule plasty	+	–
6	Tumor	36	M	Partial P1 (f)–MP = PIP D IV	MP: 0/10/70° PIP: 0/20/50°	–	+	–
7	Trauma	27	M	Complete DIP III–PIP III (homodigital transposition)	0/20°/60°	–	–	–
8	Trauma	19	M	Complete PIP IV–PIP III (heterodigital transposition)	0/30°/60°	Extensor tendon adhesion = tendolysis Sagittal malalignment	–	–
9	Trauma	25	M	Complete PIP DIV–PIP DV (heterodigital transposition)	0/30°/60°	Sagittal malalignment	–	–
10	Trauma	32	M	Complete PIP III–MP II (heterodigital transposition)	0/20°/80°	–	–	–
11	Trauma	42	M	Complete MP II–MP III (heterodigital transposition)	0/20°/50°	Bowstring phenomenon = pulley plasty	–	–
12	Trauma	34	M	Complete MP V–MP IV (heterodigital transposition)	0/20°/60°	Malalignment (rotation 10°)	–	–
13	Infection	37	F	Complete PIP(f) II–PIP II (free microvascular transplantation)	0/30°/50°	Extensor tendon adhesion = tendolysis (×2)	–	–
14	Trauma	28	M	Complete PIP(f) II–PIP III (free microvascular transplantation)	0/30°/70°	Extensor tendon adhesion = tendolysis	–	–
15	Tumor	34	M	Complete PIP(f) II–PIP IV (free microvascular transplantation)	0/15°/55°	–	–	–
16	Trauma	16	M	Complete PIP(f) II–MP II (free microvascular transplantation)	0/15°/70°	–	–	+

(f): transplantation from the 2nd toe

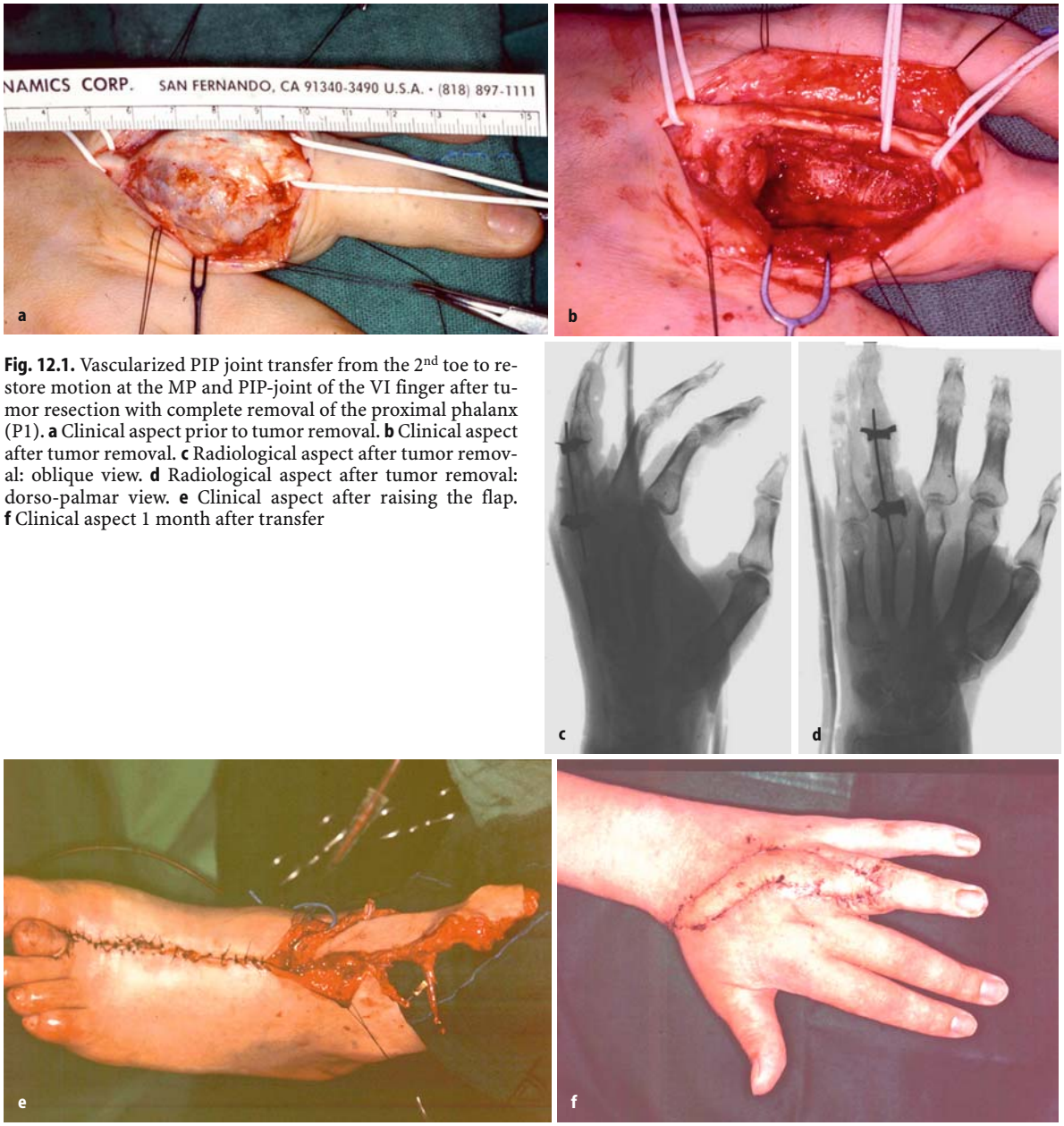


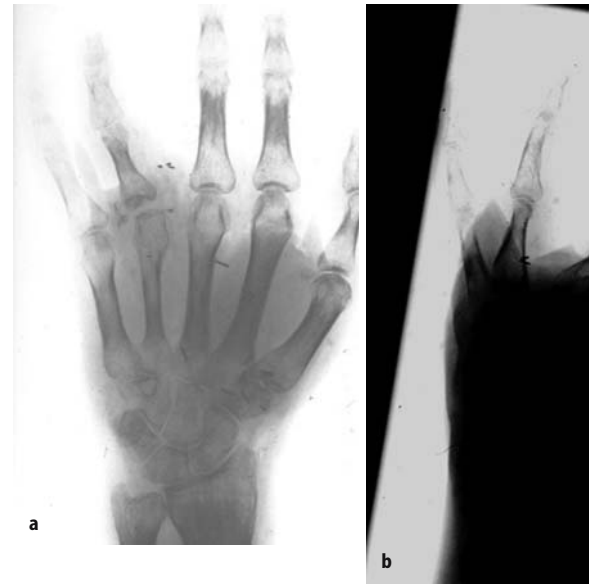
Fig. 12.1. Vascularized PIP joint transfer from the 2nd toe to restore motion at the MP and PIP-joint of the VI finger after tumor resection with complete removal of the proximal phalanx (P1). **a** Clinical aspect prior to tumor removal. **b** Clinical aspect after tumor removal. **c** Radiological aspect after tumor removal: oblique view. **d** Radiological aspect after tumor removal: dorso-palmar view. **e** Clinical aspect after raising the flap. **f** Clinical aspect 1 month after transfer

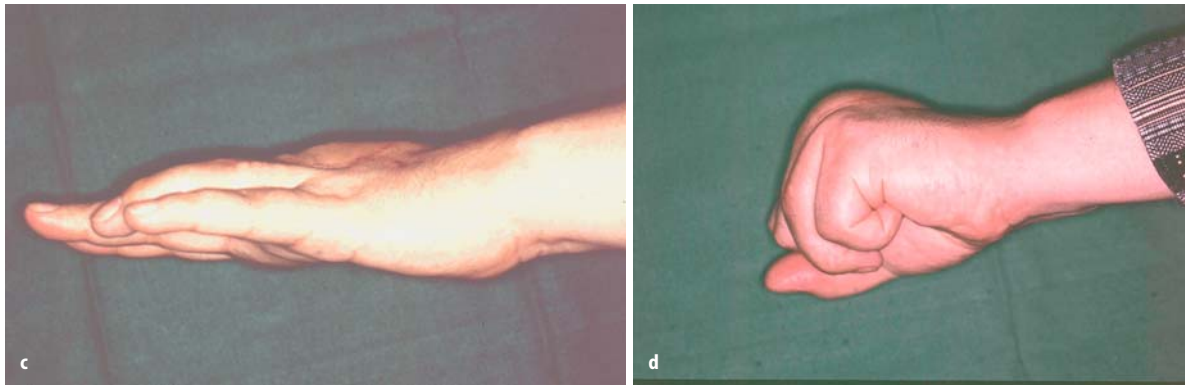
great toe [17, 29]. In the case of loss of basic phalanx (P1), vascularized transfer of P1 from the second toe allows for biarticular joint reconstruction (Fig. 12.2a–e).

12.4.2 Complete Vascularized Joint Transfer

In a complete vascularized joint transfer, the graft will be completely denervated at the donor site and not reinnervated at the recipient site. Therefore no postoperative or secondary pain should be felt at the level of the transplanted joint. As joint congruity the transfer, degenerative changes at the cartilage should not occur at an early stage. Based on our results and results in the literature with a follow-up of more than 10 years, up to now degenerative changes have not been seen in the sense of a "Charcot joint" [5] and a higher rate of degenerative arthritis of the transplanted joints has not been present when compared to the adjacent finger joints [5, 18].

Heterodigital joint transfer – i.e., reconstruction of a missing finger joint with a finger joint from another finger – represents the ideal substitute. However, care must be taken over the high donor site morbidity.





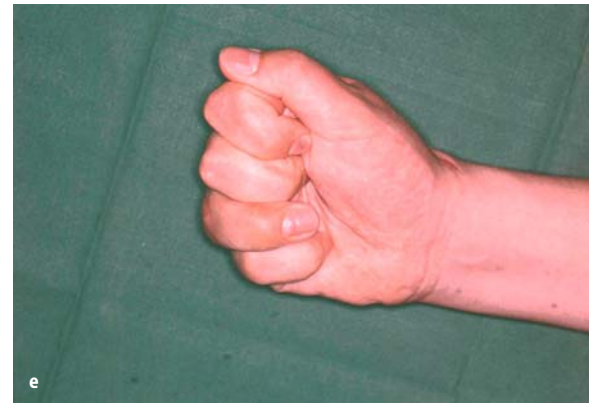


Fig. 12.2. Vascularized PIP joint transfer from the 2nd toe to restore motion at the MP and PIP joints of the VI finger after tumor resection with complete removal of the proximal phalanx (P1). **a** Postoperative X-ray 1 year after transfer: dorsopalmar view. **b** Postoperative X-ray 1 year after transfer: lateral view. **c** Clinical aspect 1 year after transfer: extension. **d** Clinical aspect 1 year after transfer: flexion (lateral view). **e** Clinical aspect 1 year after transfer (palmar view)

Therefore heterodigital vascularized joint transfer (pedicled or free microvascular) is only indicated if a joint can be harvested when following the "tissue bank concept" [2, 8, 12 – 14, 16]. Especially in the case of polydigital hand trauma [10, 12, 15], this possibility should always be evaluated, as otherwise lost material can be used to improve global hand function without the creation of any additional donor site morbidity [2, 8, 14, 30] (Fig. 12.1a–f). According to Foucher et al. [31], the mean total amount of active motion after complete vascularized joint transfer in emergency situations is 45° for vascularized complete MP joint grafts and 42° for vascularized complete PIP joint grafts.

Homodigital vascularized joint transfer offers an interesting method, because of the acceptable impairment of global hand function after DIP joint arthrodesis and a significant increase in motion at the PIP joint. Moreover, donor and recipient site are at the same digit. This technique is indicated in the case of PIP joint destruction without additional bone loss in the adult, but it is contraindicated in the adult in the case of a negative digital Allen test and additional bone loss. Because of insufficient growth, the technique is contraindicated in children [32, 33]. Probably because of insufficient personal experience it is not a technique of first choice in our hands. According to Foucher, who has the only known larger series, the technique offers a mean active range of motion of 57° with a mean extension lag of 18° [5, 12, 33].

Free vascularized complete joint grafts from the second toe are rarely indicated. In children, indications

are: (1) congenital joint defects without additional soft tissue defects (i.e., flexor tendon) [21, 32] and (2) all the traumatic defects at the MP joint level and PIP joint defect with the possibility of reconstruction of a functional digit with regard to the adjacent soft tissue defect (especially extensor mechanism) [18]. Because of better growth potential, vascularized MTP joint transfer (two epiphyses) from the foot should be used for MP joint reconstruction at the hand [19, 32]. The MTP joint graft must be turned around 180° to make a hyperextension joint from the foot, and a hyperflexion joint in the hand [32]. Defects at the PIP joint of the hand are best reconstructed with PIP joints from the foot [22, 32, 33]. In adults vascularized complete joint transfer is hardly indicated for reconstruction of the CMC and MP joints of the thumb, which are most often treated with an arthrodesis. At the MP joints of the fingers (DII–V), vascularized joint grafts are only indicated in the case of contraindications for total joint prosthesis [32]. Vascularized joint transfer should be discussed in cases of: (1) young active manual workers where prostheses have a high failure rate, (2) additional capsule/soft tissue lesion, (3) additional bone defect, and (4) after failed total joint prosthesis with major secondary bone defect [12, 17, 32].

Because of better functional results, MP joint reconstruction should be done with reversed MTP joints [5, 7, 32]. In the case of additional soft tissue defect at the finger, several options are possible. In moderate skin defects a small dorsalis pedis flap can be raised with the toe transplant. In larger soft tissue defects reconstruction with initial soft tissue reconstruction and secondary toe joint transfer can be done in the same operation (single stage reconstruction with a chain flap) or in two separate operations (multiple stage reconstruction) 3–6 weeks apart [5].

Indications for vascularized joint transplantation from the foot for PIP joint reconstruction on the hand can be considered if either arthrodesis or total joint replacement is contraindicated. Contraindications for free vascularized joint transfer from the foot do not differ from the general contraindications for the use of microsurgical techniques. Primary healing after free vascularized joint transfer from the toe is achieved in 85–90% of patients [5]. Bony union is achieved after 4–6 weeks regardless of patient age and the osteosynthesis technique [5]. Active range of motion of the transplanted toe joint depends on: (1) etiology of joint defect at the hand, (2) age of the patient, (3) donor site, and (4) recipient site.

Traumatic joint defects show a better range of motion than congenital joint defects [17]. According to Tsai and Bobb [26], mean active range of motion in children after trauma is Ex/Flex 0/7°/76°, and after congenital joint defect it is Ex/Flex 0/5°49°. The functionally worse results are explained with additional soft tissue deficits, especially at the flexor tendon level [17, 18].

Children show a higher range of motion than adults [18]. According to Tsai and Bobb [26], mean active range of motion after trauma in children is Ex/Flex 0/7°/76°, and in adults Ex/Flex 0/28°/70°. The higher range of motion in children can be explained with some adaptation of the toe joints during growth. In contrast to children, adults can expect only good or fair results. The most striking problem in the adult is an extensor deficit of about 30° [12, 34, 35]. This extension lack is caused by: (1) preoperatively preexisting hammer-toe deformity at the donor site, (2) insufficient tension of the extensor tendon [32], (3) too long an intercalated joint graft, which increases the physiological dominance of the flexor tendon over the extensor tendon [14], (4) a thicker plantar plate of the toe joint, and (5) a bowstring phenomenon of the flexor tendon caused by injury to the pullies at the finger [5].

Depending on the recipient site, PIP joint transfer from the second toe to the MP joint does better than PIP joint reconstruction. Mean total amount of active motion is 65° for MP joint and 43° for PIP joint [32]. Increase in active range of motion even after years has been documented for the MP joint recipient site [19].

With regard to the donor site, MP joint graft from the foot shows better results than PIP joint graft from the foot for reconstruction of MP joint defects in the hand [19, 32].

The aesthetic result after vascularized joint transfer from the second toe depends on: (1) age of the patient and (2) recipient site. Children show better aesthetic results than adults, which can be best explained by anatomical adaptation during growth. Joint reconstruction at the MP joint level of the hand is less obvious than at the PIP joint level.

With patent microvascular anastomoses there is no doubt in the literature that there is normal skeletal growth in free vascularized joint grafts from the second toe, although shortening and overgrowth compared to the contralateral foot joint are reported [19, 26, 29, 35–37]. With regard to growth, selection of donor site is very important. The MTP joint graft has a higher growth potential because it has two epiphyses compared to one epiphysis for the PIP joint graft. Furthermore the growth plate closes earlier in the foot than in the hand.

The most severe complication is loss of the free microvascular joint graft, which occurs in about 7% of patients [5]. In the case of persisting vascular occlusion after multiple revision, the joint graft can be covered with a local or free flap and saved as a non-vascularized joint graft [5]. According to Tsai and Bobb [26], the rate of functional failures, because of pain, stiffness ad/or impaired range of motion, can be rated at about 21%. Infections are seen in about 7% [26]. There are no spe-

cific data on secondary surgery in these patients [17]. Based on our own experience secondary surgery is necessary in more than 50 % of patients. Most often extensor tendolysis is performed. Another less well known problem is skeletal malalignment.

12.5 Conclusions

Joint destruction in the thumb and fingers can lead to significant functional (pain, impairment of active and/or passive range of motion, loss of power and growth impairment in children) and aesthetic impairment of global hand function. Requirements for adequate treatment are: (1) reduction of pain, (2) restoration of a functionally adequate range of motion, (3) sufficient stability during movement and loading, and (4) normal growth potential in children.

There are different treatment options available such as: (1) joint denervation according to Wilhelm [38], (2) perichondrium grafts [39], (3) tissue engineering [40], (4) interposition arthroplasty [41, 42], (5) finger joint prostheses [43, 44], (6) arthrodesis [45], (7) joint transplantation from the hand or foot [46 – 50], and ultimately (8) finger amputation [10, 32].

Although the choice of different treatment options for the individual patient depends on: (1) defect related factors (degree and localization of joint destruction, etiology of joint destruction, etc.), (2) treatment-related factors, and (3) patient related factors (general health of the patient, age, gender, functional impairment), some general guidelines can be given.

Based on the experience with treatment of rheumatoid arthritis, indications for (operative) treatment should primarily be based on the functional impairment seen during clinical examination, not on visible joint deformities on X-ray. Very often significant joint defects seen on X-ray lead to surprisingly few impairments of range of motion. These patients very often present with aesthetic impairment and/or pain. If the patient is able to fulfill the activities of daily living and functional range of motion at the hand level (MP 61°, PIP 60°, DIP 39°) is preserved [51], symptomatic pain treatment such as oral medication (non-steroidal antirheumatics, etc.) or minimally invasive operative finger joint denervation according to Wilhelm [38] should be considered first. In the case of well preserved joint capsule and bony joint elements, cartilage reconstructive procedures such as perichondrium transplantation [39] or possibly in the future tissue engineering (matrix/chrondrocyte grafts) [40] should be considered next. Only if these less invasive procedures do not succeed should more invasive operations be considered.

Resection/interposition arthroplasty [41, 42] and resection/silicone spacer arthroplasty [43] should only be considered if the soft tissue structures (capsule, ligaments) around the joint are still preserved or can be reconstructed secondarily [1]. However, care must be taken to avoid heavy manual work, as repetitive heavy loading will lead to early weakening of soft tissues and subsequent loss of function of the joint.

In the case of coexisting soft tissue and bone defect, joint replacement [44] or arthrodesis [45] are the only options. Within the last few years several finger prostheses have been used. In spite of continuing improvement total joint replacement nowadays only shows adequate results in elderly and/or less active patients. In young active patients there is a high rate of loosening within a short period of time. Another inconvenient aspect of total joint prosthesis is the lack of growth potential; therefore children and skeletally immature patients must be excluded [44].

Arthrodesis leads to reduction of pain but also mobility [45]. In the adult patient, arthrodesis is a good indication in isolated (monoarticular) joint destruction of the CMC joint and MP joint of the thumb and the PIP and DIP joints of the long fingers. However, care must be taken that the adjacent joints proximal and distal to the arthrodesis are still intact, as they will have to compensate for the reduced movement afterwards. When performing an arthrodesis in children (chondrodesis) care must be taken not to injure the growth plates. As cartilage and not bone is still present, a higher rate of non-union or "pseudarthrosis" must be anticipated [52]. Regardless of age, arthrodesis of the MP II–V joints will lead to severe impairment and is contraindicated.

Finger or even ray amputation is an exception and is only indicated in the fingers – not on the thumb – if there is no chance of reconstruction of a functional digit and the remnant represents a significant hindrance to global hand function [31, 32]. Care must be taken in manual workers, as resection of one metacarpal head will reduce power grip in up to 20 % of patients.

Vascularized joint transfer from the finger or the second toe offers the unique possibility of reconstructing a joint defect at the thumb or fingers using autologous tissue, which fully preserves its growth potential [2, 8, 10, 14, 15, 18, 19, 31, 32, 35, 53 – 56]. Vascularized joint transfer at the finger in children is indicated because of lack of other therapeutic options offering normal growth potential. In adults vascularized joint transfer is indicated when a contraindication for a prosthetic joint replacement or an arthrodesis exists. Whenever possible the "tissue bank concept" according to Chase should be applied in finger joint reconstruction using a vascularized joint graft from either an amputated or a worthless digit. The results of a vascularized joint transfer have to be compared to those of persisting joint defect, prosthetic joint replacement, arthrodesis, or ultimately amputation of the finger involved. Patients should be informed about

the following: (1) the risk of failure (vascular failure, tendon adhesion, joint stiffness, etc.) is about 10%. (2) The expected active range of motion depends on etiology, age, donor site and recipient site. Traumatic joint defects show a greater active range of motion than congenital defects. Children do have more active joint motion than adults. (3) Because of minor donor site impairment and rapid recovery of normal gait, the whole second ray should be amputated after harvesting a joint graft at the second toe. (4) Hospitalization takes about 2–3 weeks. Immobilization of the hand (palmar forearm splint) and the foot (lower leg cast) should be applied for 4–6 weeks. Intensive physical therapy is necessary for at least 3–6 months. Additional splinting is recommended for about 6 months. (5) Extensor tendolysis is necessary in a large number of cases but should not be executed earlier than 6 months after transplantation.

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13 Versatility of the Lateral Arm Flap

F. Haas, E. Scharnagl

13.1 Introduction

A remarkable number of flaps for a variety of indications have been developed in the past 30 years, ranging from thin fascial and fasciocutaneous to osteocutaneous to large and bulky myocutaneous flaps. The option of reconstructing complex defects in a one-stage procedure with a high success rate and acceptable functional and cosmetic results makes these flaps attractive in reconstructive surgery. When plastic surgeons are confronted with defects after trauma or after tumor surgery, it is important to choose an appropriate flap suited to the patients' specific needs, whereby both the recipient site requirements and the donor site aspects must be considered. The lateral arm flap is a reliable flap with a fasciocutaneous/septocutaneous blood supply, which is suitable for reconstruction of small to medium-sized defects. It is an especially good option for reconstruction in the head and neck region including intraoral defects and the pharyngoesophageal segment, as well as the hand, forearm, elbow and arm, foot and lower leg. In a single procedure, this flap can cover defects after loss of skin, fascia, muscle, tendon, bone and nerve. Its advantages include a constant vascular anatomy and a great variety of tissue composition combined with low donor site morbidity. The lateral arm flap was developed in China by Song in 1982 [18]. Anatomical studies describing the flap's anatomy in detail followed [5, 8, 14, 17, 22], and the flap's versatility and clinical application were reported [15, 21]. Flap modifications enlarging the flap's dimensions [13, 16] and a variety of tissue compositions have contributed to its versatility [1].

13.2 Anatomical Aspects

13.2.1 Vascular Supply

13.2.1.1 Artery

The lateral arm flap is based on the deep brachial artery and the posterior radial collateral artery, i.e., the posterior branch after its bifurcation (Fig. 13.1). The deep brachial artery is the first major branch of the brachial artery, with its origin just below the lower border of the teres major muscle. At this point it averages 2.0 mm in diameter [19]. It closely follows the radial nerve, accompanied by its paired brachial veins, first running posteriorly between the medial and the lateral head of the triceps muscle and then along the spiral groove of the humerus to the lateral side of the arm, being overlaid by the long and the lateral head of the triceps muscle, supplying this muscle and the humerus [19]. The artery emerges from beneath the lateral head of the triceps and pierces the lateral intermuscular septum. The bifurcation of the deep brachial artery into its anterior (the anterior collateral artery) and posterior branches – the posterior branch or posterior radial collateral artery that pierces the septum and supplies the lateral arm flap – can be of five different types and knowledge of the localization of this bifurcation is important when

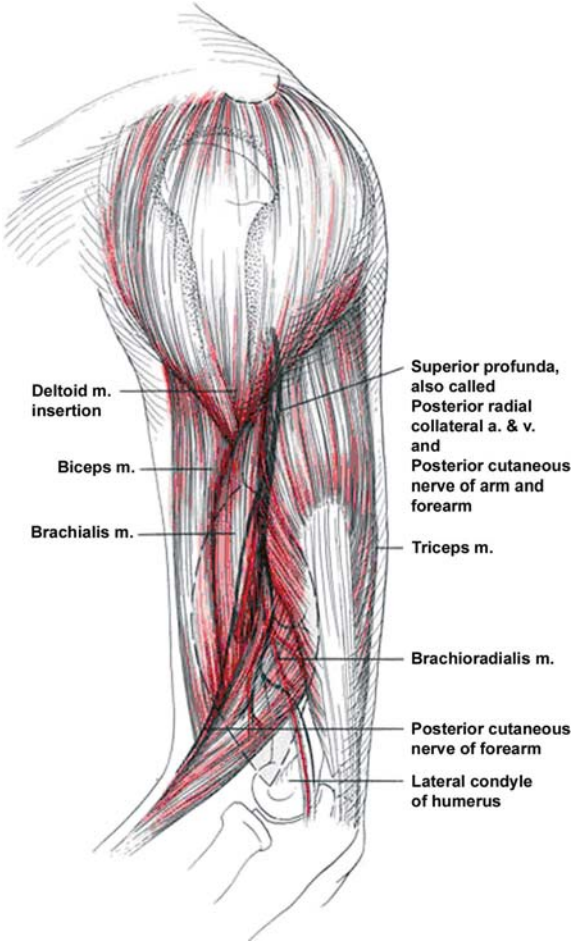


Fig. 13.1. Important anatomical structures of the lateral arm region

raising the flap. Dissection of 30 cadaver arms showed a distal bifurcation in 16 of the 30 cases [17]. With the distal bifurcation, the deep brachial artery bifurcates at the level of the brachioradialis insertion. In 7 of the 30 cadaver arms the artery did not bifurcate and reached the lateral intermuscular septum as a single vessel. An intermediate bifurcation at the level of the deltoid insertion on the humerus was found in three cases. With a proximal bifurcation, which was found once, the deep brachial artery bifurcates in the spiral groove. In three cadaver arms a double bifurcation with a high bifurcation approaching the septum posteriorly and a low bifurcation approaching anteriorly was found [17]. The small and inconsistent anterior radial collateral artery accompanies the radial nerve in the anterior compartment of the arm running between the brachialis muscle and the brachioradialis muscle and ultimately may anastomose (in two-thirds of cases) with the recurrent radial artery deep in the cubital region under the brachioradialis muscle [6]. The posterior radial collateral artery enters the lateral intermuscular septum in the region of the deltoid muscle insertion between the triceps muscle posteriorly and the brachioradialis muscle anteriorly, coursing to the lateral epicondyle. When dissected to its origin, the pedicle length averages 10.2 cm measured retrogradely from the beginning of the first proximal cutaneous branch [19]. Usually the posterior radial collateral artery leaves the septum in the cubital region near the anterior aspect of the lateral epicondyle. There it empties into the lateral epicondylar plexus that is regarded as an anastomotic network between the posterior and anterior collateral arteries proximally and branches of the recurrent interosseus and recurrent radial arteries distally [2, 12].

The posterior radial collateral artery gives off branches to fascia, skin, muscle, tendon and bone.

Fasciocutaneous Perforators

The posterior radial collateral artery gives off four to seven fasciocutaneous branches, with an average of 4.5 branches from 1 to 15 cm to the lateral epicondyle, the largest of which is located an average of 9.7 cm superior to the lateral epicondyle [2, 19].

Fascial Perforators

In comparison to fasciocutaneous perforators, branches are classified as true fascial vessels only when they terminate within the fascia, arborizing into fine networks of capillaries. There is an average of 2.3 fascial branches from 1 to 8 cm proximal to the lateral epicondyle directed posteriorly over the triceps muscle and 1.8 branches directed anteriorly over the brachialis muscle. In the distal continuation of the artery over the lateral epicondyle the average number of fascial perforators is 5.5 per flap [19].

Branches to Triceps Muscle and Tendon

An average of 3.8 branches pass from the posterior radial collateral artery to the triceps muscle. They are distributed from 2 to 10 cm proximal to the lateral epicondyle. The muscular perforators can be followed an average of 3 cm before they divide into multiple smaller branches [8, 19]. A mean of 3.6 muscular perforators from the posterior radial collateral artery to the lateral portion of the triceps tendon per flap (range 2–7) is noted. At least one muscular perforator of the posterior radial collateral artery (mean 1.6) enters the proximal 5 cm of harvested tendon, and at least one perforator (mean 2.0) enters the distal 5 cm [8].

Branches to the Bone

For many years authors recommended including a cuff of surrounding muscle with the harvested bone segment to maintain the vascular connections to the humerus through vessels from the fascia to the periosteum [1, 15].

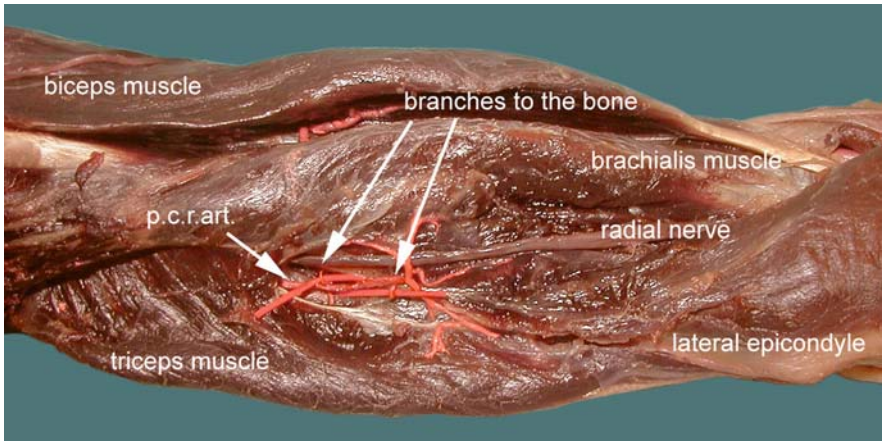


Fig. 13.2. Cadaver arm with dissected PRCA after opening the intermuscular septum. Two branches directly supplying the humeral bone are marked

But anatomical studies proved that the vascular supply of the proximal lateral aspect of the humerus is based on branches from the posterior radial collateral artery directly supplying the bone [10, 20]. An anatomical dissection of 30 cadaver arms by Haas et al. found one direct branch to the bone arising from the posterior radial collateral artery in 14 arms and two direct branches to the bone in 16 arms (Fig. 13.2). In both groups, the most branches were found between 3 and 6 cm proximal to the lateral epicondyle and in 60% at least one branch was present 4–5 cm above the epicondyle (Fig. 13.2) [10].

13.2.1.2 Veins

The venous return from the flap requires only a single venous anastomosis. The flap is drained by two venous systems: the two concomitant veins of the deep brachial artery and the superficial veins. The deep venous network consists of the two concomitant veins of the deep brachial artery. This is a reliable venous system with an average diameter of 2.8 mm (range 2–5 mm). There are always at least two communicating branches between the two veins [14].

Experience shows that the two concomitant veins join to form a dominant deep brachial vein in most cases. In practice, the concomitant veins are the venous network of choice.

Theoretically, the large-caliber superficial veins that are tributaries of the cephalic vein can be used for venous drainage as well.

13.2.2 Nerves

13.2.2.1 Posterior Cutaneous Nerve of the Arm

This sensory nerve is a proximal branch of the radial nerve with an average diameter of 1–2 mm arising in the anterior compartment of the arm after the radial nerve has reached the septum. It can also arise in the spiral groove from a common trunk with the nerve of the lateral head of the triceps muscle. Piercing the brachial fascia near the deltoid insertion, it provides sensation to the dorsal upper arm to the level of the olecranon. The posterior cutaneous nerve of the arm innervates the skin of the flap, allowing it to be used as a sensate flap [17].

13.2.2.2 Posterior Cutaneous Nerve of the Forearm

This nerve is also a sensory branch of the radial nerve arising between 1 and 5 cm below the posterior cutaneous nerve of the arm, supplying the skin area on the posterolateral aspect of the forearm. Exceptionally, this nerve and the posterior cutaneous nerve of the arm arise from a common trunk and have a similar course. The nerve can also be absent, as seen in 2 of 30 cases [17]. Normally the posterior cutaneous nerve of the forearm courses with the posterior radial collateral artery and pierces the lateral intermuscular septum to run alongside the artery of the flap. It divides at the distal upper arm into an upper branch supplying the posterior inferior upper arm and a lower branch supplying the side of the arm and elbow. In many cases the nerve has to be sacrificed, so that there is an area of hyposensitivity in the region supplied by this nerve [14, 22].

13.3 Tissue Composition

Complex defects after ablative procedures or after trauma require a versatile flap. The variety of tissue composition possible with the lateral arm flap allows the design of a flap adapted to the patient's needs (Table 12.1).

Table 13.1. The different combinations of tissue possible with a lateral arm flap

Fasciocutaneous	Fascia	Skin				± Nerve
Myofasciocutaneous	Fascia	Skin	Triceps muscle			± Nerve
Tendofasciocutaneous	Fascia	Skin		Triceps tendon		± Nerve
Myotendofasciocutaneous	Fascia	Skin	Triceps muscle	Triceps tendon		± Nerve
Osteofasciocutaneous	Fascia	Skin			Bone	± Nerve
Osteomyofasciocutaneous	Fascia	Skin	Triceps muscle		Bone	± Nerve
Osteotendofasciocutaneous	Fascia	Skin		Triceps tendon	Bone	± Nerve
Osteomyo-tendofasciocutaneous	Fascia	Skin	Triceps muscle	Triceps tendon	Bone	± Nerve
Fascia alone	Fascia					
Myofascial	Fascia		Triceps muscle			
Tendofascial	Fascia			Triceps tendon		
Myotendofascial	Fascia		Triceps muscle	Triceps tendon		
Osteofascial	Fascia				Bone	
Osteomyofascial	Fascia		Triceps muscle		Bone	
Osteotendofascial	Fascia			Triceps tendon	Bone	
Osteomyotendofascial	Fascia		Triceps muscle	Triceps tendon	Bone	
Bone alone					Bone	

13.3.1 Fasciocutaneous Lateral Arm Flap/Fascial Lateral Arm Flap

The fasciocutaneous lateral arm flap – consisting of fascia, subcutaneous tissue and skin, supplied by fasciocutaneous perforators of the posterior radial collateral artery – is the classic version of the flap. Originally, the lateral arm flap was designed and harvested between the deltoid insertion on the humerus and the lateral epicondyle and was only used to cover small defects. The flap's length was restricted to 15 cm and it did not extend to any significant degree beyond the lateral epicondyle. In 1991, Kuek et al. reported that the mobilization of a larger skin island was possible based on the vascular continuation of the posterior radial collateral artery. In the elbow region the posterior radial collateral artery terminates in a large epicondylar plexus including the interosseous recurrent artery and the recurrent radial artery. These vessels supply the skin paddle distal to the lateral epicondyle [2, 12, 16]. The average length of this extension distal to the epicondyle is 7.9 cm with extensions up to 12 cm through which the skin island can be designed distal to the elbow on the upper forearm. There a thin and pliable skin paddle can be harvested. The flap's total length can be enlarged up to 35 cm and the split flap technique achieves a flap with greater width and a still reasonable length [16]. There is a decrease in flap thickness from the proximal to the distal part that must be taken into account when the flap is adapted to the recipient area. This modification with its added dimensions contributed to the flap's development and popularized its use in regions where a pliable flap is needed [11]. It is also possible to harvest only the skin in the region of the lateral epicondyle and the proximal third of the lateral forearm. This method was introduced as "The distally planned lateral arm flap" by Hamdi et al. in 1996 [3, 13]. The blood supply of this flap is based on the most distal septocutaneous perforator and the distal termination of the posterior radial collateral artery over the lateral epicondyle. It includes a few centimeters of upper arm skin and a large paddle of thin and pliable forearm skin, which makes it ideal for reconstruction of superficial defects on the extremities and in the head and neck region. Obligatory inclusion in its pedicle of the posterior cutaneous nerve of the forearm gives the flap the potential to be sensate. The skin region innervated by this nerve is mostly harvested with the distal lateral arm flap so that the resulting area of anesthesia at the donor site can be neglected. This modification provides a thin flap with a long pedicle. It is less bulky and involves less sensory loss on the donor site than the classical lateral arm flap [3, 12, 13]. It is now common to harvest only the distal arm-proximal forearm part of the lateral arm flap when only a small skin paddle is required. When a split lateral arm flap is harvested, the width can be enlarged without additional compromises to the donor site.

13.3.1.1 Operative Technique for the Split Flap

The fasciocutaneous flap is harvested in the usual way. Then the lateral intermuscular septum is examined carefully to find the position of the fasciocutaneous perforators. Skin, fascia and subcutaneous tissue are split in two halves between two perforators, leaving the septum and the axial vessels intact [15]. The two resulting halves may be manipulated to lie alongside each other by turning the distal half by 180 degrees. This doubles the effective width of the flap and the donor

site may still be closed primarily. A composite lateral arm flap including muscle, tendon, bone and nerve may be similarly split when required. When a large flap is needed an extended lateral arm flap is raised. Then the procedure is performed as described for the split flap. This achieves a flap with a remarkable length and width for reconstruction of large defects without additional donor site complications.

When a **sensory flap** is required, the posterior cutaneous nerve can be incorporated in a lateral arm flap. When the nerve is carefully included in the flap and nerve sutures to a sensory nerve are carefully performed at the recipient site, the lateral arm flap can provide sensation to the recipient site with excellent two-point discrimination. A neurosensory lateral arm flap is especially useful in reconstruction of intraoral defects and surgery on the extremities where protective sensation is important [11]. The second sensory nerve of the lateral arm region is the posterior cutaneous nerve of the forearm. It can be used as a vascularized nerve graft to bridge nerve defects. When the nerve is dissected proximally, a vascularized nerve graft of up to 12–16 cm is available with the lateral arm flap. When the skin island is extended inferior to the lateral epicondyle (extended lateral arm flap), a neurosensory flap can be harvested based on the posterior cutaneous nerve of the forearm as it is the supplying nerve for this skin territory. When harvesting a sensory flap, care must be taken not to mistake one of the nerves for the radial nerve. In cases where only a segment of vascularized fascia is needed, a lateral arm fascial flap consisting of the fascia with its supplying vessels can be harvested.

13.3.1.2 Dimensions

The width of the skin island that can be raised depends on the circumference of the patient's arm. The average skin paddle measures 12 × 5 cm, but skin islands measuring up to 30 cm in length and flaps with a width of 16 cm have been reported [15]. The width should be restricted to one-third the circumference of the arm to facilitate primary closure of the donor site defect. On average the width can be up to 6 cm. The area of fascia that can be taken separately is larger and can be up to 20 × 14 cm [17]. When several "miniflaps" for reconstruction of multiple defects are required, up to four separate smaller skin flaps can be harvested based on separate perforators of the posterior radial collateral artery [15].

13.3.1.3 Reverse Lateral Arm Flap

A reverse lateral arm flap based on a distal vascular pedicle was first described by Culbertson et al. in 1987 [7]. The flap is nourished by perforators of the posterior radial collateral artery, which in turn obtains its blood supply from the recurrent interosseous artery. In 1993 Coessens et al. described their clinical experience with another reverse lateral arm flap [4]. This flap is also nourished by the posterior radial collateral artery, but obtains its blood supply from the recurrent radial artery. Both variations present a reliable vascular pedicle and good options for reconstruction of adjacent defects. The fasciocutaneous component is harvested in the usual way, but the vascular pedicle is only dissected proximally. The flap is elevated in a proximal to distal direction, ensuring inclusion of the vessels and perforators lying within the septum. Since the posterior radial collateral artery anastomoses with the recurrent interosseous artery around the lateral epicondyle, a sufficient amount of subcutaneous tissue should be included with the distal vascular pedicle in order to both protect and enhance the arterial inflow and venous drainage of the flap. Lastly, the skin bridge between the donor site and recipient wound is either incised for transposition of the flap or tunnelized to let the flap pass through. The flap has excellent color and texture because of the proximity of the donor and recipient sites.

13.3.1.4 Proximal Pedicle Lateral Arm Flap

A lateral arm flap based on the proximal pedicle can be useful to restore coverage in adjacent regions like the shoulder, the axilla and the arm. The fasciocutaneous component is raised as usual, but proximally the vascular pedicle is left intact. In the proximal dissection of the flap, the lateral fibers of the triceps muscle are divided to expose the vascular pedicle, and at the level of the deltoid insertion on the humerus the bifurcation of the deep brachial artery is exposed. The dissection is completed, the flap is based on its vascular pedicle, and the flap can be rotated to a regional defect.

13.3.2 Lateral Arm Flap Including a Vascularized Segment of the Humerus

- **Osteo**fasciocutaneous
- **Osteo**myofasciocutaneous
- **Osteo**tendofasciocutaneous
- **Osteo**myotendofasciocutaneous
- **Osteo**fascial
- **Osteo**myofascial
- **Osteo**tendofascial
- **Osteo**myotendofascial
- Bone alone

The osteocutaneous lateral arm flap is a modification of the classical lateral arm flap including a vascularized

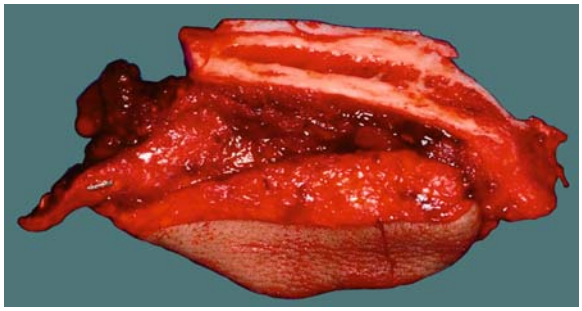


Fig. 13.3. Lateral arm flap including a segment of vascularized humerus

fragment of the distal humerus for reconstruction of defects measuring up to 10×2 cm (Fig. 13.3). A segment from the lateral cortex of the humerus above the lateral epicondyle can be harvested with the lateral arm flap for reconstruction of skeletal defects. The osteocutaneous lateral arm flap's advantages are the rapid dissection and the excellent and constant segmental blood supply to the bone allowing multiple osteotomies for segmental reconstruction. Disadvantages are that the bone is predominantly cortical and that donor site complications occur when the limit of 1.5–2 cm in width is not respected. Some authors even recommend limiting the width of the bone graft to 1 cm to avoid late humeral fracture [15, 22]. The bone shaft's length cannot exceed 10–11 cm. When harvesting the bone segment with a microsaw, care must be taken not to damage the radial nerve and the axial vessels.

13.3.3 Composite Lateral Arm Flap Including Muscle and Tendon

Muscle:	**Myo**fascial
	Myofasciocutaneous
	Osteo**myo**fascial
	Osteo**myo**fasciocutaneous
Tendon:	**Tendo**fascial
	Tendofasciocutaneous
	Osteo**tendo**fascial
	Osteo**tendo**fasciocutaneous
Both:	**Myotendo**fascial
	Myotendofasciocutaneous
	Osteo**myotendo**fascial
	Osteo**myotendo**fasciocutaneous

Triceps tendon and/or muscle can be incorporated in a composite lateral arm flap (Fig. 13.3).

A segment of muscle from the lateral head of the triceps may be harvested for increased flap bulk to refill soft tissue defects. Triceps tendon from the lateral part of the tendon can be harvested when reconstruction of tendons is necessary. Skin and muscle paddles within the lateral arm flap are supplied by distinct muscular and cutaneous perforators of the posterior radial collateral artery.

Therefore, orientation of the skin paddle of the flap is not restricted by the orientation of the muscle paddle. When only a strip of tendon is required, a cuff of muscle must be preserved to maintain vascular connections of the muscular perforators [8]. Normally a segment of at least 10×2 cm of triceps tendon can be harvested without donor site complications. This limit should be respected to avoid disruption of triceps muscle function.

13.3.4 Typical Case Reports

13.3.4.1 Case 1 (Fasciocutaneous)

A 66-year-old patient with a chronic defect after previous surgery on the Achilles tendon was referred from the orthopedic department (Fig. 13.4). A neurosensory fasciocutaneous lateral arm flap measuring 8×4 cm

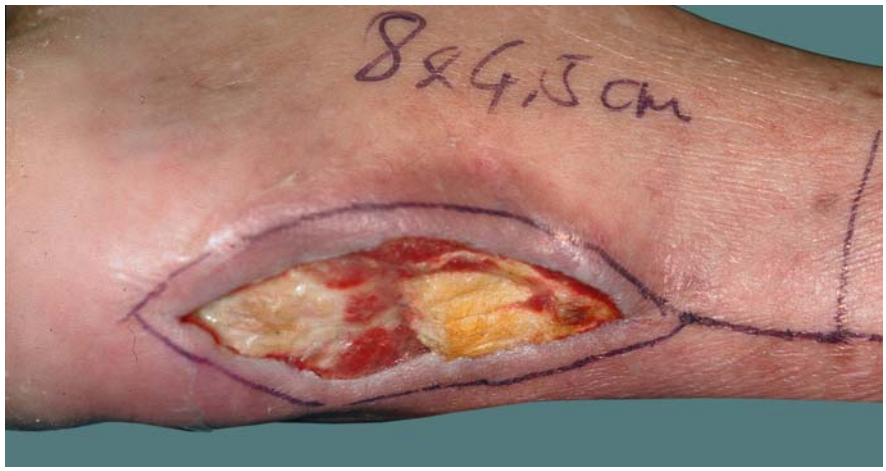


Fig. 13.4. Chronic tendocutaneous defect of the Achilles region

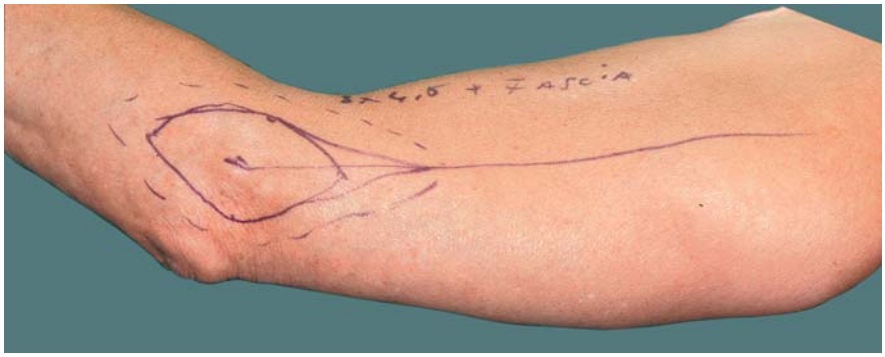


Fig. 13.5. Flap planning on the left arm

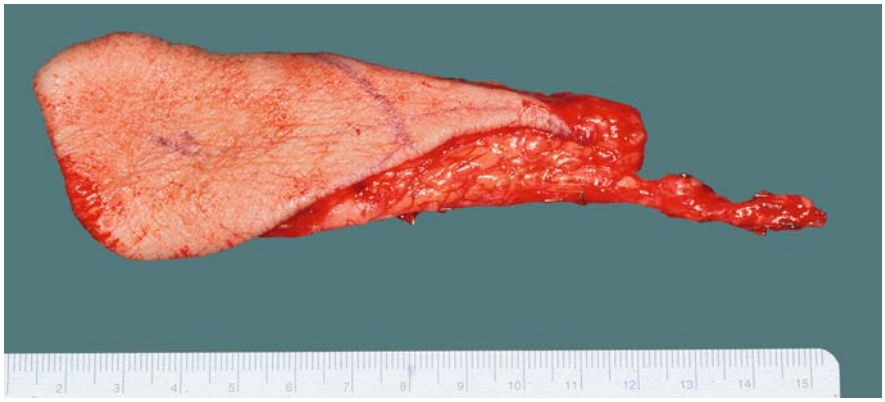


Fig. 13.6. Harvested fasciocutaneous flap

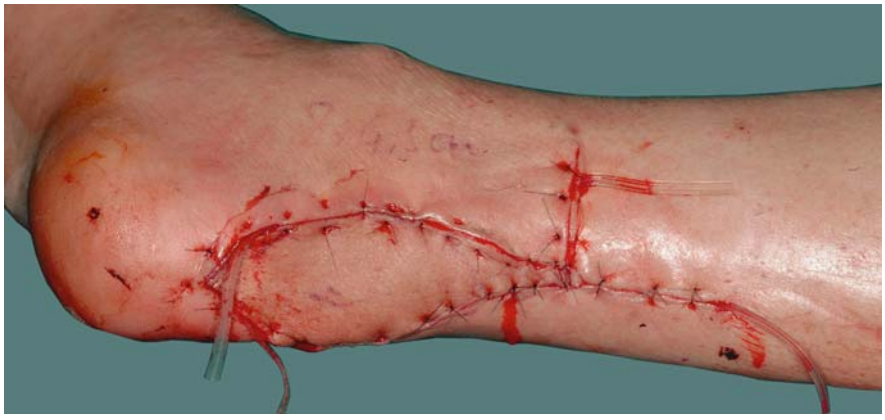


Fig. 13.7. Flap in place after microsurgery and tendon reconstruction

was elevated while radical debridement was performed on the leg (Figs. 13.5, 13.6). To strengthen the Achilles tendon, a strip of fascia lata was harvested and sutured into the partial defect. The graft and the Achilles tendon were covered with fascia to reconstruct gliding tissue [11]. After performing the vascular anastomoses (artery end-to-side), the posterior cutaneous nerve of the forearm was sutured end-to-side to the sural nerve to restore protective sensibility (Fig. 13.7). Six months after surgery the cosmetic and functional outcome was good with only minimal impairment of plantar flexion (Fig. 13.8).

13.3.4.2 Case 2 (Osteotendocutaneous)

A 48-year-old patient was treated at our department because of an open defect fracture of the proximal phalanx of the right thumb with loss of the overlying soft tissue (extensor aponeurosis and skin) with a heterologous bone graft, a palmaris longus tendon graft and a Foucher flap (Fig. 13.9). Due to a flap necrosis we performed a revision and reconstruction with an osteotendocutaneous lateral arm flap. A 4×1-cm-large piece of the humeral bone was included as well as a strip of the triceps tendon (Fig. 13.10). After radical debridement (Fig. 13.11), the metacarpophalangeal joint was surgi-

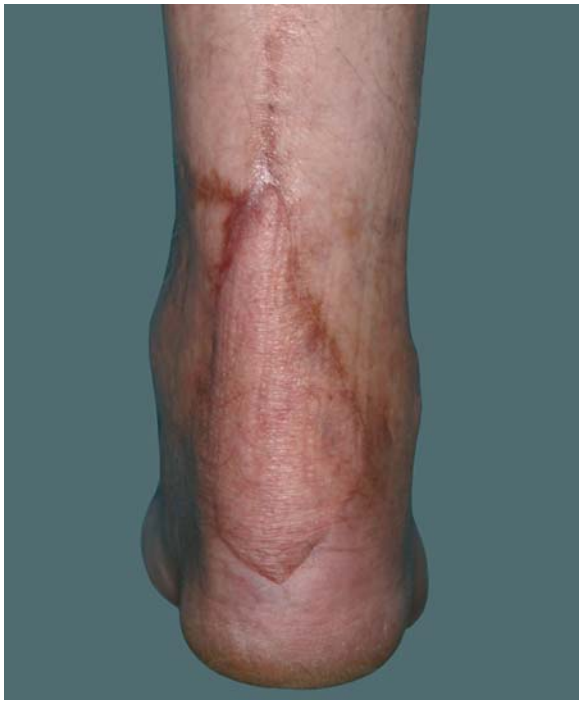


Fig. 13.8. Result 6 months after surgery

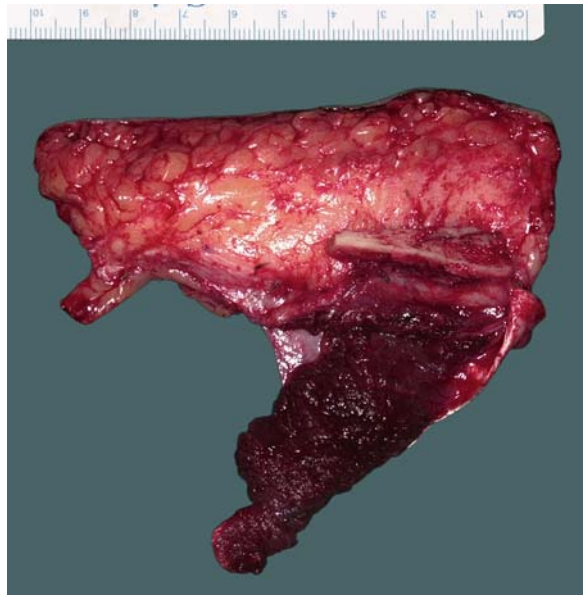


Fig. 13.11. Lateral arm flap including triceps tendon and humeral bone

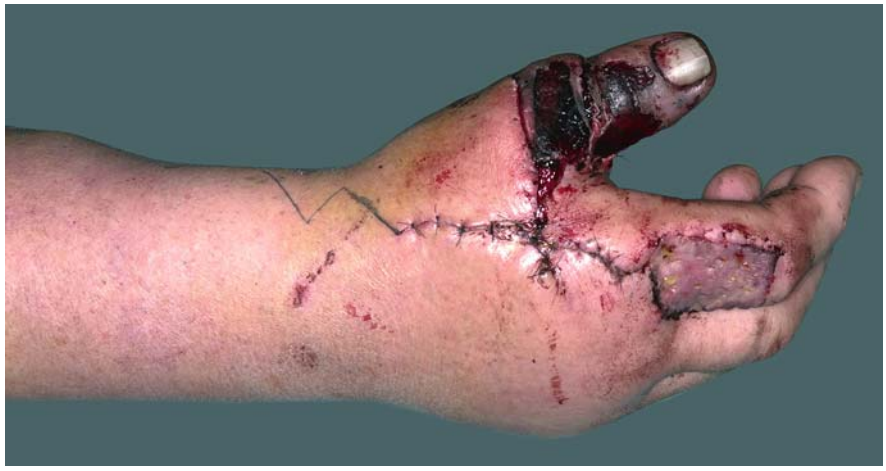


Fig. 13.9. Necrotic Foucher flap on the right thumb

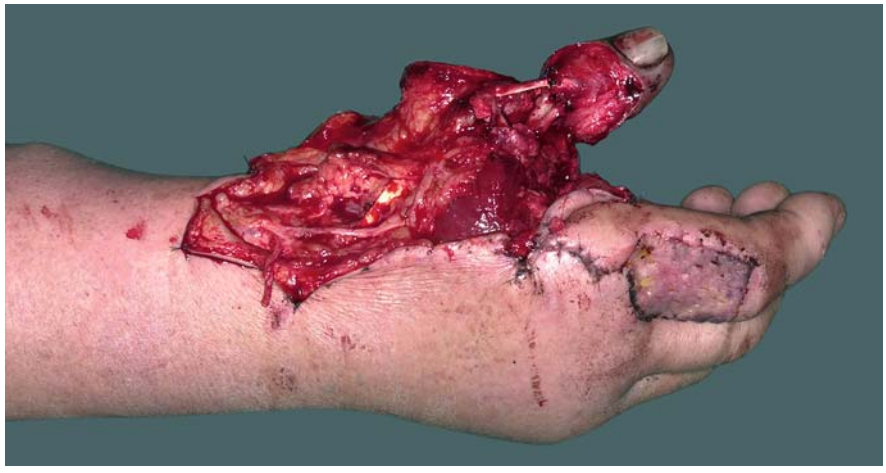
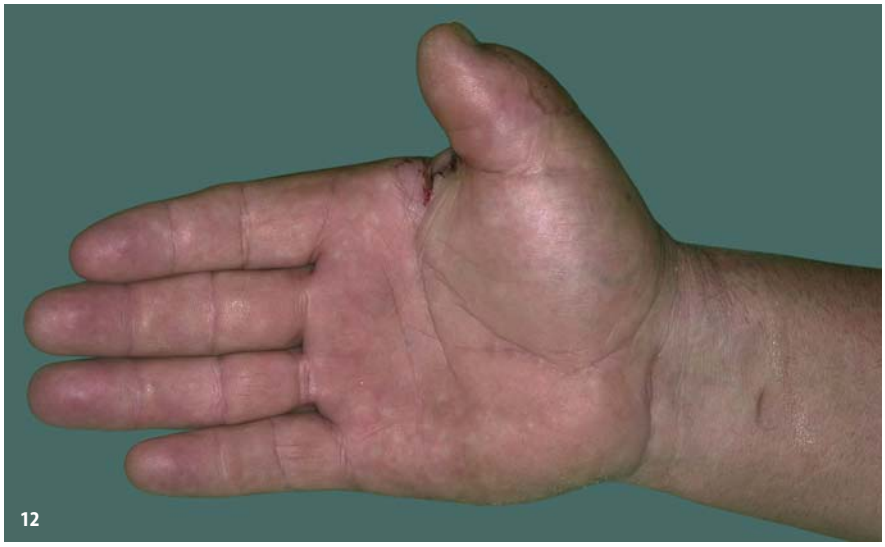
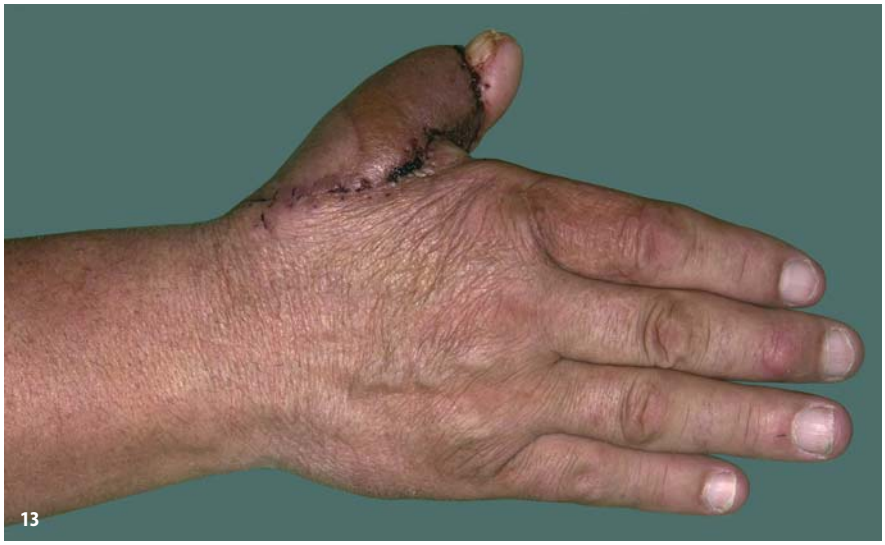


Fig. 13.10. Thumb after radical debridement





Figs. 13.12, 13.13. Appearance 1 week after defatting procedure

cally fixed with the vascularized bone and the extensor aponeurosis was reconstructed with the strip of the triceps tendon. Subsequently to microsurgery (artery end-to-side) and uneventful healing postoperatively, 9 months later flap thinning by liposuction was necessary because of bulky subcutaneous tissue (Figs. 13.12, 13.13).

13.3.4.3 Case 3 (Tendocutaneous)

After resection of a myxofibrosarcoma of the right hand, a 60-year-old woman was transferred to our institution. A neurosensory tendomyofascio-cutaneous lateral arm flap was harvested measuring 9.5×4 cm and including a strip of triceps tendon for reconstruction of the extensor tendon (Fig. 13.14). Vascular anastomoses to the radial artery and a concomitant vein were performed and the posterior cutaneous nerve of the forearm was sutured to a superficial branch of the radial nerve (Fig. 13.15). Two years after reconstruction, the aesthetic outcome was excellent and the func-

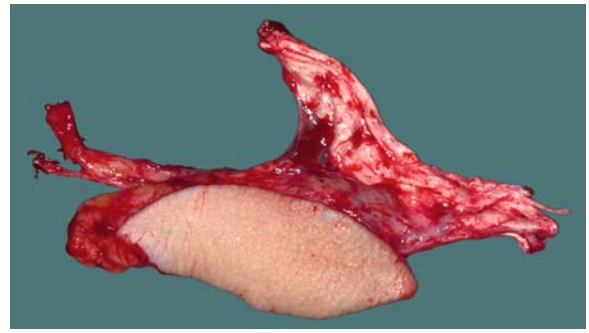


Fig. 13.14. Lateral arm flap including triceps muscle and tendon

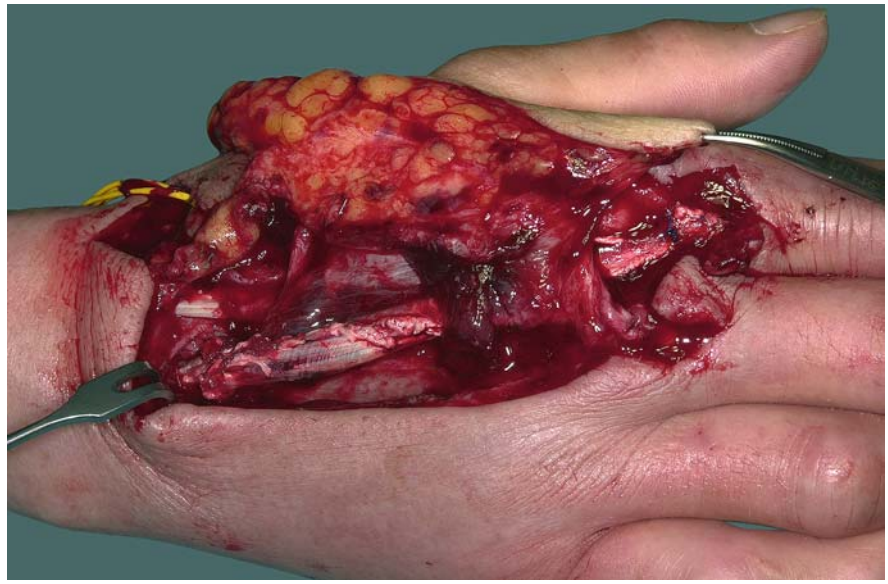
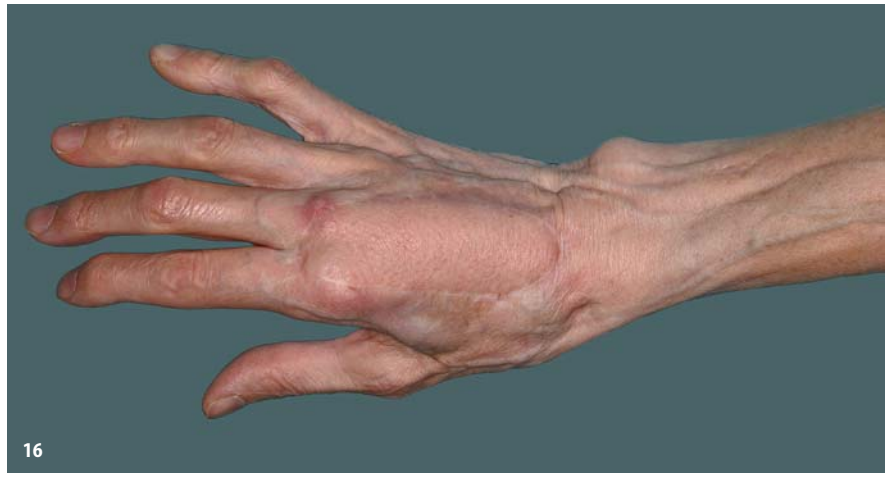
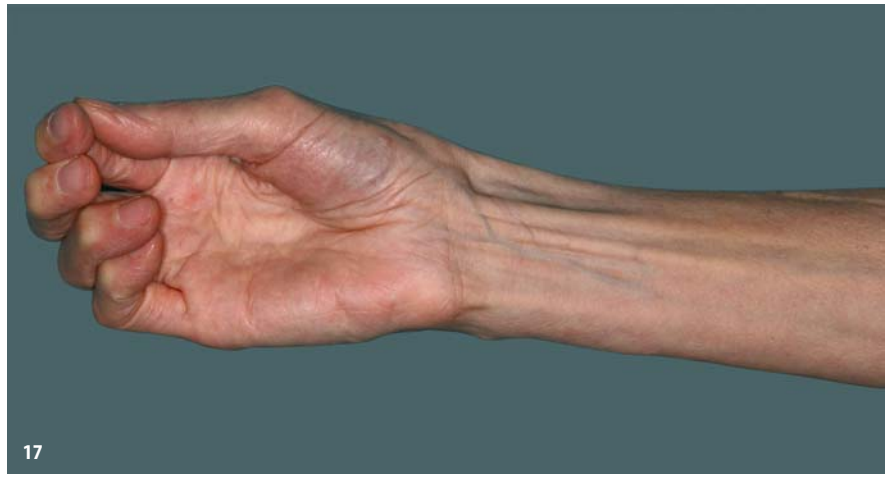


Fig. 13.15. Flap in place, reconstruction of the extensor tendon with a strip of triceps tendon





Figs. 13.16, 13.17. Appearance and functional result 2 years after reconstruction

tional result was acceptable except for a flexion deficit in the metacarpo-phalangeal joints II–IV (Figs. 13.16, 13.17).

13.4 Conclusions

A variety of flaps are available, and ultimate success depends on the optimal choice of flap.

For reconstruction of small to moderate-sized defects in regions where a thin and pliable flap is needed, the lateral arm area provides a reliable donor source and offers the following advantages:

1. **The predictable and reliable vascular anatomy of the flap.** Only the localization of the bifurcation of the deep brachial artery may vary, but the arterial vessel diameter (1.5–2.0 mm is ideal for the preferred end-to-side anastomosis) and the course of the posterior radial collateral artery in the lateral intermuscular septum are constant. There is a constant number of fascial and fasciocutaneous perforators, muscular perforators to the triceps muscle, branches to the triceps tendon and branches directly supplying the bone. Short pedicle length has been criticized in previous reports, but additional pedicle length may be obtained by detaching the lateral head of the triceps muscle to pursue the deep brachial artery in the spiral groove. The flap can be safely extended over the lateral epicondyle (average 7.9 cm).
2. **The rapid dissection.** The flap may be harvested in a bloodless field under a tourniquet. Especially in oncologic, multimorbid patients, it is important to reduce operating time. This is possible with a two-team approach, with one team raising the flap, and the other team resecting the tumor and/or preparing the recipient site. In patients with upper extremity defects, both flap and recipient site may be prepared in a bloodless field under single regional block anesthesia, when the flap is transferred to the ipsilateral extremity.
3. **With the lateral arm flap it is possible to create 15 differently composed flaps** (Table 12.1), consisting of skin, fascia, muscle, tendon and bone adapted to specific needs. The flap has the potential to be sensate when a sensory branch is included.
4. **The variable thickness of the skin paddle of the lateral arm flap** allows the surgeon to harvest the skin island depending on the requirements at the recipient defect: When a very thin and pliable flap is required, the skin over and distal to the lateral epicondyle is taken along with the flap; when a thicker flap is needed, the skin between the deltoid insertion and the lateral epicondyle is harvested.
5. **The low donor site morbidity of the lateral arm flap.** In most cases the donor site can be closed primarily. There is no vascular compromise to the arm, elbow function is not affected, and donor site morbidity is restricted to aesthetic considerations

There are only a few limitations restricting the use of the lateral arm flap: The amount of tissue available restricts its use to the reconstruction of small to moderate-sized defects. The flap may be bulky, especially in obese patients and women, and requires secondary contouring in regions where a very thin flap is needed [9]. The donor site scar (Fig. 13.18) is visible and can become hypertrophic in younger patients. Postoperative sensory disturbances in the dorsolateral forearm area might be disturbing to the patient but improve in time.

The variations in tissue composition possible with the lateral arm flap make this flap unique in reconstructive surgery. With excellent long term results and high patient contentment, combined with low donor site morbidity, we can recommend the use of the lateral

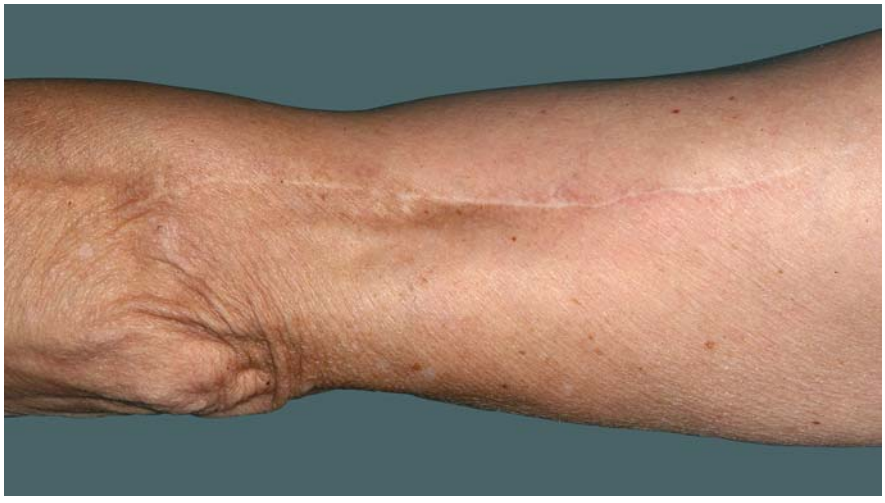


Fig. 13.18. Typical donor site 1 year postoperatively

arm flap in trauma and tumor patients. We find that the lateral arm flap is a reliable and versatile flap in the reconstruction of small to medium-sized defects of the head and neck area and the extremities.

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14 Three Tricks for Microvascular Fibular Grafting of Osteonecrosis of the Femoral Head

H. Kuokkanen

14.1 Introduction

In our practice we have performed microvascular fibular grafting for osteonecrosis of the femoral head since 1996. Our indications for the procedure are a symptomatic hip with grade I–II disease and age less than 50 years [3]. In patients younger than 40 years, grade III disease is also considered an indication for microvascular reconstruction. We have followed the technique described by Urbaniak in 1995 [3]. This technique was described in detail again in 2004 [1]. In our practice we

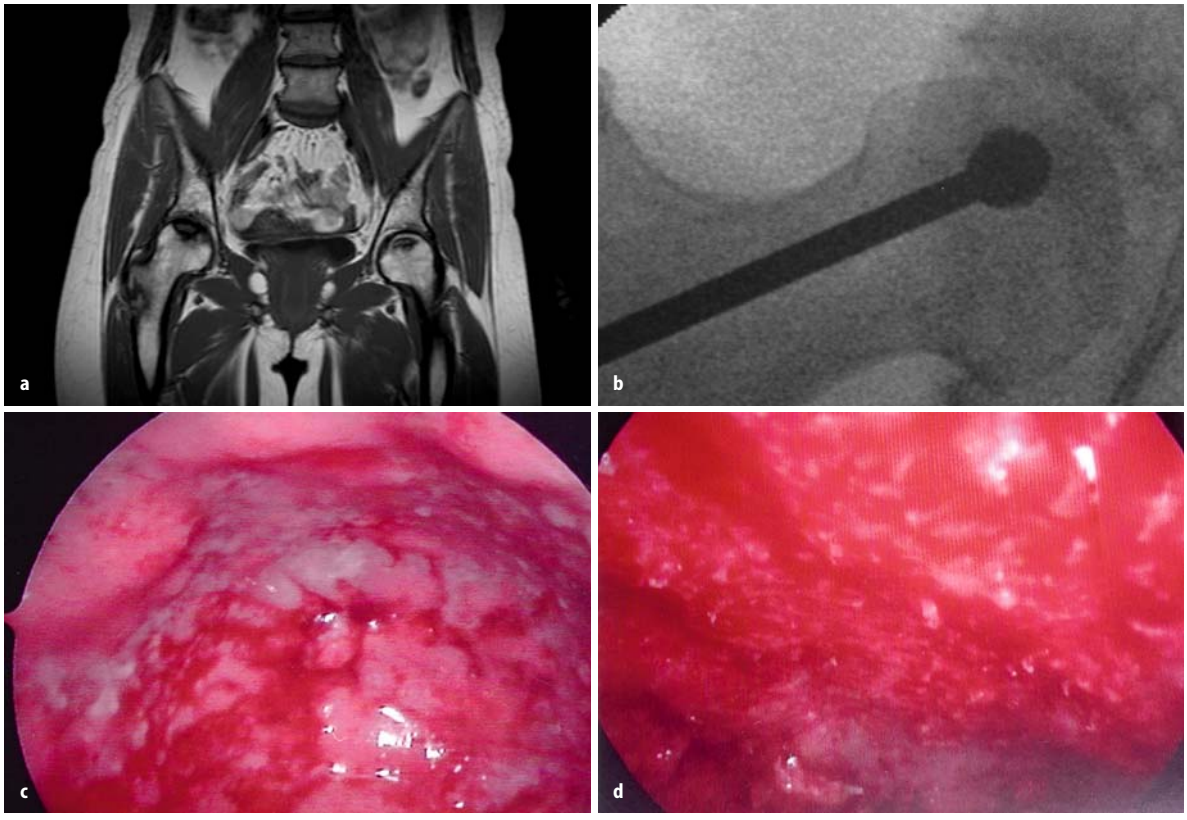

Fig. 14.1. a Femoral head necrosis, grade II on the right side and grade I on the left side, in a 20-year-old woman after massive corticosteroid treatment. The symptomatic right hip was operated on. **b** Peroperative X-ray to control the removal of the necrotic bone. **c** Primary peroperative endoscopy through the drill hole. White necrotic bone is seen on top of the drill hole. **d** Endoscopic view after removing the dead bone. Bleeding bone is seen over all the defect

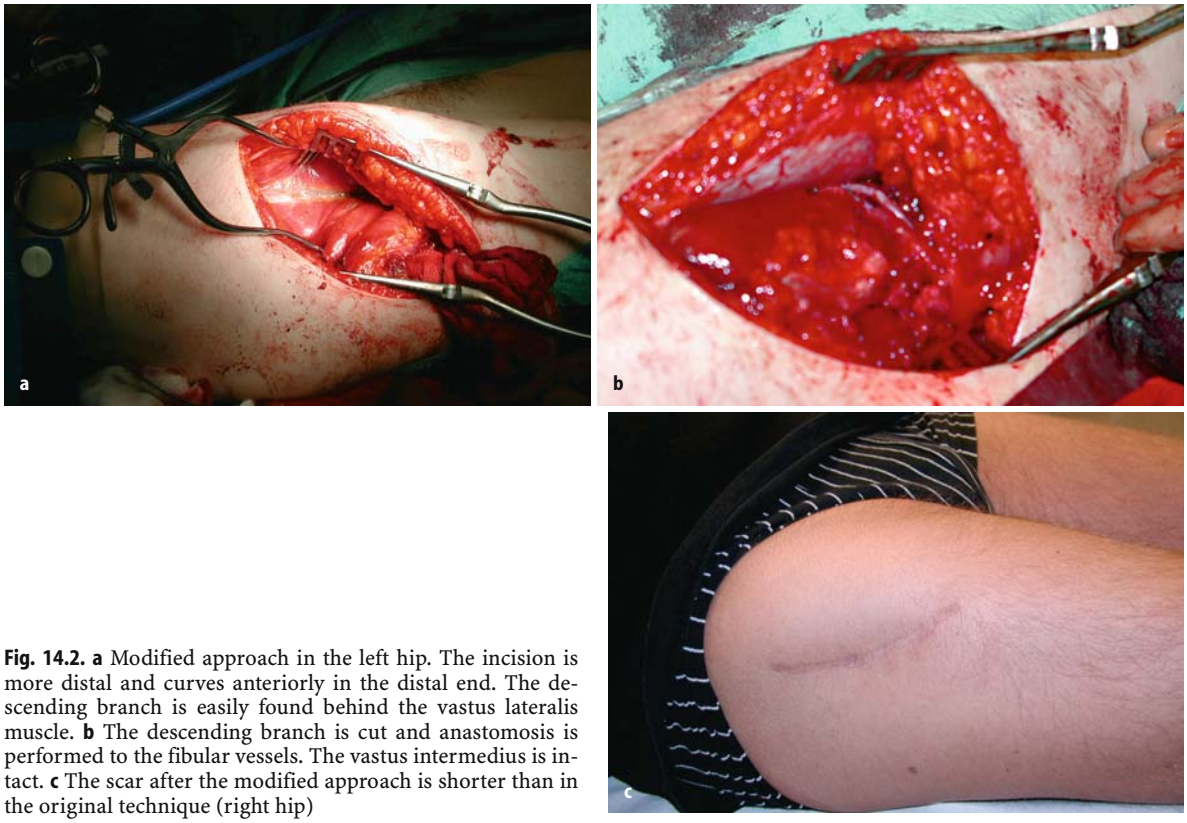

Fig. 14.2. a Modified approach in the left hip. The incision is more distal and curves anteriorly in the distal end. The descending branch is easily found behind the vastus lateralis muscle. **b** The descending branch is cut and anastomosis is performed to the fibular vessels. The vastus intermedius is intact. **c** The scar after the modified approach is shorter than in the original technique (right hip)

have developed some modifications to the basic technique which we find to be helpful for the operation. The modifications are described in detail in this article.

14.2 Endoscopically Assisted Removal of the Necrotic Bone

Primarily we remove the necrotic bone under peroperative X-ray control. The MRI images are used as a map in order to localize the dead bone (Fig. 14.1a). However, there has been some uncertainty as to whether all the dead bone is removed properly. This is because the disease itself is not visible on the plain radiographs (Fig. 14.1b). Different techniques such as computer assisted drilling or contrast medium imaging of the defect have been suggested to make the removal of the diseased bone more reliable [1, 2].

In order to make sure that a healthy level of bone is reached, we decided to try endoscopic visualization inside the drill hole. This method is easy with a long straight scope planned for hip arthroscopies. With the endoscope the necrotic bone can be seen from inside the femoral head (Fig. 14.1c). Sufficient removal of the dead bone can be confirmed by the endoscope when the bleeding level of bone is reached (Fig. 14.1d).

14.3 Modified Approach and Donor Vessels

In the original method the ascending branch of the lateral femoral circumflex artery and the concomitant veins are used as donor vessels for microvascular anastomosis. However, these vessels can occasionally be quite small. In addition, when using the ascending branch, cutting of the vastus intermedius muscle is needed to be able to reach the fibular vessels without tension [1].

After getting used to the anterior lateral thigh flap and its pedicle, the descending branch of the same origin, we tried using it as a donor vessel in femoral head reconstruction (Fig. 14.2a, b). The artery of the descending branch and its concomitant vein are normally nearly the same size as the fibular vessels. In addition, we have found harvesting of the descending branch easier. If the descending branch is used, the incision of the skin is done more distally than in the original technique and it can be shorter (Fig. 14.2c). Cutting of the intermedius muscle is not normally needed when the descending branch is used.

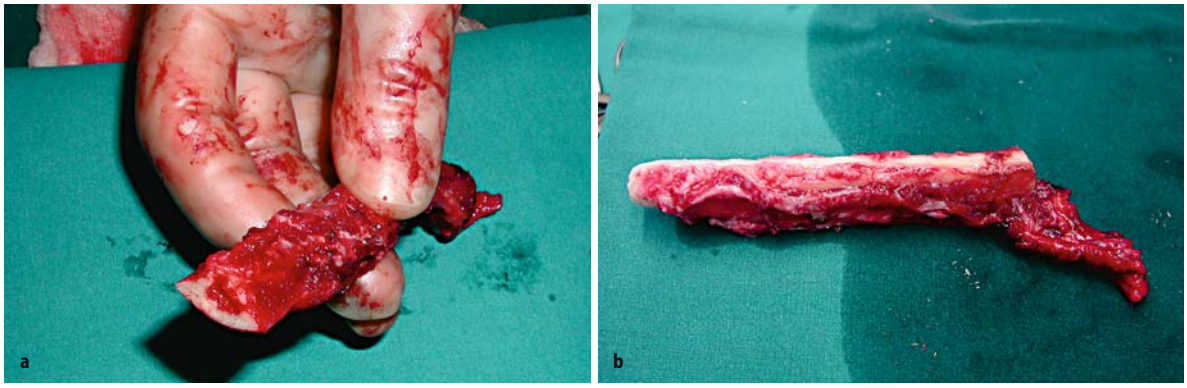

Fig. 14.3. a The natural shape of the distal tip of the fibular graft. **b** The anterior edge of the fibula is removed to make the diameter smaller

14.4 Shaping of the Fibula

The shape of the fibula is not perfect for filling a defect in the femoral head. Sometimes the cut distal tip of the fibula can be quite flat (Fig. 14.3a). A 21-mm reamer is used in the original technique in the femur for a larger fibula. The larger the hole in the lateral cortex, the bigger the risk of a subtrochanteric fracture.

In microvascular reconstruction of the mandible, we have found that even several osteotomies can be made to the fibula without compromising the circulation of the bone. With that experience in mind we started to shape the fibula to make the circumference smaller needed for reaming of the femur. A periosteal incision is made to the anterior edge of the fibula opposite the vascular pedicle. The edge is subperiosteally exposed and a few millimetres is removed with a high frequency round tip burr (Fig. 14.3b). By this method the size of the fenestration in the femoral cortex can be reduced. However, the size of the hole has to be large enough to provide sufficient space for the vascular pedicle. At the end of the operation the bleeding of the grafted fibula is checked to make sure that the pedicle is not in compression.

14.5 Conclusions

In our hands endoscopy of the femoral head makes the operation a little longer but makes the procedure more accurate. The equipment needed for the endoscopy is available in all orthopaedic units and does not produce any extra costs. We feel that using the descending branch as a donor vessel makes the operation faster and less traumatic for the patient. Shaping of the fibula adds to the operation time but minimizes the risk of an iatrogenic fracture of the femur.

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Application of Flaps for Coverage of Foot Wounds with Tendon and Bone Exposure Based on a Subunit Principle

15

Zun-Li Shen, Wan-Xing Jia, Ming-Zhong Hou, Xie-Qing Huang, Yan-Xian Cai, Lan Wang, Yi-Xiong Huang

15.1 Introduction

Foot wounds with exposure of tendon or bone are usually a result of trauma, resection of malignant skin tumors, burn injury, or neurotrophic ulceration. Reconstruction of this particular region presents a great challenge due to the limited local soft tissue availability and weight-bearing requirement. Until now, a great number of reconstructive alternatives have been described in the literature, including cross-leg flaps, local fasciocutaneous flap or free flaps [1]. However, it is not clear how to choose the appropriate flaps for the different parts of the foot [2, 3]. Based on location and extension of the soft tissue defects, we used 11 local fasciocutaneous or free flaps for reconstruction, and a subunit repair principle was then established.

15.2 Patients and Methods

15.2.1 Patients

Between August 1999 and December 2005, 25 patients were treated in our department. There were 20 males and 5 females, ranging in age from 6 to 83 years, with a mean age of 56 years. The preexisting conditions necessitating subsequent reconstruction were resection of malignant melanoma or malignant junctional nevus in 11 patients, post-traumatic soft tissue defects in 10 patients, burn injury in 2 patients, and neurotrophic ulceration in 2 patients. The size of soft tissue defects varied from 2×2 cm to 9×8.5 cm.

15.2.2 The Subunits of a Foot and the Application of Flaps

According to function, anatomic structure and reconstruction requirements, the foot can be divided into five subunits: plantar forefoot and dorsal forefoot region, plantar hindfoot and dorsal hindfoot region as well as ankle region. If the midfoot region is involved, a predominant defect region is defined as one of the five above-mentioned subunits. A complete degloving of plantar or dorsal foot soft tissue was not seen. The soft tissue defects presented in different subunits and the subsequent flap applications are summarized in Table 15.1.

15.2.3 Reconstructive Options for Different Subunits of the Foot

15.2.3.1 General Repair Principle

In the case of a malignant skin carcinoma in the foot region, a wide local excision was performed and the intraoperative biopsy showed the clear margin of the wound. Then the wounds were covered primarily by a flap.

If soft tissue defects in the foot were caused by trauma, burn or neurotrophic denervation, a complete debridement was first performed, including removal of the necrosis tissue and granulation tissues as well as the unstable scar around the wounds, then an antibiotic therapy ensued. After the local wound bacterial culture confirmed that there was no bacterial contamination, a secondary flap transfer was performed for the wound coverage.

When transposing a flap as a reverse-flow flap, a teardrop skin paddle was usually designed over the flap pedicle. After flap elevation, an incision was made be-

Table 15.1. The subunits and flap coverage

Subunits	Cases	Flaps (number)
Plantar forefoot	2	Partial toe flap (1), filleted toe flap (1)
Dorsal forefoot	3	Local DPF (2), free LLLF (1)
Plantar hindfoot (weightbearing region)	8	MPF (4), MRF+LCF (1)
Plantar hindfoot (non-weightbearing)	3	SNCF (3)
Dorsal hindfoot	2	SNCF (1), PTAF (1)
Ankle (medial malleolus)	3	MSMF (2), LSMF (1)
Ankle (lateral malleolus)	1	Free ALTF (1)
Ankle (Achilles tendon)	3	Local RT (2), SNCF (1)

DPF dorsalis pedis flap, *LLLF* lateral lower leg flap, *MPF* medial plantar flap, *LCF* lateral calcaneal flap, *SNFF* sural neurocutaneous flap, *PTAF* posterior tibial artery flap, *MSMF* medial supramalleolar flap, *LSMF* lateral supramalleolus flap, *ALTF* anterolateral thigh flap, *RT* rotational flap

tween the flap donor site and the defect site. An open tunnel was then prepared and the teardrop skin paddle left on the pedicle was used to cover the tunnel.

15.2.4 Reconstruction of the Plantar Forefoot Region

When the wound was located in the plantar forefoot region, a digital pulp flap in reverse fashion or a filleted digital flap was used.

15.2.5 Reconstruction of the Dorsal Forefoot Region

For the dorsal forefoot wound, a local dorsalis pedis artery flap was rotated for the wound coverage. In one case, there was an extensive soft tissue defect in this region (Fig. 15.1a). The patency of the peroneal artery, posterior tibial artery and anterior tibial artery was confirmed prior to the operation. A free ipsilateral lateral lower leg flap transplantation, based on the peroneal vessels, was performed. According to the size of the soft tissue defect, the lateral lower leg flap was designed in the lateral middle of the lower leg (Fig. 15.1b). The dissection started from the anterior aspect of the flap, and deep in the fascia, then a main cutaneous perforator could be recognized in the middle of the leg, which usually came from the septum and arose from

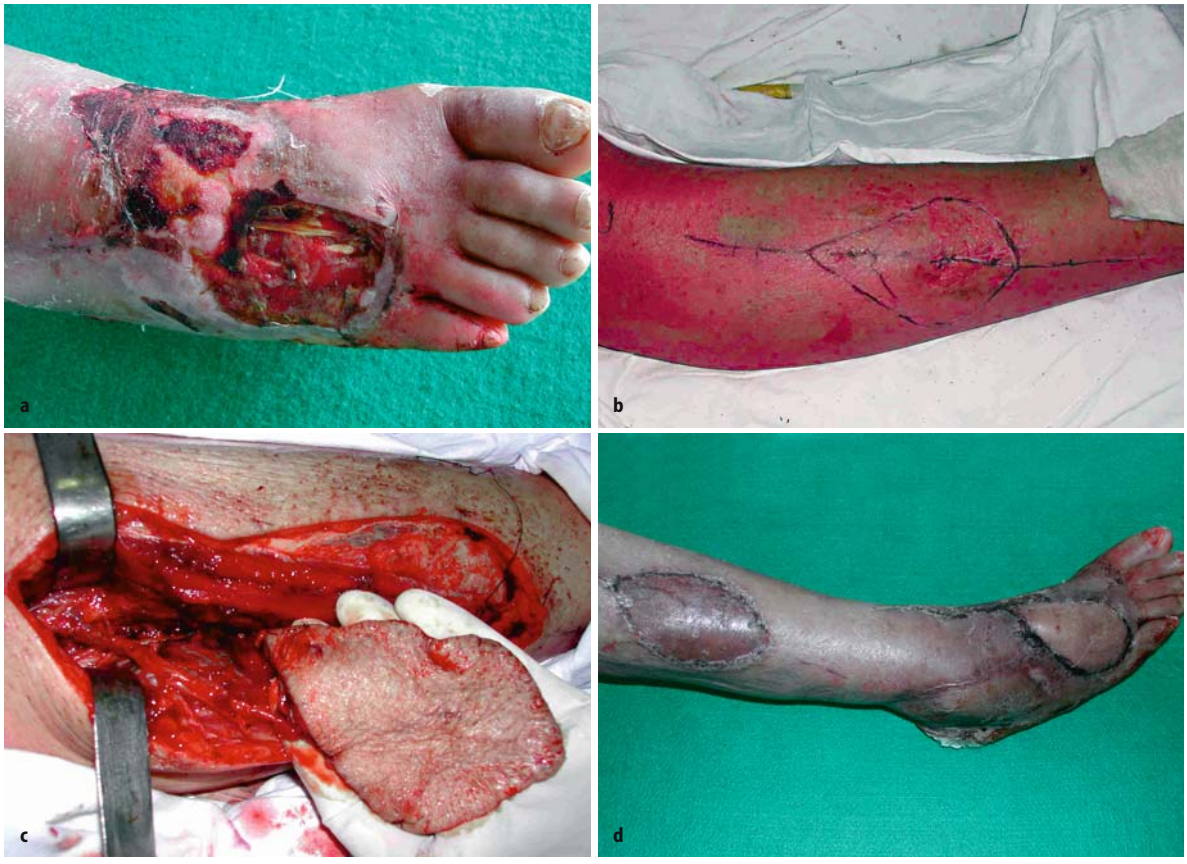

Fig. 15.1. a View of a defect in the dorsal forefoot. **b** A free lateral lower leg flap was designed. **c** The flap was elevated and the pedicle based on peroneal vessels was exposed. **d** Postoperative view of the flap and donor site

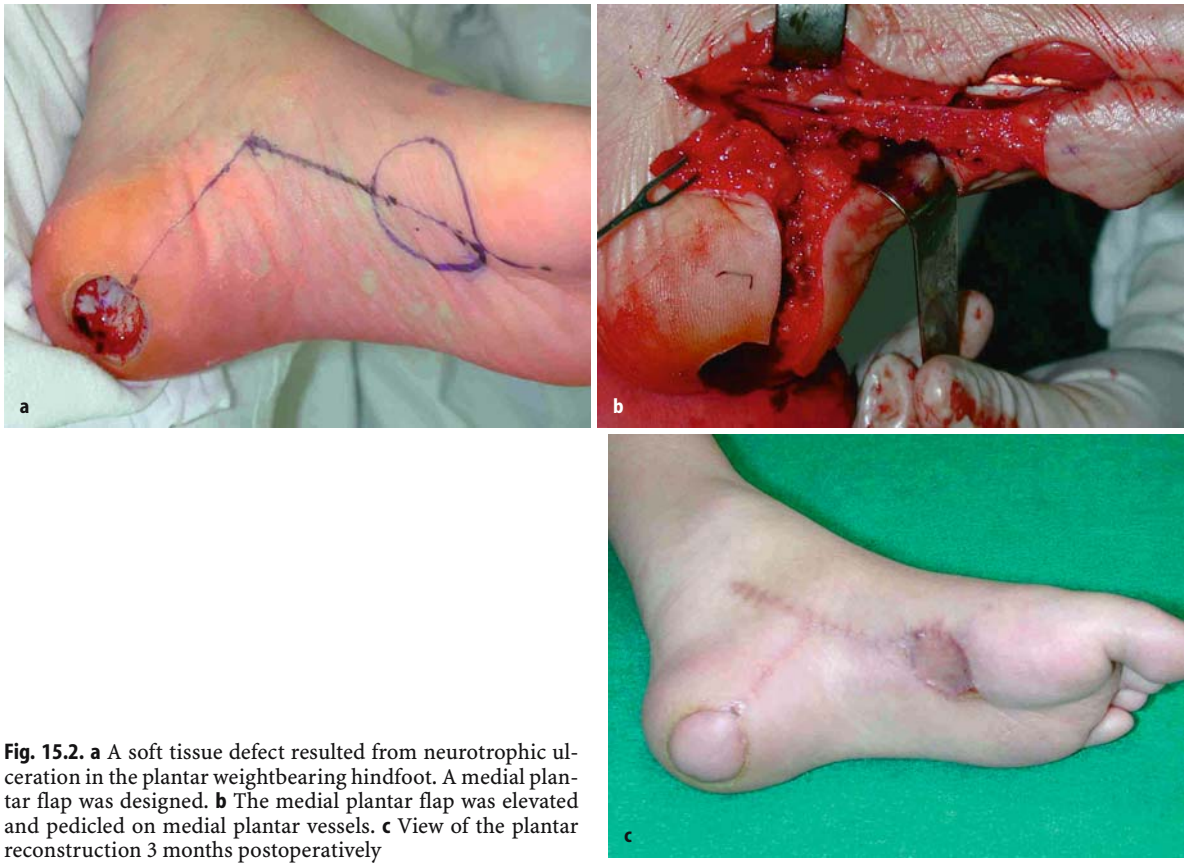

Fig. 15.2. a A soft tissue defect resulted from neurotrophic ulceration in the plantar weightbearing hindfoot. A medial plantar flap was designed. **b** The medial plantar flap was elevated and pedicled on medial plantar vessels. **c** View of the plantar reconstruction 3 months postoperatively

the peroneal artery (Fig. 15.1c). The perforate artery and two concomitant veins were then dissected in connection with the proximal peroneal artery and the accompanying veins. Finally, the flap was elevated, the peroneal vessels were anastomosed to the dorsalis pedis vessels and the donor site was repaired with a split-thickness skin graft (Fig. 15.1d).

15.2.6 Reconstruction of the Plantar Hindfoot Region

The plantar hindfoot wounds were usually covered by a medial plantar flap. After the confirmation of patency of the dorsalis pedis and posterior tibial arteries, the flaps were designed in the instep region according to the size of the defects (Fig. 15.2a). The flaps were dissected in the direction from the medial to lateral side, and the posterior tibial artery was first recognized proximal to the flap. The abductor hallucis muscle was divided and the medial plantar vessels were exposed. The medial plantar vessels should be incorporated within the flap during a meticulous dissection (Fig. 15.2b). Using an interfascicular dissection technique, the cutaneous nerve fascicles originating from the medial plantar nerve were retained within the flap. An incision was made between the flap donor site and the defect. Finally, a proper tunnel was prepared for the pedicle inset and the flap was transferred to cover the defect (Fig. 15.2c).

In the lateral heel region, a calcaneal flap was applied (Fig. 15.3a). The flap was dissected from distal to proximal in a supraperiosteal plane. The lateral calcaneal artery and the lesser saphenous vein as well as the sural nerve should be incorporated within the flap (Fig. 15.3b). After flap elevation, the flap was transferred to the recipient area with a skin paddle over the pedicle and the donor site was covered with a split-thickness skin graft (Fig. 15.3c).

Sural neurocutaneous flaps were also used in the coverage of this region (Fig. 15.4a). A line was marked from a point halfway between the Achilles tendon and the lateral malleolus at the ankle extending to the midline between the two heads of the gastrocnemius muscle. Usually, we designed a teardrop skin paddle over the pedicle (Fig. 15.4b). After the proximal sural nerve and the lesser saphenous vein were ligated and divided, the flap was raised under the deep fascia with a pedicle as wide as 3 cm and to include the sural nerve and the lesser saphenous vein. About 5 cm above the tip of the lateral malleolus, a main perforator arising from the

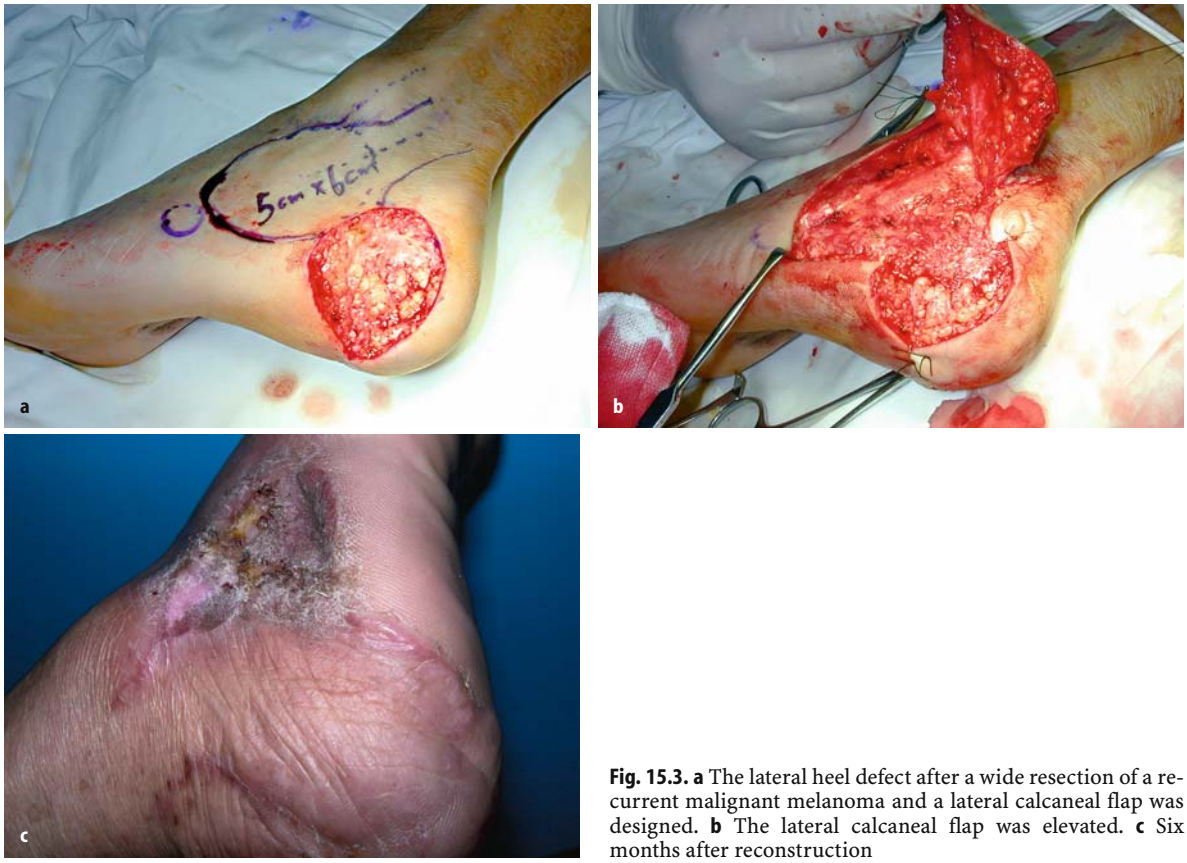

Fig. 15.3. a The lateral heel defect after a wide resection of a recurrent malignant melanoma and a lateral calcaneal flap was designed. **b** The lateral calcaneal flap was elevated. **c** Six months after reconstruction

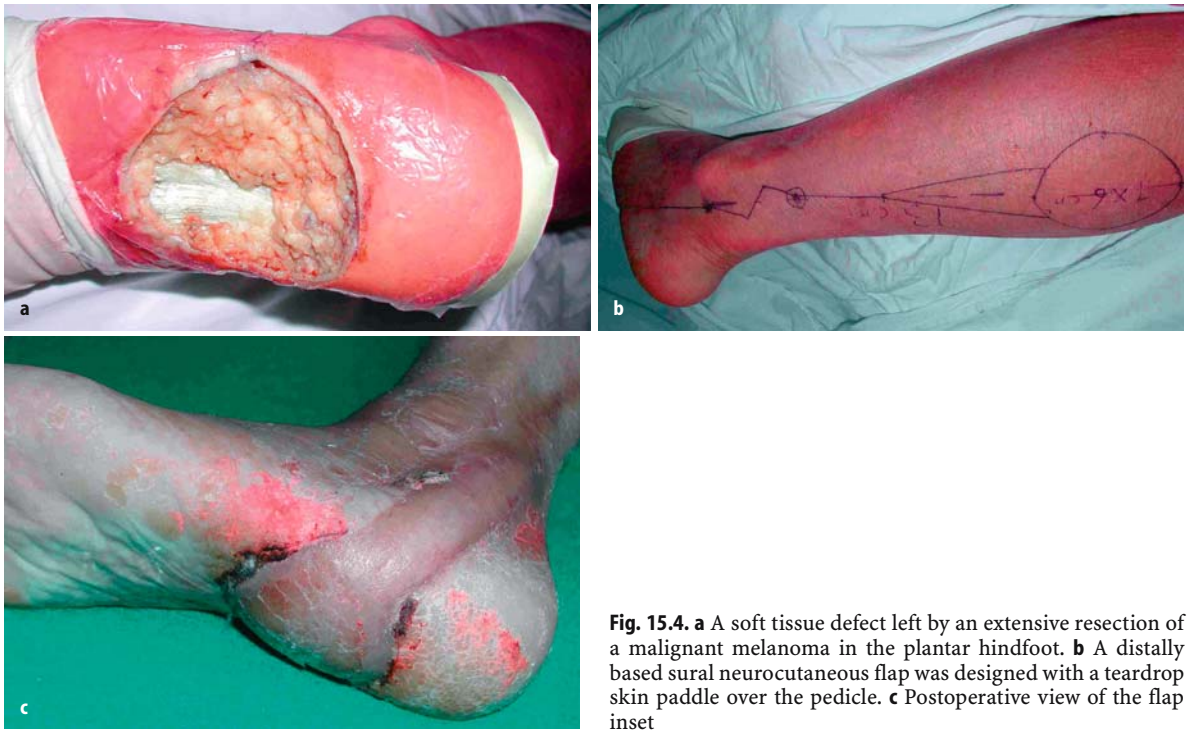

Fig. 15.4. a A soft tissue defect left by an extensive resection of a malignant melanoma in the plantar hindfoot. **b** A distally based sural neurocutaneous flap was designed with a teardrop skin paddle over the pedicle. **c** Postoperative view of the flap inset

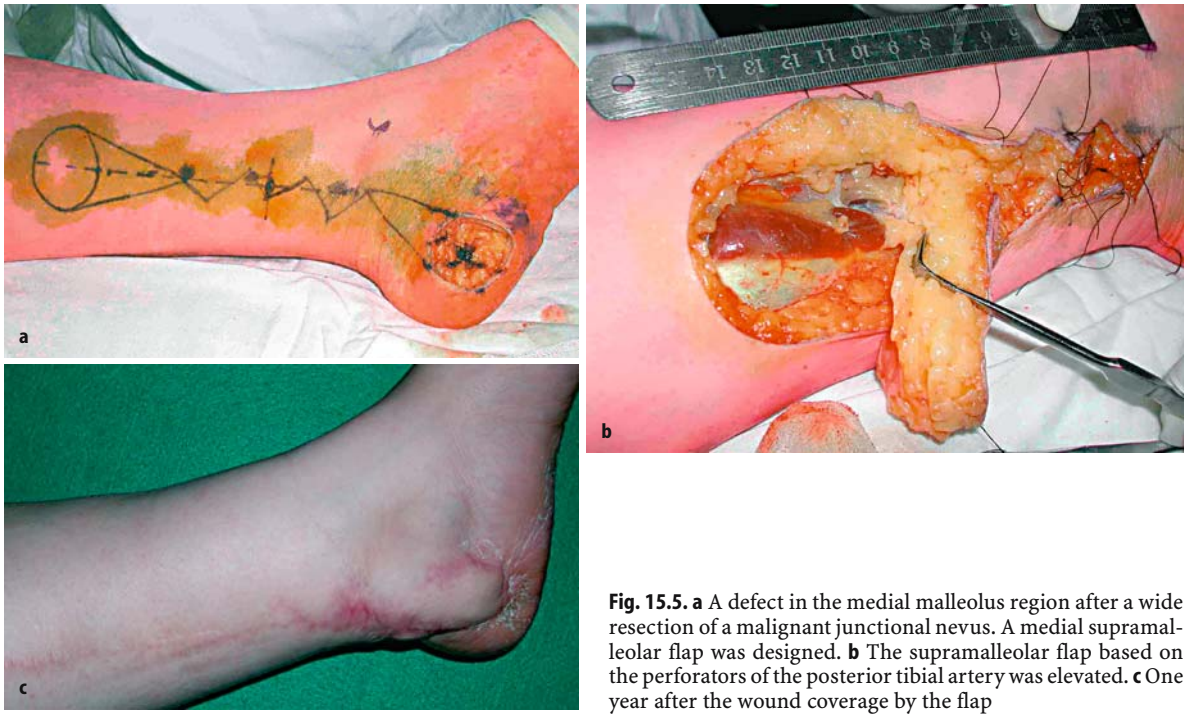

Fig. 15.5. a A defect in the medial malleolus region after a wide resection of a malignant junctional nevus. A medial supramalleolar flap was designed. **b** The supramalleolar flap based on the perforators of the posterior tibial artery was elevated. **c** One year after the wound coverage by the flap

peroneal artery could be recognized. The flap was rotated based on the pivotal point to cover the hindfoot region (Fig. 15.4c). The donor site could be closed directly when the width of the flap was less than 4 cm. The pedicle region could be closed primarily by suture of the skin paddle to the tunnel skin.

15.2.7 Reconstruction of Dorsal Hindfoot Region

The posterior dorsum wounds were covered by a sural neurofasciocutaneous flap, as described above. A reversed posterior tibial artery flap was used in our early case. The flap was designed along the medial edge of the tibia and the pivotal point was above the tip of the medial malleolus. The posterior tibial artery and two concomitant veins were first exposed in the proximity of the flap. The flap was then dissected under the deep fascia; the posterior tibial vessels and their perforators were included. The flap was finally rotated to cover the defects in the foot.

15.2.8 Reconstruction of Ankle Region

This region can be subdivided into three regions: the lateral malleolus region, the medial malleolus region and the Achilles tendon region.

In the lateral malleolus region, the soft tissue defects were reconstructed using a free anterolateral thigh flap. The flap was based on the descending branch of the lateral circumflex femoral artery. A line was drawn between the anterosuperior iliac spine and the lateral border of the patella. Centered in the midpoint of the line, the flap was then outlined and a dissection started in the direction from lateral to medial under the deep fascia. A large fasciocutaneous perforator was usually seen arising from the lateral circumflex femoral artery. Then, the pedicle was dissected leaving several strips of the vastus lateralis muscle fiber attaching to the pedicle, which prevents any damage or kinking of the pedicle. Finally, the flap was elevated and the lateral circumflex femoral vessels were anastomosed to the dorsalis pedis vessels. The donor site could be primarily closed when the flap width was less than 6 cm. Otherwise, skin grafting was necessary.

When the defect was located around the medial malleolus (Fig. 15.5a), a medial supramalleolar flap was used. The flap was supplied by posterior tibial artery perforators. Flap dissection was performed between the medial edge of the tibia and middle part of the gastrocnemius muscle under the deep fascia (Fig. 15.5b). The pivotal point of the flap was about 6 cm above the tip of the medial malleolus, where a main perforator arising from the posterior tibial artery could be found. The flap was elevated with a pedicle width of 3 cm and rotated to the recipient site through a widely undermined tunnel (Fig. 15.5c).

When the soft tissue defect was located in the proximal part of the medial malleolus region, a lateral supra-

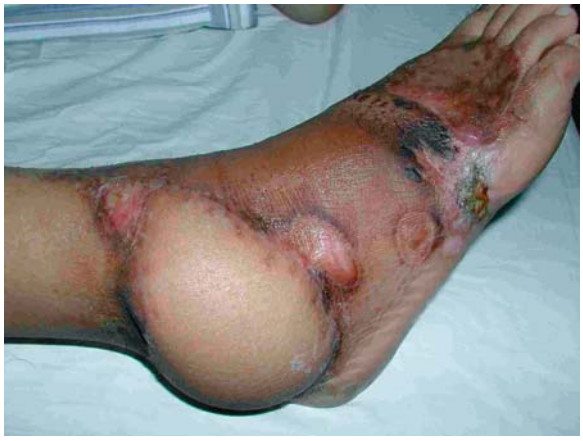

Fig. 15.6. Six months after a free anterolateral thigh flap transplantation to reconstruct the lateral malleolus region. The flap was too bulky and secondary debulking was necessary

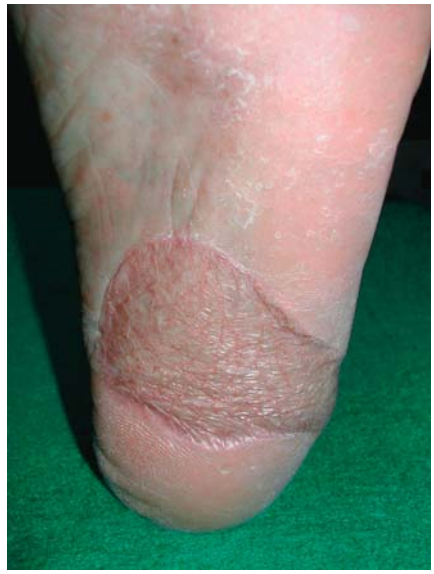

Fig. 15.7. Two years after reconstruction of the plantar hindfoot with a distally based sural neurocutaneous flap. No recurrent ulceration or skin breakdown was observed

malleolar flap, which was based on perforators from the peroneal artery, was used for the coverage. The axis of the flap was the midline drawn from the anterior tibial crest to the posterior margin of the fibula. The pivotal point was about 5 cm above the tip of the lateral malleolus. The flap was dissected under the deep fascia leaving a subcutaneous pedicle 3 cm wide to improve the venous return. To avoid compression, a wide tunnel was made between the pivotal point and the recipient site. Finally, the donor site was closed by a split-thickness skin graft.

The soft tissue defects located in the ankle Achilles tendon region were covered by a sural fasciocutaneous flap or regional rotation flaps.

15.3 Results

All cases were followed up from 3 months to 67 months, with an average of 30 months. Two cases with regional rotation flaps for the Achilles tendon's coverage underwent marginal flap necrosis and healed by local wound care. One patient ambulated 2 weeks after the sural neurofasciocutaneous flap transfer was used to cover the heel region; the wound dehiscence and partial superficial skin necrosis occurred between the flap and donor site. It was healed by wound dressing changes. All the other flaps survived uneventfully. However, the free anterolateral thigh flap was bulky in the lateral malleolus region (Fig. 15.6). It had to be debulked half a year after the first operation. It was demonstrated that all flaps had normal or protective sensitivity without any skin breakdown (Fig. 15.7). All patients ambulated well and could wear normal shoes.

15.4 Discussion

It is vital for a foot to support standing and walking. Any soft tissue defects in the foot will impede the normal activities of patients. The skin and soft tissue underneath are different in various parts of a foot. The plantar skin is glabrous and thick with solid anchorage to the deep structure. Therefore, the reconstruction aim is to restore the stability of the foot skin to adapt to the weight-bearing and to resist shearing force. In addition, a good sensibility should be taken into account for the reconstruction. The skin in the foot dorsum is thin and pliable, while the ankle region has great tension during movement, and a good stability is required for shoe-wearing. Considering these structural differences, we thought that the subunit repair principle could assist us in choosing proper flaps in the reconstruction of the foot.

In the case of small soft tissue defects in the forefoot, partial toe fillet flaps or webspace flaps based on the plantar circulation could be used without toe amputation. Sometimes, these defects were associated with diabetes mellitus or peripheral vascular disease. Thus, the toe fillet flap was often the primary reconstructive choice [4]. Recently, it was reported that the medial plantar flap could be transferred as a distally based pedicled island flap. The small to moderate size wound located in the plantar forefoot could be repaired with this glabrous skin flap [5, 6]. The precondition of this procedure was that the dorsalis pedis artery and the posterior tibial artery should be patent. In the lateral or

medial site of the forefoot, a local dorsal pedis flap could be rotated to cover small or moderate-sized wounds satisfactorily.

According to our own experience, a distally based fasciocutaneous flap could not cover the forefoot reliably. A free flap had to be used to repair this region when there was an extensive soft tissue defect. In our series, a free ipsilateral lower leg flap based on the peroneal vessels was applied. This flap was thin with a constant vascular anatomy. The procedure could be performed by one microsurgical team using one tourniquet. However, the main disadvantage was having to sacrifice the peroneal artery and the dorsalis pedis artery, and the fact that the perfusion of the foot may be compromised. The confirmation of the patency of the posterior tibial artery was necessary prior to the operation. Alternatively, the contralateral lateral lower leg flaps or forearm flaps as well as the medial sural artery flap [7] can be selected as free flaps for the coverage of the forefoot.

The plantar hindfoot, especially the weightbearing region, requires thick, sensorial, durable and glabrous skin. The medial plantar artery flap raised from the nonweightbearing instep of the plantar foot is a sensate flap. The skin texture is similar to that of the weightbearing region. Therefore, it is an ideal approach to resurfacing the plantar hindfoot region [8]. However, the flap offers limited soft tissue for coverage of an extensive soft tissue defects in the lateral heel. The lateral calcaneal artery flap has provided a good alternative to this defect [9]. We used the medial plantar flap combined with a lateral calcaneal artery flap in this situation. Both flaps had good sensibility and provided durable skin and soft tissue; no recurrent ulceration was observed postoperatively. When the soft tissue coverage was located in the instep region, a distally based sural neurocutaneous flap was transferred and fit this region well.

For the soft tissue defect located in the dorsal hindfoot, the distally based sural neurocutaneous flap was a good reconstructive option [10, 11]. In our previous series, we used a distally based posterior tibial artery flap. The flap was very reliable and provided enough soft tissues for wound coverage. However, the sacrifice of a main artery of the foot may worsen the injured foot. Thus, the flap should not be the first choice for reconstruction.

In the ankle region, local rotational flaps were attempted for the wound coverage in two cases. The partial flap loss resulted in delayed wound healing due to the tight tension of the local tissue. So, it seemed that a local rotation flap was not appropriate for reconstruction of this region. The lateral calcaneal flap and medial or lateral supramalleolar flap were good alternatives for wond coverage in the lateral or medial malleolus region [12 – 14]. They had the common advantage of not sacrificing the main blood vessels of the foot. However, they were only suitable for coverage of small to moderate-size wounds as they do not provide sufficient skin and soft tissue. For the coverage of extensive soft tissue defects, we used a free anterolateral thigh flap. The disadvantage was that the flap was very bulky and made shoe-wearing difficult. Recently, a thinned anterolateral thigh flap was described and may be used instead of the traditional anterolateral thigh flap [15]. Alternatively, when the main perforator is not jeopardized by the trauma, the distally based sural neurocutaneous flap is suitable for reconstruction of extensive soft tissue defects in this region [16].

The main complication of reverse flow flaps was venous congestion. In our series, we did not see this complication. We thought the following points might play a vital role in the raising of a reverse flow flap for reconstruction of foot soft tissue defects. Firstly, the pivotal point of the flap should be detected before the operation using Doppler ultrasound or angiography. The distance from the pivotal point to the closest edge of the skin defect was measured. A 1- to 2-cm length should be added to the pedicle length for the rotation of the pedicle. The design of flaps was 1 cm larger than the original size of the defects to facilitate the final closure of the wounds. Secondarily, the flaps were elevated under the deep fascia plane and superficially in the subdermal plane to protect the pedicle. The subcutaneous pedicle should be as wide as 3 cm to improve the venous return. Finally, a wide tunnel was made between the pivotal point and the recipient site. A teardrop skin paddle was left over the pedicle to facilitate the closure of the tunnel. Drainage was necessary to prevent the postoperative hematoma under the flaps. All these measures contributed to a wound closure without tension and allowed good perfusion of flaps. However, the reverse flow flaps were primarily non-sensory flaps and could not resist the shearing force during standing and walking in an early postoperative period. Otherwise, a persistent ulceration likely occurred at the junction between the flap and the local skin. Therefore, it was suggested that patients wear protective shoes and avoid weight-bearing prior to normal ambulation.

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Basic Techniques

IV

The Use of Frogskin as a Biological Dressing for Temporary Cover of Burn Wounds

16

N. Sarto Piccolo, M. Sarto Piccolo, M.T. Sarto Piccolo

16.1 Introduction

Most burns experts will agree that third degree burn wounds should be excised by the end of the first postinjury week. The wound should be closed if one is to minimize or avoid the deleterious effects of the hypermetabolic changes which occur after a major burns injury. Early excision and grafting has significantly decreased morbidity and mortality in burns patients. In selected cases, this method offers a better chance of a faster recovery, with marked reductions in metabolic consumption, as a consequence of the prompt closure of the wound.

This method became progressively more popular after Dr. Jazenkovic reported her clinical experience in 1970 [1]. The users of this technique, however, soon realized that there was an urgent need for immediate closure of the wound, since organic losses were even greater via a non-covered, excised wound.

Although an autograft is the most desirable way to cover the excised wound, patients with extensive injury usually have very limited donor areas. Several authors have suggested alternatives for this coverage, these being that allograft (cadaver skin) is still considered the gold standard, although this option was already suggested by Brow (1942) and Artz (1955) [2, 3].

Alternatives are inter-vivo skin transplantation (allograft), xenografts and the use of other biological tissues and of industrial or bioengineered products.

There are several alternatives used around the world which may serve to cover the burn wound, ranging from honey to potato peel, to the different methods of using cultured keratinocytes, to a most diverse selection (and use) of biological tissues and bioengineered skin substitutes. Cuono (1987), Poulsen (1991) and Klugston (1991) recommended cultured epithelial cells from the patients themselves or from other donors, and bioengineered tissue usage was demonstrated as long ago as 1988 by Heimbach and in 1989 by Tompkins [4–11].

Allograft inter-vivo skin transplantation has been practiced in our country for several decades, and the major difficulty with this procedure is the difficulty of finding willing donors, usually a relative or close friend of the patient, who has to be convinced to donate skin, at rather short notice. The sudden news of a burns accident with a loved one and the emotional impact of the severity of the injury may hinder clear decisions for the closest relatives, who would be the most logical donors, delaying or making this procedure improbable in the recommended time (the first postburn week).

Cadaver skin (allograft) then becomes the most recommended way of covering an excised burn wound in large burns with limited donor sites. The difficulty with this procedure in our country is that there are only two tissue banks, which although they are open to donate skin for government insured patients (about two-thirds of our burns patients), do not have enough skin to distribute for the 31 registered tertiary care burns centers in Brazil.

In our country, xenograft transplantation becomes the next available and feasible everyday alternative, since the industrial and/or bioengineered products are extremely expensive and are usually not financially supported by most insurance companies [12–16].

Pigskin has been used worldwide for several decades with good success, by Bondoc (1971), Yang (1980), Alexander (1981) and Heimbach (1987). The idea is that the injured body will not recognize the foreign tissue for some time and that temporary adherence will lead to cure of more superficial burns and to good protection on deeper or excised wounds. The problem with this technique in our country is that it has long been unavailable due to government imposed difficulties on the legal importation of these products, making them extremely expensive, and over time most companies lost interest in importing them for commercial sales within Brazil [17–21].

As a consequence of these difficulties, we have had to look for alternatives. Locally, the most logical alterna-

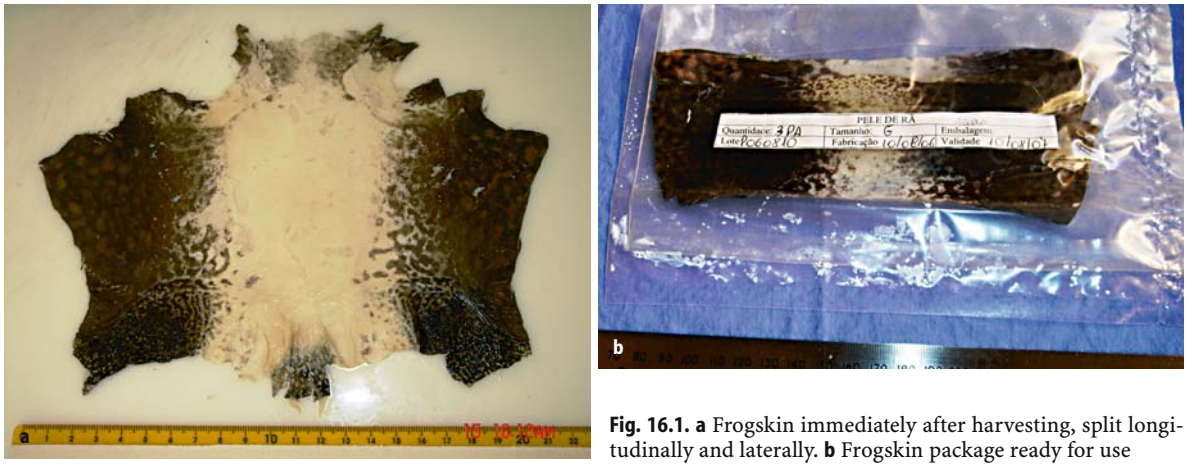


Fig. 16.1. a Frogskin immediately after harvesting, split longitudinally and laterally. **b** Frogskin package ready for use

tive was to attempt the use of frogskin as a temporary cover for these wounds, since there was practically an unlimited supply of these animals in our region due to the large number of commercially raised frogs which are slaughtered for their meat, which is sent out to several countries in Asia and also to the USA and some countries in Europe.

We originally tried frogskin on full thickness burns in Wistar rats, and it turned out to be a most useable biological dressing, with the added advantage of having its own antibiotic and other active substances within its skin. Magainine was described by Zaziass as a dipeptide with antibiotic properties which would be present within the structure of the skin of the frog. We use the skin from the frog known as *Rana catesbiana* (Shaw), also called the bullfrog [22].

Although we had this idea originally and independently in 1989, when searching the literature later, it was found that the use of frogskin had already been attempted by Fowler in 1899 and by Ricketts in 1890. These surgeons used live frogskin placed directly over a burn wound [23, 24].

Based on previous experiences of other authors with irradiated tissue, we are now also running a study where the "traditional" frogskin (prepared fresh and then kept frozen), which has been in use since 1989, is compared to freshly prepared frogskin which is irradiated and kept on a shelf at room temperature. If the comparison shows similar results with the irradiated skin, the advantage would be the elimination of the need for conservation at low temperatures, which, from the public health point of view, would make its use more widespread even in the most remote areas where the maintenance of products in a freezer may be a cost issue [25].

16.2 Materials and Methods

The frog will usually yield a piece of skin with an average size of 120 cm^2, which is prepared in our laboratory by a proprietary method, making it sterile/aseptic, when it can be immediately used or saved in a regular freezer for future use. It is used in full thickness wounds, after excision, where it is removed when autograft becomes available for definite cover as donor areas or more superficial wounds heal. It is also used as a biological dressing for deep second degree burns.

Frogs 180 g in weight are killed at the frog farm, and the skin of the body ("below" the neck) and extremities is removed as one would remove a glove from a hand. It is split on one of the sides longitudinally and divided into 1-kg sublots, which are kept refrigerated at 2 °C. In the laboratory, the skin is cut into a rectangular shape, usually yielding a fragment of 15 × 8, which is meticulously cleansed and prepared sequentially on sterilizing and detoxifying solutions. The "extra" pieces of irregular skin are also prepared for use around fingers or smaller wounds (Fig. 16.1a, b). "Prepared" skins are kept on sterile vacuum packed bags in a –20 °C freezer.

When needed, the skin is thawed and applied directly to the wound, covering it completely, as with any other graft. Its adherence is believed to be a function of fibrin bridges and the naturally occurring reactions of the wound to a graft. Fine mesh gauze may be applied with or without topical agents and the dressing is changed every 2 days.

Non-adherent skin fragments are substituted by fresh ones and the dressing replaced in a similar fashion. Xenograft loses its adherence as epithelial tissue or granulation tissue is formed on the wound. It can also be removed for definite autografting of the excised wound. In our routine, wounds are excised sequentially on the 2nd, 4th and 6th days postburn – the wound is covered with frogskin

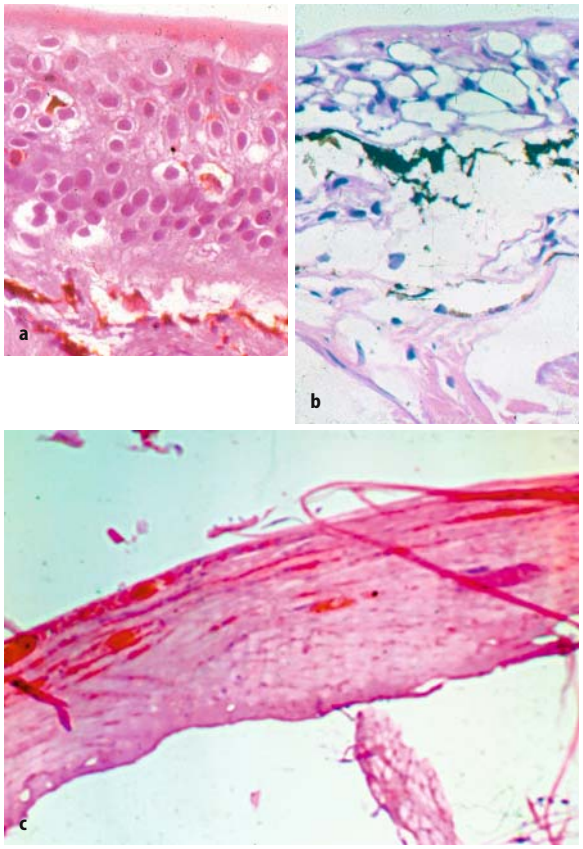


Fig. 16.2. a Photomicrograph of fresh frogskin, demonstrating a thick and well organized epidermis; absence of papillae with a dermal gland at the center of the figure. Muscle tissue can be identified in the lower portion of the image. H&E, ×400. **b** Photomicrograph of frozen frogskin, demonstrating a thinner epidermis, due to "thickening" of the dermis due to dislodgement of several of its cells as a consequence of vacuolization, probably filled with water crystals. H&E, ×400. **c** Photomicrograph of a frogskin specimen removed from a wound 12 days after application. Note the complete loss of cellular identity, probably as a consequence of progressive desiccation of this tissue. H&E, ×400

on day 2, and on day 4 another area is excised and covered with frogskin and the area originally covered with frogskin on day 2 has the xenograft removed and is autografted on day 4 and so on, as long as donor areas are available. If not, the wound is kept covered with frogskin until there is enough skin available to autograft it.

Candidates for this method of coverage are patients with excised wounds, deep second degree burns, donor areas and those with electrical injury. The biological dressing is also especially efficient in covering noble tissues such as nerves and tissues which may become exposed in deeper wounds, such as electrical injury wounds or in surgical wounds from fasciotomies and escharotomies.

For this chapter, we have considered the use of this material from 1 January 1990 up to 31 December 2005.

16.3 Results

In the last 16 years, the Pronto Socorro para Queimaduras in Goiânia has seen 188,578 burns patients. Of this population, this method of treatment was applied to 9,240 cases (4.9%) of partial thickness burns; it was used in 3,205 cases of excision (1.7%) and was also used frequently in donor areas, being applied to 4,615 patients (2.4%). The average adherence time was 9.8 days (2–20 days).

Examination of fresh frogskin under the microscope will demonstrate a relatively thick epidermis, similar to that in human skin or pigskin, and a dermis less thick than the epidermis, the opposite of human skin or pigskin. Frozen frogskin biopsy will indicate a thinner epidermis, with several dermal cell layers with vacuoles apparently filled with water crystals. The basal lamina is very evident and there is a cleft dividing the dermal stroma from the muscular plane, probably with function on the skin movement. The stratum corneum is apparently absent. An "older" specimen, removed from the wound at 12 days, will show a rather leathery appearance, with complete loss of cellular identity (Fig. 16.2a–c).

Second degree burns can greatly benefit from the use of this biological dressing, including a great deal of comfort and a practically painless wound for the patient (Fig. 16.3a–d).

Fig. 16.3. a Second degree burns covered with frogskin. **b** Same patient, 12 days after frogskin application. **c** Same patient, removing frogskin. **d** Same patient, after removal of frogskin, showing healed wound

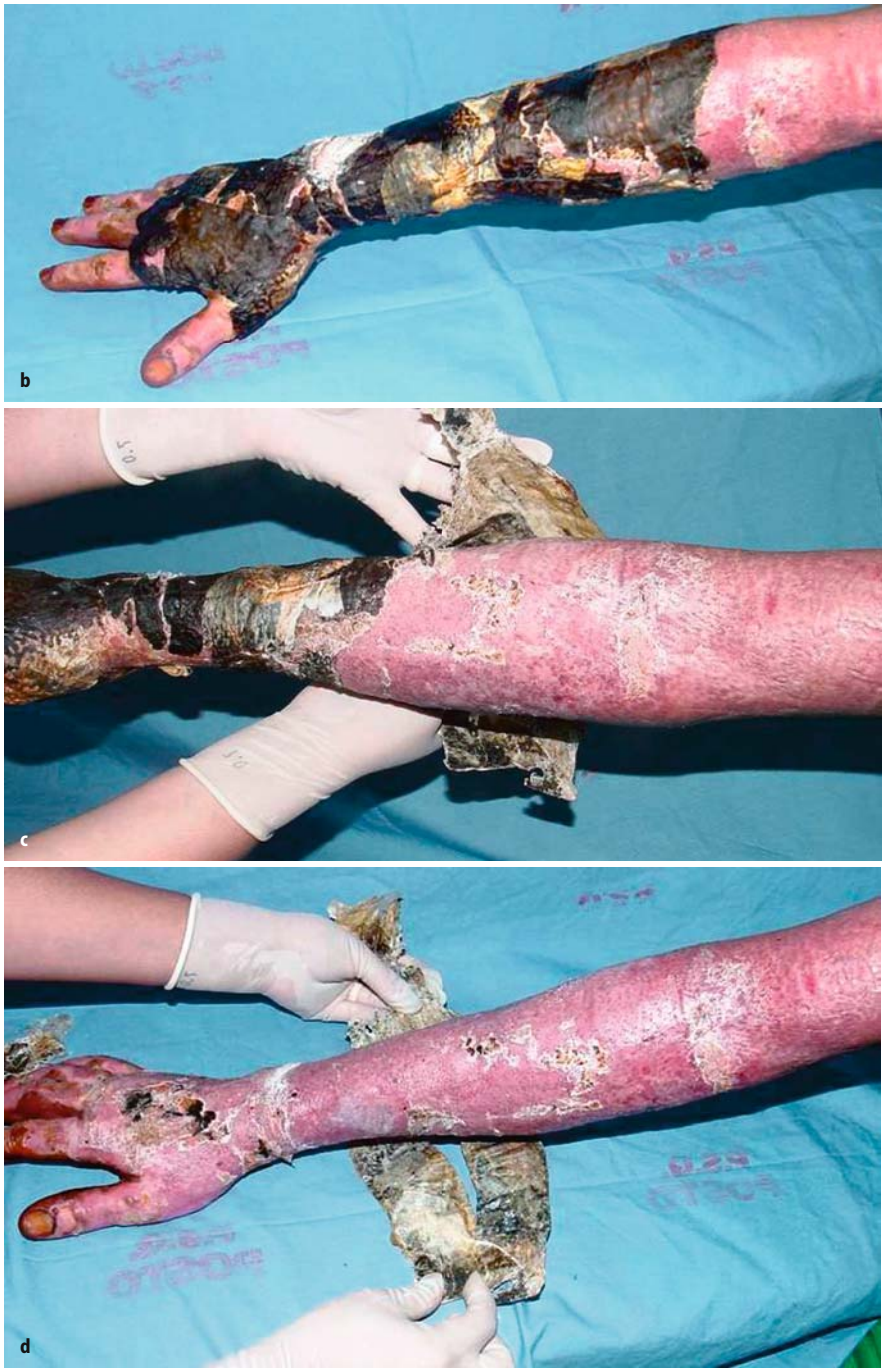
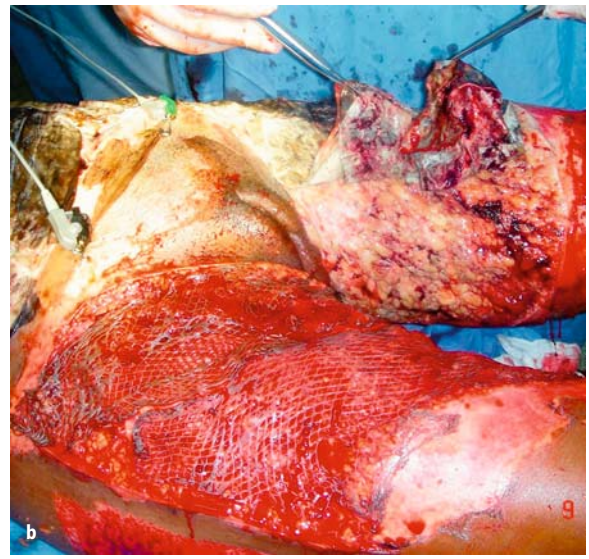


Fig. 3 (*Cont.*)

Excision and grafting is commonly performed in our institution as depicted above. Frogskin can be removed at any time for definite autografting. Our excision cases are excised to fascia in 1 %, to deep dermis in 19 %, and to fat in 80 % (Fig. 16.4a–f). Donor areas are also preferentially covered with frogskin (Fig. 16.5).

16.4 Discussion

The benefits of early excision and grafting have already been demonstrated by several authors. This method of treatment has become our method of choice for deep partial burns which may have evolved to deeper lesions and for full thickness burns, infected or not, aiming at early closure of the wound [26–31].



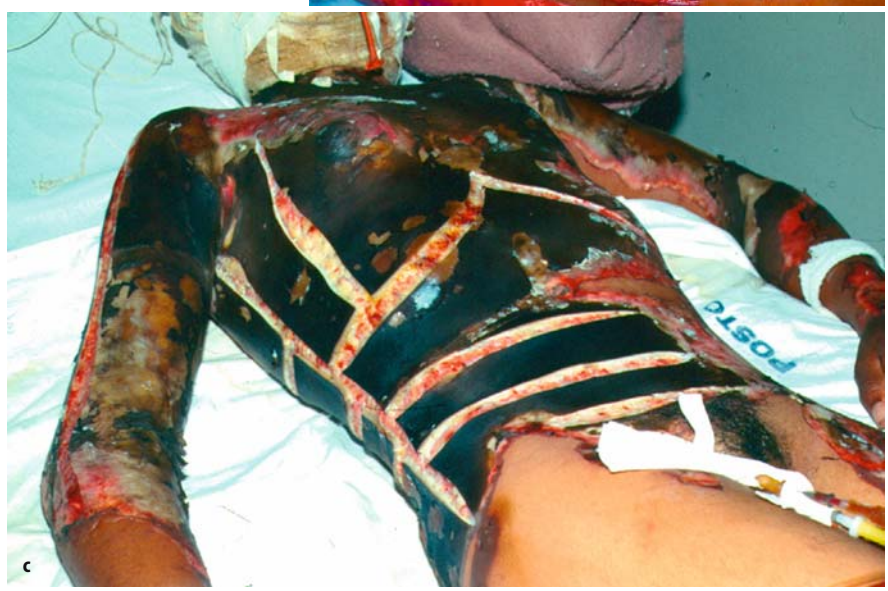


Fig. 16.4. a Third degree areas excised to fat 2 days before this picture. **b** Same patient, with the right thigh already grafted and with frogskin being removed from the left thigh. **c** Patient with full thickness burns. **d** Same patient, with wounds excised to fat. **e** Same patient, with frogskin applied 14 days before. **f** Same patient, 4 days after autografting

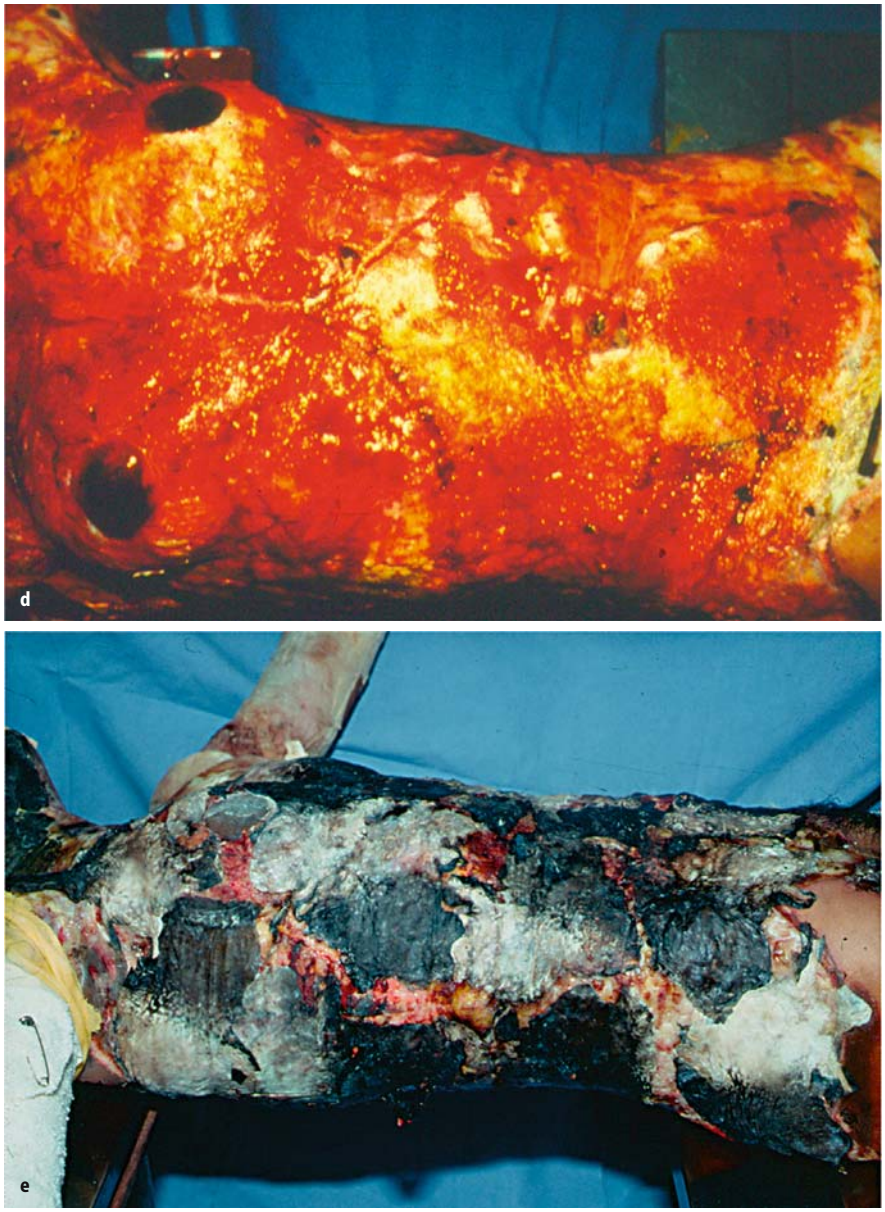


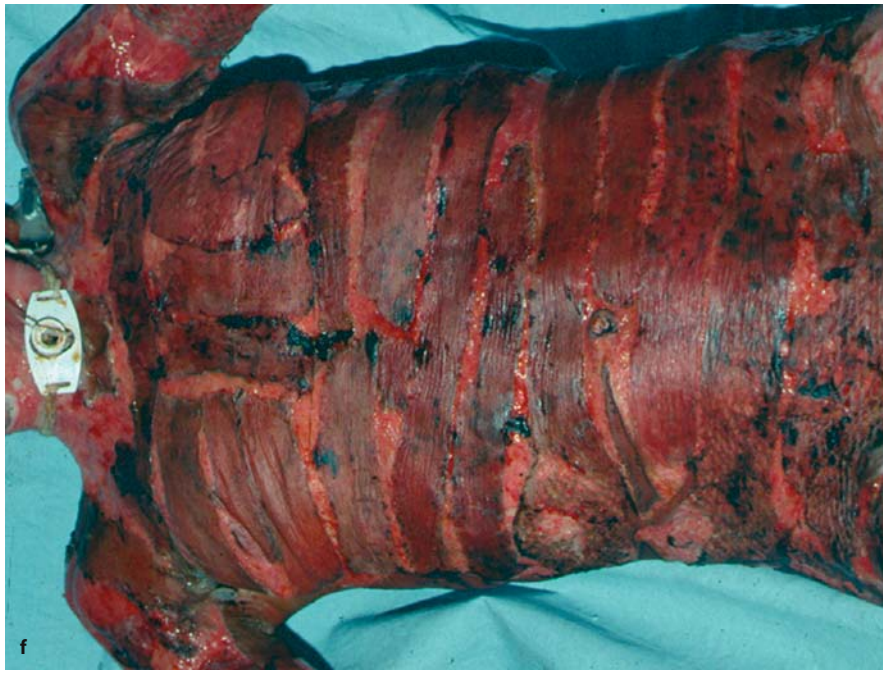
Fig. 4 (*Cont.*)

In our service, we will excise up to 20% of the body surface area per session. Repeated procedures are performed at 2-day intervals and we prefer not to excise to fascia, since the aesthetical result may be very poor, in excess of the distal edema which may occur as a result of removal of superficial veins and lymphatics. Although there have been publications suggesting methods to evaluate the depth of the resection during an excision procedure, we prefer to graft the excised bed on the 2nd day after the original procedure, when the potential receptor area is reevaluated and there is a greater chance of autograft survival [32–34].

We try to obtain closure of the wound using the patient's own skin. When the viability of the excised area is dubious, or the patient does not have enough donor areas, we prefer to cover the wound temporarily with allograft as an inter-vivo transplantation or from a tissue bank [35].

Biological dressings decrease metabolic losses, and may prevent infection and provide more comfort for the patient. These are used as alternatives to auto- or allografting. Although several factors must be considered when choosing one of these materials, the main one is still the cost-benefit ratio. In our country, amniotic membrane is used by some services which have connections to maternity hospitals and allograft is under regulation by the Federal Government.

The Ministry of Health guidelines are not sufficient



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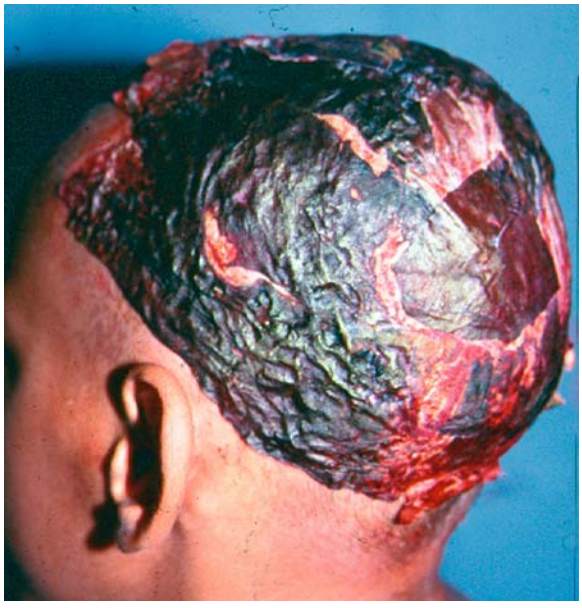

Fig. 16.5. Frogskin in a scalp donor area, 8 days after application

to regulate the reception of allograft from the two existent tissue banks, although, even if easily feasible, there would not be enough material to cover all burns centers, making the tissue banks operational only in large cities, and also where donors are more prevalent. We obtain consent for the treatment of all of our patients [36, 37].

Pigskin is currently the most widely used xenograft around the world. It has been very well studied during recent decades, and has benefitted from several technical innovations. As with epithelial cell cultures, the use of these materials in our country is limited and very expensive. In the past few years, the introduction of bioengineered materials has opened up a new horizon in burns surgery. However, its cost is excessive, but its use can be justified in first world countries where its use may mean a saving in the overall cost of treatment, since it will definitely shorten the total treatment time [38–45].

When one compares the use of frogskin to pigskin, one can point to several advantages, mainly from the financial point of view. There is no need for the use of a dermatome to harvest the frogskin, which is used in its full thickness (about 0.5 mm). It is easy to obtain and easy to apply. The skin can be kept in any regular freezer, without any intention to maintain its viability. In 1986, Zaziass, of the National Health Institute, at Bethesda, MD, described a dipeptide, magainine, contained within the frog skin, with antibiotic properties [46].

The method we currently use to chemically render the skin aseptic or sterile will allow us to keep the frog skin in a regular freezer for up to 6 months. Adherence to the wound bed is very good, with a progressive "loss" occurring due to cure or granulation tissue formation. Early removal from tangentially excised wounds may lead to bleeding at the site, due to vascular ingrowth up to the xenograft.

As for its advantages, we can mention its practically unlimited availability, low cost and relatively easy preparation. It can be applied together with any topical

agent, and it also will prevent wound desiccation, diminishing water losses and possibly heat loss. As it "takes," it can also diminish wound contamination, creating a microambient protecting the developing tissues. It increases patient comfort in relation to the treatment area, and the patient also requires fewer blood products and less pain medication. As for its disadvantages, we can mention that it requires a very rigorous method for preparation, a sterile routine for its single use, and it cannot be resterilized. It is dead tissue, with temporary adherence or take, and it will progressively desiccate as time elapses.

How important (or not) the fact is of the dermal layer being relatively thin in the frogskin, when compared to human or porcine skin, has yet to be established. As the skin is frozen, the dermal layer structure is altered slightly by the formation of water crystals, but it is believed that adherence is a function of fibrin bridges and the other naturally occurring reactions when a graft is applied. It progressively "loses" its adherence as the wound heals or granulation tissue is formed.

Low cost, practically unlimited availability and the ease of preparation and handling are considered its main advantages. It is easily applied and its care is similar to the care of any other graft. We consider that the use of frogskin is another good option for the temporary cover of excised and deep second degree burn wounds, surgical wounds from escharotomies and fasciotomies as well as for donor areas [47].

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17 Wound Bed Preparation by Hydrosurgery

M. Gonzalez Rodriguez de Azero, R. Vanwijck

17.1 Introduction

A wound bed may be prepared by various non-surgical débridements: autolytic facilitated by interactive dressings, larval therapy using sterile maggots and enzymatic débridements using collagenases. These are all effective in selected wounds but tend to be slow.

Physical débridements use whirlpool treatments to slough off necrotic tissues from the wound; the main drawback of this option is the vaporization of bacteria loaded droplets outside of the wound despite the use of protection devices.

Surgical débridement may create a very clean wound but it is not selective since healthy collateral tissue is also removed.

Hydrosurgery combines physical and surgical débridements. Water dissection works by a high-pressure jet of sterile saline that travels parallel to the wound and creates a Venturi effect which removes the necrotic tissues. It minimizes the amount of normal tissue that is accidentally removed with the usual surgical débriding techniques.

We report our experience of 55 hard-to-heal wounds in 40 patients successfully treated with a new technology, the Versajet; 46 wounds were covered with a skin graft immediately after the hydrosurgical treatment.

17.2 Materials and Methods

17.2.1 Hydrosurgery

The Versajet hydrosurgery system contains a power console that projects saline in a sterile circuit that is forced through a small gap (8 – 14 mm) at pressure and which can reach 15,000 pounds per square inch. The water jet passes parallel to the wound and is captured by an evacuator port (Fig. 17.1). The Venturi effect associated with the water jet spares viable tissue and precisely targets damaged tissues, which are pulverized and aspirated into the handpiece.

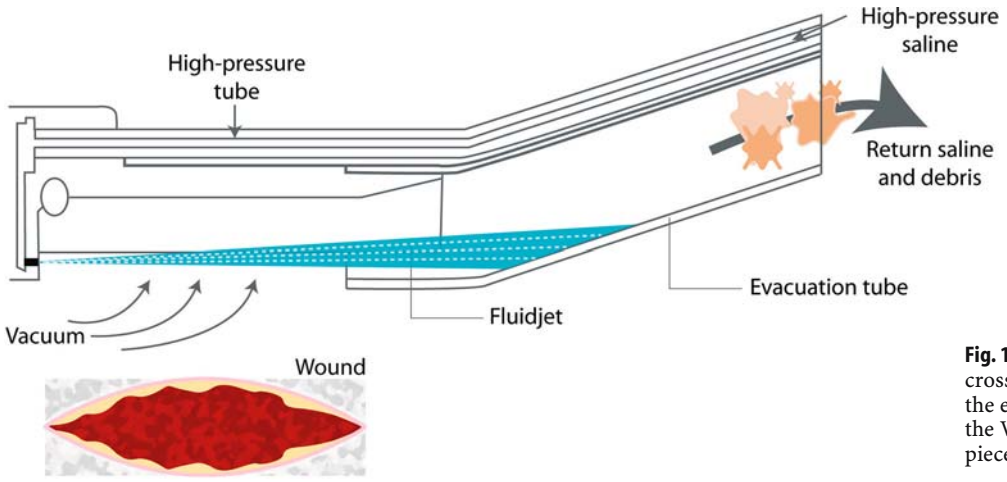

Fig. 17.1. Schematic cross-section of the extremity of the Versajet handpiece

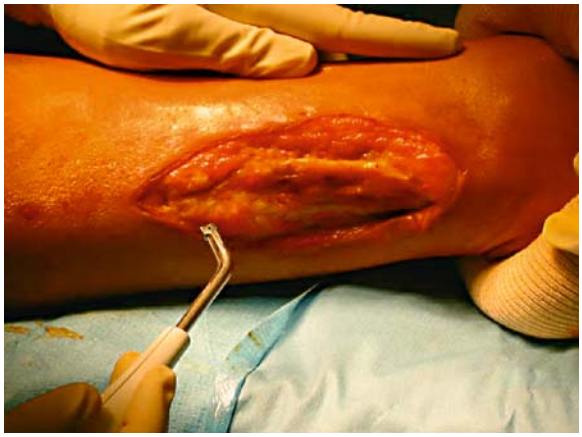

Fig. 17.2. The Versajet handpiece on a venous ulcer

The surgeon can accurately control the cutting, debriding and aspiration effects by adjusting the console power settings from 1 to 10 as well by angulating the handpiece.

In most cases we employed a standard handpiece with a 45° angled tip and a 14-mm working window (Fig. 17.2). The small size of the cutting nozzle allows easy maneuver of the water dissector into small spaces. It is particularly useful when débriding large areas or when preparing a wound bed for skin grafting.

17.2.2 Patients

Sixty-nine wounds in 40 patients (26 men and 14 women; mean age 67 years) were débrided with the Versajet over a 7-month time period. No patient was on anticoagulant therapy. All treatments were performed with the patient under general or regional anesthesia. Table 1 describes the treated wounds. Of the 11 traumatic wounds, 9 were degloving of the legs in elderly patients and 2 were third degree burns.

Table 17.1. Wounds treated by hydrosurgery

Traumatic	11
Arterial ulcers	10
Diabetic foot	5
Venous ulcers	5
Mixed ulcers	4
Pressure sores	3
Necrotizing fasciitis	1
Drepanocytic ulcer	1
Total	**40**

Hydrosurgery of the necrotizing fasciitis was secondary to classical radical surgical treatment of this disease.

Seven wounds presented clinical signs of infection with abundant, purulent malodorous exudates, necrotic tissues or thick fibrin slough.

Four wounds (three arteritic patients and malleolar ulcers in a patient suffering from drepanocytosis) were painful. Pain was evaluated using the visual analog scale.

Forty-six wounds in 25 patients were immediately covered after hydrosurgery with autologous meshed skin graft. The others were covered for 48 h with a non-adherent dressing, then with various interactive dressings until complete healing was obtained.

17.3 Results

The Versajet débrides the wound of granulation tissue, fibrinous exudates and bacterial contamination to the level of the wound bed; the plane of dissection can be regulated and controlled precisely. The degree of punctuate bleeding was comparable to that with cold knife débridement.

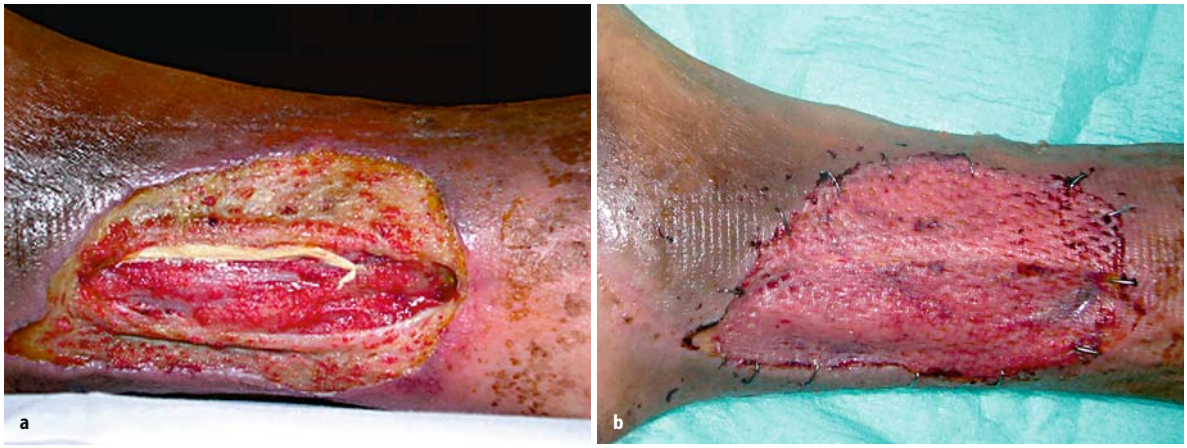

Fig. 17.3. a Venous ulcer before débridement with Versajet. **b** Engraftment after 10 days

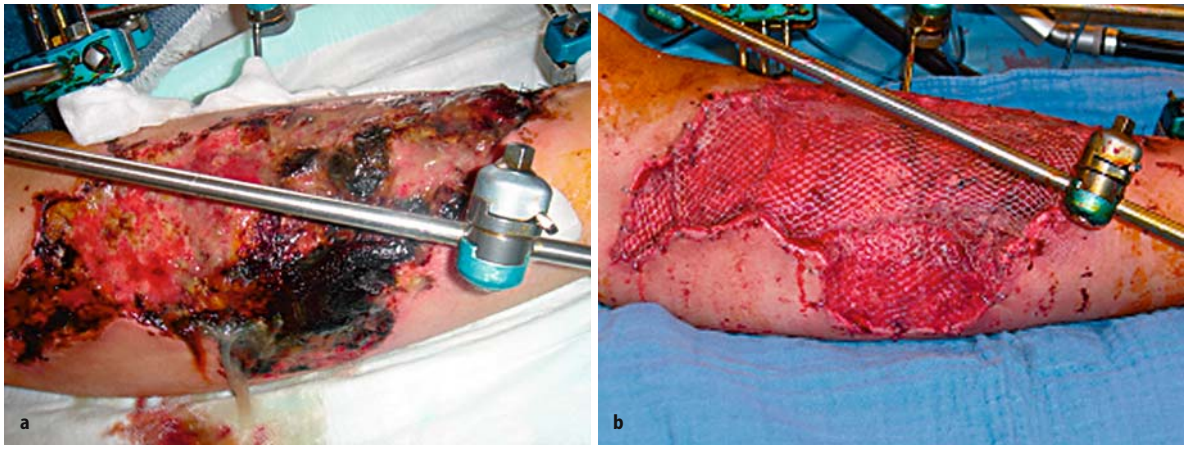

Fig. 17.4. a Traumatic wound before débridement with Versajet. **b** Immediate skin grafting

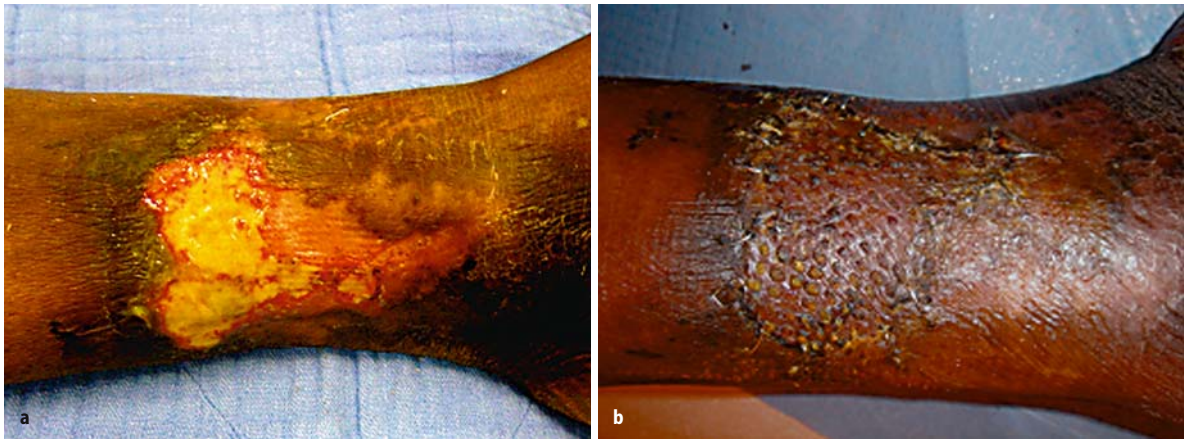

Fig. 17.5. a Drepanocytic ulcers before débridement with Versajet. **b** Engraftment after 3 weeks

Except for one peroperative bleeding which was easily controlled, no surgical complications occurred. No adverse infectious effects such as cellulitis were identified.

The Versajet was inadequate for excision of leathery dried eschars or tendons. As compared to cold knife débridement, it creates a smoother less irregular wound surface ready to receive a skin graft.

The result of engraftment was total (40 wounds) (Figs. 17.3 – 17.5) except in two patients with chronic venous ulcers where secondary infectious lysis (*Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli*) of the graft occurred (Fig. 17.6); two additional hydrosurgery-skin graft sessions were necessary to heal the wounds.

The treatment dramatically reduced the pain in algic patients, even those whose débrided wounds were not covered with a skin graft.

17.4 Discussion

The Versajet system enables the surgeon to simultaneously hold, cut and remove damaged tissue and contaminants precisely without the collateral trauma associated with current surgical modalities. It precisely targets damaged tissue and spares viable tissue. Débridement of wounds and other soft tissue lesions is achieved in a single quick step [1, 3].

It has the advantage over other equipment based on pulsed high pressure water jets in that it avoids the vaporization of bacterial loaded droplets [4].

It débrides irregular and complex contours, which can often be quite difficult to perform with conventional knives, for instance in the surgical treatment of superficial to mid-partial thickness burns in areas such as the face, hand and foot, which can be difficult to reach and contour with conventional modalities [5, 6].

In addition, débridement with the Versajet can be interrupted as soon as punctuate bleeding is observed in the treatment of superficial wounds.

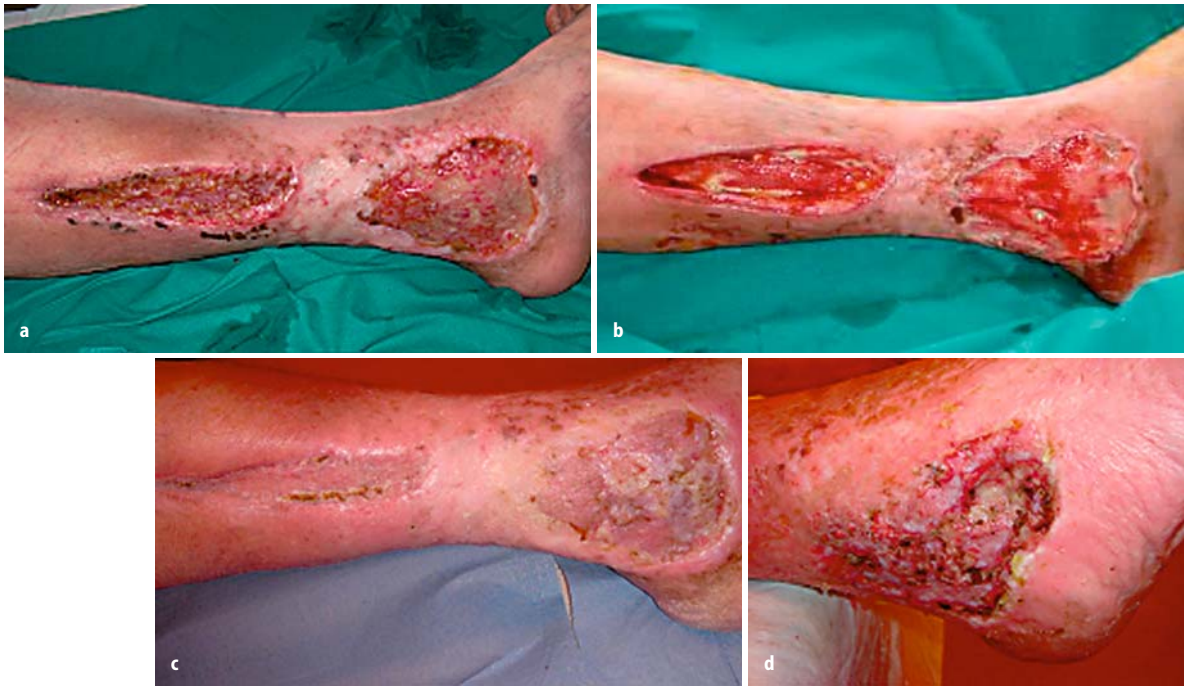

Fig. 17.6. a Venous ulcer before débridement with Versajet. **b** After débridement. **c** Successful immediate skin grafting. **d** Late bacterial lysis of the graft

In our hands, the main advantage of hydrosurgery in the treatment of various surgical wounds, subacute or chronic, is the quality of the wound bed obtained with this technique, which allows immediate skin grafting with a high rate of success of engraftment.

The combined use of most dressings and Versajet is synergistic. The unwanted tissue is mechanically removed, making the subsequent action of most interactive dressings easier.

Another advantage is the pain relief observed after débridements of arterial or vasculitis ulcers. The device washes the wound but also probably aspirates proinflammatory cytokines and proteases; biochemical analysis of the collected liquids would be interesting to confirm this hypothesis.

Although we did not perform quantitative bacterial analysis of the treated wounds, studies have demonstrated that high pressure pulsatile lavage efficaciously reduces the bacterial load of the wound and prevents the diffusion of microbial contamination deeper in the wound [2, 8].

Total engraftment was observed in most patients except for two with chronic venous ulcers where we observed delayed lysis of the grafts by *Pseudomonas aeruginosa, Staphylococcus aureus or Escherichia coli* probably in ambush in the depth of the wound bed.

Based on this negative experience, we no longer immediately graft venous ulcers after débridement until favorable qualitative (absence of multiple resistant bacteria) and quantitative (less than 10^5 organisms/g) bacterial analysis is obtained. Additional hydrosurgery sessions must be scheduled until an adequate bacterial load of the wound is reached.

The need for a general or regional anesthesia is one of the drawbacks of this type of débridement. Some authors perform it at the bedside after applying anesthetic ointment (lidocaine/prilocaine) 1 h prior to débridement [7], but the etiology, size and depth of most of our wounds make débridement under local anesthesia rather unrealistic.

Another drawback is the high cost of the disposable handpiece, but from a hospital economics point of view, hydrosurgery shortens the healing time, thus permitting a total saving in wound management.

Hydrosurgery with Versajet is a major advance in the débridement of subacute and chronic wounds; it has dramatically modified our attitude toward wound bed preparation. It has also opened a new trend in the treatment of hard-to-heal wounds.

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The Face

V

Advances in Understanding the Surgical Anatomy of the Face

18

B.C. Mendelson

The scientific approach to improved results in facial rejuvenation surgery has required a better knowledge of surgical anatomy than that provided by the classical descriptions. During the past 35 years major advances in understanding of facial soft tissue anatomy have resulted through the involvement of plastic surgeons in aesthetic surgery. These advances have occurred in three phases, according to the anatomical component being appreciated at the time.

1. The era of the SMAS, from the early 1970s
2. The era of facial ligaments, from late 1980s
3. The "era of facial spaces" is predicted to be the next phase

18.1 The Era of the SMAS

To understand facial anatomy requires an appreciation of the superficial fascia of the face and how it is uniquely different from the superficial fascia elsewhere in the body. The superficial facial muscles (the muscles of facial expression) are enclosed within the superficial fascia and move the facial soft tissue over the facial skeleton. This contrasts with skeletal muscles elsewhere in the body, including the muscles of mastication, which are located beneath the investing deep fascia and move bones.

The importance of the superficial fascia of the face in facial aging and its use in rejuvenation of the cheek and neck was first demonstrated by Skoog in 1969 [14]. The fact that laxity of the facial skin could be corrected using this fascia, without tension being applied directly to the skin, was a revelation of profound significance [15].

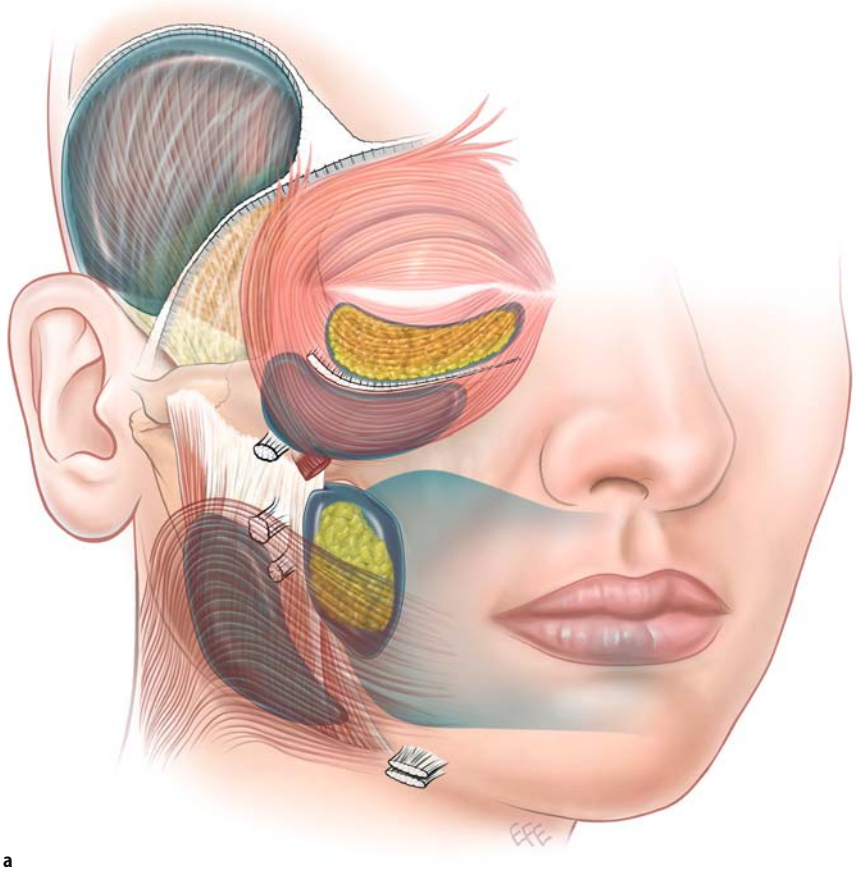
The anatomical reason for the success of superficial fascia tightening became more understandable from the classical work of Mitz and Peyronie, who introduced the term "superficial musculoaponeurotic system" (SMAS) to describe the anatomy of the deep layer of the superficial fascia [12]. The SMAS explains the relationship and connections between the superficial fascia, the muscles of facial expression and the overlying dermis. The important part of the SMAS in facial ageing is over the mobile, expressive front part of the face where the muscles of the eyes and the mouth are located.

18.2 The Era of the Retaining Ligaments of the Face

The cleft between the superficial and deep facial fascias, the sub-SMAS plane, is commonly known as the deep plane [3]. The anatomy of this plane is complex and is only now becoming understood in a way that is useful for the surgeon. Four types of structure are present within the sub-SMAS plane: (1) the deep attachments of the facial muscles, (2) retaining ligaments of the face, (3) areolar spaces, and (4) facial nerve branches.

Attachments between the SMAS and the deeper structures were recognised to be significant by Papillon [1]. Release of these attachments, from the underside of the SMAS to the periosteum over the zygoma, allowed greatly improved surgical redraping of the SMAS medial to the attachments. Subsequently, the attachments were described by Furnas in 1989 [2] and termed the **retaining ligaments of the cheek.** It was also recognised that the retaining ligaments continue into the dermis. The masseteric cutaneous ligaments, near the anterior border of the masseter, were later described [16].

It is now appreciated that the retaining ligaments of the face have a formal arrangement for attachment of the superficial fascia to the facial skeleton. The ligaments have a general pattern of being concentric



a

Fig. 18.1. The facial spaces. **a** youthful; **b** aging face. The upper temporal space and the premasseter space overlie the respective muscles of mastication over the lateral face. The prezygomatic space overlies the prominence of the zygoma and is separated from the preseptal space of the lower lid by the orbicularis retaining ligament, which attaches to the inferior orbital rim. The buccal space and the upper part of the vestibular recess of the oral cavity underlie the mid cheek.

around the orbital and the oral cavities. The ligaments around the oral cavity have a C-shaped arrangement, formed by the transverse group of zygomatic ligaments, at the lateral end of which descends the vertically arranged masseteric cutaneous ligaments, down to the mandibular ligament [7].

Overall, there is a vertical line of attachment of the facial ligaments (temporal, periorbital and perioral) along the junction between the anterior face and the lateral face. This line coincides with the lateral extent of the skeletal attachment of the muscles of facial expression for the anterior face.

The ligamentous fixation to the dermis accounts for the shape of the cutaneous grooves on the face. Between the grooves skin folds and bulges appear because the soft tissues underlying these are more mobile, not being restrained in position by retaining ligaments [4]. If the ligaments are responsible for the grooves, what structure is beneath the bulges to explain the mobility?

The effect of attrition of the ligaments with aging is most evident where the ligaments are finer, which is at the periphery of their outer end. This results in increased mobility of the tissues at the periphery of the ligament in contrast to the greater resistance to mobility remaining near the centre of the ligament [6].

18.3 The Era of the Facial Spaces

The group of structures occupying the largest area in the interval between the superficial and deep facial fascias are the facial spaces. These were originally described as being areas of loose areolar connective tissue [12, 16] but, in fact, they are true cleft-like spaces within the soft tissue of the face. With the inclusion of the skeletal cavities, together they make up the **spaces of the face**. The purpose of this chapter is to advance understanding of facial anatomy by pointing out that true spaces exist in the face and they offer advantages for the surgeon.

The word "space" suggests that a void of soft tissue is present. Similar to the pleural spaces in the chest, the facial spaces appear "closed" due to the boundary tissue layers (parietal and visceral pleura), being apposed in situ. The true space is revealed only when the space (thorax or facial cleft) is entered during surgery. The

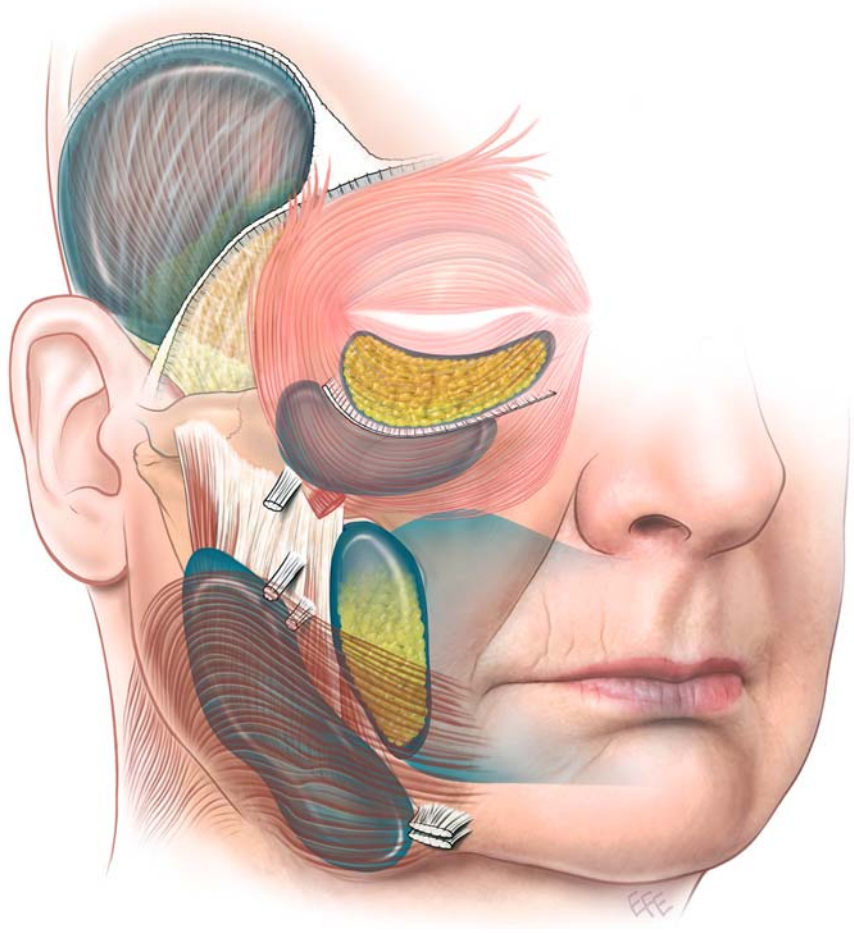


Fig. 18.1. b Aging is associated with enlargement of the spaces in the more mobile areas, especially the preseptal space of the lower lid, prezygomatic space, buccal space and the jowl recess of the premasseter space

difference is that the spaces in the face have areolar tissue within the "potential" space which needs to be separated (bluntly) to reveal the "actual" space. The pleural spaces function to allow mobility. The facial spaces allow mobility of the overlying superficial fascia, which has muscles enclosed. As a corollary, wherever a facial muscle is located, look for an associated space.

18.3.1 Characteristics of the Facial Spaces

1. Have definite boundaries
2. No structures course through a space, either ligamentous or neurovascular
3. Have no structural significance (ligaments provide structural fixation; spaces allow movement)

18.3.2 The Individual Facial Spaces (Fig. 18.1, a)

The oral cavity is the largest of the facial spaces and it allows much of the movement of the mid cheek as well as movement of the muscles of the lips. The submuscular space of the lids, between the septum orbitale and the overlying preseptal orbicularis, allows mobility of the lids. The space contributes to the pattern of aging changes, particularly the development of lower lid bags [8].

The sub-SMAS spaces include the large upper temporal space overlying the deep temporal fascia [13]. In the middle third of the face, the prezygomatic space overlies the body of the zygoma, and allows contraction displacement of the orbicularis oculi, pars orbitale, which results in zygomatic smile lines. When laxity occurs in the structure of the roof of the prezygomatic space, malar mounds are the result [10]. The buccal space (also called masticator space) is also within the middle third of the face. It is functionally a "space" even though the connective tissue content forms a structure, the buccal fat pad. The lower boundary of the space and buccal fat pad is just below the parotid duct in youth [5]. With aging, the inferior boundary may descend to become inferior to the level of the oral commissure and bulge into the lower face where it contributes to the formation of the labiomandibular fold [11].

In the lower third of the face, the premasseter space overlies the lower part of the masseter fascia and allows movement of the mandible relative to the overlying platysma [11]. Laxity of the roof and of the attachments at the anteroinferior boundary of the premasseter space results in laxity of the overlying platysma, which then bulges to form the jowl.

18.3.3 Aging of Facial Spaces (Fig. 18.1, b)

Changes of the spaces occur with the aging process, but these changes are not uniform. The amount of change relates to the amount of movement which occurs in the area of the particular space, movement of the jaw being the greatest and temple movement the least.

The aging change consists of a diminution of the tightness of the space, due to distension of the roof. Subsequently this laxity of the roof appears as a surface bulge, e.g. malar mounds over the mid cheek and jowls over the jawline. Usually there is some associated expansion of the dimensions of the space secondary to laxity of the ligamentous fixation at the boundary of the space, e.g. lower lid bags extending over the inferior orbital rim. It is *easier* to dissect the aged spaces as they open more readily and the areolar tissue within separates more readily.

18.3.4 Surgical Significance of the Facial Spaces

The spaces are inherently "safe" surgically because they are areas which are completely free of important anatomy. All nerves, vessels, ligaments and muscles are outside the facial spaces. The retaining ligaments provide the reinforcement that determines the specific location of the boundary membrane. In some areas the facial nerve branches course directly outside the lining membrane.

The technique of dissection used when operating in the sub-SMAS plane should be related to the character of the particular area being dissected. Within the spaces, blunt dissection is all that is required to rapidly extend to the boundaries of the space. As the dissection is opening a pre-existing cleft in the tissue layers bleeding does not occur. This contrasts with the usual subcutaneous dissection of the face, which is only millimetres more superficial, and is on the surface of the muscle which forms part of the roof of the space, be it platysma or orbicularis. Accordingly, when the dissection is correctly performed, bruising is avoided and there is not the risk of facial nerve damage. When operating outside the spaces, the dissection technique is changed to precise semisharp dissection in order to separate facial nerve branches, if needs be, away from facial ligaments, prior to lysing the necessary ligamentous bands.

The principle of surgical correction of aging changes, when operating in the sub-SMAS plane, involves advancing the lax composite flap (the roof of the space) in the required direction and fixing it there [9]. Usually the area of laxity requiring correction is located medial to one of the spaces. The amount of surgical release required at the medial boundary of the space is determined by the state of the retaining ligaments (in relation to the medial boundary).

If the medial ligaments have weakened considerably, sufficient correction is usually achieved by simply redraping the roof of the space without the need for further medial dissection. However, if redraping the roof of the space does not provide satisfactory correction of the laxity medial to the space, additional dissection is needed through the medial boundary, to release the residual ligamentous restraint. This is where the precise dissection is required, as the facial nerve branches tend to be in proximity to the ligaments. This extra dissection is more likely to be required in younger patients on account of the greater strength of the residual ligamentous resistance.

18.3.5 The Course of the Facial Nerve and the Facial Spaces

The branches of the facial nerve are in predictable locations relative to the spaces. Application of this understanding greatly assists the surgeon when operating in the sub-SMAS plane. The branches are always outside the spaces as they course outward across the sub-SMAS plane. The nerves travel perpendicularly from the surface of the deep fascia to gain the underside of the superficial fascia in proximity to the main retaining ligaments (zygomatic and masseteric cutaneous).

18.4 Conclusions

An appreciation of the recently described soft tissue spaces of the face offers advantages for the surgeon involved in facial rejuvenation.

The spaces should be looked for and then utilised, as they are pre-existing clefts in the tissue planes. This reduces the need for much of the traditional surgical dissection, which is associated with bleeding, bruising and swelling. Facial nerve branches are always just outside the spaces.

If further surgical release is required, it is only in the smaller areas outside the spaces where precise release of residual ligamentous restraint may be needed.

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19 In Preparation for Facial Transplantation

M. Siemionow, Y. Kulahci

19.1 Introduction

The human face has an important role in a person's identity and communication; hence it defines a functionally and aesthetically important unit. In addition, the face's expressive function has social and psychological importance [38].

Disfigurement or deformity of the face causes both functional and social isolation. Reconstruction of facial defects, especially after deep burns, tumor excision or trauma, remains a challenging task for plastic surgeons. Current reconstructive procedures for facial deformity include a variety of flaps for coverage [3, 6, 36, 39].

The surgical options are well established and include combinations of standard skin grafting, application of local flaps, tissue expansion, prefabrication, and free-tissue transfers [7, 20, 27, 29, 30, 37, 54].

Unfortunately, the aesthetic outcome of the currently available conventional reconstructive procedures for facial reconstruction is not satisfactory in the long term follow-up since quite often the result is a tight, mask-like face with a lack of facial expression and an unsatisfactory cosmetic appearance. Severely burned patients are often subjected to multiple surgical procedures, sometimes exceeding 30 operations, in search of an improved appearance [45].

Advances in composite tissue allograft (CTA) transplantation have opened up a new era in the reconstructive field. After the first hand transplant in France in 1998, the success achieved in the field of CTA has opened up a new option for facial reconstruction [17].

The best result after facial avulsion injury was obtained following replantation of the total face and scalp with adequate hair growth on the scalp and normal animation of the facial expression muscles [55, 59].

Based on the experience with clinical CTA transplants, the next logical step for facial reconstruction will be consideration of facial transplantation. Apart from the technical and immunosuppressive issues which apply to all CTA transplants, face transplantation raises additional ethical, social and psychological issues that need to be addressed. Face transplantation may be considered a treatment option for patients left with severe facial disfigurement despite the application of numerous reconstructive autologous tissues procedures. Many studies have been performed and published on the technical, immunosuppressive, and ethical issues of face transplantation both supporting and criticizing this challenging procedure. We will outline current approaches to facial reconstruction as well as experimental studies on the feasibility and immunological aspects of facial allograft transplantation [10, 32, 58].

19.2 Conventional Reconstructive Methods for Face Reconstruction

According to the traditional reconstructive ladder, the conventional methods for reconstructing facial deformities include: skin grafts, local and distant flaps, prefabricated flaps, expanded flaps, and free flaps. The success of these methods varies. According to the literature successful results have been obtained by using

monoblock full-thickness skin grafts for total face resurfacing [4, 19, 47].

Although color and texture matches are reasonably satisfactory in the short term, in long-term follow-ups skin graft contractures and color changes result in an unsatisfactory final outcome.

Since the introduction of prefabricated flaps for the reconstruction of facial subunits [20], satisfactory results have been reported with prefabrication and expansion of the normal tissues in the vicinity of the defect [28, 37].

Axial pattern flaps, prefabricated from the supraclavicular skin using antebrachial fascia based on the radial vessels, have been used to reconstruct the entire face after severe burn injuries [54]. Unfortunately, in facial burns, the adjacent skin is also partially or completely damaged, making adequate reconstruction almost impossible.

Tissue expanders have been applied to expand the adjacent skin to achieve sufficient tissue of identical color and texture for facial reconstruction [7, 27, 60]. Tissue expanders can also be used to create full-thickness skin grafts for complete or partial resurfacing of the face [52]. As with prefabricated flaps, however, adjacent skin may be involved in the injury, which may prohibit the use of tissue expanders. Other potential problems relate to the choice of expander, the site of insertion of the expander, the elevation and suturing of the expanded flap, and the management of the free margins of the flaps [27].

The first free-tissue transfer was performed to reconstruct a patient with deformities after burns [23]. This innovation led to enormous advances in reconstructive microsurgery, and different types of free tissues were transferred from distant parts of the body to reconstruct facial deformities. The facial subunit approach, introduced by Burget, was based on modifying the recipient defect and donor tissue [9]. Feldman introduced "the single sheet concept" in resurfacing of the whole face after facial burns [21]. This concept led to a bilateral, extended scapular-parascapular free flap, incorporating bilateral superficial circumflex scapular vessels, that was used for total face resurfacing in patients with severe facial burns with good-to-fair results [3]. Although various types of free flaps have been used for reconstructing the face, the functional and aesthetic outcome has not been optimal.

Miller et al. reported the first successful replantation of the entire scalp [31]. Thereafter, replantation cases of partial or complete scalp avulsions were reported, including forehead, ear, eyebrow, and eyelids, with abundant regrowth of hair and return of scalp sensibility [13]. Successful replantation of different avulsed segments of the face, including the nose, ear, and upper and lower lips, was also reported [14, 22, 24].

Although many cases of scalp and face segment replantation have been reported worldwide, only two successful cases of total face and scalp replantation have been reported [55, 59].

In the first case, replantation was performed in two pieces, based on the medial canthal vein and the facial vein and artery on the right side and the labial artery with its vein and superficial temporal artery and two concomitant veins on the left side. Three years after replantation, the patient recovered satisfactory animation of the oral musculature and profound growth of hair on the scalp [55]. In the second case, the face was avulsed as one piece, including the entire scalp, right ear, forehead, eyebrows, right cheek, nose, and upper lip. This replantation was based only on a single superficial temporal artery and two veins. Four months postoperatively, the patient had hair growth and normal mimetic function [59]. Because the optimal outcome was obtained after replanting the avulsed segments of the face and scalp, every effort should be made to achieve successful replantation, even if the avulsed scalp and face contain several lacerations and contusions.

Although many techniques have been described for reconstructing severe facial injuries, total resurfacing of the face with a single soft, pliable tissue, matched in color and texture, is almost impossible. There is simply no such tissue in the body that is of similar quality to give the characteristics of a normal face. The final outcome after all these conventional reconstructive procedures is far from ideal because they result in a tight, mask-like face with lack of facial expression and an unsatisfactory cosmetic appearance. Recent advances in composite tissue allograft transplantation have initiated a new period in the field of reconstructive surgery.

19.3 Facial Allograft Transplantation

Facial transplantation is the next step in CTA transplantation to treat patients whose facial disfigurement cannot be resolved by conventional methods of reconstructive surgery.

In the literature, successful scalp transplantation was reported between identical twins [8]. A woman had 50–60% of her scalp avulsed. Initial coverage with split-thickness skin grafts and subsequent multiple punch grafts from her identical twin were performed with moderate success. The twins were HLA identical and had identical blood groups. Mixed lymphocyte reaction was nonreactive. From her identical twin, the patient received two free scalp flaps measuring 19 × 3.5 cm and 17 × 3 cm, respectively, in two sessions. The flaps were based on superficial temporal arteries. At 6 months follow-up, without any immunosuppressive regimen, the flaps provided adequate hair growth.

It is difficult to anticipate the look of a face after transplantation because patients with severe facial dis-

figurement undergo multiple reconstructive procedures. However, computer studies suggest that the face would display more of the characteristics of the recipient skeleton than of the donor soft tissues [32, 47].

Skin, as a component of CTA, is considered to be the most antigenic tissue of the body. A vascularized skin allograft, unlike nonvascularized skin allograft, is a good source for dendritic cells, which migrate from the donor to the recipient through hematogenous and lymphatic systems. These cells are important in allograft acceptance.

Our recent research has shed light on the methods of tolerance induction for composite tissue transplants. We used different models of highly antigenic CTA transplants (hind limb, full face, hemiface and groin skin flap models), including skin, as a component of these transplants, for tolerance induction [15, 16, 33–35, 40–44, 56, 57].

Reconstructive surgeons attempting to transplant facial allografts must demonstrate the technical feasibility and applicability of this surgery, develop protocols for lifelong immunosuppression, and resolve the associated ethical, social, and psychological issues. Other issues that also need to be solved are obtaining Institutional Review Board approval, identifying appropriate recipients and finding appropriate donors [47].

19.4 Technical Feasibility and Applicability

The outcome of conventional reconstructive procedures is unsatisfactory because most of the tissues used do not have the quality and characteristics of the face. For obtaining optimal functional and aesthetic results in facial reconstruction, facial allograft transplantation seems to be a reasonable option once conventional reconstructions have failed.

In the past, two successful cases of total face and scalp replantation have been reported with excellent outcomes [55, 59] and recently two cases of partial face transplantation have been reported [18, 25].

French surgeons performed the first partial facial transplant, using the nose, lips and chin to repair the face of a 38-year-old woman disfigured by a dog [18]. The second partial facial transplant was done by a Chinese team on a 30-year-old man who was mauled by a bear [25].

Experimental studies on hemifacial and full-facial transplantation in dog and rodent models have been performed with success. Our cadaveric study revealed that after injection, methylene blue dye perfused skin and dermal plexuses of the flap and was well visualized from the external carotid artery up to the terminal branches of the facial and superficial temporal arteries [48].

The vascular anatomy of the human face is well known. There are rich vascular plexuses in the subcutaneous tissue. The face is bilaterally supplied by the branches of the external carotid arteries, mainly the facial and superficial temporal arteries, and it is drained by the external jugular and facial veins. An entire facial skin flap, based on the external carotid arteries, could be transplanted. Different components of the facial tissues can be incorporated in this flap, including skin, facial expression muscles, the facial nerve, and bones. Initially, not to further complicate this already complicated procedure, only skin should be transplanted for face resurfacing. Once facial skin flap transplantation is successful, other components of the face can be considered as a reconstructive option in the future [47–49].

One of the crucial issues that should be considered when planning facial transplantation, as with any microsurgical procedure, is the risk of failure of the vascular anastomoses. Vascular failure, diagnosed in the early stages of transplantation, can be treated by exploring the vascular pedicles and redoing the anastomoses. If all attempts to salvage the flap fail, the rescue procedure should be planned and the defect should be covered with vascularized skin flaps or autologous skin grafts [47].

19.5 Experimental Models of Facial Transplantation

19.5.1 Dog Hemifacial Transplant Model

Hemifacial allograft transplants were performed between two dogs to prove the viability of facial transplants using facial artery and external jugular vein as pedicles. A skin muscle flap in the superficial musculoaponeurotic system plane was harvested based on the facial artery and external jugular vein. In the recipient animal the arterial and venous anastomoses were performed to the lingual artery and external jugular vein, respectively. The recipient dog received CsA (4 mg/kg/day) and prednisone (1 mg/kg/day) for immunosuppression to prevent hyperacute rejection of the allograft. In this model, the flap was acutely rejected by day 6 following transplantation and the dog was put to death [5].

19.6 Face Transplantation Models in Rat

We have used different experimental models of CTA transplants under varying immunosuppressive protocols to induce tolerance for composite tissue allografts. In preparation for facial allograft transplantation in humans we have centered our studies on facial skin

transplant models and investigated tolerance induction strategies in these models. This included both full face and hemiface transplant models [15, 16, 44, 56, 57].

19.6.1 Full Face/Scalp Transplant Model

We have confirmed the feasibility of the total facial/scalp allograft transplantation across major histocompatibility complex (MHC) barriers in the rodent model for the first time. Transplants were performed between semi-allogenic LBN ($RT1^{l+n}$) donors and Lewis ($RT1^{l}$) recipients. In the donors, based on the bilateral common carotid arteries and external jugular veins, the entire facial skin and scalp flap including both ears were harvested. In the recipient, a facial/scalp defect was created by excising facial skin, scalp and external ears. The facial nerves and muscles, and the perioral and the periorbital regions, were preserved to avoid functional deficits which could interfere with animal feeding, breathing and eye closure. Both common carotid arteries were used to vascularize the full facial/scalp flap. Arterial anastomoses were performed to the common carotid arteries (end-to-side) or external carotid arteries (end-to-end) of the recipients. Venous anastomoses were performed to the external jugular and anterior facial veins (end-to-end). Postoperatively the recipient animal received CsA monotherapy at a dose of 16 mg/kg/day, tapered to 2 mg/kg/day over 4 weeks, and maintained at this level during the follow-up period of over 200 days [44, 56].

19.6.2 Modifications of Full Face/Scalp Transplant Model

Recently, to improve the survival of facial/scalp allograft recipients, we have introduced a new approach by modifying the arterial anastomoses in the recipients. Single (unilateral) common carotid artery of the recipient was used to vascularize the entire transplanted facial/scalp flap. Different modifications of the arterial anastomoses were performed. With these modifications postoperative mortality of the animals was significantly reduced by avoidance of complications associated with bilateral common carotid artery anastomoses. In this model facial/scalp allograft transplants were performed between fully allogeneic ACI ($RT1^{a}$) donors and Lewis ($RT1^{l}$) recipient rats. The same CsA immunosuppressive protocol was used as in the previous model and resulted in over 180 days of facial/scalp allograft transplant survival.

The full face/scalp transplant model is technically challenging and takes over 6 h to perform. To improve the survival of facial/scalp allograft recipients, two different modifications of the arterial anastomoses in the recipients were introduced. Unilateral common carotid artery of the recipient was used to vascularize the full transplanted facial/scalp flap.

In the first modification, following the arterial anastomosis between the left common carotid artery of the donor face flap and the left common carotid artery of the recipient (end-to-side), the right common carotid artery of the flap was anastomosed to the left common carotid artery of the flap using end-to-side technique.

In the second modification, following the arterial anastomosis between the left common carotid artery of the donor face flap and the left common carotid artery of the recipient (end-to-side), the right common carotid artery of the flap was anastomosed to the long stump of the internal carotid artery on the left side of the face flap in end-to-end manner.

These arterial modifications have significantly reduced the complications associated with the bilateral common carotid artery anastomoses and subsequently the postoperative mortality of the animals. Full facial/scalp allograft transplants were performed between fully allogenic ACI ($RT1^{a}$) donors and Lewis ($RT1^{l}$) recipients. The same tapered dose CsA monotherapy immunosuppressive protocol was used and over 180 days of facial/scalp allograft transplant survival was achieved [57].

19.6.3 Hemiface Transplant Model

To further shorten surgery time and brain ischemia time, we have introduced a hemifacial allograft transplant model which is technically less challenging compared to the full facial/scalp model. This model was used to test induction of operational tolerance across MHC barriers. Hemifacial allograft transplants were performed between semi-allogeneic LBN ($RT1^{l+n}$) (Figs. 19.1 – 19.3) and fully allogeneic ACI ($RT1^{a}$) do-

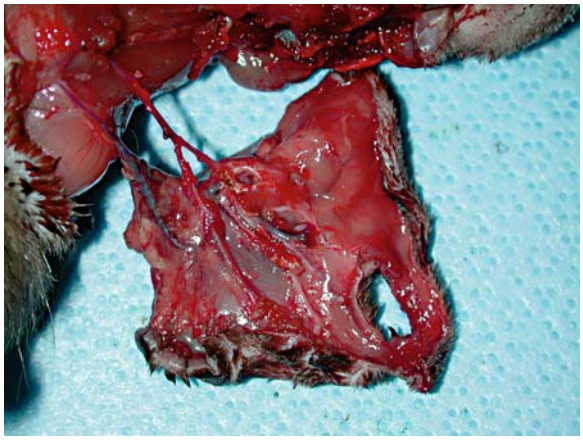

Fig. 19.1. Hemifacial/scalp flaps including the external ear and scalp, based on the common carotid artery and external jugular vein, were harvested from the donors

Fig. 19.2. Hemifacial allograft transplants were performed between semi-allogeneic LBN ($RT1^{l+n}$) donors and Lewis ($RT1^{l}$) recipients

nors and Lewis ($RT1^{l}$) recipients. Composite hemifacial/scalp flaps including the external ear and scalp, based on the common carotid artery and external jugular vein, were harvested from the donors. In the recipient, the hemifacial/scalp skin, including external ear was excised. The arterial and venous anastomoses were performed to the common carotid artery (end-to-side) and to the external jugular vein (end-to-end), respectively. The same CsA monotherapy immunosuppressive protocol was used and 400 days survival was achieved for semi-allogeneic transplants and 330 days in the fully MHC mismatched hemifacial transplant recipients [15, 16].

19.7 Preparation for Face Transplantation in Humans

Our success in both full and hemiface transplant models in the rodent model under CsA monotherapy and recent developments in the field of CTA transplantation in humans have stimulated us to develop a facial transplantation model in humans.

To date, there are only two scalp transplantations described in the literature. The first was performed between identical twins [8]. The patient had scalp avulsion and was treated initially with skin grafts taken from her identical twin. The twins were HLA identical

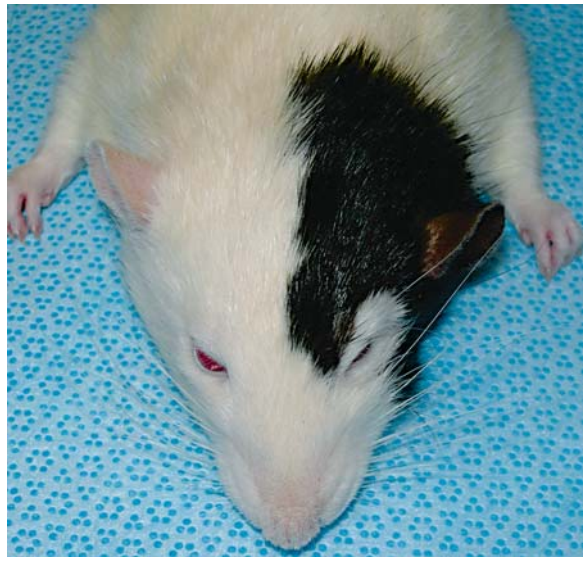

Fig. 19.3. The appearance of the semi-allogenic hemifacial allograft transplants under low dose CsA monotherapy at 200th day post-transplant

and had identical blood groups. Two free scalp flaps, based on the superficial temporal vessels, were performed in two separate sessions. Six months after surgery, without any immunosuppressive regimen, the patient presented with adequate hair growth on the transplanted scalp flaps.

The second scalp transplant was recently performed in a 72-year-old woman with stage IIIC recurrent cutaneous malignant melanoma on the vertex [26].

Wide excision of the tumor including the scalp, facial/cervical skin and two ears was performed. The defect was reconstructed by CTA, including scalp and both external ears, transplanted from a brain-dead young man. The patient received tacrolimus, mycophenolate mofetil, steroids and Zenapax as an immunosuppressive protocol. The follow-up of 4 months was presented. This transplant raises many technical, ethical, social and legal concerns as this elderly cancer patient was not the proper candidate for such extensive treatment requiring lifelong immunosuppression therapy [46].

On 27 November 2005, a French team led by Dr. Dubernard carried out the worlds's first partial face transplant using the nose, lips and chin from a brain-dead living donor to repair the face of a 38-year-old woman who had been bitten by a dog. Tissue around the wound had contracted, making it difficult to eat, talk and breathe, and reconstructive surgery would have required four or five operations with uncertain results. After 1 week of surgery the patient ate, drank, and spoke normally. Besides the immunosuppressant treatment, injection of stem cells from the donor's bone marrow was given to help prevent tissue rejection. Dr.

Dubernard said that it would be at least 6 months before they knew how much feeling or motor control the patient would have eventually. Although the surgeons were pleased with the patient's progress after this face transplant, whether this operation represents the opening up of a new frontier in reconstructive surgery depends on the clinical outcome [2, 11, 18, 53].

In April 2006, a Chinese surgery team led by Dr. Guo Shuzhong performed the world's second partial face transplant. The patient, a 30-year-old farmer, was severely disfigured when he was mauled by a black bear in 2004. The patient's injuries were so severe he had become a social outcast, going out in public only when necessary. There was no upper lip, all the upper teeth were exposed and the patient had also lost the front wall of his maxillary sinus and part of his cheekbone, leaving him prone to infections. From the donor, the surgical team took the whole nose, upper lip, a little tissue from the left side of the face and more than two-thirds from the right side, including the skin, subcutaneous tissue and muscle along with bone from the nose and malar area. They used the donor's masseter muscle to fill in the front wall of the maxillary sinus. In the beginning they prepared six blood vessels for anastomosis. But during surgery, the doctors discovered that anastomosing one artery and vein would suffice. One difference from the procedure of the French surgeons was that the Chinese surgical team transplanted bone and salivary gland tissue [25].

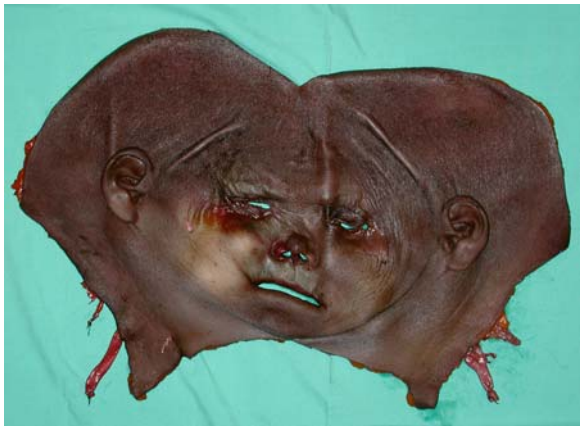

Fig. 19.4. The appearance of the harvested entire face and scalp flap including the external ears based on the external carotid arteries and external jugular and facial veins

19.7.1 Cadaveric Studies

In preparation for facial allograft transplantation in humans we performed a series of cadaver dissections [48, 49].

To study the technical feasibility of face transplantation we harvested the entire face and scalp including the external ears based on the external carotid arteries and external jugular and facial veins (Fig. 19.4). Methylene blue dye injection revealed integrity of the vascular territories of the harvested facial/scalp flap. We also measured the total surface area of the harvested facial flaps with and without scalp and the surface areas of the alternative conventional flaps. The mean surface areas for total facial/scalp flap with and without scalp were $1{,}192 \pm 38.2$ cm^2 and 675 ± 22.3 cm^2, respectively. It was found that the largest alternative conventional flap (bipedicle scapular-parascapular flap) covered only 50% of the total facial/scalp defect. We concluded that a perfect match of facial skin color, texture and pliability could be achieved only by tissue of similar characteristics, which can be supplied by facial skin transplantation from the human cadaver donors [48].

In another cadaver study to simulate clinical circumstances, we performed a mock facial transplantation. Total facial/scalp flaps were harvested from the donor cadavers and transplanted to the recipient cadavers. During flap harvesting from the donor cadavers we measured the time of facial/scalp flap harvesting and the length of the vascular pedicles and sensory nerves that were included in the flap. In the recipient cadaver after excision of the facial skin in the form of a monoblock full-thickness skin graft, time of facial flap inset into the recipient was evaluated and the optimal sequences of flap attachment were outlined. We estimated that the total mean time of facial flap harvest and inset into the recipient cadaver was 5 h and 20 min. According to this study we also suggested the best sequences of flap inset and anchoring procedure [49].

In addition to this anterior standard face harvesting technique, we have also developed a new technique, the coronal-posterior approach, for facial/scalp flap harvesting in the cadaver model. Our goal was to gain the extended length of sensory nerves within facial flaps via the osteotomy approach. In this study, ten fresh human cadavers were dissected. The whole facial-scalp flap was harvested in five cadavers using the anterior standard approach and in five cadavers using the posterior-coronal approach. The length of the supraorbital and infraorbital nerves was extended by osteotomy at the level of exit of the nerves from the foramina and mental nerves by sagittal split osteotomy of the mandibular ramus (Fig. 19.5). The mean length of the supraorbital, infraorbital and mental nerves in the posterior-coronal approach was 3.52 ± 0.31 cm, 4.65 ± 0.20 cm, and 5.6 ± 0.14 cm, respectively. This is an increase of 2.02 ± 0.16 cm, 2.19 ± 0.05 cm and 2.58 ± 0.23 cm, respectively, compared to the standard anterior approach, without osteotomy. Thus we have introduced a new technique for facial/scalp flap harvesting. Using this coronal-posterior approach we have gained an extended length of sensory nerves within the facial flap

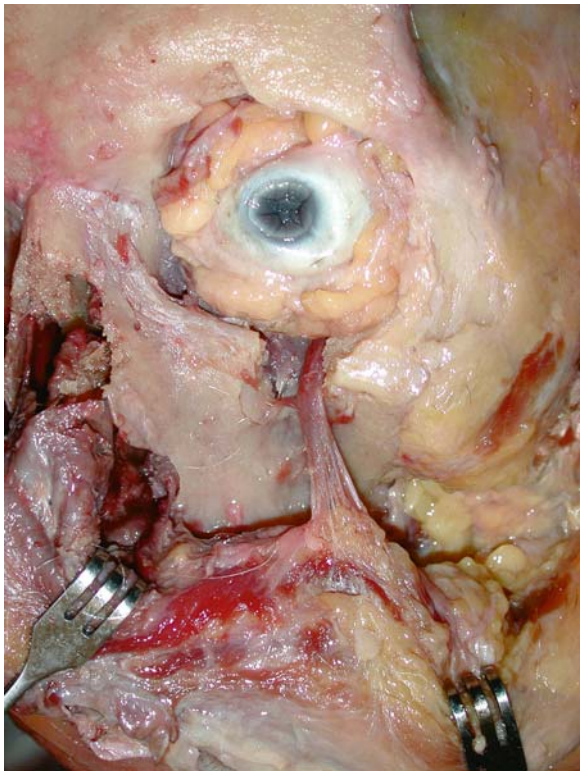

Fig. 19.5. With a coronal-posterior approach an extended length of infraorbital nerve was achieved after osteotomizing the infraorbital rim and infraorbital groove

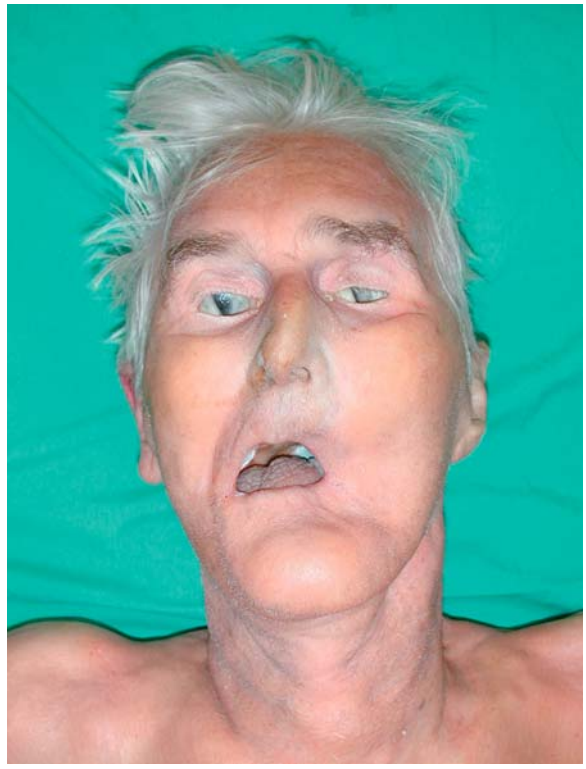

Fig. 19.6. The appearance of the donor facial/scalp flap before harvesting

which will facilitate nerve coaptation and will reduce the surgery time required for face transplantation [51].

Based on these cadaver studies we have confirmed the technical feasibility of facial skin transplantation and this has further encouraged us to address one of the most debatable issues following face transplantation, which is related to "identity transfer." To test this, we performed a series of cadaver studies to evaluate facial appearance of the recipient cadavers following mock facial transplantation [50]. The appearance of the harvested facial/scalp flaps was also assessed after mounting them on artificial head models made of glass and Styrofoam. We have found that the facial features of the recipient cadavers after facial skin flap transplantation from different donors were a combination of donor and recipient features. In contrast, when the harvested donor flaps were mounted on the artificial head models serving as the recipients, the donor flap took the appearance of the recipient's head model (Figs. 19.6, 19.7).

19.7.2 Social, Ethical and Psychological Issues

Over the past 4 years, there has been a vigorous social, ethical and psychological debate within the medical community over whether the pros and cons of facial transplantation have been considered comprehensively enough to allow such a challenging operation to be performed [10–12, 18, 32, 58].

During the first year the risk of acute rejection is estimated to be about 10%, and the risk of loss of graft function due to scarring from chronic rejection is predicted to be 30–50% over 2–5 years. The risks due to immunosuppressive treatment include life-threatening infections, cancers, and organ damage. Also the patients would be suffering from psychological trauma [18].

There is, however, an agreement that if this procedure is considered in the future, a team of experts from different specialties should evaluate the potential candidates for the facial transplantation [45].

The French National Ethics Advisory Committee refused an application by a team of plastic surgeons led by Lantieri to perform transplantation of facial subunits, based on the inherent risks of the procedure [58, 61].

The Louisville group has outlined the ethical criteria and weighed up the risk/benefit factors taking into account the physical, aesthetic, psychological, and social dimensions of facial disfigurement, reconstruction, and transplantation. They did, however, state that "the

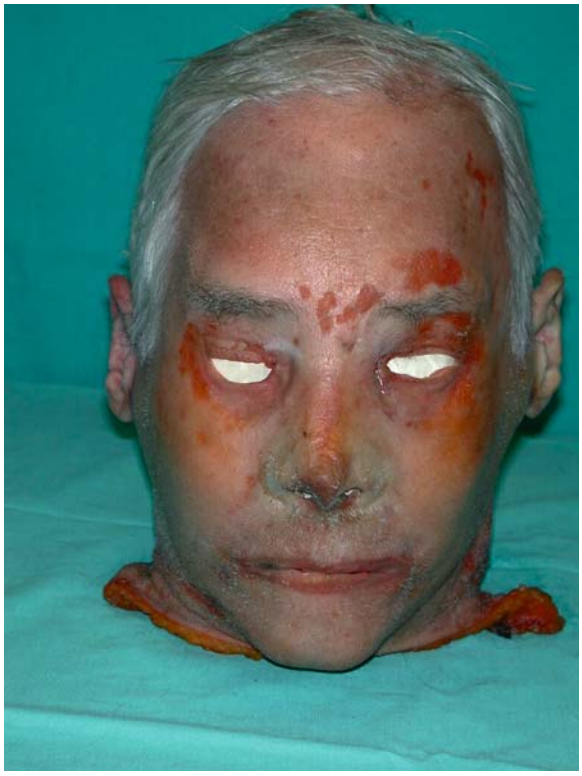

Fig. 19.7. When the donor flap was harvested and mounted on the artificial head models serving as the recipients, the donor flap took the appearance of the recipient's head model

time has come to move facial transplantation research into the clinical phase." Based on the work of Moore they emphasized the significance of public discussion as an ethical requirement before any innovative surgery is carried out [58].

Agich and Siemionow, however, stated that none of the work done by Moore clearly argues that open display and public discussion is an ethical requirement for innovative surgical procedures. They emphasized that the rights of patients with severe facial deformities to improve their quality of life should be included in any discussion on facial transplantation and the suffering of patients with severe facial disfigurement must be re-centered in the public ethical discussions [1].

Opponents of the transplantation procedure have raised the issue of the consequences of facial flap rejection. They argue that the psychological consequences of graft rejection will be enormous and that issues related to facial identity are considered an important ethical contraindication [12, 32].

It is clear that the psychological consequences of graft rejection would be significant, but in order to be prepared, in our protocol we have outlined all the rescue procedures, which will include the application of autologous skin grafts to provide face coverage similar to or better than the pre-transplant condition [1].

Based on over 15 years of research on the technical and immunological aspects of CTA transplants and the biological evidence that facial transplants work in the experimental set-up, we performed a series of cadaver studies to investigate the feasibility, anatomy, and technical aspects of facial flap harvest. All this data served as the basis for an IRB protocol, which was submitted for review and evaluation.

After 10 months of debate on the medical, ethical and psychological issues related to facial transplantation, The Cleveland Clinic Foundation's Institutional Review Board approved the protocol presented by Dr. Maria Siemionow. This approval permits the Clinic to screen and evaluate patients with severe facial disfigurements and considers them as potential candidates for facial skin transplantation [45].

19.8 Future Approaches

At this stage, the appearance of the recipient's face after facial transplantation is difficult to predict. However, computer based modeling studies suggest that the face would take more of the characteristics of the recipient skeleton than the soft tissues of the donor [32]. Our cadaver studies have shown that it is difficult to assess facial appearance since all the cadavers looked alike usually with wide open eyes and lacking facial expression. The recipient cadaver appearance after mock facial transplantation was neither like the donor nor the recipient but was a mixture of both. When the harvested flaps were mounted on head models they looked more like the models [50]. In the future, head models of different size and shape can be used to assess the appearance of facial flaps. In addition, computer simulation software can also be used to predict facial appearance after transplantation. 3D CT scans of different bony skeletons of faces can be draped with different cadaver facial skin flaps and the correlation of donor and recipient features can be evaluated.

At this stage we have substantial anatomical knowledge, microsurgical skills and immunological expertise to make facial transplantation a clinical reality. However, before we proceed, the risk/benefits of lifelong immunosuppression should be validated, and the ethical and psychological factors should be presented and discussed with potential candidates. The patients with severe facial disfigurements should be informed about all the available reconstructive options, including facial allograft transplantation. When the risks and benefits are presented and understood by psychologically stable candidates, it should be the patient's right to choose what is crucial for their life.

19.9 Conclusions

Patients living with severe facial deformities may wish to assume the risks of allograft transplantation if they have the chance to obtain a more normal appearance. Facial allograft transplantation would revolutionize the field of transplantation and reconstructive surgery. The advantages and disadvantages of this promising procedure should be thoroughly discussed with recipients and their families. Although the likelihood of success and the long-term functional and aesthetic results remain unclear at this time, facial allograft transplantation will one day become a clinical reality. When this time comes, we believe that well informed and psychologically stable patients should have the right to decide whether to undergo this procedure [47].

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20 Reconstruction of the Head and Neck Area with Tissue Expanders

E. Csorba

20.1 Introduction

The use of rubber balloons in skin expansion was first implemented by Neumann in 1957, during temporo-occipital area expansion for ear reconstruction. The tissue expanders developed by Radovan 20 years later have been widely used for the past 29 years [15, 20].

Tissue expansion is a mechanical process, which increases the surface area of the skin lying above the expander. Due to the enormous adaptability of the skin, a larger amount of similar tissue can be gained. The enlarged tissue can be used to cover the defect, which results from excising tumors, or scars. There are several procedures to close the defect, one of which is tissue expansion. If there is healthy tissue around the site of the future defect, this procedure is simple, facilitating good aesthetic results, which otherwise would require a more complicated method, such as transfer of distant skin, and subcutaneous tissue.

Reconstruction with expanders always requires two surgical procedures. During the first operation, the expander is inserted in the proper place. During the second operation, the filled up socket is removed, following lesion excision. Then the defect is covered with the expanded skin and subcutaneous tissue without tension. The scar can be hidden in many places.

20.2 Types of Prostheses

The expanders are mainly silicone packets with a self-sealing injection port. The silicone envelope can be round, rectangular, tubular, croissant, or versatile in shape, while its size varies from 1 to 2 cc up to more than 1,000 cc. The surface is smooth or textured. Some consider that the textured expander can be inflated more easily, and does not migrate. The self-sealing injection port may lie on top of the expander, or be connected with a longer tube, in which case the port needs a separate place, not too close to the expander.

Osmed tissue expanders have been available since the early 1990s. These are self-filling devices, consisting of an osmotic active hydrogel contained in a silicone shell with several holes in it. Through these holes the body fluid is gradually absorbed, and the weekly injection process becomes unnecessary. The expander stays in place from 10 days to 6 months [3, 5, 18].

20.3 Skin Alteration Due to Expansion

The skin becomes thinner above the expander, the epidermis thickens, and in the basilar layers the mitotic rate is increased. The thickness of the dermis layer decreases, and the elastic fibers are fragmented. The dermal appendages move away from each other. The underlying muscles and fat are atrophied. On occasion the process of fat atrophy is irreversible. Temporary impressions on the bones make diagnosis possible for a few months. A fine capsule develops around the expander. Vascularity of the skin increases rapidly, which stems from the number and the caliber growth of the capillary. If the expansion is not forced, these changes are reversible. If the expansions are forced to fill, irreversible tissue damage might occur [2].

20.4 Diagnosis

The decision regarding the use of an expander needs a proper discussion between the surgeon and the patient, when the surgeon explains all the available procedures. The discussion also gives an opportunity to identify the patient's habits, and whether he or she, or parents in the case of a child, are ready to undergo the two operations and the weekly expansion. If the patient is not ready mentally, it is better to look at other alternatives to solve the problem.

The surgical procedure has to be carefully planned, from the beginning to the end, to decide on the most suitable area for the expansion around the lesion. In the beginning the surgeon has to decide where the final scar will be located, and to see if the patient will be able to accept it.

There are two decisive measurements when choosing the correct expander size: these are the length and the width of the lesions, taking into consideration the shape of the lesion as well. Attention should be focused on the shape of the expander, and if there is enough healthy tissue around the lesion.

If there is not enough healthy tissue in any of the directions, the surgeon has to decide whether several smaller expanders should be used.

The incision to be used for insertion has to be identified, and attention should be paid to the location of the self-sealing injection port, which should be far enough away from the expander to avoid damaging it during the filling injection. Instead of a magnetic search it is better to use sight and to palpate the port through the skin.

20.5 Surgical Procedure

The expander can be inserted with the patient under local or general anesthesia. During the second procedure more tissue is transposed, the expander and the self-sealing injection port are removed; therefore general anesthesia is recommended for this procedure. The inserting incision is incorporated into the final reconstruction area, at a suitable distance from the side of the prosthesis. The expander must have an envelope about 1.5 times larger than the expander. The self-sealing injection port can be placed under the lesion. Attention should be paid to the edges of the expander to avoid wrinkling; often wrinkling is the cause of extrusion of the prosthesis.

During the operation, filling the expander with some saline is advised, in order to decrease the dead space; however, the suture line cannot be under tension. Inserting a suction drain for 24 h is possible. On the next day the patient can be discharged, and treatment is continued on an outpatient basis.

The filling of the expander starts 3 – 5 days postoperatively, and continues at 5- to 7-day intervals. During the filling the patient feels a mild tension, which will remain for a few hours. The surgeon should follow carefully the color of the overlying skin; if the skin becomes pale, some fluid should be withdrawn, until the paleness disappears [14].

The filling of the expander will continue until enough expanded skin is generated to cover the defect without tension. The expansion must not be forced for quicker growth; the skin will suffer permanent damage [14]. The use of multiplex smaller expander reduces the expansion time.

It is advisable to wait 10 – 14 days after finishing the expansion; by this time the skin's retractability decreases, making it easier to cover the defect during the second operation.

During the final operation the fine capsule can remain in place, and the bending line can be incised for better rotation of the flap. Finally the flap will replace the excised area, allowing a tensionless suture line, which is satisfactory both anatomically and aesthetically. At the end of the operation the use of a suction drain is advised for 24 h.

20.6 Complications

The rate of complications after expander procedures will continue to decline with experience. With the increase of completed procedures will come a decrease in complications (both in number and severity) [17].

The early complications are:

- Infection from contamination, and subsequent removal of prosthesis [6].
- Postoperative bleeding. Reoperation is necessary; the expander can be replaced after bleeding is controlled.
- Insufficient size of envelope
- Wrinkled expander
- The self-sealing injectable port is too close to the envelope (its placement under the expander is spontaneous when increasing the expander size)

Late complications can arise; yet the continuation of expander filling and the completion of the entire procedure is possible. One such late complication is skin necrosis above the edges of the expander, where the tension of the expanding skin culminates. During treatments with expanders, the patient is able to continue his or her daily routine [13].

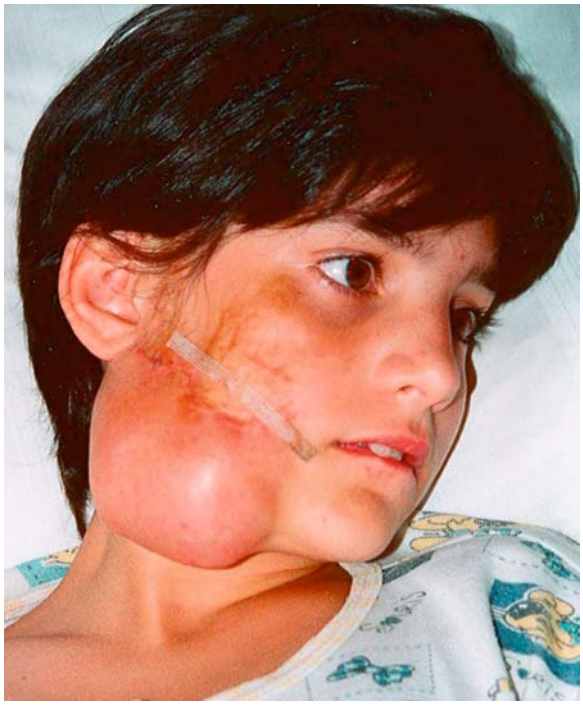

Fig. 20.1. Burn scar on the face, filled up expander placed under the neck

20.7 Expander Application

The use of the expander is recommended for all congenital and acquired skin (mucosal) defects [17, 22] (including tumors, and scars after thermal or other injuries), which do not need acute closure [1, 7]. The expanding procedure requires at least 4 – 8 weeks. It is also well applicable in pediatric patients. Expanders can be applied to various places, in various ways, on the body. The expanded tissue can be used as a rotational or as an advanced flap [10].

The full thickness skin graft achieves a better cosmetic and functional result than the split skin graft. The donor area of full thickness skin is limited; therefore a preexpansion procedure is applied to enlarge the area of harvest. After removing the expander, the donor area can be closed primarily.

Another method is to enlarge fasciocutaneous, myocutaneous flaps. The preexpanded flap can be a free flap [12, 19].

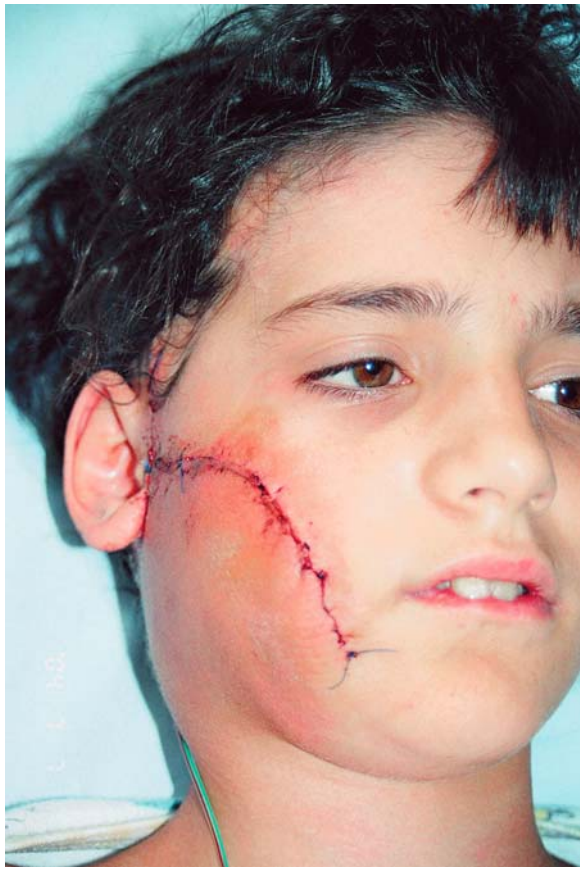

Fig. 20.2. The scar is excised; the suture line crosses the physiologic line, and the auxiliary lines are hidden as practiced during facelift procedures

20.8 Face, Head and Neck Reconstruction Using Tissue Expanders

The increasing use of tissue expanders is considered one of the major advances in reconstructive surgery, especially on the face, head and neck area.

20.8.1 Face

All reconstructive procedures of the face should minimize the new scars [7].

The symmetry (eyebrows, eyelids, and the angle of the mouth), the function, the color, and the thickness of the skin have to be considered. Careful attention must be paid to hair bearing areas, especially in children, who develop these areas later in life.

The suture lines can be hidden within natural lines, or in hidden areas. The most commonly used hiding areas are in front of and behind the ear, the nasolabial fold, or the infraorbital region. There are some cases

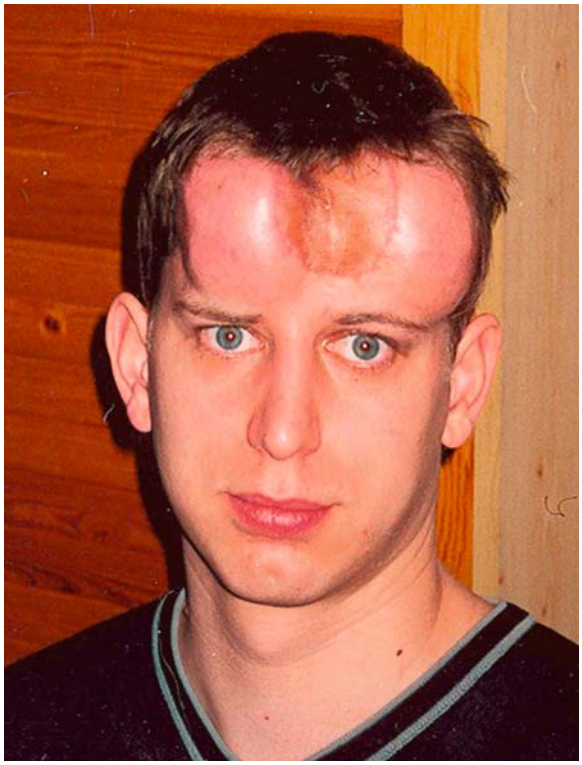

Fig. 20.3. Multiplex successive excisions are performed, and the size of the nevus remains the same. Two expanders are placed into the two sides of the nevus, and then filled

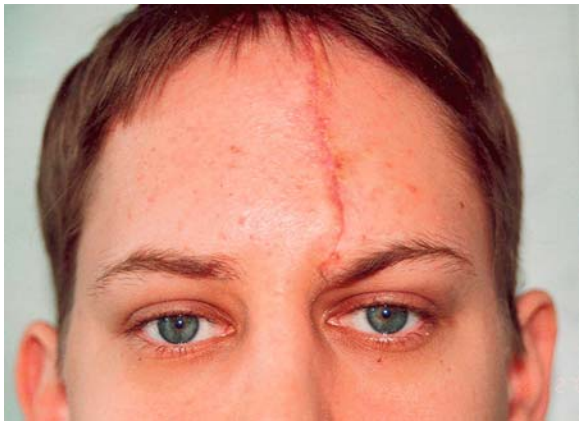

Fig. 20.4. The tumor is excised, the suture line is vertical, and the auxiliary sutures are in the hairline

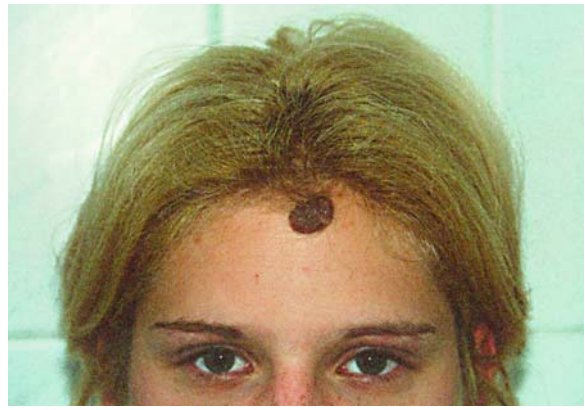

Fig. 20.5. Congenital nevus on the forehead

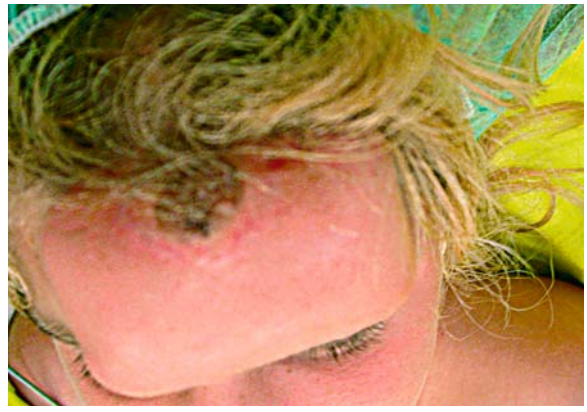

Fig. 20.6. The expander is centrally based from the nevus, filled up

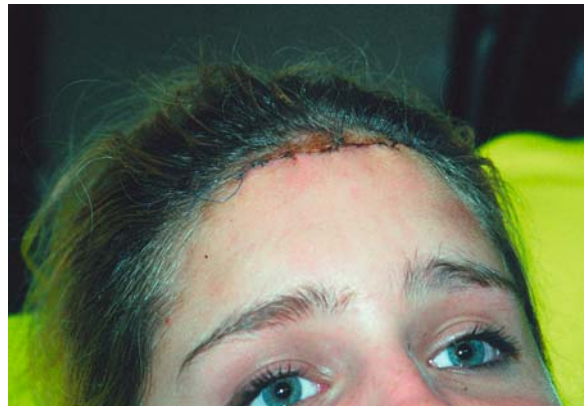

Fig. 20.7. The nevus is excised; the suture line is on the hairline

where you cannot avoid the suture through the physiological face lines, but the goal is to avoid them (Figs. 20.1, 20.2).

The donor area is limited on the face, forehead and neck; there is not sufficient healthy tissue to accommodate the appropriately sized expander. In these cases the surgeon is forced to compromise to excise only one part of the lesion, and to repeat the procedure after some time. It is advisable to wait several months between these two procedures, until the donor area becomes soft and the underlying tissue is free from edema.

The weight of the flap can increase the tension on the lower eyelid or on the angle of the mouth, so it is wise to fix the flap on the underlying fascia, or muscle.

If a larger amount of skin is needed to cover the defect on the forehead, the skin can be expanded from

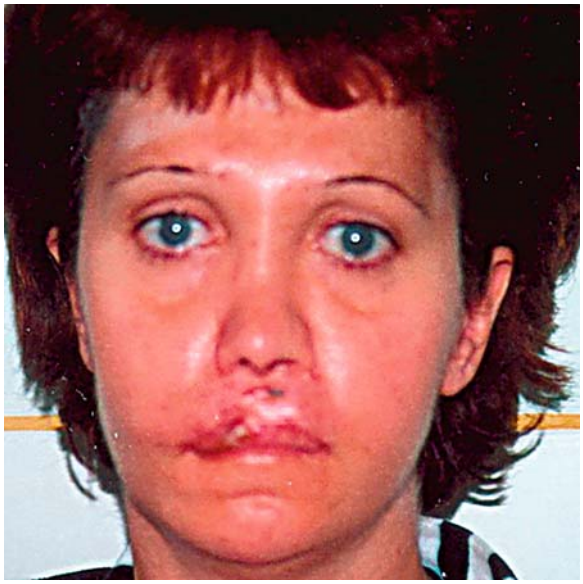

Fig. 20.8. Two small expanders are inserted from the lip line; extrusion has occurred

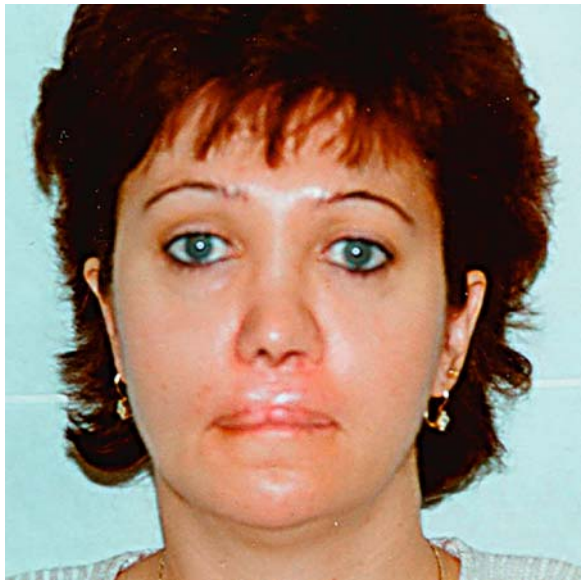

Fig. 20.10. Final result

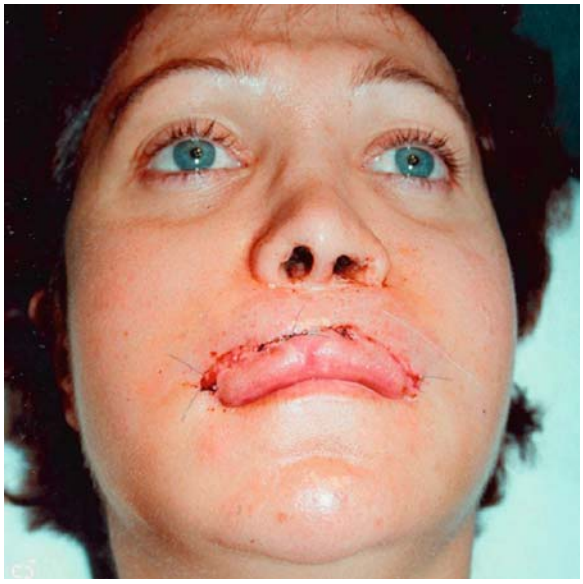

Fig. 20.9. The procedure could be finished, widening the upper lip

two sides, and the suture line can be placed vertically in the middle of the forehead, with the auxiliary suture lines hidden in hair bearing areas (Figs. 20.3, 20.4). In other cases, when the lesion can be solved only by a suture line, which is horizontal on the forehead, a visible scar is produced. The skin of the forehead can be expanded centrally based from the lesion, so it will be possible to place the suture line hidden on the hairline (Figs. 20.5 – 20.7).

Facial skin is expandable even if the patient has undergone several previous operations.

In congenital malformations, especially after cleft lip, many operations have occurred previously, leaving the distance from the nasolabial angle to the lip very narrow and scarred, and the lip itself thin. The use of two small expanders increases this distance (Figs. 20.8 – 20.10). With a sufficient amount of skin, it is possible to widen the lip, and the resulting increase in this distance gives the patient a more aesthetic appearance. The expanders can be inserted from the upper lip line, and later on the incision scar will be excised. The expanded tissue gives the opportunity to widen the upper lip.

To cover an incomplete or complete nose defect, responded flaps, such as the nasolabial or frontal flap, can be used [8, 16]. In one case the nasolabial flap had been used unsatisfactorily previously. Reusing the nasolabial flap displaces the angle of the mouth. With the preextended nasolabial flap, however, the problem can be solved (Figs. 20.11, 20.12). The authors prescribed a preexpanded flap on the anterior part of the chest wall, and with a pedicled form the expanded skin covered the complete nose defect [11].

The lower face can be restored using expanded neck skin [9]. The color and thickness are very similar to those of the lower face, so it is ideal for the reconstruction of lower face defects. In the case of undamaged neck skin, you can use two expanders (rectangular) to reconstruct the whole aesthetic unit of the lower face (Fig. 20.13). The self-sealing injectable pad can be placed above the sternum, or behind the ears. The underlying vessels will not be injured. It is ideal to place the two rectangular expanders on the sides of the neck, so that neither is lying over the trachea, yet they will expand the skin in the median line without causing any feeling of discomfort, or coughing, or tracheomalacia.

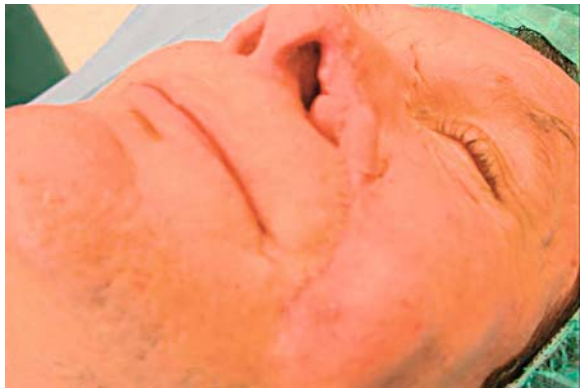

Fig. 20.11. Partial nasal defect, expanded nasolabial fold

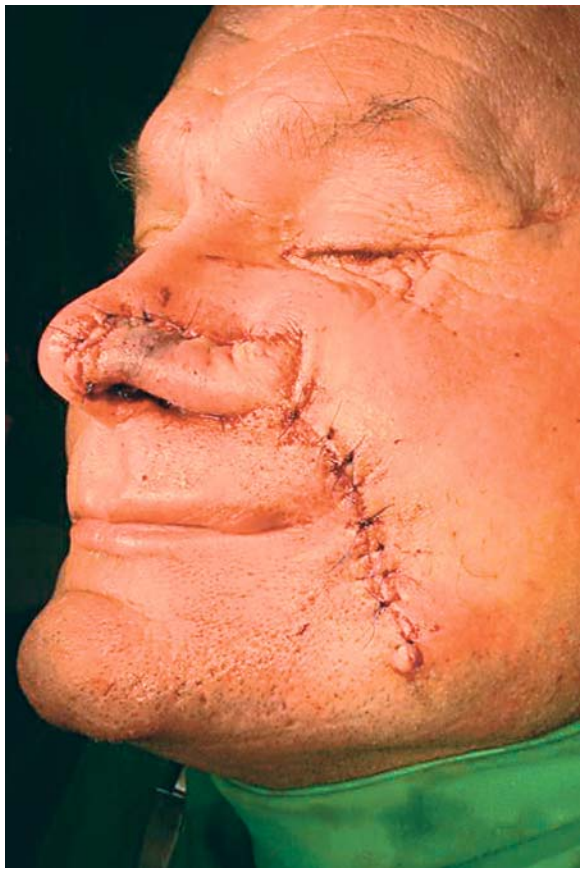

Fig. 20.12. The expanded pedicled flap sutured to the alar defect

The majority of face reconstructions follow an injury, mostly a burn injury. Early excision and grafting prevent the patient from developing adherent, and deforming, scars. Places known to be predisposed to scarring should be transplanted in carefully; for example on the eyelid, a full thickness skin graft gives a reasonable result, and on the face the grafting should follow the aesthetic units. The edges of the grafts could be placed on the physiological lines, or on the lateral side

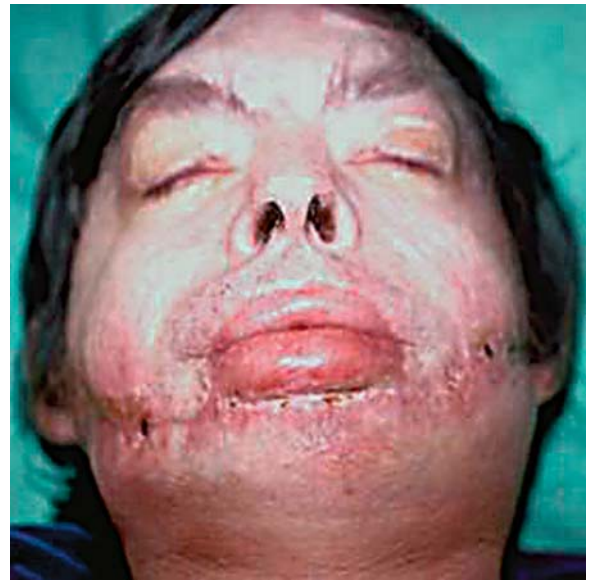

Fig. 20.13. The distal part of the face is replaced with extended neck skin. The upper and lower eyelid are reconstructed with full skin graft

of the face. The more careful the excision of the necrotic tissue, and the grafting, the fewer scars will develop and will need reconstruction.

20.8.2 Neck

The neck is a key point in treating a burn injury after scalding and flame injuries. When the neck is exposed to flame, the injury suffered is deep. When excising the necrotic tissue, the split skin graft causes an adherent scar which will be retracting. The postoperative immobilization is doubtful. It is useful to line the split skin graft with cultured dermal allograft. Following this method, less adhesive scar will develop later on. Postoperative scars could develop despite the most careful surgical methods. The head will be bent forward or pulled to one side as the result of strong scarring of the neck. The distorting scars deform the mouth, and can even hinder the closing of the mouth. If there is free, healthy tissue on the anterior side of the neck, it can be expanded, and used to cover the defect resulting from the scar. Sometimes there is no healthy tissue in the surrounding area; in which case an expander can be placed under the healthy skin, and fascia of the shoulder. The size of the expanded area can enlarge the approaching fasciocutaneous flap; this large, long, pedicled flap can cover the whole neck area (Figs. 20.14, 20.15).

The use of two expanders is advisable in the median line defect. These defects expand the healthy tissue from two sides, both horizontally and vertically. The applied expanders will expand in both directions, and

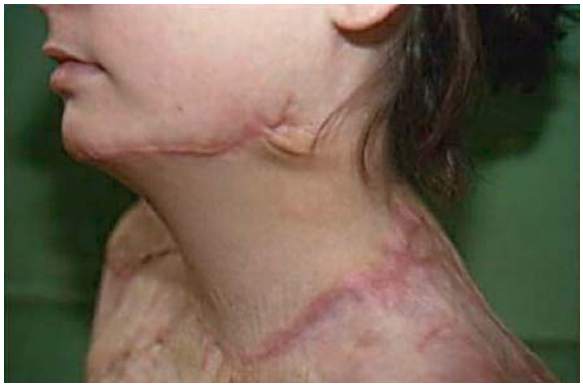

Fig. 20.14. Severe contracture of the neck. One expander is under the shoulder area, below the fascia

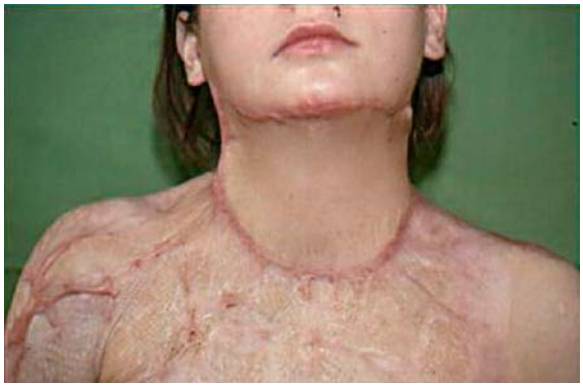

Fig. 20.15. Large fasciocutaneous flap replacing the contacting scar of neck

the vertical and horizontal shortening of the skin can be resolved (Figs. 20.16 – 20.19).

In cases where the entire neck area is scarred, it is possible to expand the upper part of the chest wall, but it is important to consider the unsatisfying aesthetic results, especially in females.

20.8.3 Scalp

The continuity of the hairline is an important aesthetic factor to take into consideration during restoration. Hairline, and the reconstruction of the scalp, is a common demand from patients.

Injury of the scalp is common in children, usually from hot liquid scalding. The scalding results in a dermal burn, and the hair bulb is destroyed.

It is reasonable to use an expander during the reconstruction of the bald area. The scalp can expand to double its size. The expander should be inserted into an envelope prepared under the galea, above the periosteum (Figs. 20.20, 20.21).

Usually two, or more, expanders are needed for this type of reconstruction, in the shape of a croissant, or a versatile expander which can adapt in shape. The use of large expanders is not encouraged; it is better to use smaller, but multiplex expanders.

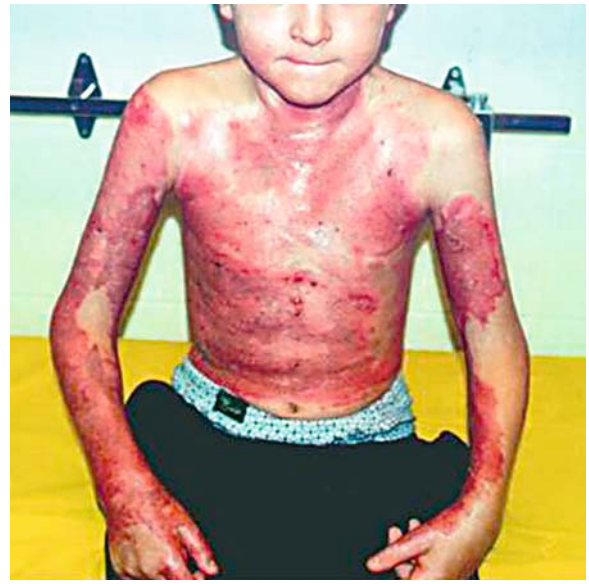

Fig. 20.16. Ten-year-old boy after 60 % deep burn

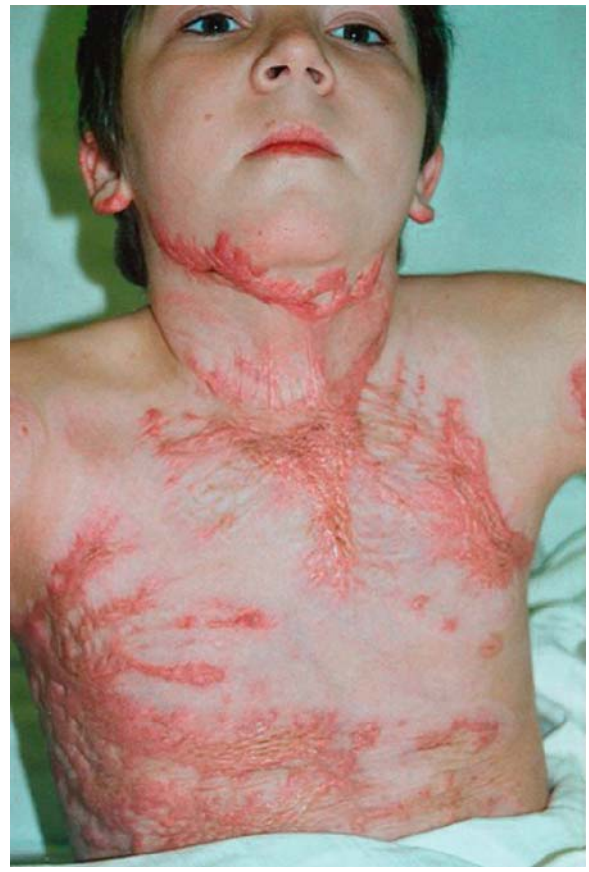

Fig. 20.17. Scars in the neck area

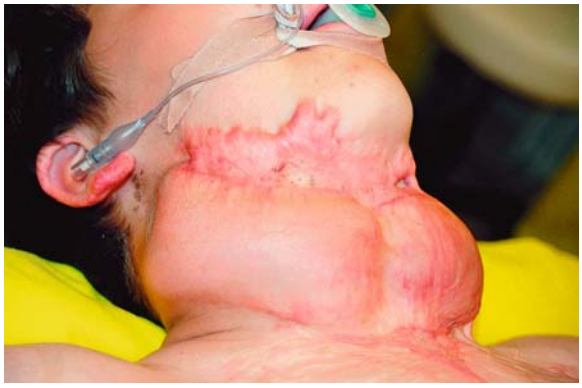

Fig. 20.18. Expanding the two sides of the neck with two prostheses

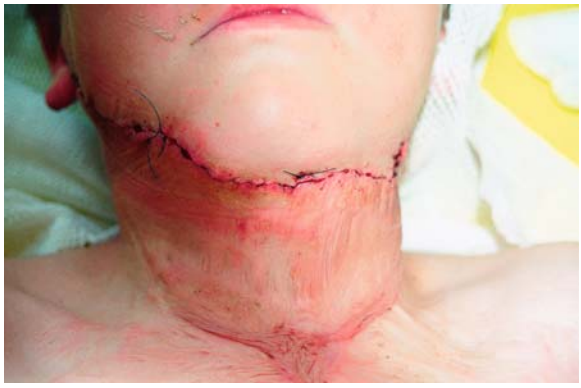

Fig. 20.19. Final result

At the beginning the expansion is difficult, with a small inflation volume; later on it becomes easier. If there is enough room, it is wise to follow the line of temporal, occipital or frontal arteries, to increase the circulation of the flap.

20.9 Conclusions

The face, neck and head can be considered one aesthetic unit, and if just one of these is compromised, the social conduct of the patient can change; these patients often become introverted, and sooner or later will be affected psychologically. The use of expanders provides the surgeon with a very reliable, simple method of reconstruction. The patient and the surgeon have to keep in mind the possibilities of complication from expander use, and accept that there will be some scarring on the operated area. However, the benefits of expander-aided reconstruction outweigh the risks in cases where the outcome brings a significant improvement in the patient's standard of living. The surgeon should always outline a realistic outcome to the patient, and communicate clearly the risk.

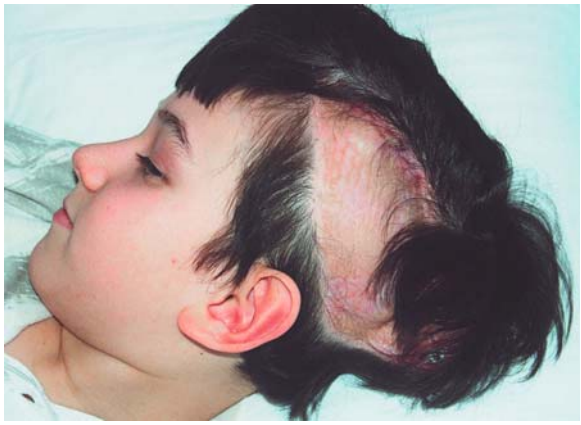

Fig. 20.20. Meshed split skin graft on the scalp, expanded with two cylindrical expanders

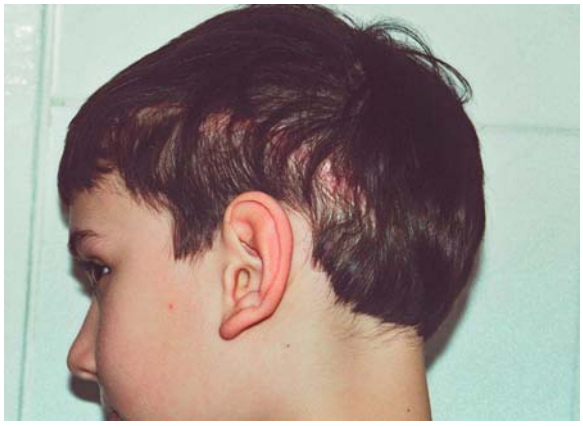

Fig. 20.21. Reconstructed baldness

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The Utility of Biomaterials in Reconstructive Facial Plastic Surgery

21

M.B. Habal

21.1 Background

Biomaterials used today for the reconstruction of the facial skeleton fall into two categories. The first is the fixation of the different components of the facial skeleton and the second is the filling of discontinuity defects of the facial skeleton. We have purposely avoided the use of any of the fillers and soft tissue augmentation so far and focused on the skeletal configuration. However, the standard of care today in the treatment of patients with simple or extensive craniofacial fractures or after osteotomies involves the utilization of multiple biomaterials for fixation purposes. The biomaterials used should be inert, producing minimal inflammatory reaction to adjacent tissues and exhibiting no biological response. The goal of using biomaterials is to maximize the positive final outcome of treatment for the patient and to minimize complications that may ensue from the patient's condition. This chapter outlines the applications of biomaterials and their utility for the trauma surgeon treating various problems in the craniofacial region. This work is by no means inclusive of all biomaterials used in facial surgery practice but addresses those most frequently encountered in the treatment of the common abnormalities today.

21.2 Introduction

Today, the application and utility of biomaterials are essential for standard-of-care treatment of patients with extensive craniofacial trauma. It is, therefore, imperative that surgeons using biomaterials have a comprehensive knowledge and understanding of the implications and effects of these materials when used in living biologic systems. The biochemistry and composition varies from system to system so that the details of the variables become as important as the mechanics of application. By definition, most biomaterials in use today are inert. They do not initiate any major inflammatory response or reaction and are easy for the practicing surgeon treating facial trauma to use.

In the past, controversy arose regarding the nature of the application of biomaterials in patients because of the high degree of contamination found in traumatic wounds. The differences in the use of biomaterials in elective craniofacial surgery and their application in traumatic injuries are related to considerations of clean versus clean/contaminated or grossly contaminated wounds of the facial skeleton. It was thought that the use of biomaterials in clean/contaminated (type II) or grossly contaminated (type III) wounds should be delayed, and immediate application limited to clean conditions such as type I wounds. Other issues involving the use of biomaterials in facial surgery were related to open versus closed wounds and the situation of internal contamination from the paranasal sinuses. These concerns compelled surgeons to defer the use of all biomaterials in craniofacial surgery related to primary trau-

ma, and it had become a principle that such biomaterials should only be used in the former type of wounds rather than the latter two types. These concerns were alleviated as early as the 1970s. The presence of a good blood supply to the head and neck area may be the factor that differentiates trauma surgery in the craniofacial region from that in other regions of the body.

Biomaterials used today in facial trauma are divided into two categories: biomaterials used in immediate trauma repair and those used for delayed reconstruction. Biomaterials are also used operatively for immediate skeletal fixation and for delayed recreation and reconstruction of facial structures. In secondary reconstruction of traumatic defects, biomaterials are used as contour fitting materials, and these procedures are most often deferred until after immediate surgical repair. Fixation of the craniofacial skeleton has undergone a major evolution in the past 20 years. However, our search continues for the ideal fixation device. The future of all skeletal fixation devices lies in the use of new biomaterials and new combinations of these materials. In addition, the use of contour fitting biomaterial will eventually follow the same process as in the past: that of the time element involved in the body's ability to incorporate these materials as a component that is not easily differentiated from adjacent tissue.

The last important concept that we need to go over in this chapter is that of regeneration as it affects the use of biomaterials in the craniofacial region. Biomaterial implants have the ability to allow surrounding bone to regenerate new bone while using the applied material as a scaffold. A knowledge of the longevity of all the applied biomaterials is essential, as well as an understanding of the processes that are involved in either total elimination by hydrolysis, incorporation, or regeneration [1, 2].

21.3 Safety Considerations

The applications and use of biomaterials in any biologic system are always associated with a major question: Are these biomaterials safe to use or are they capable of causing harm? It is also of import to know if there are any by-products that will be, under any circumstances, harmful. Safety issues are the fundamental focus of the Food and Drug Administration (FDA) and its European equivalents. These agencies study all the biomaterials that are to be used for medical purposes, their efficacy, and the animal studies required before the premarket studies (PMS) are designed to collect data from clinical applications. Data is then analyzed and if the biomaterial is found to be safe and efficacious it is then released for marketing to doctors' offices and the hospitals for use in human patients. All the biomaterials discussed in this chapter have passed through this process and its final applications.

21.4 Fixation of the Facial Skeleton

A review of the history of skeletal fixation is helpful for the understanding of the situations in which we work today. Skeletal fixation in the craniofacial region has gone through many advances in the past few decades. Most of these advances have followed major international conflicts involving the complex treatment of large numbers of casualties.

Initially, fractures of the craniofacial skeleton were treated without fixation by allowing the bones to heal in open soft tissue, then performing the repair at a later time. Fractures were also treated with closed reduction after manipulation. The next development was the use of an external apparatus for fixation. This method was useful until the external fixation was removed and the repaired structures collapsed again.

Internal fixation then came into practice and required the use of rigid fixation. Use of the plating system began at the turn of the century, with the use of stainless steel plates. The use of Vitallium and titanium plating followed. In the latter part of the last century, the use of resorbable plating systems evolved and they have advanced to their present status today. Resorbable plating systems remain the state of the art for skeletal fixation.

The evolution of biocompatible resorbable polymers offers the surgeons of today a new array of options for craniofacial skeletal fixation. Some of the potential benefits of resorbable polymers include greater ease and accuracy of contour adaptation, clear radiographic presentation due to the absence of X-ray scatter, elimination of the need for secondary surgeries for device removal, and reduced risk of stress shielding of the underlying bone. Known as polyesters, these copolymers have chemical, physical, material, mechanical, and biologic properties different from those of metal fixation devices. Knowledge of these differences will facilitate the utilization of resorbable implants in fixation for craniofacial trauma.

Among the bioresorbable polyester facial fixation devices approved for clinical use by the FDA, copolymers of lactides and glycolides are available. The first copolymer of *l*-lactide and glycolide (LactoSorb, W. Lorenz, Jacksonville, FL) was approved by the FDA in 1996. The lactide in LactoSorb is a homopolymer of the levo form. The ratio of the *l*-lactide monomer to the glycolide monomer is 82:18 in poly (*l*-lactide-co-glycolide), to take advantage of glycolide's rapid degradation time. Strength declines to approximately 70% by 6–9 weeks and resorption is complete by 12 months.

More recently approved in 1998 is a copolymer produced from a mixture of 70% *l*-lactide monomer and 30% *d,l*-lactide monomer (MacroPore, MacroPore Biosurgery, Inc., San Diego, CA). This 70:30 ratio in poly (*l*-lactide-co-*d,l*-lactide) DLLA retains approximately 70% of its initial strength after 9 months, and approximately 50% after 12 months, with resorption completed by 24 – 36 months. Additional resorbable polyesters from Bionx, Leibinger (delta system and the new delta system), Synthes (resorbable system), KLS Martin (resorb-X), and Iona (two systems) are all FDA approved and available for surgeons to use. The differences among these systems are the ratios of the copolymers used in the compositions that affect their longevity, a consideration of importance to surgeons. The deciding factor regarding which system to use is the individual surgeon's preference and ease in clinical application.

In view of these considerations, the primary focus in this chapter will be on the use of poly (*l*-lactide-co-*d,l*-lactide) for skeletal repair and fixation, due to the extensive clinical experience of the authors and to the commonalities this system shares with other systems that use similar materials in different compositions. The acronym (DLLA), L-La/D,L-La copolymer, will also be utilized to designate a copolymer of the two monomers, *l*-lactide and *d,l*-lactide.

21.5 Physical Properties

Poly (*l*-lactide), which has a high crystallinity, is characterized by its strength and long degradation time. Conversely, a polymer created from *d,l*-lactide has little strength and degrades rapidly. Combining *l*-lactide and *d,l*-lactide results in a copolymer with the intermediate characteristics of strength for 6 – 9 months and resorption in 24 – 36 months. In addition, the copolymer is optically clear and noncrystalline, resulting in minimal foreign body reactions by tissue. It should be noted that, even within a given copolymer, strength and degradation characteristics can vary according to the degree of polymerization. Therefore, the manufacturer must maintain this within the desired range. A common measure of the degree of polymerization is called intrinsic viscosity (IV) and, for any given polymer, the IV correlates with molecular weight. To measure IV the polymer is dissolved in a standardized, known amount of chloroform and then passed through a viscometer. The length of time that it takes for passage is used to calculate the IV.

At sufficiently high temperatures all materials change from hard to soft and finally to liquid. The temperature at which a material changes from hard to soft is known as the glass transition temerature (Tg). For 70:30 poly (*l*-lactide-co-*d,l*-lactide) the Tg is 55°C (131°F), thus allowing heat to be utilized for contouring these implants.

Contouring an orbital floor liner illustrates this property. After making a template of the orbital floor, the template is held against the orbital floor liner, then placed in a water bath and heated above Tg. The floor liner becomes soft in a few seconds and simply drapes over the template when lifted from the water bath. In a few more seconds the floor liner cools below Tg and can be removed from the template. The liner is then ready to be placed in the patient. It is useful to note that 70:30 poly (*l*-lactide-co-*d,l*-lactide) has shape memory, and if placed back in the water bath it will return to its original contour, thus enabling additional opportunities to re-contour it. If only a portion of an implant needs to be recontoured, only that portion needs be placed back in the water bath. Cyclic heating of 70:30 poly (*l*-lactide-co-*d,l*-lactide) to 70°C can be performed multiple times with no change in material strength or IV.

21.6 Chemical Properties

When lactic acid undergoes polymerization, ester bonds are formed and H_2O is released. Therefore lactide copolymers are also known as polyesters. Resorption of lactide copolymers takes place as a reversal of this process, with sorbtion of H_2O and scission of the ester linkages. This bulk hydrolysis of lactide copolymer implants continues until single lactic acids molecules are released, which are then metabolized into glucose or into CO_2 and H_2O via the Krebs tricarboxylic acid cycle.

A variety of factors are known to affect the rate of lactide copolymer resorption. A higher IV or molecular weight means there are more ester linkages that undergo scission, and this process results in a longer resorption time. A larger implant size or volume will also require more scission before implant resorption can be completed. If the polymer is packed more tightly in an orderly crystalline pattern, there is less space for H_2O access and resorption will take longer than for noncrystalline implants. Since hydrolysis occurs both on the implant surface and within its interior, implant porosity will increase surface area, facilitate H_2O access, and decrease resorption time. The molecular configuration of copolymers may alter resorption time. Greater vascularity of the implant host site, as well as flexural bending from functional loading, appear to be associated with an increased rate of hydrolysis.

21.7 Toxicology

The toxicology of lactides has been of minimal concern, due to the relatively small volumes of implant material, slow degradation rates, and short serum half-lives. The serum half-life of the levo form is 15 min; for the *d,l* form it is 22 min. The normal resting blood lactate level is 1.1 – 2.8 mM/l. After muscular activity it will rise tenfold to 10 – 23 mM/l. If the assumption is made that degradation occurs over 2 months, with first order kinetics and a half-life of 74 h, a 100-g implant would release 0.18 mM/l of lactide acid in the 1st min, far less than the changes resulting from muscular activity. Two of the largest sheets of 70:30 L-La/D,L-La copolymer weigh only 18 g, and degradation actually takes place over a much longer 18 – 36 month time interval. Even with first order kinetics starting instantly, the 18 g of lactide copolymer would result in an increase in blood lactate levels of only 1.1 %.

21.8 Histology

The histological responses to 70:30 L-La/D,L-La copolymer have been well studied. There is an initial acute inflammatory response following implantation. By 72 h there is a narrow zone of fibrinous exudate, edematous granulation tissue, and a modest degree of fibroblast proliferation. By 7 – 14 days the granulation tissue has matured into a thin, cellular, fibrovascular capsule [3, 4]. Measurements of in vivo tissue pH adjacent to 70:30 L-La/D,L-La copolymer implants have detected no change during degradation [5, 6].

21.9 Mechanical Properties

The tensile strength of lactide is approximately 30 % of the strength of bone. With a tensile strength of 70 MPa, lactide materials can readily be designed to accommodate the failure loads for nonweight-bearing bones. When designed as 1.0-mm-thick plates, the tensile strength is approximately 190 N or 45 lbs. When metal screws are overtorqued, the threads strip the bone. When lactide screws are overtorqued, the heads sheer off. The sheer strength of 2.0-mm screws is approximately 85 N or 20 lbs. As the 70:30 L-La/D,L-La copolymer undergoes hydrolysis, its mechanical strength will decrease. At 3 months, strength remains near 100 %, decreasing to 90 % at 6 months, 70 % at 9 months, 50 % at 12 months, and 0 % by 18 months.

21.10 Plate Selection for Fracture Fixation

As with all fixation systems, clinical experience eventually determines the choice of implant design that is most likely to produce a successful outcome. As a starting point, it is recommended that the surgeon select a copolymer design one size larger than the titanium system currently employed. An example from the authors' experience is the substitution of titanium with PLA for genioplasty. A traditional metal plate with two holes on each side and 2.0-mm screws would normally have been used; however, this patient insisted on resorbable over metal fixation. To ensure adequate stability, the 70:30 L-La/D,L-La copolymer plate was contoured from a piece of 1.0-mm-thick mesh with four holes on each side and attached with 2.4-mm screws. While this design may be excessive in strength, it is appropriate to be conservative until clinical experience is acquired.

21.11 Clinical Experience

The following comprises a review of the authors' clinical experience with biomaterial use in craniofacial fixation.

21.11.1 Resorbable Fixation: Zygomatic and Midface Fractures

The natural extension of surgical experience with metal plates is to use resorbable plates of similar designs, such as in malar fracture fixation. The principles of exposure and reduction of fractures remain unchanged when resorbable plates are employed. The holes for lactide screws require tapping and maximal screw insertion torque. The plates can be precontoured by dipping in a hot water bath and, after inserting one or two screws, can be further contoured by using a flat heat applier, a gauze sponge dipped in the warm water bath, or by dripping warm water onto the plate. Resorbable plates are easily trimmed in situ using a cautery tip attachment. Resorbable mesh may be used in place of metal mesh, such as in an orbital floor fracture. Resorbable mesh is easily trimmed with scissors. It is helpful to leave the leading edge of the mesh uncut so it can be inserted with less likelihood of engaging adjacent soft tissues. Fragments of bone can be incorporated into either resorbable plates or meshes.

With increasing experience, it became apparent to the authors that resorbable mesh offered more sites for fixation and provided greater strength when contoured in three dimensions. By allowing custom shapes to be cut with multiple mesh spaces for screw or tack fixation, the surgeon is freed from the geometric restric-

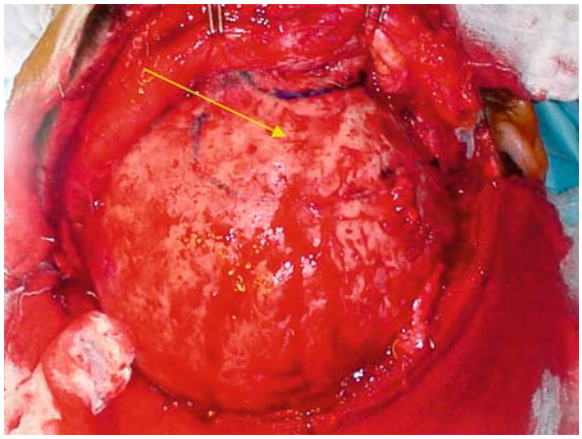

Fig. 21.1. Skull defect

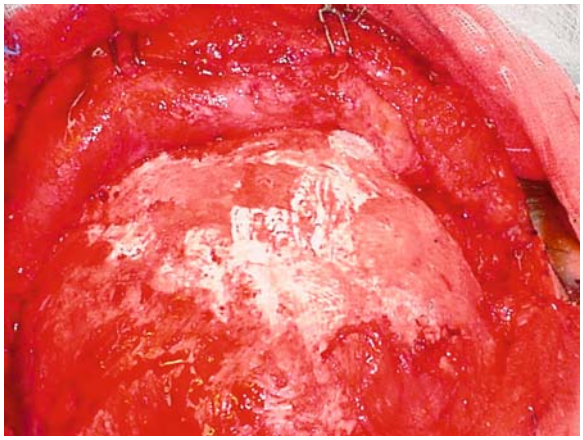

Fig. 21.2. Defect repaired with the new biomaterial tricalcium phosphate

tions of limited selection for metal plate designs. Combined with the speed and ease of adapting mesh to three-dimensional contours using warm water, it is not surprising that the use of resorbable mesh with screw or tack fixation has become even more prevalent than resorbable plates in our craniofacial and midfacial reconstructions.

21.11.2 Resorbable Fixation: Fronto-orbital Fractures

The properties of resorption and the ease of contouring have enabled complex fixation requirements of fronto-orbital fractures to be readily accomplished. By using the resorbable mesh as a template, accuracy of bone fragment fixation can be facilitated.

In a 2-year-old girl, kicked in the forehead by a horse, the neurosurgeon outlined his planned craniotomy. Prior to making the bone cuts, a sheet of resorbable mesh was contoured over the fracture site to match the normal right forehead. The fragments were then reduced into this template on the back table, fixated with tacks, and then returned to the patient after completion of the neurosurgical repair. Additional tacks placed around the mesh periphery secured the reduction, restoring the girl's forehead symmetry.

When trauma results in bony defects, easily contoured resorbable mesh can be shaped into a template for the bone graft reconstruction. In an 11-year-old girl, anterior cranial base fractures were sustained in a motor vehicle accident. Following acute debridement she was transferred for definitive care of her CSF leaks and fronto-orbital bone defects. To provide neurosurgical access to the anterior cranial base, the remaining frontal bone flap and orbital rim were removed. Contoured resorbable meshes were then used to rebuild the fronto-orbital construct from split cranial bone grafts from the flap, along with the portions of the orbital rim that had been removed. A nice fronto-orbital contour was achieved after the construct was fixated around its periphery.

21.11.3 Resorbable Fixation of Secondary Craniofacial Trauma Reconstruction

Perhaps no area of secondary craniofacial trauma reconstruction has been as challenging as the cranio-orbital fractures of the complex curvatures and multiple planes involved in the frontal bone, the orbital rims, and orbital roof. The availability of easily contoured, large resorbable sheets makes it possible to form templates using in situ anatomy for ex vivo back table assembly of the bone graft reconstruction.

In a 59-year-old man, kicked in the right fronto-orbital area by a horse, osseous debridement was carried out at the time of initial neurosurgical repair. Three months later he underwent reconstruction of his defect, which included absence of the frontal bone; supraorbital, lateral, and medial orbital rims; and orbital roof. A full thickness bone flap from the right parietal skull was split, and the inner table was replaced and fixated with a resorbable mesh that was contoured before the craniotomy. A template of the desired orbitocranial defect was formed using a sheet of 0.75-mm-thick MacroPore mesh, and the cranial bone graft was then cut to fit into the mesh template and fixated with tacks. The construct was fitted into the defect and secured around the periphery with additional tacks. Three months later the cranio-orbital contour was excellent, the patient's preoperative diplopia completely resolved, and a ptosis correction was scheduled to complete the reconstruction.

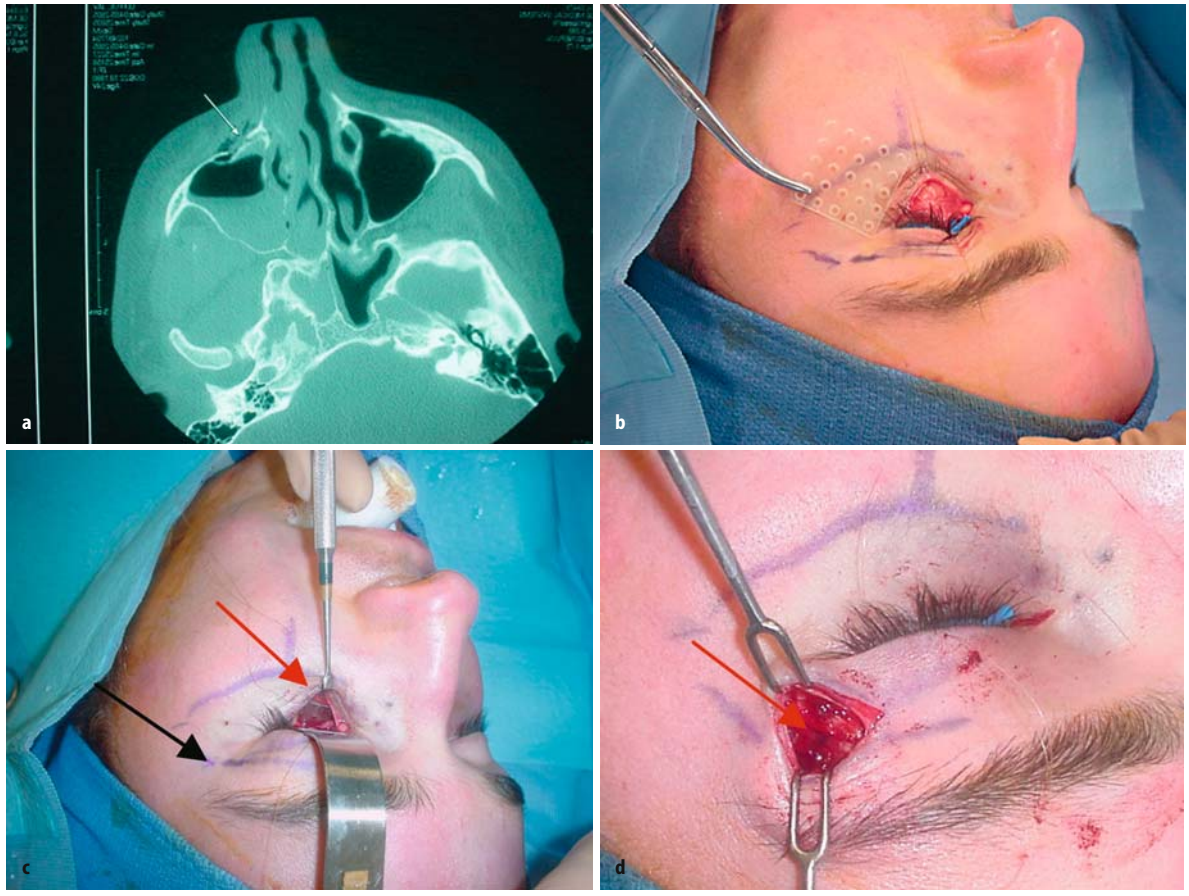

Fig. 21.3. Orbital fracture treated with bioresorbable plating system, a new biomaterial PLA. **a** Patient with a fractured orbit; **b** PLA panel shaped to insert in the orbit via transconjunctival; **c** PLA inside the orbit; **d** transpalpebral PLA fixation

21.12 Evolution

Our experience is primarily with a pediatric craniofacial population, in a practice that stresses treatment of traumatic injuries of the craniofacial skeleton. However, our application of the techniques of fixation is similar to controlled osteotomies, noncontrolled osteotomies, as well as multiple craniofacial fractures. Over time our initial utilization of preformed plate design has been replaced by the use of sheets of mesh, which are easily cut to fit the requirements of repair for a given fracture. This choice is a matter of preference. With complex reconstructions, we have found that easily contoured resorbable mesh permits quick creation of templates that guide bone graft assembly to a precise and accurate reconstruction. We anticipate that techniques will continue to evolve as more experience is gained with the properties of resorbable copolymers used for craniofacial fracture fixation and reconstruction.

21.13 Other Utility Biomaterials

The above descriptions of biomaterials reflect those that are used most often in clinical practice. Today there are many surgeons who prefer the use of metallic implants, particularly titanium, for the correction of facial fractures. Two points, however, must be stressed. First, in children, it is the standard of care to use bioresorbable plates and screws to mechanically stabilize the craniofacial skeleton, and it is impermissible to do otherwise. In these patients there is a higher likelihood of screw migration, growth disturbances, and a need for unnecessary secondary operations. Second, for the adult population, repeated surgery may also be avoided with the use of bioresorbable plating systems.

Other biomaterials are used to a lesser extent in patients with craniofacial trauma. Their use is limited to delayed reconstruction and, very rarely, such biomaterials are applied in the primary care of patients with multiple facial injuries. Fixation of the skeleton in the correction of facial fractures is the primary use for bioresorbable co-polymers. When a defect in the craniofa-

cial areas must be reconstructed, the use of bone grafting is the treatment of choice for those patients. However, if that treatment is not an option or will precipitate a major disability for the patient, the surgeon should be knowledgeable in the applications of those biomaterials in use and familiar with the indications and contraindications of all such biomaterials.

21.13.1 Polymethyl Methacrylate

The use of methyl methacrylate was popular after World War II. However, analyzing that experience, we have learned that such biomaterial should not be used in type II wounds or in any contaminated areas of the craniofacial skeleton. Infection and fistulization often result, even when the biomaterial utilized for the repair has been present for over 30 years. The utility of the application of methyl methacrylate is in covering large defects in the skull. It is also used to protect the brain when skull defects are present. The reported incidence of infection varies due to the longevity of use and because of the transient nature of the population in this country. The lack of standardized records, continuity of care, and information reporting contribute to the inaccuracy of existing data. Methyl methacrylate is also used to correct contour abnormalities in patients with trauma. The same principles apply for the avoidance of use in contaminated areas and type II and III wounds. This biomaterial application should always follow a list of strict indications and contraindications to achieve the best possible outcome for trauma patients. The last aspect that should be noted is that reconstruction of large defects in the skull may achieve the immediate purpose for the desired result, but the patient will end up with a shatter effect if the area is subjected to other blunt trauma. Reinforcement with metallic mesh did not alleviate that issue.

21.13.2 Silicones

Silicone rubber in the form of room temperature vulcanizing silicone (RTV) or prefabricated silicone components was used in skull repair, but was found to have no added value. Use of silicone was very popular in the early 1970s, and served in reconstruction to fill defects in areas of traumatic injury or for contour abnormalities. The applications for silicone today are limited. This material is capable of causing major complications in dynamic sites due to its ability to erode the underlying bone.

21.13.3 Polyetherurethane Terephthalate and Medpor

Both materials are used in a similar fashion to silicone but have less utility in trauma patients. We have extensive experience in the use of polyurethane mesh as a contour and enhancer for bone regeneration for large defects in the skull. However, large sheets of bioresorbable biomaterial have replaced its use by obviating the need for secondary surgery to remove the implant [7].

21.13.4 Bone Substitutes

To complete this discussion, we must also note the various bone substitutes that are in use today and available in most operating rooms. Bone substitutes react with the surrounding tissues to make the application more appropriate. Their main use is for filling defects that need a scaffold. These biomaterials do not stand sheer force, even after they consolidate, and are mechanically unstable. A second, more useful, application is for contour abnormalities.

We are not going to put a recommendation on any one of these biomaterials, but we will list them in a systematic way that will help those interested know the differences between each component.

21.13.4.1 Biomaterials as Bone Substitutes

1. Osteo Inductive: Demineralized bone implants vary from 17 % to 99 %. Use should be species specific, so that there is no crossing of species boundaries. Dynagraft 17 %
2. Osteo Conductive: Calcium sulfate, calcium phosphate, and calcium carbonate combinations. Norian, Mimex, Bonepaste
3. Bioactive and Interactive: Composition is changed when in contact with the biological system. Bioglas
4. Tissue Engineering: Active cells and active scaffold are needed. Scaffolds used vary from hydroxyapatite to collagen to most of the degradable carriers. The stem cells used must be autologous in nature. Such uses in the trauma patients are under study today and have limited applications.

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Innovative Techniques in Noma Reconstructive Surgery

22

E.H.M. Hartman, P.A. Van Damme, S.H.H. Suominen

22.1 Introduction

Noma (orofacial gangrene, necrotizing ulcerative stomatitis, stomatitis gangrenosa, or cancrum oris) is a devastating orofacial gangrene that occurs almost uniquely among children in less developed countries, during the weaning period [5, 6, 10, 11, 37, 38]. The most important risk factors are: poverty, malnutrition, a compromised immune system, poor oral hygiene and a lesion of the gingival mucosal barrier, as well as an unidentified bacterial factor [5]. The disease has an estimated global yearly incidence of 25,600 – 140,000 cases and a mortality rate of approximately 90% [13]. Patients who survive the acute noma stages generally suffer from its sequelae, including serious facial disfigurement, trismus and ankylosis, oral incontinence, and speech problems. This is why noma has been called "the face of poverty" [10, 26]. The complex facial defects can be classified with the NOITULP system, as proposed by Marck in 1998 [27]. NOITULP is an acronym of Nose, Outer lining, Inner lining, Trismus, Upper lip, Lower lip and Particularities. Every item is validated and given a score from 0 to 4 (Table 22.1).

The Noma Children's Hospital in Sokoto, Nigeria, is an international center for research and treatment of noma patients and training of healthcare professionals in Africa. To date it is the first and only one of its kind and it is situated in the West African sub-Saharan, Sahel region.

Table 22.1. NOITULP classification

NOITULP	Loss of tissue				
	0	1	2	3	4
Nose	0	1/4	1/2	3/4	1
Outer lining	0	1/4	1/2	3/4	1
Inner lining	0	1/4	1/2	3/4	1
Trismus	Full mouth opening	< 4 cm	< 3 cm	< 2 cm	< 1 cm
Upper lip	0	1/4	1/2	3/4	1
Lower lip	0	1/4	1/2	3/4	1
Particularities[a]					

[a]Particularities: pathological findings relevant for reconstruction (e.g., loss of orbital floor)

22.2 Treatment

This chapter deals with the various reconstructive procedures of the sequelae of noma. Since it is beyond the scope of this article, no description of the treatment of acute or fresh noma will be given here.

Depending on the extent of the defect that is caused by noma and depending on the existence of trismus or ankylosis, which is reflected in the NOITULP classification of the patient, a variety of surgical procedures are performed. The main reconstructive principles which apply to the treatment of this patient group are:

1. Excision of all scar tissue to achieve healthy tissue margins and to visualize and quantify the extent of the defect (Fig. 22.1)
2. Treatment of the ankylosis between mandible and malar-maxillary complex (Fig. 22.2)
3. Closing of the defect by transposition of vital soft tissue for reestablishment of the orofacial functions and aesthetics and to prevent reankylosis (Figs. 22.3 – 22.6)
4. Postoperative care and particularly physiotherapy is of the utmost importance. Exercises to gradually open up the mouth with wooden spatulas (Fig. 22.7) or a TheraBite [37] (Fig. 22.8) for at least

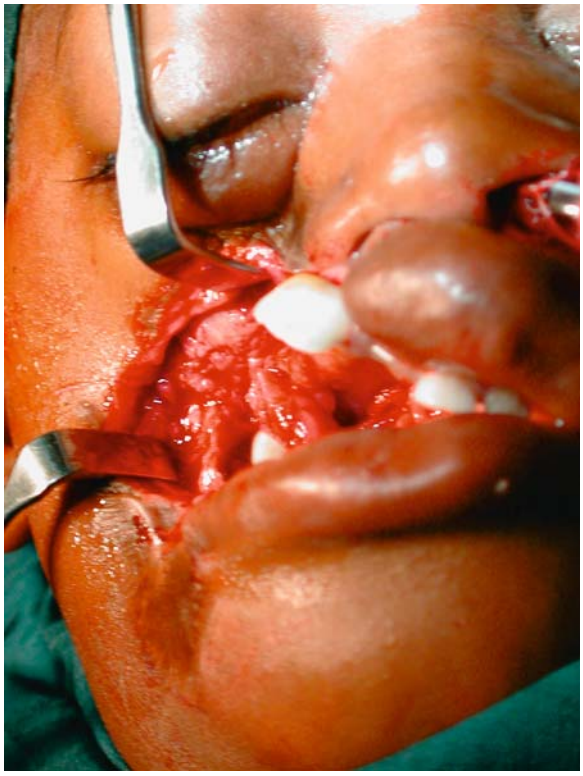

Fig. 22.1. In this 8-year-old girl with a NOITULP of 0444100, all scar tissue was excised

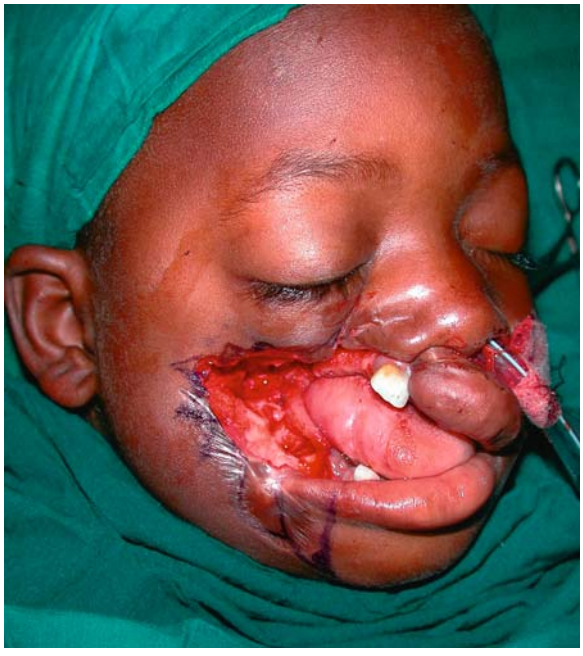

Fig. 22.2. After excision of this scar tissue, a bony ankylosis was treated

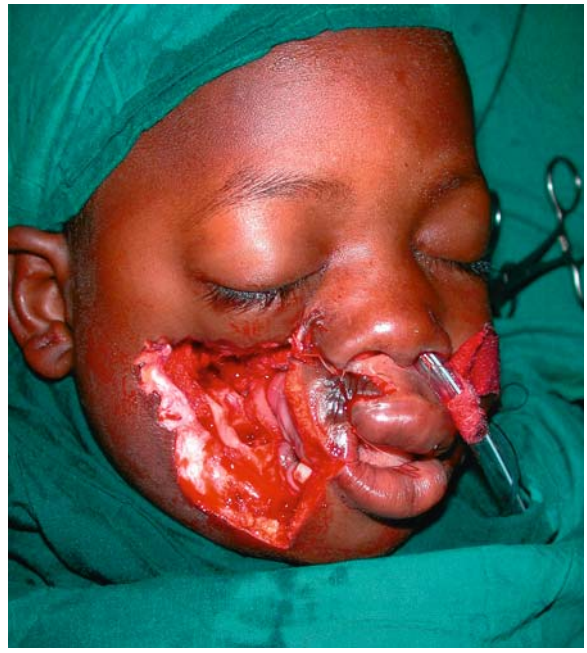

Fig. 22.3. To restore continuity of the upper and lower lip, an Estlander flap procedure was performed

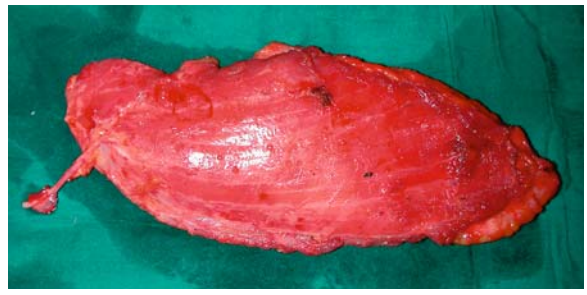

Fig. 22.4. A free latissimus dorsi flap was used to reconstruct the remaining defect

6 weeks, but preferably much longer, are a *conditio sine qua non* for the success of this kind of surgery.

22.2.1 Excision of Scar Tissue

The visible defect in noma sequelae is always the end result of an initially much wider defect that healed by secondary intention, with contraction and constriction. The purpose of scar removal is to release all adhesions so that facial components can be drawn back to their anatomical position and the true extent of the defect is visualized. It is quite easy to underestimate the true size of the defect before the scar has been excised. Proper removal of scar tissue also ensures vital margins and promotes healing of the newly introduced flaps. However, not all scar is hard and useless; sometimes a part of the scar tissue can be transposed and used for

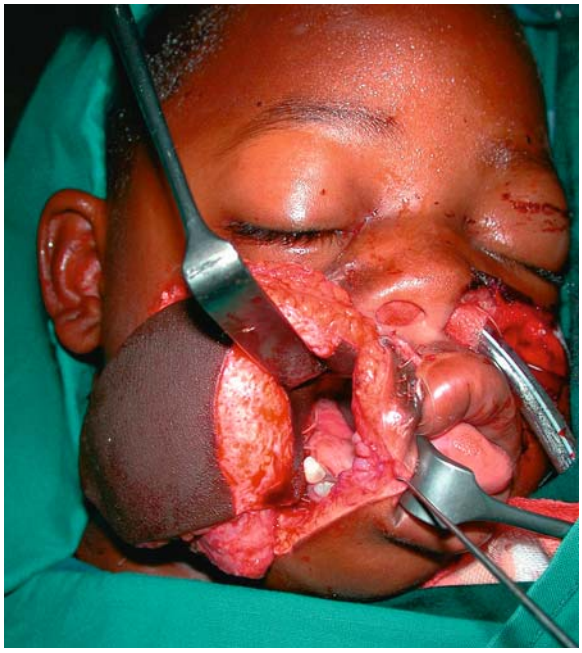

Fig. 22.5. The skin island was used for inner lining; a deepithelialized part of the flap was used to restore the cheek/lip continuity

Fig. 22.6. A deepithelialized part of the skin was used for transposing vital tissue between the mandible and the maxilla to prevent reankylosis

a part of the lining as a turnover flap [23]. As the skin part of the scar tends to be of a darker color, it is preferable to use it for inner lining and then use a flap for the outer surface reconstruction.

Fig. 22.7. Wooden spatulas are used for postoperative exercises. The importance of this physiotherapy cannot be overestimated

Fig. 22.8. A patient using a TheraBite, a modern method for postoperative exercises

In noma of the cheek the scar tissue often prevents mouth opening. So-called ankylosis can either be fibrous or bony, or a combination of both. In established noma, generally extra-articular muscular damage (buccinator, orbicularis oris, medial pterygoid, masseter and temporal muscles) has initially caused trismus, which together with soft tissue scar contracture has developed into fibrous ankylosis [14]. In the more severe cases a bony union between the maxilla and the mandible is responsible for ankylosis [14].

Since we are dealing with young children, growth and development disturbances will be encountered. Facial asymmetry and tooth eruption disturbances are the consequences, especially when bony bridging occurs between the “fresh” wound edges of the mandible

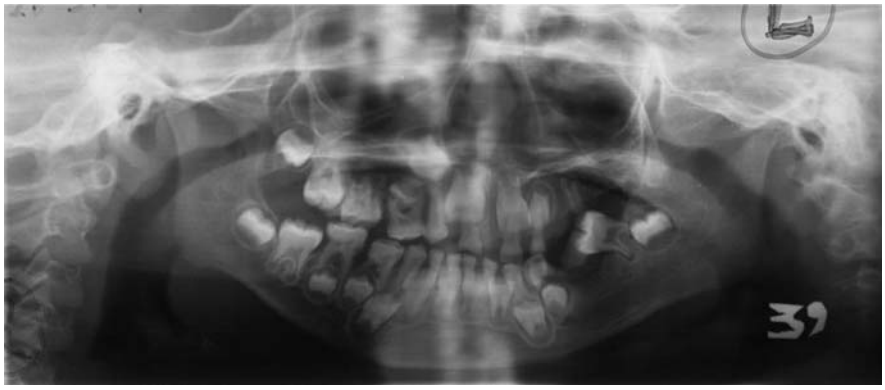

Fig. 22.9. Noma ankylosis left side

on one side and the malar-pterygoid-maxillary complex on the other side, when the medial pterygoid and masseter muscles are involved or invaded by the gangrenous infection, and necrotectomy (debridement) has been performed. Furthermore, enlargement of the coronoid process has been noticed on both the affected and nonaffected side. The reason for this hypertrophy of the so-called muscular process is still unclear, but it might be reactive overstimulation of the inserting temporal muscles. Whether or not the lateral pterygoid muscle is involved, at least on the affected side, should be one of the themes of further research. Inactivity, i.e., inability to move the mandible, leads to irreversible damage to the cartilaginous articular surfaces and the articular disk of the temporomandibular joint (TMJ). This mechanism affects both TMJs and surrounding structures, as well as capsule and ligaments, depending on the duration and extent of the disorder.

Up to May 2004, in Sokoto, it was impossible to obtain proper orienting radiographic images of the situation in the case of ankylosis. Since then, it has been possible to generate orthopantomograms showing the extent of the bony ankylosis in particular cases (Fig. 22.9).

When parts of the scarred tissues are preserved, they can be used as (part) of the new intraoral lining, however, with the inherent risk of renewed limited opening of the mouth [23]. Sometimes the skin part is used as a free graft to interpose between the "fresh" bony surfaces to prevent reankylosis, or when the TMJ itself is involved to interpose between the remnants of the glenoid fossa and the condylar head.

22.2.1.1 Dental Deformities Caused by Noma

The most often discolored and tight scarred perioral and peridental soft tissues can either be excised in total or partially preserved.

When they are fully removed an overview of the residual oral situation is possible, allowing an initial depiction of the defects in the extra- and intraoral lining. Most often the dental situation is one of crowded teeth, with adverse labiobuccal or lingual version or inclination of erupted deciduous and permanent incisors, cuspids, and (pre)molars: this is called dental anarchy [36]. Frequently the permanent teeth are malpositioned, retained and impacted, sometimes with crossing over in the mandibulo-malar-maxillary ankylosis complex. Very often there is an accumulation of dental plaque and calculus with gingivitis, gingival retraction, periodontitis and dental caries. There is a fetid odor and easy gingival bleeding upon removal of the calculus or the loose teeth. In cases of limited opening of the mouth (less than 40 mm measured between the 11 and 41), this is the moment to inspect and evaluate the cause of this restriction.

22.2.2 Treatment of Ankylosis

When "only" fibrous ankylosis is diagnosed, the technique to apply is to try to open the mouth preferably using a Heister clamp/instrument (Fig. 22.10). Several other devices for mouth opening exist but they are less effective and less safe. Nevertheless, the instruments should be used carefully in order not to fracture the mandible, or damage the teeth, especially in young patients. The advised sequence is the following: try to open the mouth digitally or with an instrument, e.g., a raspatory or a tongue spatula. If there is enough space to introduce the Heister, use this instrument alternating the left and right side (preferably protecting the teeth by a silicone tube covering of the ends of the instrument), or simultaneously when you have two instruments. Frequently, there are large amounts of dental calculus on the lingual aspect of the lower teeth. These may break down, and prevention of lung aspiration has to be taken care of. Protection of the teeth, to prevent luxation, avulsion and fracture of them, should also be applied. Most often, there is a progressive resistance against further opening.

Then, via a buccal inferior vestibular approach a coronoidotomy or better still a coronoidectomy can be

Fig. 22.10. The Heister mouth gag, which can be used in ankylosis surgery

performed, after administration of local anesthesia in that area with epinephrine 1/80,000 and subperiosteal preparation, with a reciprocating saw or a chisel and a hammer. This is preferably performed on both sides in cases of hyperplasia or hypertrophy of the coronoid process (Fig. 22.11). Usually, it is not easy, not to say quite difficult, to take out the coronoids. They can best be preserved in physiologic salt solution when used for transplantation purposes, for instance for reconstruction of the infraorbital rim (Fig. 22.12).

When the mouth has been opened fully, up to the limits of extensibility, quite often there are signs of luxation in the joint(s) (the condylar head has moved beyond the top of the articular eminence), like sounds of clicking and crepitations when the mandible is moved by hand.

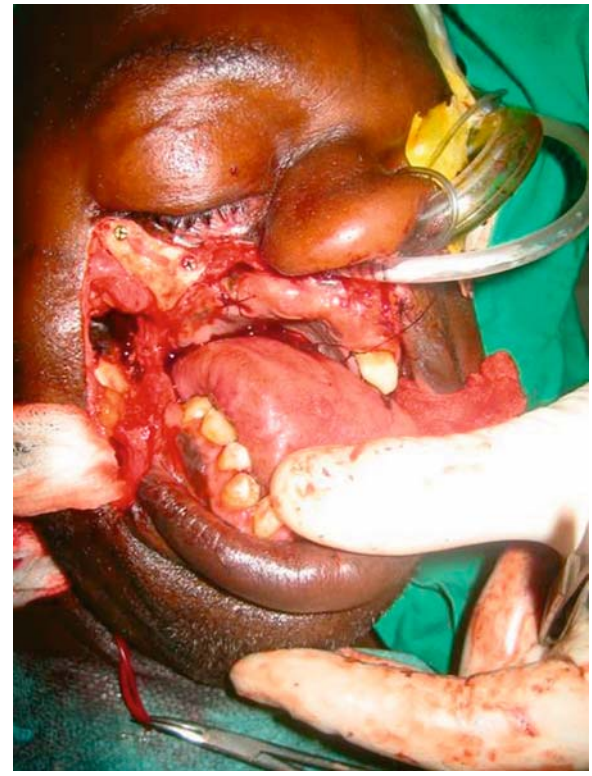

Fig. 22.12. Resected coronoid process used as a bone transplant to reconstruct the infralateral orbital rim

In case of heavy fibrous or a bony ankylosis, osteotomy or better still ostectomy of the bony bridge between the malar-pterygoid-maxillary complex and the mandible has to be performed (Fig. 22.2).

Preoperative orthopantomographic imaging is a tremendous help in the estimation of the extent of this ankylosis. Sometimes the teeth are dispersed or scattered in this area in a criss-cross fashion and these will hamper the osteotomy procedure performed with the saw.

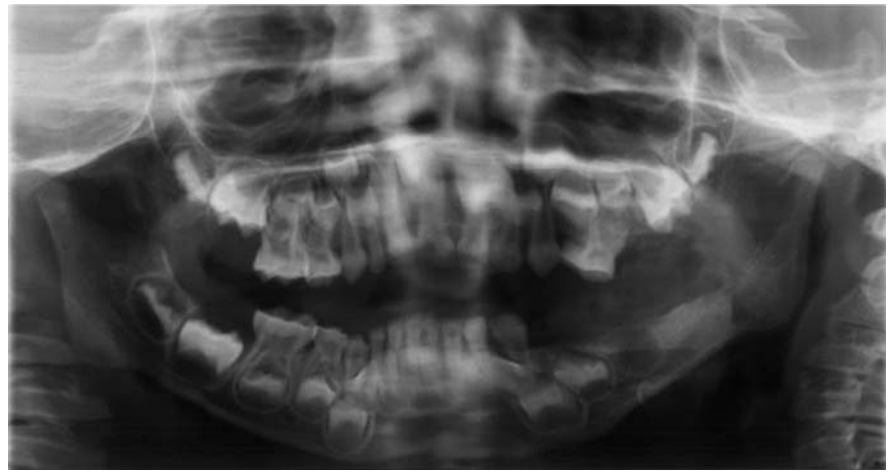

Fig. 22.11. Noma left side postoperative bilateral coronoidectomy

The teeth, including the roots, in this section have to be removed during the surgical procedure. A hammer and chisel in combination with a bone nibbler (rongeur) and the Heister instrument may be of help. Care has to be taken to prevent damage to the mandibular (inferior alveolar) and lingual nerves at the medial aspect of the ascending ramus of the mandible. The same holds for the maxillary artery at the medial side of the condylar process of the mandible. Once it has been opened enough, the edges can be smoothed and rounded using a drill and diamond burrs or fraises. Only then is the true extent of the defect visible. In order to stop the bleeding in this area, and to fill the defect and to prevent reankylosis, it is advised to interpose vital soft tissues.

22.2.3 Closing of the Defect

In order to close the defect which has been recreated, it is necessary to transpose vital soft tissue into this defect. As the visible defect is the result of the shrinkage and constriction of an initially much larger one, one must always be prepared to transpose/transfer a flap large enough or even a bit larger. One bigger flap is usually to be preferred over several smaller flaps, and additional scarring in the surroundings should be avoided if possible. Local options provide a better color match but at the expense of new visible scars.

A wide variety of flaps is at the disposition of the reconstructive surgeon. We will consider the available options with the reconstructive ladder in mind (Fig. 22.13): use "easy" local flaps if possible, and "less easy" regional flaps or "difficult" free flaps when needed.

Fig. 22.13. The reconstructive ladder, as painted by Armando, a Dutch artist (Amsterdam, 1928)

22.2.3.1 Local Flaps

Forehead Flap

The forehead flap is maybe the oldest flap described for reconstructive surgery and is especially suitable for nose reconstruction due to its pliability and the good color match. A median flap can be transposed on the supratrochlear or supraorbital vessels. This can be done either in one stage or using a tubed pedicle that is divided at a later stage. Although often designed in the midline, the flap can also be drawn obliquely to either the ipsilateral or contralateral side, to obtain more length. A clover leaf like design with three leaves is typical of a total nose reconstruction. A drawback is that since most patients are children or adolescents, the donor defect can often not be closed primarily, but will heal by secondary intention with contraction, which will result in an additional visible scar in the face (Fig. 22.14). It is not advisable to skin graft the donor site, because this is likely to result in even more conspicuous scars.

A lateral forehead flap is raised on a branch of the superficial temporal artery, and all of the forehead skin can be raised on this flap. However, this obviously leaves a large disfiguring scar and brow function is per-

Fig. 22.14. The donor site of the forehead flap might cause conspicuous scars in the donor site

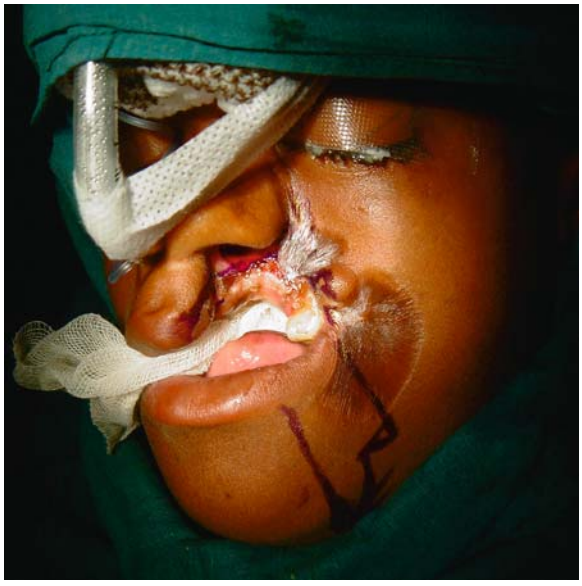

Fig. 22.15. For smaller cheek defects, an Estlander flap can be an almost ideal flap

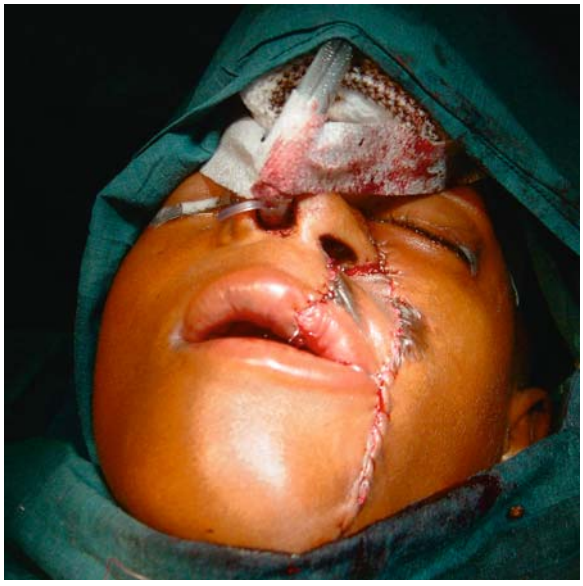

Fig. 22.16. The defect has been reconstructed with "like with like" and the donor site has been closed primarily

manently lost. Therefore we feel this is only a secondary option and to be used only in carefully selected cases like salvage procedures.

Abbe Flap

The Abbe [1] and Estlander [12] flaps are the most frequently used flaps in noma surgery. Noma defects are situated near the mouth and usually a part of the lip is missing. Therefore it is logical to borrow from the intact lip and "replace like with like" to restore oral continence. These flaps can easily be used in combination with other flaps like the cheek rotation flap or even free flaps. The Abbe flap is designed in the intact lip so that it is transposed on the labial artery to fill a defect. The mouth is therefore partially closed for several weeks until the second small operation in local anesthesia, in which the pedicle is divided and the flap is trimmed. The lip can carry a skin island of several centimeters to reconstruct a larger defect. This procedure is typically used for central lip defects. Special attention should be given to the aspects of mouth opening, food intake and oral hygiene during the healing phase of these flaps. The major drawback might be the restricted mouth opening possibilities, especially in cases of preexisting trismus or ankylosis.

Estlander Flap

Most lip defects are in the corner of the mouth and the Estlander flap is a natural choice [12]. Like the Abbe flap, this flap is based on the labial vessels and can carry an even larger skin island with the lip. The dimensions of this flap can be of sufficient size to reconstruct smaller defects of the cheek (Figs. 22.15, 22.16). The donor site can be closed primarily. Just like the Abbe flap, this flap is often combined with pedicled or free flaps: after restoring the continuity of the lips by the Estlander flap, the cheek defect is closed with a separate skin flap, like an anterolateral thigh flap.

Cheek Rotation Flap

The cervicofacial rotation advancement flap as described by Mustardé [28] is well recognized for reconstruction of cheek defects. The vascularity stems from the facial artery. In lateral noma defects the vascularity from the facial artery might be at risk. Wide undermining in the appropriate tissue layer and elevation of the flap will allow for adequate covering of locoregional defects with tissue of adequate thickness, texture and color match. Especially in the elderly, the laxity of the skin permits primary closure of the donor site. This flap can be used in conjunction with other flaps.

22.2.3.2 Regional Flaps

Temporoparietal Fascia Flap

As has been described in earlier publications, the intraoral lining of a through and through defect can be supplied by using a prefabricated temporalis fascia flap covered with a partial thickness or split skin graft (Fig. 22.17) [7]. In this technique, the need for two separate operations is a clear disadvantage, although Nayak presented good results when skin grafting the flap in

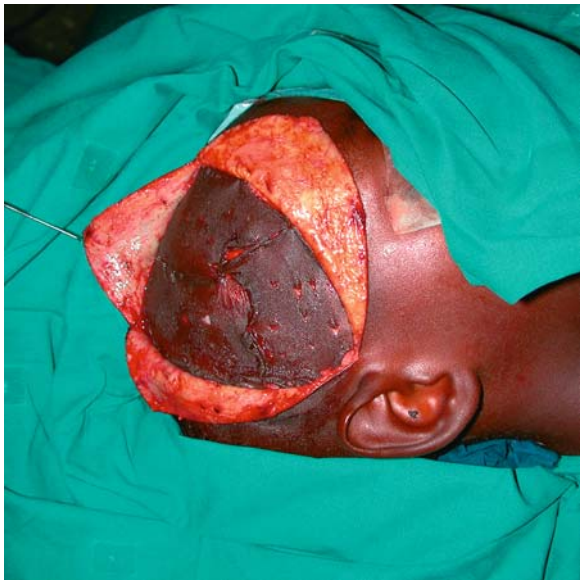

Fig. 22.17. In this 9-year-old boy a prefabricated temporoparietal fascia flap is to be used for inner lining of his NOITULP 1420200 defect

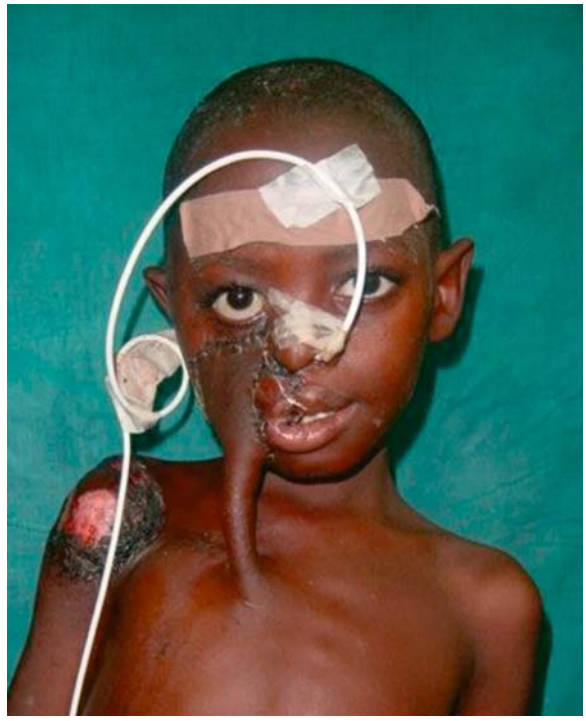

Fig. 22.18. In this same boy a delayed deltopectoral flap has been used. Note the disfiguring donor site of the DP flap

one operation [29]. In order to introduce the flap, a coronoidectomy and sometimes even an osteotomy of the zygomatic arch is mandatory. The zygomatic arch can be left interrupted or can be reconstructed by repositioning of the osteotomized segment and fixation with osteosyntheses. Of course, a skin graft is not ideal for reconstruction of intraoral soft tissue: the tendency of skin grafts to contract can cause a fibrous or fibrotic trismus [14]. This can occur, even in patients who did not have any problems with their mouth opening before the reconstruction [8, 16, 29]. In these cases, a resection of all fibrotic tissue to correct the trismus is mandatory. Subsequently the defect will have to be closed by another skin flap [16].

Deltopectoral Flap

The pedicled deltopectoral [PD] flap was originally described by Bakamjian in 1965 [4], who used it in pharyngo-esophageal reconstruction. The vascular supply comes from the second intercostal perforator of the internal mammary artery. To enhance the reliability of the flap, especially in extended flaps as used in noma surgery, it is advised to perform a delay procedure 1 week before transposing the flap. This is done by raising the distal tip of the flap and dividing the cutaneous branch of the thoracoacromial artery in the triangle of the infraclavicular fossa. Although this flap is reliable and gives a good color match in reconstructions in the face, it has some disadvantages. As in all pedicled flaps, a second operation is necessary after 3 weeks to cut the pedicle and inset the proximal part of the pedicle into its original place (Fig. 22.18). Further, closure of the donor site at the shoulder with a split skin graft leaves a disfiguring donor site, especially for young girls (Fig. 22.19). These are the main reasons why this flap would not be our flap of first choice.

Pectoralis Major Flap

Ariyan described the use of the musculocutaneous pectoralis major flap in 1979 [3]. This flap is very reliable and has been the workhorse in head and neck reconstructive surgery for decades. In noma patients the flap has been used [2], but in contrast to patients with head and neck cancer, no neck dissection is necessary and so tunneling the flap under the skin of the neck can be difficult. The tight neck skin of these patients can cause compression of the bulky pedicle with subsequent (partial) failure of the flap. Of course it is possible not to tunnel the pedicle, but then the pedicle has to be divided in a separate procedure at a later time.

Latissimus Dorsi Flap

A bulky flap like the latissimus dorsi is most useful in NOITULP 44 cheek outer and inner lining defects. This flap comprises a part or the entire latissimus dorsi muscle with an overlying island of subcutaneous tissue and fat. The skin island can be designed in a horizontal or an oblique manner (the latter producing superior scars

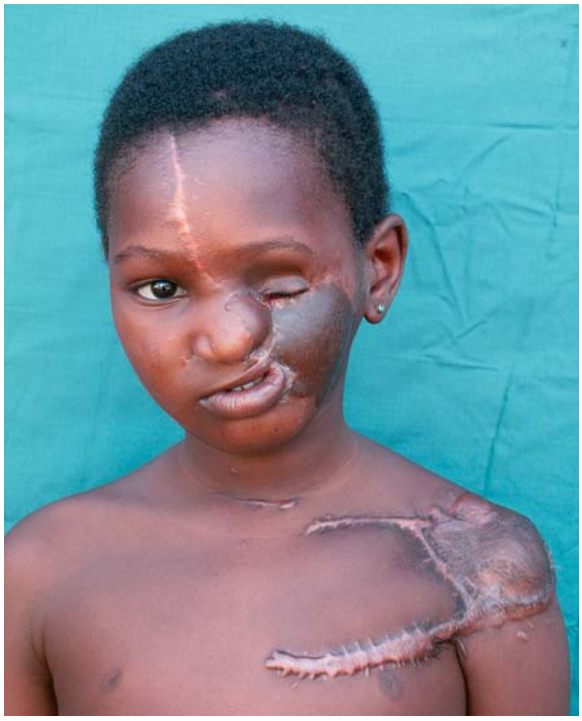

Fig. 22.19. A young girl was operated on by previous teams. Her defect was reconstructed using a DP flap and a forehead flap. The scars over the shoulder and over the breast are disfiguring

at the donor site), and depending on the patient flaps of 8 – 10 cm in width can still be closed primarily. Typically, this flap has been used as a tubed pedicled flap, as it is easy and reliable to raise. However, tubing the pedicle comprises its length and there is a risk of dehiscence. Alternatively the flap can be tunneled through a subcutaneous tunnel, but then a risk of compression arises. A third option is to open a channel for the pedicle and place it there under direct vision, maybe also with a part of the skin island over the pedicle to prevent tightness. These are all usable methods, but often the pedicle length simply is not long enough. If the flap can be inset without tension as a pedicled flap, there is no problem, but it can be safer to transfer the same tissue as a free flap, anastomosing either to the superficial temporal vessels or to the vessels of the neck.

When used as a musculocutaneous flap, this flap is quite bulky, even in these thin noma patients. This will necessitate secondary revision operations to debulk the flap.

Therefore it can be wise to raise the skin island only with a small muscle cuff or without muscle as a true thoraco-dorsal artery perforator flap (TDAP [20]). This will produce a much less bulky flap. Dissection of the perforators increases pedicle length by several centimeters facilitating the inset.

Fig. 22.20. An 18-year-old boy is classified as a NOITULP 1444200, which means that he has a complete trismus with a complete absence of inner and outer lining of the cheek

Supraclavicular Flap

The supraclavicular flap was first described by Lamberty and Cormack as an axial pattern fasciocutaneous flap [25]. Pallua used the supraclavicular flap as an island flap for the release of a mental scar contracture [30]. In a recent anatomical and clinical study by the same author, the arterial part of the pedicle of this flap – the supraclavicular artery – was confirmed to be a constant branch of the transverse cervical artery [31]. The vascular territory of this flap extends from the supraclavicular region to the shoulder cap [18, 19]. The area of this angiosome ranges from 10 cm in width and 22 cm in length, to 16 and 30 cm, respectively. The supraclavicular flap may supply the noma reconstructive surgeon with skin with a texture and color that makes it suitable for reconstructions in the facial area. The inset of the flap, as with all flaps, is of the utmost importance. The reliability of the distal part of the flap can be improved either by using a fascial pedicle [9], or by using a delay procedure in order to use the flap for reconstructing outer as well as inner lining in a one stage procedure. Usually, there is little donor site morbidity, because the donor site can be closed primarily after wide undermining. Although this is not a perfect flap, it does give the reconstructive surgeon the opportunity to close large defects in the face in one operation, without the need for microsurgical skills [17] (Figs. 22.20 – 22.23).

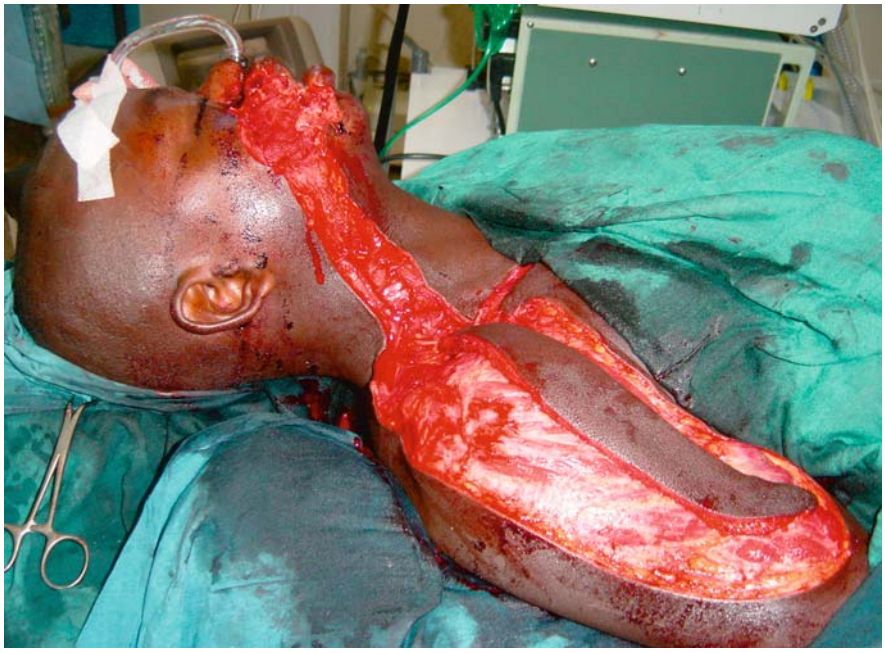

Fig. 22.21. After excision of all scar tissue and release of the ankylosis, the supraclavicular flap has been raised

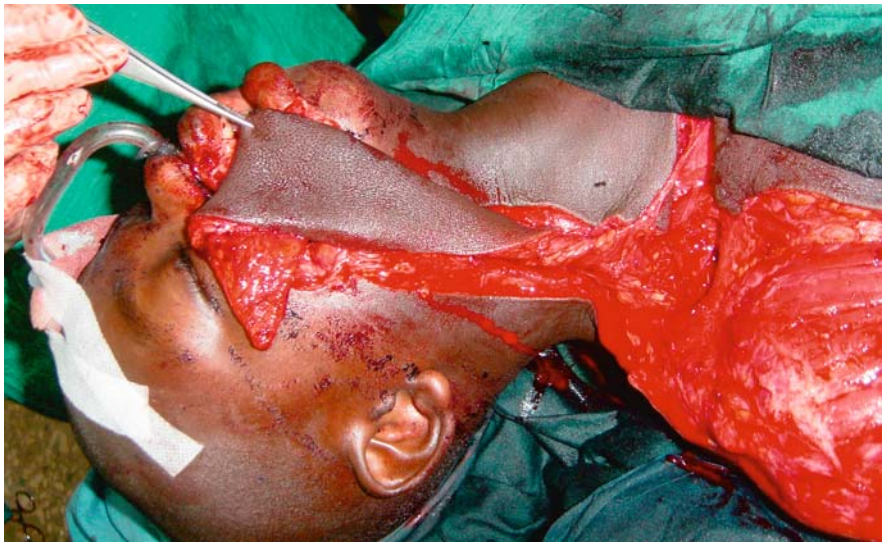

Fig. 22.22. The supraclavicular flap is folded upon itself for reconstruction of inner and outer lining. The pedicle is not tunneled under the tight skin of the neck, but inset into the incision in the neck, to prevent circulatory problems due to compression

Submental Flap

Through and through defects often require free flaps, but the submental flap is a good option for smaller defects. The submental area provides a thin pliable flap with good color match to the cheek and a well hidden donor site.

The flap is based on the submental branch of the facial artery [32]. The dissection of the pedicle is quite tedious and requires loupe magnification. However, it is worthwhile as if the pedicle is freed down to its base at the carotid artery, the flap can be transposed to cover defects of the buccal area, or even the upper lip. It can also be raised on reverse flow from the nasolabial artery [21], but this is rarely usable in noma patients as this area is often involved in the scar.

The submental island flap can also be raised as an osteocutaneous flap to reconstruct a defect in the premaxilla area, including a submental segment of the mandible. However, the flap is at its best in coverage of lateral buccal defects or for intraoral lining after trismus release. A skin island of at least 6 × 12 cm has been raised even in children, and a 2 – 4 cm extension of platysma muscle can be included if extra filling is needed for a dead space after coronoidectomy and trismus release. Most noma patients need both inner and outer lining and as the flap is thin and pliable it tolerates folding to provide both inner and outer lining. It may of

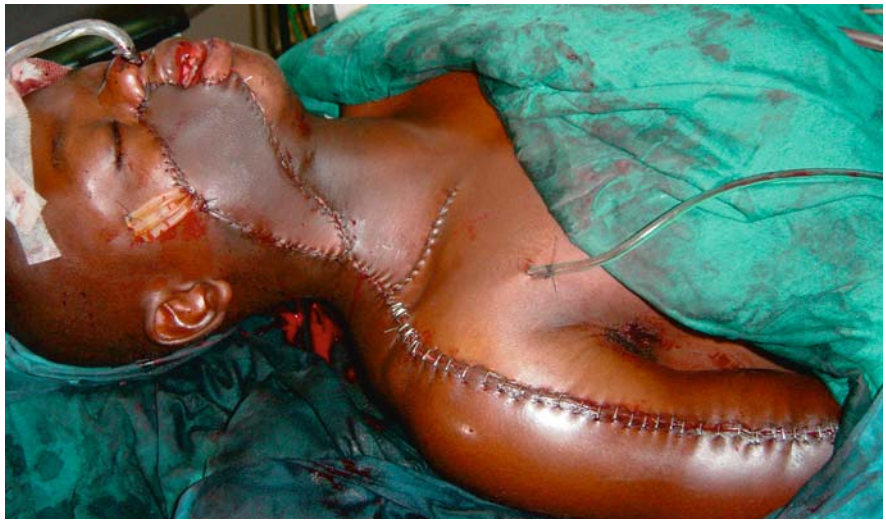

Fig. 22.23. The direct postoperative result: with one pedicled flap the defect is reconstructed

course be combined with other local flaps, like the superficial temporal fascia flap [7], but in large defects a free flap is probably more advisable. Caution is advised when using the submental flap on patients with big lateral through and through defects as experience has shown that the artery may then be involved in the scar and be rudimentary. A pulsating artery should be palpable preoperatively.

The donor defect should be designed so that it can be closed primarily and that it will be well hidden under the chin. The initial tightness of the donor defect may even support trismus rehabilitation by opening the mouth.

22.2.3.3 Free Flaps

Latissimus Dorsi Flap

This flap has already been discussed in the pedicled flap paragraph, but of course this flap can be used as a free flap as well. Whenever there is tension because the pedicle of the flap is short, it can be wise to change and turn the procedure into a free flap (Figs. 22.1 – 22.6). Although the problem of tension is solved, bulkiness can still be a problem. In these cases, a perforator flap can be a nice solution [20].

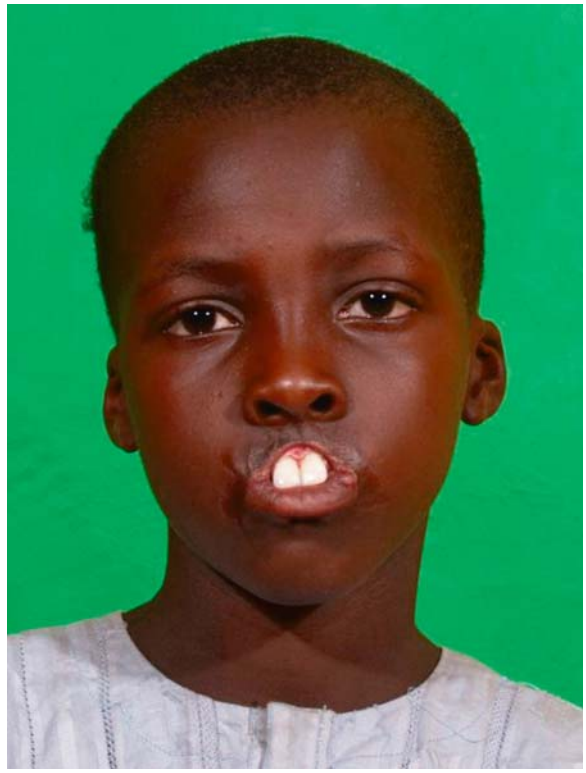

Fig. 22.24. A complete absence of the upper lip (NOITULP 0000400) is an ideal indication for a free radial forearm flap

Radial Forearm Flap

The radial forearm flap was introduced in the English literature by Song et al. [34] in 1982, but was originally developed in the Shenyang Military Hospital in China by Yang et al. [40]. It has since become the workhorse of head and neck surgeons worldwide as it is a relatively easy flap to raise, with constant anatomy well described in the literature. It provides thin pliable tissue and if a suprafascial elevation technique is used, the donor deficit is mainly of aesthetic nature. In the hands of a noma surgeon it is useful when thin coverage is needed, especially suitable for defects of the entire upper lip (Figs. 22.24, 22.25), but unfortunately it is usually too small for coverage of NOITULP 44 lateral cheek defects where bulkier flaps are necessary.

The radial forearm flap has also been raised as a tubed pedicled flap, but this technique is quite uncom-

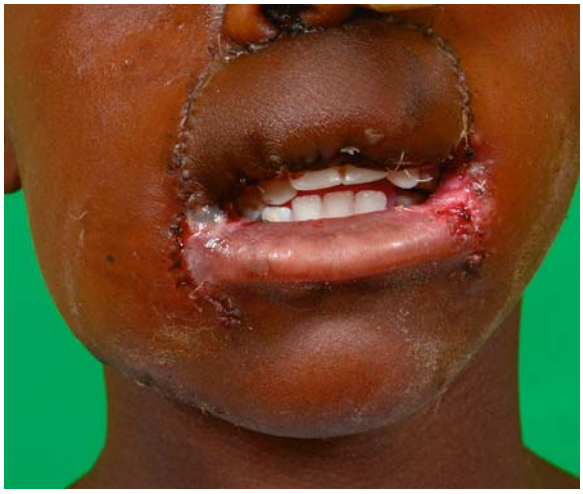

Fig. 22.25. The free radial forearm flap is folded upon itself for reconstruction of the inner and outer lining of the upper lip

fortable for the patient, requiring immobilization of the upper limb to an awkward position for a long period of weeks. The tubed pedicle is prone to be torn or twisted and a second operation is required to inset the flap properly. In our experience this method is not advisable as defects of such size can usually be covered by other simpler means.

Parascapular Flap

The pedicle of the (para-) scapular flap consists of the terminal branches of the circumflex scapular vessels, which accounts for a pedicle as long as 14 cm. The flap is associated with the subscapular vascular system, which makes it a very versatile flap: the flap can be combined with other tissues based on this same pedicle: the latissimus dorsi and serratus anterior muscle, the TDAP flap and bone from the scapula [33]. Dissection of the flap is in the lateral supine position, which enables two teams to work simultaneously. Although the flap can be quite bulky in Europeans, in noma patients the flaps are very thin and ideal for facial reconstruction. The color match of the skin island is less ideal: the skin can become much darker than the surrounding normal skin [15]. Especially in complex defects, this flap can provide a large amount of well vascularized tissue for reconstruction of inner and outer lining with one flap.

Anterolateral Thigh Flap

The anterolateral thigh flap (ALT) is a versatile flap first described by Song et al. [35] in 1984, and popularized for head and neck surgery by Koshima [21]. The skin island is designed on a line between the spine of the iliac crest and the lateral corner of the patella, and its size can range from a few centimeters around a perforator to the entire lateral aspect of the thigh. Flaps of less than 9 cm in width can as a rule be closed primarily.

The cutaneous perforators can usually be localized with the help of a hand held Doppler, but if a bigger flap is planned it is not always necessary to pinpoint the vessels as they can be found 1 – 2 cm lateral to the drawn line. In about 30 % of patients there is a septocutaneous perforator leading to the flap, but in the other 70 % the flap is nourished by a musculocutaneous perforator, which makes perforator dissection more tedious. According to our experience, the perforators may sometimes be so thin and fragile in the malnourished noma patients that the planning may have to be changed intraoperatively and converted to a musculocutaneous flap. It is advisable to keep the cranial part of the flap untouched until the quality of the perforators has been evaluated. One then still has the option of converting to a free tensor fasciae latae flap, as it can support the same cutaneous island.

If these precautions are taken into account, this flap is a useful tool in noma surgery as it can be raised as a thin perforator flap or as a bulkier musculocutaneous flap. If two good perforators can be found the flap can be divided into two separate parts to help in inset. If the donor defect is closed primarily the donor site morbidity is virtually negligible [22, 24], although sacrifice of the cutaneous nerve leads to a sensory defect in the distal thigh. In our hands this flap is the flap of choice in complex noma defects (Figs. 22.26 – 22.32).

22.3 Discussion

The smaller defects in noma surgery can be excellently reconstructed by local flaps, thereby complying with the “like-for-like” principle. The Estlander flap is an almost ideal solution for reconstruction of partial lip defects. Smaller cheek defects can reconstructed with a cheek advancement flap, with nice results. For reconstruction of nasal defects, the forehead flap remains the gold standard of choice, partly because of the very good color match of the skin. But in larger defects in the face, multiple flaps will have to be used with additional scarring as a result. In these more complex cases it is advisable to avoid this additional scarring and to proceed to larger flaps. Pedicled locoregional flaps can be a solution, e.g., submental or supraclavicular flaps. A distinct disadvantage of these pedicled flaps is the fact that the vascularity of these pedicled flaps is always less at the site where the flap is needed most. Free flaps on the other hand have a lot of advantages in these more complicated cases. Although musculocutaneous flaps can be used, usually these flaps are too bulky and they need secondary operations to thin the flaps. An example is a free latissimus dorsi muscle flap, which was used in an

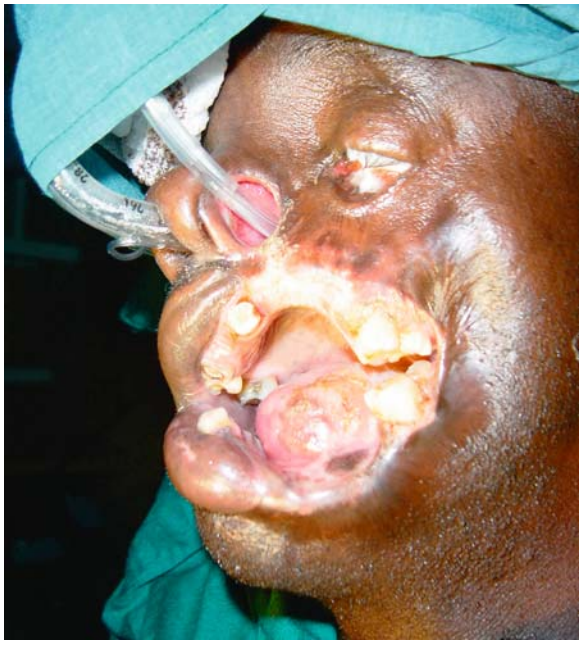

Fig. 22.26. A patient with a NOITULP of 244322 is planned for a reconstruction with an ALT flap

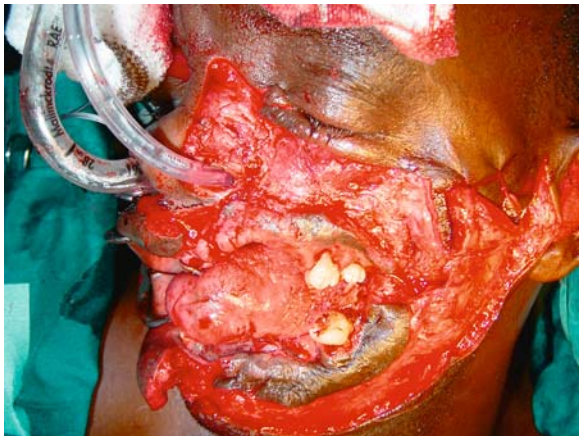

Fig. 22.27. After scar excision and trismus release, the dimensions of the defect are visualized

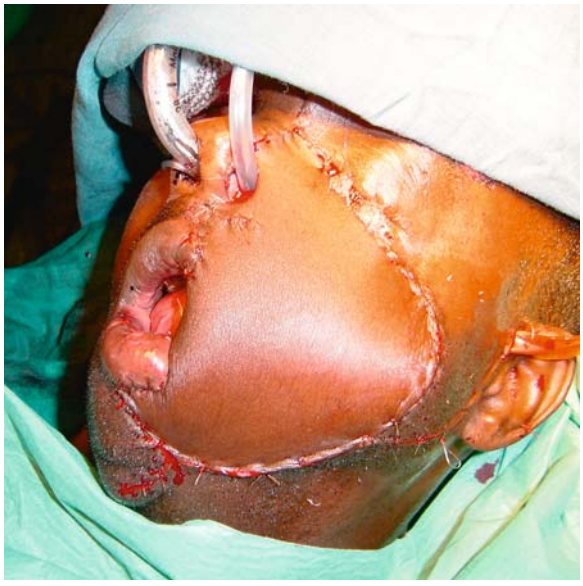

Fig. 22.28. Reconstruction of inner and outer lining is accomplished with one flap

Fig. 22.29. The short term postoperative result is promising

8-year-old girl (Fig. 22.6). Cutaneous flaps are thinner and thus more applicable for reconstructive purposes. Although the radial forearm flap is a well recognized flap which can be used for whole upper lip reconstructions, the flap is small compared to the large defects that usually are associated with the complex noma cases. Another disadvantage of this flap is the donor site morbidity, especially if a skin graft is needed for closure. The flap is preferably to be taken on the left hand site, because people in the Sahel region rely on their right hand for working and eating. Parascapular flaps have been used in noma surgery with good results. These flaps have enough volume and the donor site can be closed primarily. A disadvantage is the lateral positioning of the patient during flap harvesting, which makes the facial dissection more difficult. An alternative flap is the ALT flap. This flap can be raised with the patient in a supine position, which makes the facial dissection, performed simultaneously by a second team, easier. Especially in noma patients, this flap is very thin because the patients have hardly any subcutaneous fat, and the flap can be used with nice results with hardly any donor site morbidity [39].

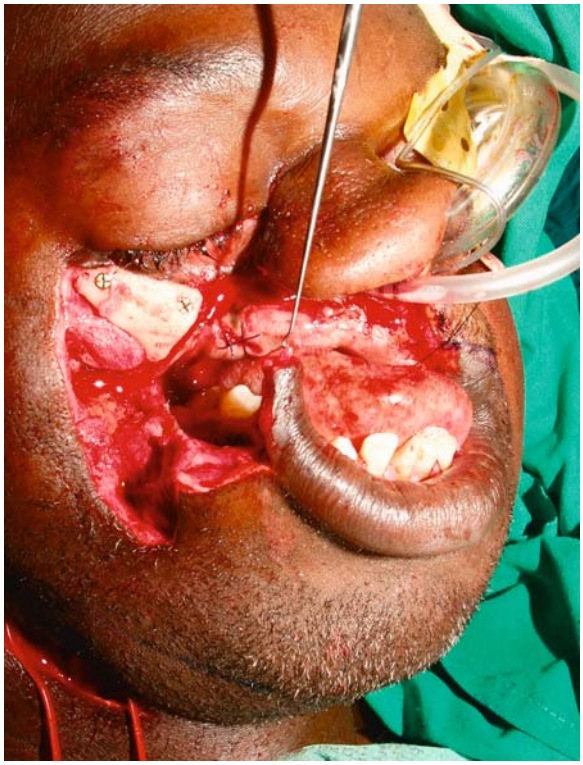

Fig. 22.30. A 40-year-old man with a NOITULP classification of 144330 is treated with a scar excision, bilateral coronoidectomy. The right bone is used for augmentation of the infraorbital rim. Note the incision just under the vermillion of the lower lip that will be used for inset of the skin flap, to become a more natural result

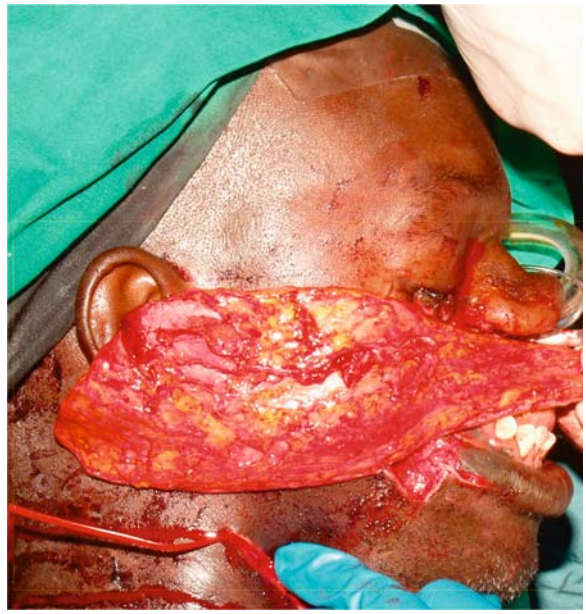

Fig. 22.31. The ALT flap is used for intraoral lining...

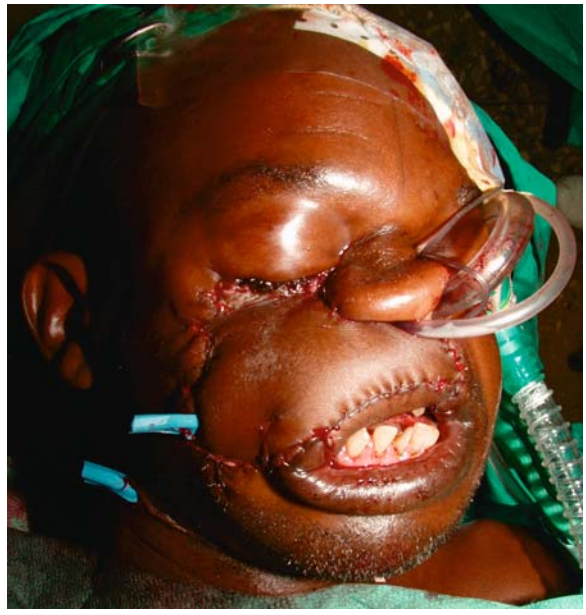

Fig. 22.32. ...and extraoral lining. The upper lip has been optically recreated by designing the transition of the inner and outer lining in the form of the upper lip

If an ALT flap is used, the operation can be done by two teams simultaneously, which will reduce the operation time. The donor site morbidity of the ALT flap is quite low: in case of a primary closure the only morbidity is a vertical scar on the upper leg. The amount of tissue can be chosen as needed. Intraoral lining as well as extraoral lining can be reconstructed with one flap. Especially in complex cases, which often include an ankylosis, there is sufficient tissue to interpose deepithelialized skin to prevent recurrence of ankylosis.

22.4 Conclusions

In this chapter about innovative techniques in reconstructive surgery for the sequelae of noma, we have shown that there is no “one and only” solution for these complex problems. Excision of scar tissue and elimination of any bony ankylosis should be performed to visualize the true extent of these defects and to provide a fresh wound bed for optimal healing of the flaps used in reconstruction. Only from that moment on should the reconstructive surgery start. Smaller defects should be replaced by local tissue according to the ’like with like” principle. Larger defects would need multiple flaps with inherent additional scarring; that is why in these cases we prefer one larger flap to multiple smaller flaps. Regional flaps, like the supraclavicular or submental flap, can be used, or free flaps, like the ALT flap or the parascapular flap, which are nice skin flaps that provide enough tissue without the problem of bulkiness in these noma patients. At the same time interposition of

vital tissue to fill the space between the bony surfaces of the mandible and the maxillo-malar-pterygoid complex, can be achieved to prevent a recurrence of ankylosis in the future. Furthermore, in order to prevent relapse of the ankylosis in the immediate postoperative period and later on, physiotherapy is mandatory, either with wooden spatulas, or with a more modern treatment in the form of a TheraBite. The innovative aims in the near future are to focus attention on one stage procedures with free revascularized flaps. When using a two team approach, for which the ALT flap is ideal, these operation sessions can be performed in a relatively short time. In this way the quality of care for these patients will be maximized and the donor morbidity minimized. Functionality and aesthetics have to go further in order to rehabilitate these patients with their faces of poverty [38].

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Aesthetic and Functional Innovations in Jaw Reconstruction with Free Fibula Flap

23

G. De Santis, M. Pinelli, F. Gargano, A. Baccarani

23.1 Introduction

Jawbone reconstruction is one of the most challenging procedures and has evolved dramatically over the past 50 years, due to numerous advances in microsurgery techniques and instrumentation. Defects in the mandible can result from benign and malignant tumours, trauma and bone atrophy and are classified according to its location [27] and amount and quality of tissues involved [9, 42]. Defects involving the mandible and adjacent structures represent a reconstructive challenge, and functional and aesthetic results are correlated most closely with the degree of soft tissue loss. In fact, combined mucosal and skin defects have worse outcomes compared to oral cavity soft tissues or bone losses alone [24].

Different methods of reconstruction can be selected, according to the defect type and associated conditions. Non-vascularized bone grafts are indicated for only small bone defects not requiring soft tissue reconstruction, defects resulting from resection of benign tumours and fracture non-unions. Previous irradiation, infection, scar tissue and lack of soft tissue covering represent contraindications to its use. Prosthetic plates and soft tissue flaps have shown high failure rates [10] and their use is limited to those cases not otherwise candidates for vascularized mandible reconstruction. Larger and anterior defects are best treated with vascularized bone grafts [12, 18, 29].

Large composite jaws defects are particularly difficult to reconstruct, such as those referred to in the past as "the forgotten patients" [5] because the methods of reconstruction and rehabilitation were unpredictable and functional outcomes were less than desirable. Pedicled osteomusculocutaneous flaps have been demonstrated to rarely be indicated in these conditions, because of the drawbacks due to a limited amount of bone, poor vascularity, limited insetting flexibility and increased morbidity [24].

23.2 Innovations in Jaw Reconstruction

In recent years, two significant advances have been made in restoring oral function for patients with jaw defects: osseointegrated implants and free flaps.

Osseointegrated implants provide an effective means of retaining, stabilizing and supporting the restored masticatory apparatus [1, 43]. Today, the free flap is considered the gold standard to predictably restore large, complex defects at the time of jaw resection, and its tissues are better suited for oral function [14, 31, 40]. Absolute indications for its use are composite defects greater than 6 cm or the presence of poor vascularized tissues [19, 35].

Although a number of donor sites are available and suitable for providing vascularized bone and soft tissue for jaw reconstruction [39], there is no ideal site for all applications. However, the fibula flap possesses a number of characteristics that make it the preferred choice in many situations [25].

Jaw reconstruction should aim to restore basic functions such as speech, chewing and swallowing which are critical for a satisfactory quality of life. Restoration of jaw function depends on tempomandibular joint function and mastication. Different anatomic features concur to achieve these goals, such as jaw height, good dental apparatus and soft tissue reconstruction. The versatile free fibula flap provides, by modifications and innovations in its surgical technique, a unique single method to satisfy different reconstructive needs and achieve good jaw functional rehabilitation.

Fig. 23.1. Preoperative view of psammomatoid ossifying fibroma causing dyplopia and unstable maxillary alveolar arch

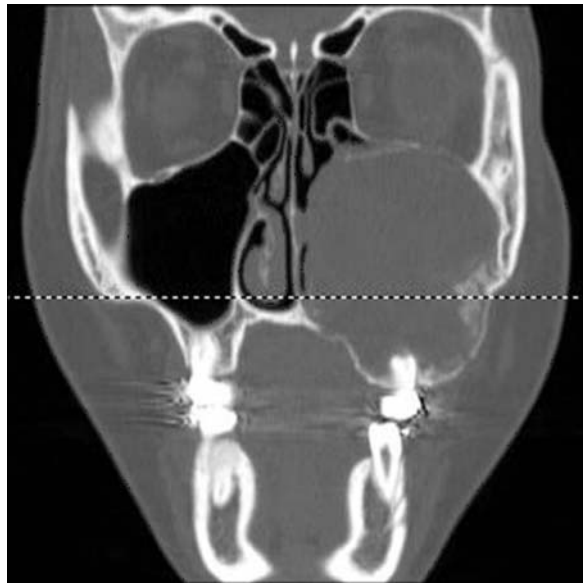

Fig. 23.2. Computed tomographic scan appearance of the fibroma ossificans tumour invading the left maxilla, nasal fossa and floor of the orbit

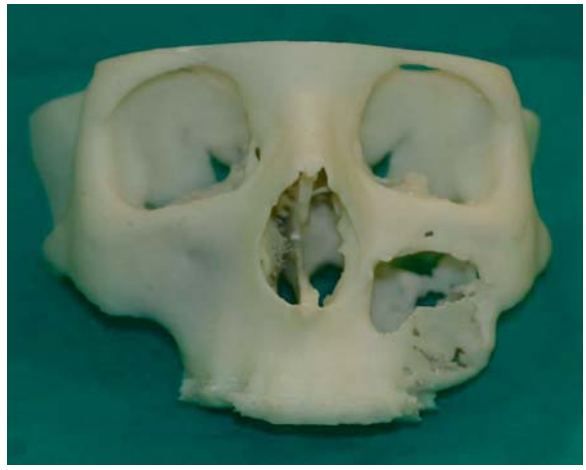

Fig. 23.3. Three-dimensional model that recreates the defect to reconstruct

23.3 Innovations in Free Fibula Flap Use

Surgical technical modifications in the fibula flap use allow functional and aesthetic innovations in terms of: (1) tridimensional reconstruction, (2) revascularization of adjacent osseous-cartilage elements, (3) bone remodelling and (4) functional rehabilitation.

23.3.1 Tridimensional Reconstruction of Complex Maxillary Defects

Three-dimensional reconstruction of the maxillary buttresses is of the utmost difficulty, especially when a single free fibula flap has to be used. Templates are useful devices for assisting in accurate graft shaping while the graft is left attached at the donor site, a practice that minimizes graft ischaemia time during the procedure. Classic methods for harvesting templates incorporate two-dimensional image reconstruction using cephalograms, computed tomography or magnetic resonance imaging.

The drawback of these techniques is a lack of a third dimension in order to achieve a virtual model of the defect. Recent advances have been made in the preoperative imaging using computed tomography applied to stereolithography models [38, 41]. Thanks to communications between the radiology, engineering and surgical laboratories, a thermoplastic material model is created using sequential scanning in coronal projections and offers the surgeon the real extension of a three-dimensional defect (Figs. 23.1 – 23.3).

Based on the preoperative evaluation of the real defect, the free fibula flap can be shaped to achieve the main reconstructive goals in complex maxillary defects, such as to give support to the orbital contents, obliterate communication between the mouth, nose, nasopharynx and anterior cranial base, reconstruct the palatal and provide enough tissue volume to achieve facial symmetry.

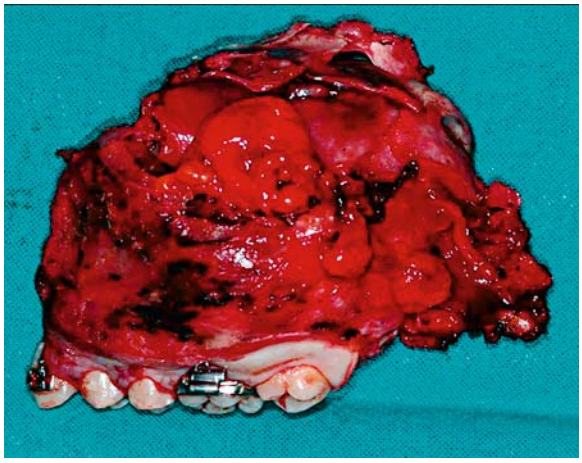

Fig. 23.4. Intraoperative specimen resected includes left maxilla, alveolar ridge, nasal fossa and floor of the orbit

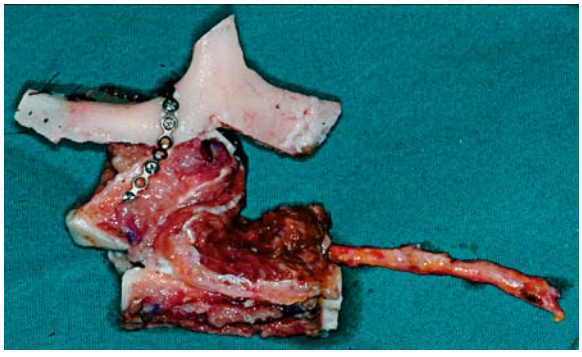

Fig. 23.5. Frontal view of the remodelled fibula: two osteotomies and plating allow the bone to be shaped to fill the defect anatomically. The zygomatic graft is secured to the flap by plates

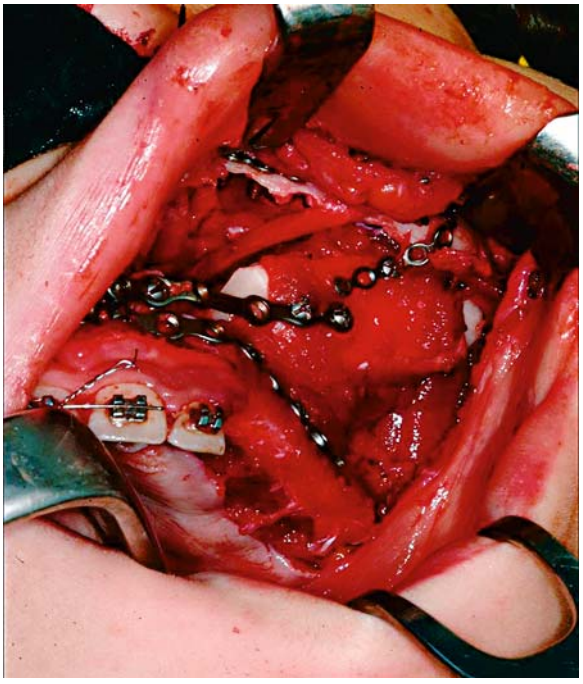

Fig. 23.6. Intraoral view of the tridimensional reconstruction of the maxilla and floor of orbit. Inset of the fibula flap. The double osteotomies give a Z-shaped flap to reconstruct the maxillary buttress; the splitting of the fibula also allows the reconstruction of the orbital floor while the zygomatic process is used as a bone graft

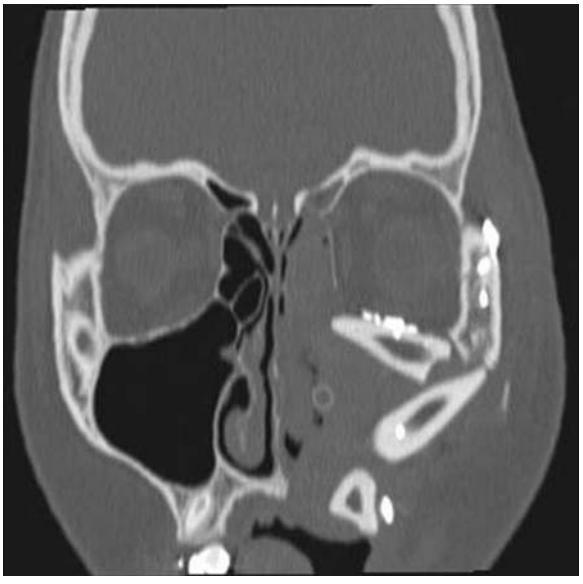

Fig. 23.7. Computed tomographic scan of the reconstruction. The Z-shaped flap reconstructs in a one-stage single-flap procedure the alveolar ridge, maxilla and floor of the orbit. The cheek bone graft is viable and revascularized by adjacent tissues

Complex maxillary and orbital floor defects can both be reconstructed in a one-stage procedure. In fact, given the segmental blood supply of the fibula, serial osteotomies can be made to reconstruct the maxillary buttress. Splitting of the bone can also provide vascularized graft for orbital floor reconstruction (Figs. 23.4 – 23.9).

Other three-dimensional reconstructions can be accomplished with the technique of the "double barrel" of the fibula flap [7]. This is particularly useful because the limited diameter of the fibula compared to the height of the mandible requires additional bone stock to match the vertical distance between the reconstructed segment and the occlusal plane. The importance of having vertical bone length is in the overloading of the osseointegrated implants that can endanger the longevity of the prosthetic restoration and rehabilitation. A fibula graft corresponding to at least twice the length of the mandible defect is harvested, halved perpendicular to its length, and the resulting struts folded on top of each other to achieve a "double barrel." The struts are then fixed to each other with screws and plates and stabilized in the defect using a reconstruction plate.

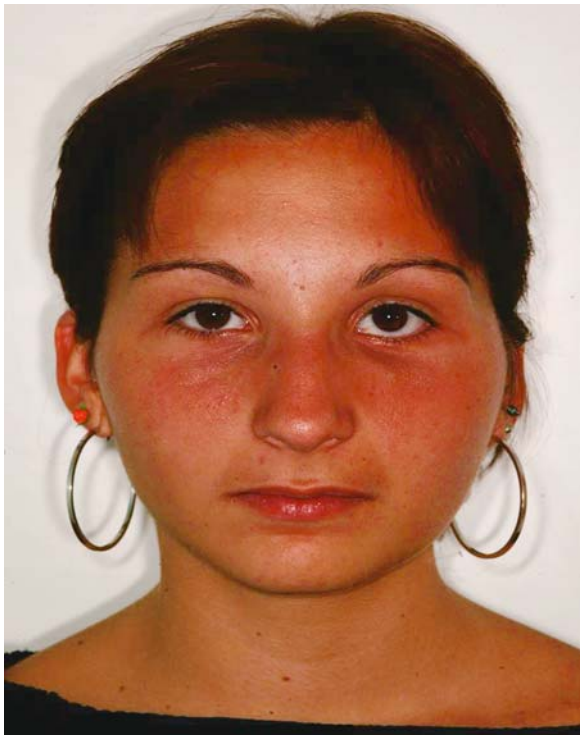

Fig. 23.8. Good functional and aesthetic results are achieved. Correction of the dystopia and reinstatement of the aesthetic contour of the face. A moderate left lagophthalmus is present

Three-dimensional combined maxillary and mandibular alveolar ridge reconstruction can be performed using a single fibula flap [32]. Performing six osteotomies of the fibula, seven bone segments are obtained (Fig. 23.10). The three most proximal segments, each 2.5 cm long, are shaped to reconstruct the mandibular ridge. The central segment of 4.5 cm is removed and the three most distal segments, each 2 cm long, are shaped as a maxillary arch (Fig. 23.11).

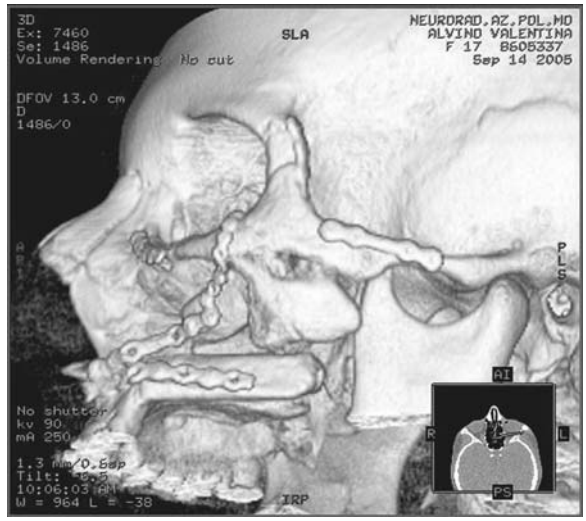

Fig. 23.9. Three-dimensional computed tomographic scan showing the combined maxillary and orbital floor reconstruction

The maxillary segments and the mandibular segments are then fixed to each other with microplates (Fig. 23.12). Once the flap is transferred to the oral cavity, mini-plates are used to fix the proximal segments of the fibula to the symphysis of the mandible, while the three distal segments are fixed to the paranasal buttresses by using two mini-plates. The vascular bundle of the fibula is placed along the vestibular side of the new mandibular arch and the palatal aspect of the new maxillary arch (Fig. 23.13).

23.3.2 Revascularization of Adjacent Osseous-Cartilage Elements

The highly vascularized fibula flap has the capacity to revascularize adjacent bone or cartilaginous graft, when they are required as an accessory specimen in the

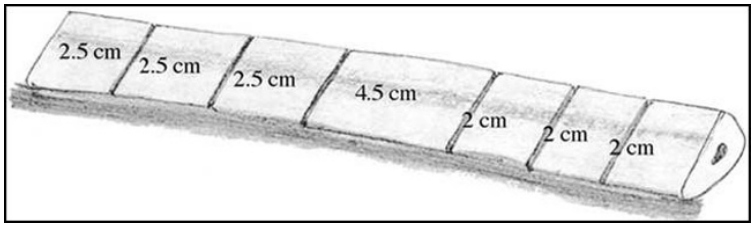

Fig. 23.10. Seven bone segments obtained

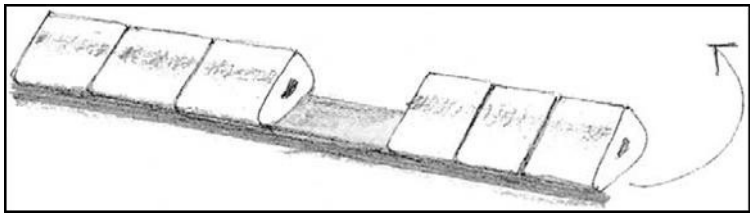

Fig. 23.11. Central 4.5-cm segment taken from the periosteal layer

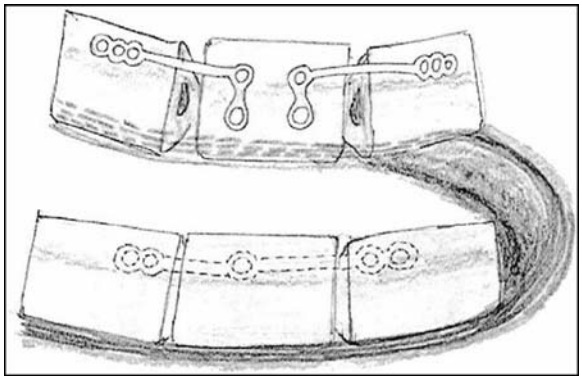

Fig. 23.12. Intersegmental fixation of the new mandibular alveolar process achieved with one straight microplate on the lingual side. Two labial L-shaped microplates were used to fix the three distal segments to be transplanted to the maxilla

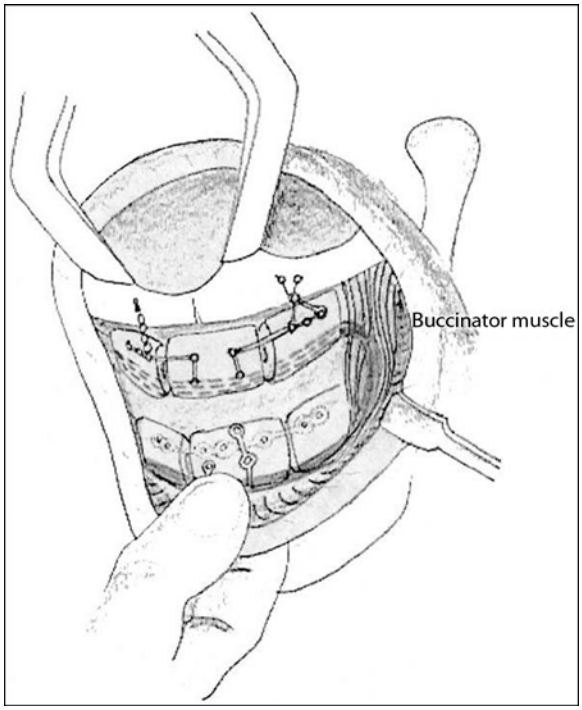

Fig. 23.13. Flap insetting. Fixation of the three proximal bone segments to the mandible, 180° counterclockwise rotation applied to the vascular bundle, and the three distal segments brought into position for fixation to the maxilla

reconstruction. The vascularized periosteum of the fibula flap has been demonstrated to quickly and easily integrate into the surrounding tissues; thus arterial ligation after 10 days does not compromise flap viability [11]. Standard X-rays, magnetic resonance imaging, bone scintigraphy and SPECT can be used to detect the revascularization of the adjacent graft [23].

This method can be applied successfully when the temporomandibular joint condyle needs to be reconstructed. The metatarsal head can be used as a bone graft (Figs. 23.14 – 23.16).

The same principle of revascularization of adjacent tissues can be used when vertical mandible height has to be restored. In these cases an alternative to the double barrel or other more recent techniques is the use of iliac bone graft inset on the fibula flap to augment the mandibular ridge (Figs. 23.17 – 23.22).

23.3.3 Bone Remodelling

Governing factors in cellular modelling and remodelling adhere to sound principles of engineering mechanics. The functional adaptation of dental supporting structures exhibits a characteristic stress distribution, promoting structural adaptation based on needs [6]. Strong correlations between loading pattern on oral implants and surrounding bone tissue and the remodelling phenomena are observed [8]. These data suggest that bone remodelling is the result of spontaneous loading movements on the implants. In fact, spontaneous reshaping of the fibula with time is often observed according to the loading forces and should be considered when planning a reconstructive procedure (Fig. 23.23, 23.24).

A classic example of induced bone remodelling is vertical distraction osteogenesis, a technique of gradual bone lengthening allowing for the natural healing mechanisms of the human body to generate new bone [26]. It offers a number of advantages over other traditional means of treatment of endochondral bone deficiencies. In fact, bone formed is of better quality and more reliable in time, because simultaneous soft tissue expansion and bone coverage are achieved during the distraction process. Recently, important results have been achieved regarding the histology and cellular biology of the remodelling event [28]. Osteogenesis in both endochondral and membranous bone distraction occurs primarily through membranous ossification with no evidence of a cartilaginous intermediate. Clinical results have shown it to be a successful method since its first applications and numerous clinical trials have demonstrated the reliability and advantages of the technique [21, 30, 36]. The vertical distraction can be applied successfully to lengthen the free fibula flap when complex defects have to be reconstructed or in young patients with segmental or subtotal bone loss (Figs. 23.25, 23.26).

Vertical distraction osteogenesis applied to the fibula flap offers the advantages of reinstating its bone stock without the need for a bone graft and simultaneous soft tissue growth. Drawbacks could be the need for two surgical procedures, a waiting time of 1 year after the primary surgery before applying the distractor to the flap, and patient compliance.

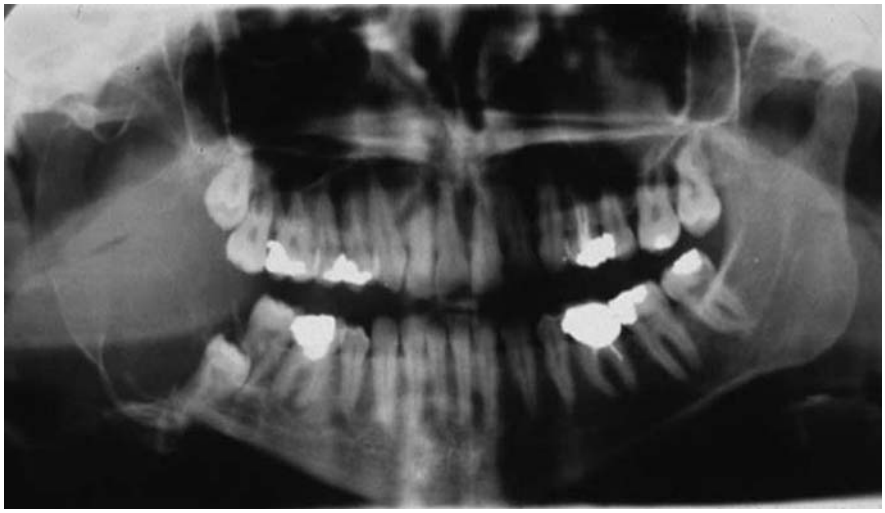

Fig. 23.14. Frontal X-rays: ameloblastoma of the ascending branch of the mandible involving the condyle of the temporomandibular joint

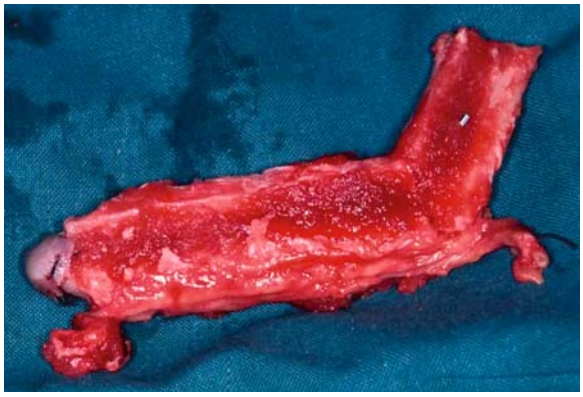

Fig. 23.15. Free metatarsal head bone graft to reconstruct the condyle

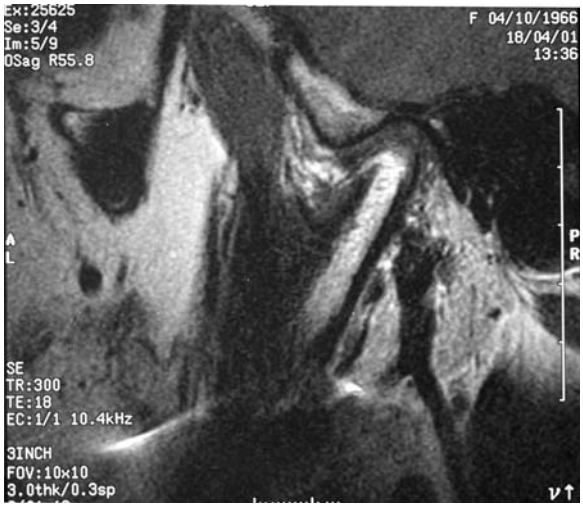

Fig. 23.16. Magnetic resonance imaging: control 6 years postoperatively. Revascularization of the bone graft that appears healthy and viable

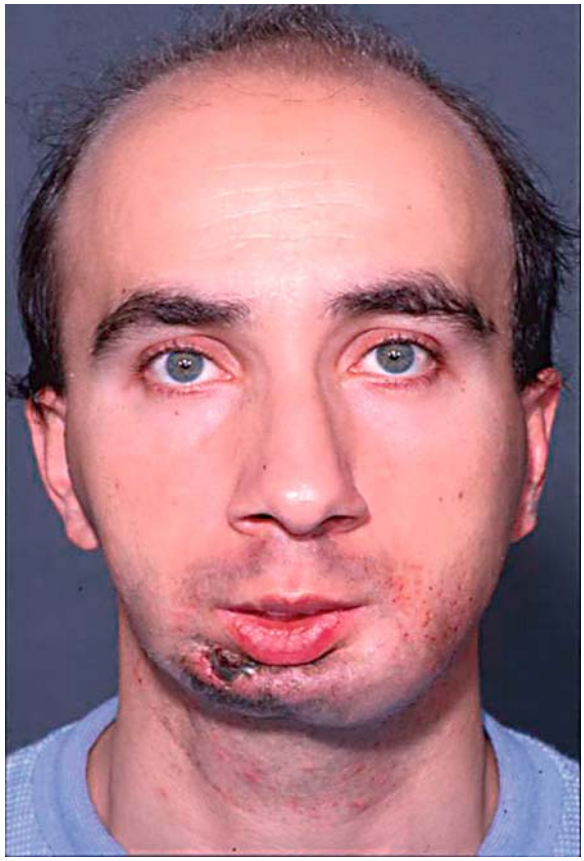

Fig. 23.17. Preoperative image of mandible non-union with exposed plate and bone loss

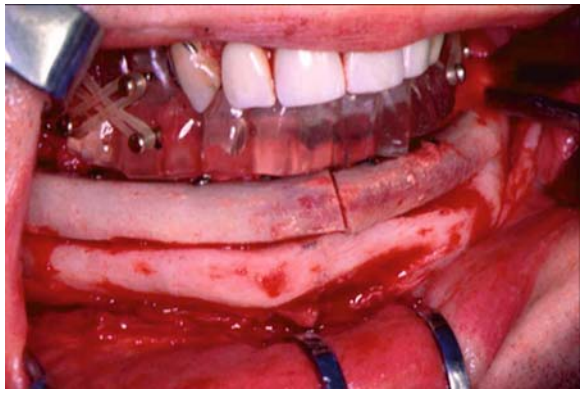

Fig. 23.18. Iliac crest graft inset over the vascularized fibula to enhance the mandible vertical height

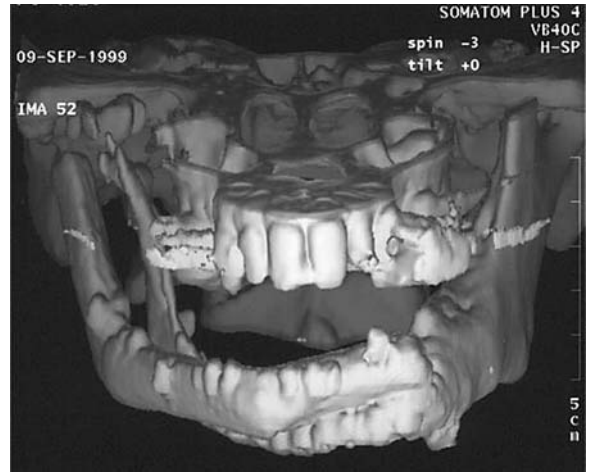

Fig. 23.20. Three-dimensional computed tomographic scan. Anteroposterior view showing the integration of the iliac crest graft

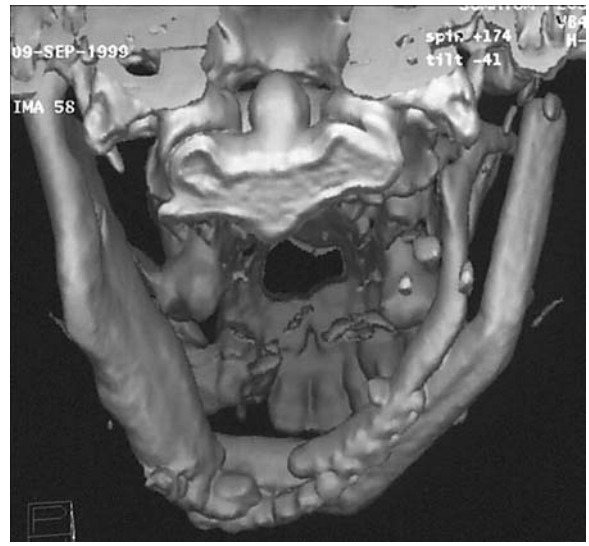

Fig. 23.21. Posteroanterior view of the same details

23.3.4 Functional Rehabilitation

Results of jaw reconstruction are evaluated by long-term functional outcome, aesthetic appearance, and bone retention. Restoration of mastication function in patients suffering from extreme jawbone atrophy or other kinds of bone loss requires alveolar bone reconstruction, placement of osseointegrated implants, and the creation of a stable peri-implant seal. A multidisciplinary treatment protocol is required in order to achieve these goals [16]. A maxillofacial surgeon, a microsurgeon, and a prosthodontist collaborate during all phases of the treatment. The rehabilitation protocol should include: (1) accurate multidisciplinary planning by instrumental evaluation and recreation of the defect model to be reconstructed, (2) alveolar ridge reconstruction or augmentation with free vascularized fibula flap, (3) osteosynthesis material removal and implant

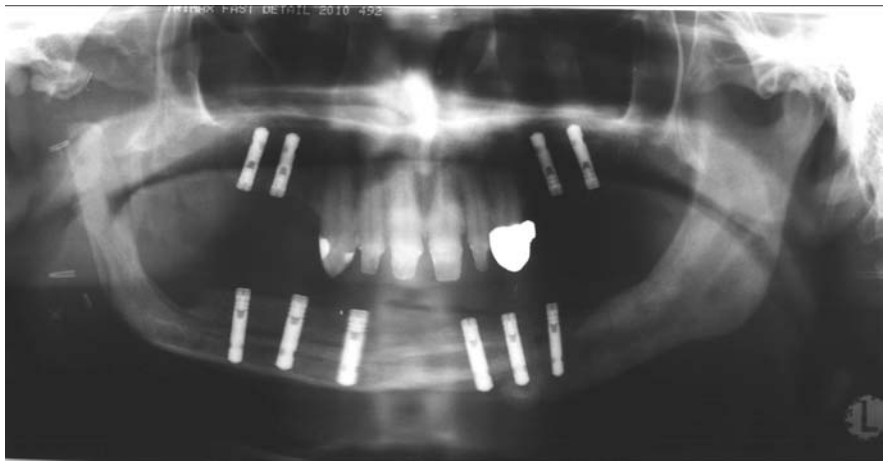

Fig. 23.19. Anteroposterior X-rays: complete revascularization and osseointegration of the implants within the graft

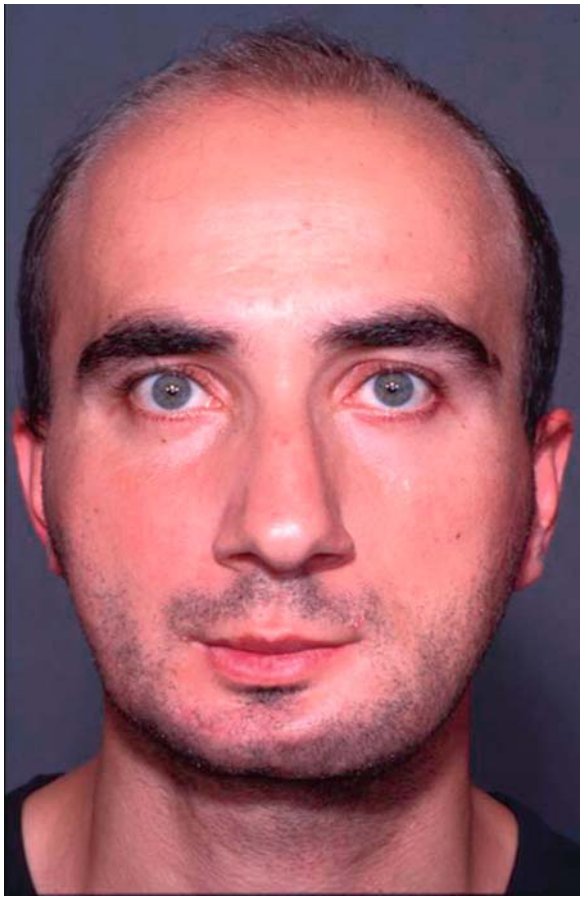

Fig. 23.22. Postoperative result with anatomic mandible vertical height and facial aesthetic contour

insertion at 6 months, (4) second-stage implant surgery and vestibuloplasty at 9 months lowering the floor of the mouth, and (5) prosthetic restoration.

The free fibula flap has shown to be ideal for the restoration of functional results. In fact, it has been demonstrated that it maintains bone height, which is a reflexion of the bone mass, in a 10-year follow-up period for 90 % of patients irrespective of previous irradiation, the placement of osseointegrated implants, and the anterior or lateral position of the reconstruction [17]. Speech, diet and aesthetic rehabilitation have to be considered in the functional rehabilitation of jaw reconstruction and are directly related to the position of the reconstructed defect and the amount of soft tissues resected. In fact, they will be worse for the anterior segments and when tongue or other soft tissues have to be replaced with autologous tissues [13].

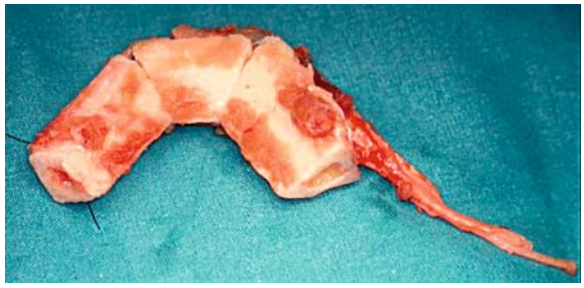

Fig. 23.23. Anterior segment reconstruction with the fibula flap. Two osteotomies allow shaping of the flap to fit on the anterior defect

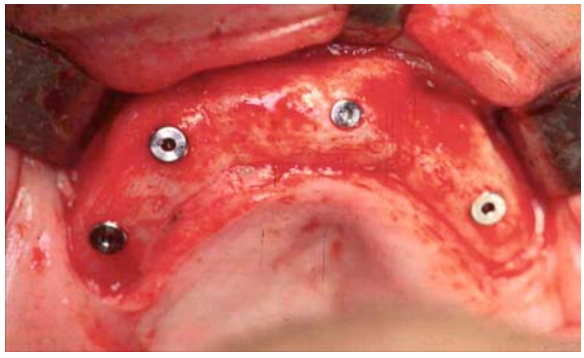

Fig. 23.24. Two years postoperatively, the flap has been reshaped according to loading chewing forces and the anterior angles appear much less evident

23.4 Innovations in Osseointegration

Dental implant stability is mandatory to obtain good and durable restored oral function in patients who underwent reconstructive surgery following mandibular and maxillary resection. It is widely recognized that the amount of cortical bone surrounding an implant has a significant correlation with initial fixation of the implant as well as removal torque [37]. Consequently, implants placed in sites that lack a distinct layer of compact bone demonstrate lower survival rates [3, 4]. The fibula is able to provide adequate bone to restore any width and height for placement of osseointegrated implants [20], and has the greatest total thickness of cortical bone when compared to the iliac crest or scapula.

The clinical success of endosseous dental implants is related to the extent of osseointegration, the process in which clinically asymptomatic rigid fixation of alloplastic materials is achieved and maintained in bone during functional loading [2]. It represents the morphological basis of secondary implant stability. Indeed, upholding of the health and integrity of bone implant complex has been shown to be essential for long-term success of endosseous dental implants. Given these facts, successful osseointegration depends on viable bone cells for osteogenesis at the bone-implant interface [15].

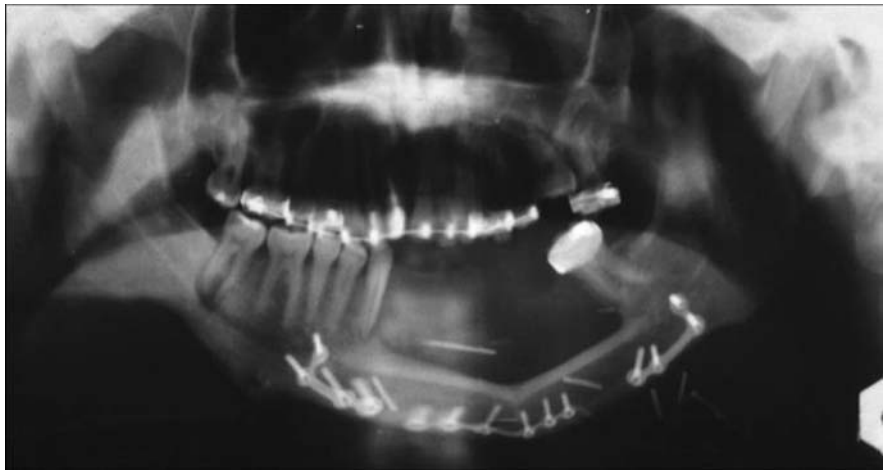

Fig. 23.25. X-rays showing the vertical height of the mandible before the beginning of the vertical distraction

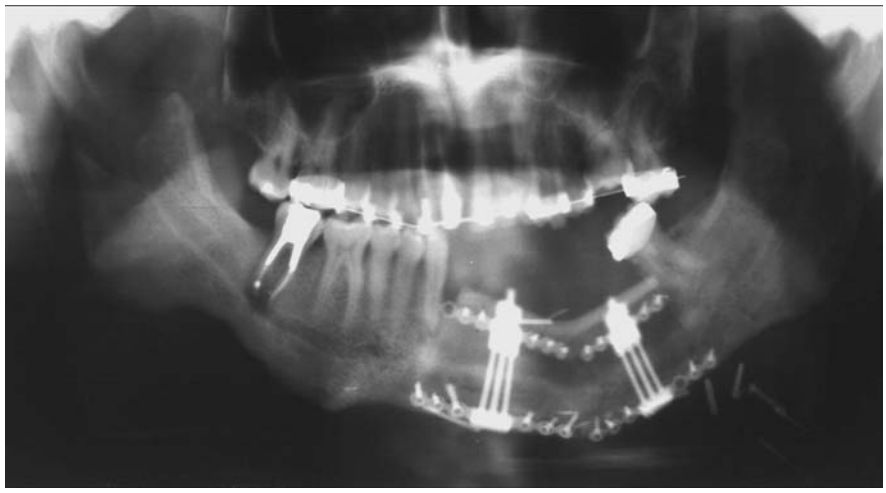

Fig. 23.26. Sequential vertical distraction allows osteogenesis and an adequate mandible height for dental implant insertion to be obtained

Osseointegrated dental implant placement typically requires a two-stage procedure.

The first-stage is planned on preoperative investigations and is performed at 6 months after the primary surgery to allow for osseointegration before performing implant insertion and the osteosynthesis material removal. The second stage of implant surgery and vestibuloplasty is at 9 months (vestibuloplasty is performed only if necessary) and prosthetic restoration.

Although the fibula may provide the strongest initial fixation of an implant, its ability to withstand functional loading and maintain osseointegration has not been completely determined. Therefore, implant stability has to be evaluated by quantity non-invasive test methods. Dental stability parameters are the amount of stiffness and damping of an implant in the surrounding bone and the height of the marginal bone surrounding an implant. In case of a failing implant, the bone around it is replaced by fibrous tissue and in case of an overloaded implant, the bone height around the implant fails.

Evaluation of primary and secondary implant stability can be performed clinically or with instrumental methods such as radiograms and resonance frequency analysis (RFA).

Clinical and radiographic examinations in case of loss of osseointegration show implant mobility and peri-implant radiolucency. X-ray images of a thin perifixtural radiolucency surrounding the entire implant suggest the absence of direct bone-implant contact. Most clinically significant changes occur in the first year of functions; thus follow-up X-rays should be taken 6–12 months after restorative installation. The most important factors for making accurate radiographs in the evaluation of osseointegration are the quality of the radiographs and the examiner's experience [22].

Recently the introduction of RFA as a commercially available technique has made it possible to obtain an objective measurement of the implant stability (implant stability quotient, ISQ) at any time during the course of implant treatment and loading. This represents a step forward in the measurement of implant sta-

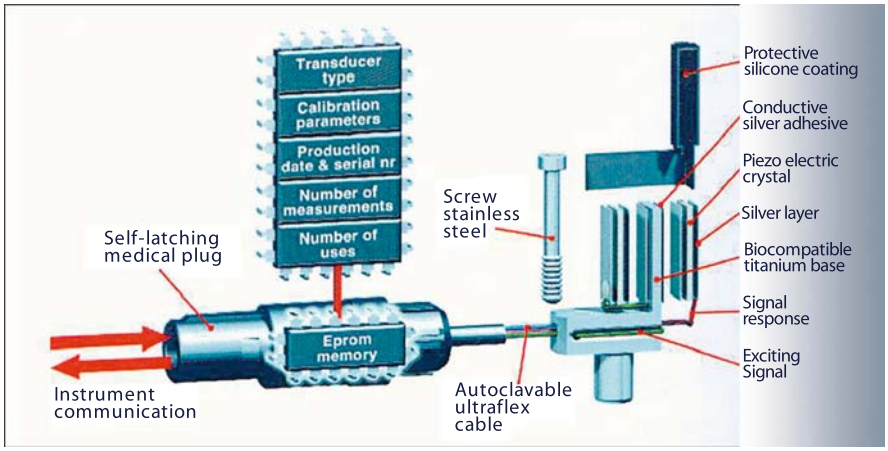

Fig. 23.27. Ostell: composition and mechanism of action

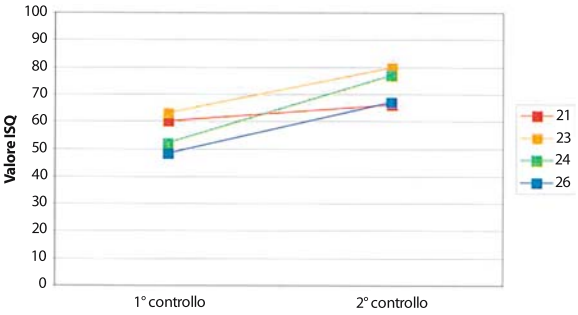

Fig. 23.28. Ostell evaluation. The graph shows the different ISQ values from first to second control

bility when compared with traditional methods [33, 34].

RFA measurements use Osstell, a small electronic device with a transducer attached by a screw to the implant that allows the results to be graphically shown on an LCD (Fig. 23.27). Osstell should measure implant stability at the time of implant insertion, 6 months later and after 1 year of functional load (Fig. 23.28). The resonance frequency reflects the stiffness in relation to the surrounding bone, amplifying with the increased height of the bone around the implant. Thus, the resonance is a function of the interface biology and implant stability.

The results support the hypothesis that the resonance frequency of an implant/transducer system is related to the height of the implant not surrounded by the bone and the stability of the implant/tissue interface as determined by the absence of clinical mobility.

Consequently, implant stability must be measured not only according to a clinical point of view but also with an objective instrumental method. To this end, RFA can detect this stability, measuring the stiffness of the implant, and can record these data on a computer.

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24 Aesthetics in Cleft Secondary Treatment

M. Duskova

The final result of cleft lip and palate treatment not only depends on the extent of the inborn defect, the development of the affected area, individual healing ability, and the therapeutic method used, but also on additional factors such as the patient's cooperation and the subjective perception of his or her deformity. Despite the considerable mental and physical demands associated with a lengthy treatment spanning from early childhood to adulthood, some patients perceive the affection so dominantly, that they are in a constant search for a possible perfection of their appearance. A typical facial deformity along with poor speech formation interferes with all channels of communication. Since 85% of professions presently depend on the exchange of information, the extent of the fault elimination and the quality of speech formation are the primary measures of cleft treatment outcome [15].

24.1 Origin of the Deformity and the Difference in Appearance

Understanding the origin of the deformity and the difference in appearance to that of a healthy individual are the basic principles for the correction of physiognomy in patients with cleft lip [3–5, 11, 16]. The main problem is a lack of soft and hard tissues in the centrofacial region, based on congenital defect and the imbalance of facial musculature with pathological insertions, followed by hypoplasia mainly of maxilla and septum with compensatory overgrowth of the mandible. Postoperative scarring accentuates the situation. When evaluating an aesthetic impression, the insufficient projection of the nasal apex and a flat upper lip are the main contributors to a pathology-like appearance [14] with either a straight or concave profile. An osseous defect of the maxillary alveolar process and the respective teeth are present in 75% of affected individuals. Bridging of the gap is necessary in 30–40% of these patients. Bone substitutes such as hydroxyapatite and lyophilized bone are not considered suitable because the material does not allow tooth eruption, the teeth are not able to migrate into the substitute, and the teeth cannot be orthodontically shifted [13]. The current generally respected therapeutic protocol includes filling with autologous cancellous bone grafts [17]. If grafting is performed prior to the eruption of a canine, the orthodontic shift enables a closure of the dental defect in 90% of cases with only 10% requiring a prosthetic reconstruction (Fig. 24.1).

With regard to hypoplasia, an aesthetic surgical correction is commonly considered at the time the development of the centrofacial region is complete. The minimum age is usually 15 years in girls and 16 years in boys [21]. It is beneficial to regard the affected region as an aesthetic unit and to perform corrections of the nose

Fig. 24.1. Sketch of typical pathology-like concave cleft profile deformity, drooping nasal tip, poor upper lip, gargoyle lower lip and huge chin

and upper lip at one time [21]. In order to achieve a rational stable result, the relationship between the jaws [21], the alveolus position, and the dental arch shape must be considered. The principle of corrective surgery is repositioning and remodelling of existing structures, and importantly the addition of the missing material [14].

24.2 Scar Flap in Correction of Nose and Lip Secondary Deformity

Regarding the insufficiency of tissues, another solution for secondary lip and nose correction other than a radical repositioning, remodelling and addition of missing tissues seems doubtful. The elasticity of the soft tissues, primarily of skin and mucosa, is often overestimated and their lack may cause a recurrence of the deformity [3, 4, 23]. The extent of missing skin and mucosa along with a delicacy of the locus unambiguously point to the local flap [2]. The frequent disproportional aesthetic labial subunits, a usually insufficient continuity of musculature, marked labial scars, and a good possibility of local shift predetermine this location as the first choice of place for the flap formation [2, 12]. The flap is formed from the lip scar resulting from primary reconstruction. It is elevated within the whole labial height, including the red rim. Its pedicle is at the lateral section of the columella base at the cleft side, i.e. in the centre of the affected region. The flap can be easily rotated according to individual needs and three-dimensionally set. In principle it means a redistribution of the skin and mucosal area of nose and lip with three-dimensional supplement and extension at the site of main deficiency [12, 14]. The average area of flap in a unilateral deformity is up to 42 mm^2, and for both flaps in a bilateral deformity the area is up to 77 mm^2. Pulled inside and up at the affected nostril the flap improves the height of the columella, the extent of the nasal mucosa on the frontal septum, and on the nostril base in the vestibule. In the lip, the flap raises its height and improves proportionality. It can also be used after decortication to fill in the lip volume.

The complete intervention consists of open rhinoplasty with the repositioning and remodelling of the existing bone and cartilage framework, and the possible addition of cartilaginous grafts. Concerning the repositioning and remodelling of apical cartilages, it is logical that the more severe the affection is, the more it is necessary to free the cartilages, to ensure their retention in a new shape and to add missing parts. Grafts are most frequently placed into the columella and nasal tip, harvested mostly from the septum, and sporadically from the concha. The resection of the basal septum surplus with release of a tight mucoperichondrium is necessary for a stable result. A preoperative and postoperative moulding can be of benefit [28]. Caution: Even though there is an improvement of the nasal passage, patients must overcome their dynamic stereotype of breathing by mouth [12]. There is then remodelling of the upper lip with the formation of the central subunit of the labial red and symmetrical lateral segments, a proportionate philtrum, circumscribed by columns, and an improved continuity of the orbicular muscle. Flap formation with a medial extension along with a scar leads to a desirable narrowing of the philtrum according to individual needs. A concavity of the distal part is achieved by the fixation of a corial suture deep into the muscle, which is effective in the absolute majority of cases. Columns formed by the eversion of rims on suturing are stable only in 40 % of subjects.

A clinical effect manifests most markedly in patients with either unilateral or bilateral cleft who have suffered from a small projection and/or drooping of the nasal tip with a short, and/or asymmetric, columella, and a short, flat and poor lip. This approach brings the parameters of nasal tip projection, length of columella, nasolabial angle, nasal angle, and lip angle into the normal range [12, 14]. The cranial rotation of the long nasal axis and nasolabial angle brought about both an improved projection of the nasal apex and the reduction of the nasofrontal angle. This led to the emergence of a convex profile and an attractive appearance [24, 26] (Fig. 24.2).

In cases with central occlusion a minor skeletal disproportion in terms of a minute maxilla and/or surplus of mental protrusion can be taken care of along with the correction of the nose and lip [11].

24.3 Onlay Augmentation of the Maxilla Subspinal Area

In cleft lip and palate patients Le Fort I advancement is the most popular method for removal of pathological occlusion and improvement of appearance at the same time. However, if the central occlusion is reached and a concave profile persists, onlay augmentation of the maxilla subspinal area is a good approach for correcting the existing contour and giving the patient a normal facial balance [24] with a hard floor for a sunken nasal base and lip. In addition, an onlay implant does not have a negative influence on speech formation, teeth occlusion, and/or hearing [11]. Autologous bone or synthetic bone substitutes can be used. The application of bone substitutes means minor surgery without secondary defects, lower treatment costs, a low demand for technical equipment and a faster recovery. Substrates are available in an amount, volume and shape to suit individual needs. They are easily applicable and

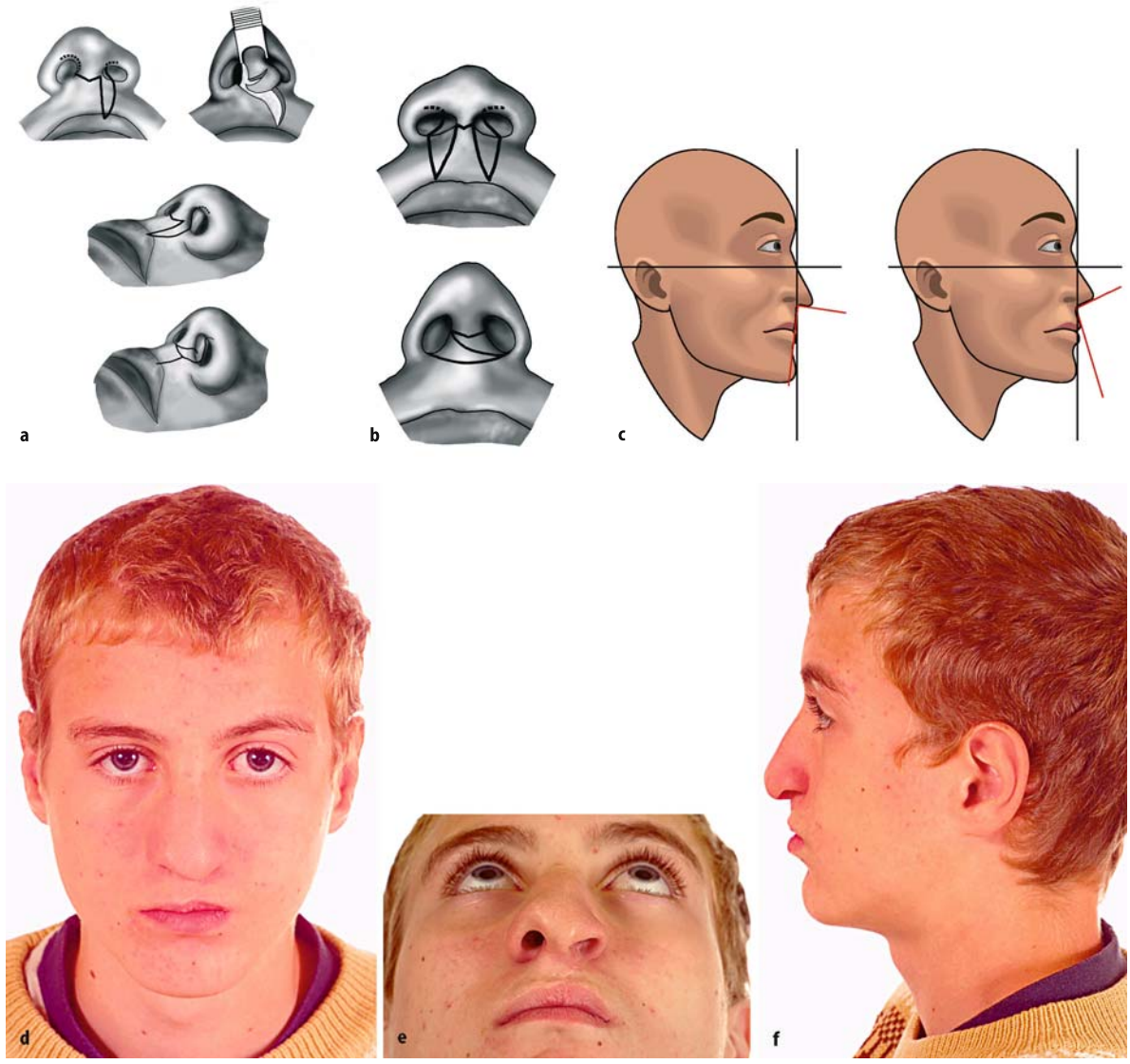

Fig. 24.2. Scar flap in correction of nose and lip secondary deformity. **a** Sketch of scar flap in a unilateral deformity. **b** Sketch of scar flap in a bilateral deformity. **c** Main trick of approach = cranial rotation of the long nasal axis and nasolabial angle. **d** A patient with a unilateral deformity prior to surgery en face. **e** A patient with a unilateral deformity prior to surgery: view from below. **f** A patient with a unilateral deformity prior to surgery: profile of cleft side

long-lasting while stored. Bioactivity with osteointegration makes them relatively resistant to infection [20]. A rich amount of soft tissue cover and perfect fixation are unambiguous conditions for the prevention of extrusion [19] (Fig. 24.3).

Most patients long for the removal of visible scars on their upper lip, which are a constant reminder of their defect. The skin texture in women allows for a good fusion of the scars with their surroundings by means of resurfacing after the lip volume has been replenished [9]. The situation in men is more complicated due to the absence of the moustache hair [10].

24.4 Augmentation by Autologous Adipose Tissue in Cleft Lip and Nose

Low projection of the upper lip and a similarly affected nasal columella appear unnatural, especially in a young face. The simple enlargement of the volume may be helpful. There are many synthetic fillers now. Using the subject's own fat cell clusters [6] and the injectable administration form involves minor invasion and practically immediate recovery. This method is relatively low cost and repeatable. The biocompatibility of autologous tissue without allergenic response is important,

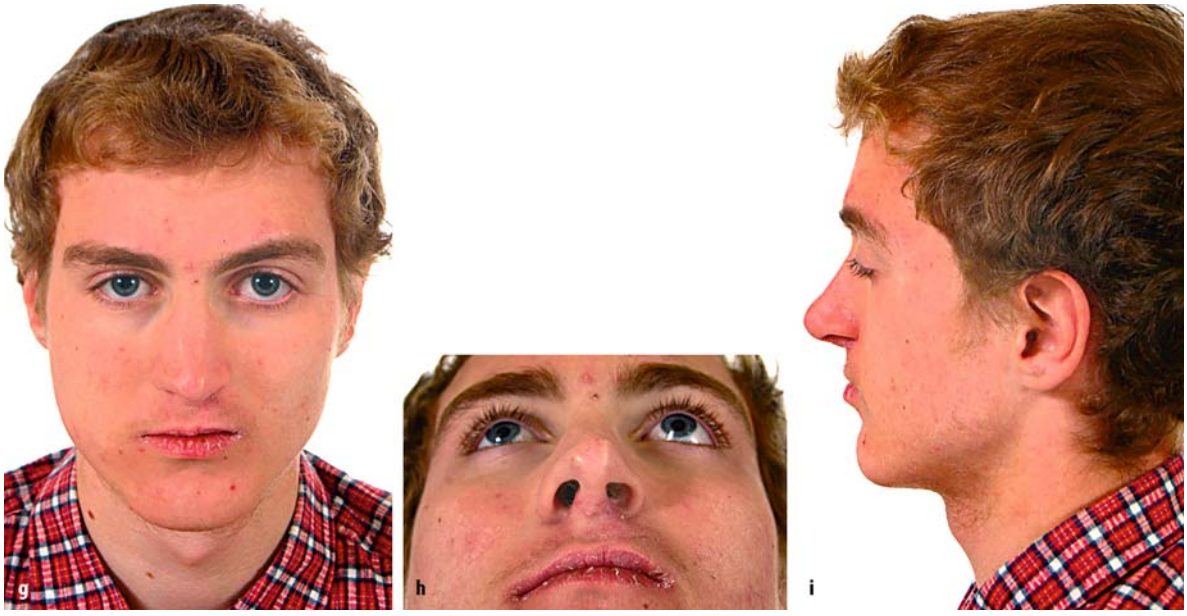

Fig. 24.2 (*Cont.*) **g** A patient with a unilateral deformity 2 years after surgery en face. **h** A patient with a unilateral deformity 2 years after surgery: view from below. **i** A patient with a unilateral deformity 2 years after surgery: profile of cleft side

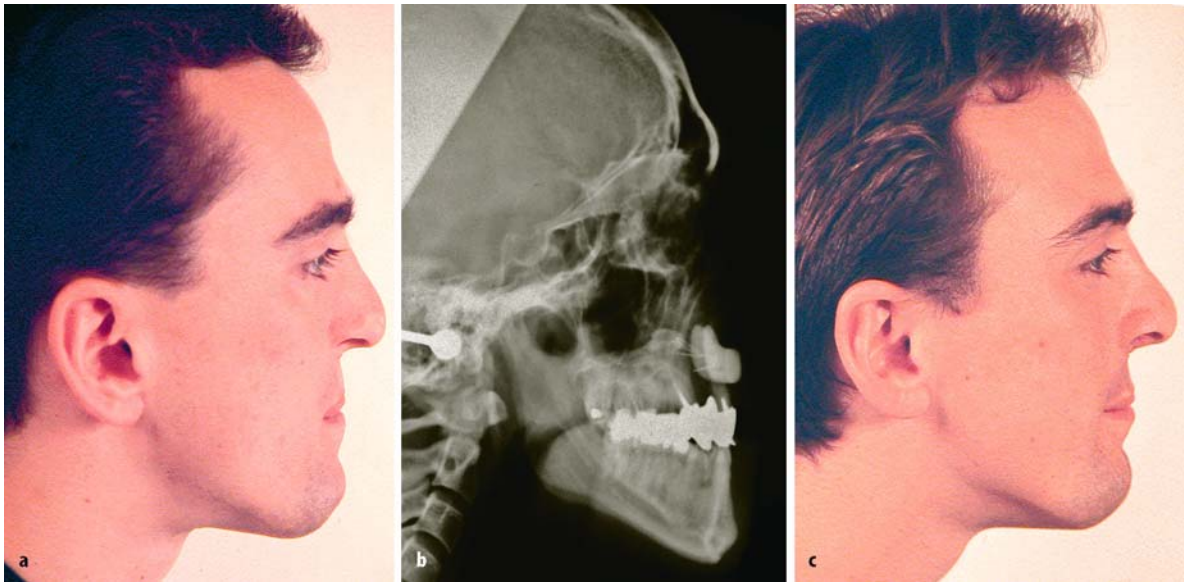

Fig. 24.3. Onlay augmentation of the maxilla subspinal area. **a** Profile of bilateral cleft patient before surgery. **b** X-ray profile of bilateral cleft patient 7 years after surgery. **c** Profile of bilateral cleft patient 7 years after surgery

since allergies are found in 74% of cleft patients [12]. Fat increases the volume of flat upper lip and nasal columella, thereby inducing a more physiological shape, and reducing the scar's visibility. The disadvantage is the temporary nature of the outcome, lasting 7 months on average (Fig. 24.4).

24.5 Moustache Reconstruction in Patients with Cleft Lip

The visibility of cleft sequelae in men may be compounded by limited or missing growth of moustache hair in the upper lip scar and/or prolabium. Despite the presence of hair follicles in the affected areas, they are incapable of reactivity and growth due to the lack of ev-

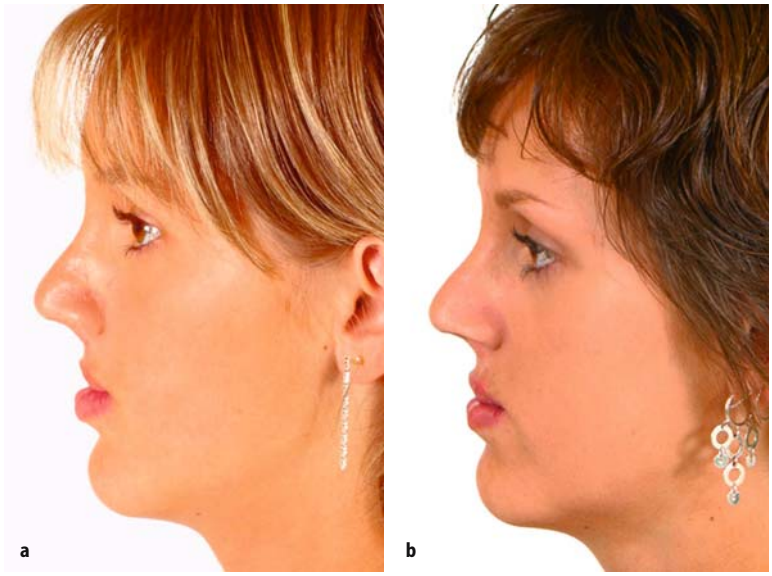

Fig. 24.4. Augmentation by autologous adipose tissue in cleft lip and nose. **a** A patient with a bilateral deformity, profile prior to surgery. **b** A patient with a bilateral deformity, profile after surgery

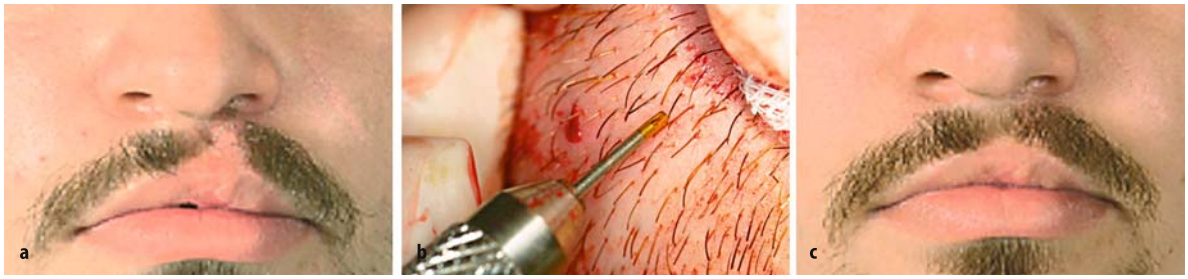

Fig. 24.5. Moustache reconstruction in patients with cleft lip. **a** A patient with a very visible scar prior to surgery. **b** Peroperative view of harvesting. **c** A patient 2 years after; three sessions were done

idence of androgenic receptors in hair follicles and hair papilla [10]. Nevertheless the site easily accepts grafts. For perfectly natural results single follicular units are most advantageous [27]. The choice of harvesting site depends on required color and quality. The occipital area is common; however, in some individuals the barb of the submental area or even the lateral part of the moustache is more acceptable. Single hairs directly harvested by special needle have many advantages. There is no visible scarring at the harvesting site, prompt healing, easy approach, no need for special surgical training, and simple and low cost instruments. Grafts are set into punctures made by the same instrument. Only changing of the needle calibre is necessary. While the normal density of follicular units is about 1 – 3/mm^2, it is better to leave enough space for good healing and to perform further transplantation in 9 months [29]. The necessary complete number of follicle units is usually about 30 for the unilateral scar and about 150 for the alopetic prolabium (Fig. 24.5).

The prosthetic reconstruction of dentition is one of the final cleft treatments. This procedure is necessary in at least 10 % of patients. The most frequent method is a solid dental bridge or a removable denture. A more natural alternative to these may be a dental implant [13].

24.6 Reconstruction of the Maxilla Alveolus for Subsequent Insertion of a Dental Implant

The maxilla alveolus reconstruction is usually performed at the time when the growth of the orofacial region is completed or being finalized [25]. The tissue reaction and healing are markedly more difficult in comparison to a similar procedure performed during the growth period. The greatest task lies in bridging the alveolar defect by bony grafts so that a resulting three-dimensional ridge is sufficiently voluminous and of a quality suitable for implantation [22]. The problems are lack and quality of mucoperiosteum for the reconstruction of shell and bone gap characteristics for bone graft intake. While the technique is similar to very common secondary bone grafting, some particular aspects must be considered, because of the problems mentioned above.

The success rate mainly depends on:

1. The presence of continuous alveolar arch flow of maxilla segments in both horizontal and vertical planes.
2. The presence of a height of the osseous poles of at least 12 mm; onlay augmentation of the built-up section does not work. The defective bone walls are spot abraded in order to stimulate the graft intake.
3. An adequate volume of cancellous bone graft is 3.7 cc on average. Harvesting through the inner side of the iliac crest is a simple procedure and leaves just a 2-cm skin scar. Special instruments are not necessary.
4. Perfect occlusion of possible oronasal fistula is necessary. The reconstruction of an adequate soft tissue shell means shifting the mucoperiosteal vestibular flap optionally from either the end of the cleft alveolar segment or the contralateral segment or even from both sides. The application of barrier membranes for tissue regeneration [18] is beneficial in the case of severely affected mucoperiosteum. Membranes can prevent growth of epithelium between particles of osseous graft; nevertheless they are expensive financially [13].
5. It is known that the graft volume diminishes from the 4th month after transplantation due to resorption. As soon as possible a graft load is advisable, which is able to limit this process. Based on histological verification and clinical findings, a bone graft is matured enough to ensure the primary stability of a fixture at 12.5 weeks after reconstruction.
6. The evident interest and positive attitude of the patient

   Prediction of complications:

1. Graft resorption increases according to gap size and to low possibility of revascularization.
2. A higher number of complications linked to the presence of the oronasal fistula and to scarring of soft tissues.
3. Due to a more gracile skeleton and the female metabolism the risk is higher in women.

Last but not least the requirement for close interdisciplinary cooperation must be mentioned. The described reconstruction is part of a complex treatment. The following are the principles of the main steps:

1. Orthodontics:
   Pre-treatment starts with the mixed dentition, using removable and fixed orthodontic appliances including transpalatal arch with the aim of harmonizing the shape and size of the dental arches. One must not forget the treatment of the lower jaw. Following the treatment of the dentition's eruption it is necessary to correct the overbite, the intercuspidation and the lateral segment cross-bite; the correction of the teeth position around the cleft gap is usually by fixed apparatus. With regard to the reactivity and integration of the osseous graft lasting at least 1 year after the transplantation, the orthodontic apparatus is active over this period.
2. Reconstruction of cleft alveolus for dental implant insertion
   This procedure requires the formation of a stable, three-dimensional voluminous alveolar crest by cancellous bone grafts with maximum support of osseo-integration. The main goals of the approach are: perfect occlusion of the oronasal fistula, gentle grinding of osseous poles, use of an adequate amount of autologous cancellous graft with an average volume of 3.7 cc, and reconstruction of sufficient soft tissue shell.
3. Insertion of dental implant
   Histologically, it has been proven that this step is possible 3 months after alveolus reconstruction. This early time and the load of the transplanted area may prevent bone resorption. Only intraosseous titanium implants of high quality are recommended. Open one-stage insertion is advisable due to soft tissue insufficiency. Because the reconstructed area usually displays a density of 3 – 4 according to Mitch, the self-cut insertion or a start using several introductory threads is more suitable.
4. Prosthetics and retention
   The dental implant may be loaded by a suprastructure 2 months after insertion. It is necessary to use a variable system of abutments, more often a longer device, either straight, but mostly angulated. A temporary plastic or definitive ceramic crown depends very much on the expertise, degree of perfection, and invention of the dental technician. It must be done according to individual needs, possibly with a gingival substitute and anchorage into the back side of the neighbouring teeth (Fig. 24.6).

24.7 Conclusions

The indication for secondary treatment of cleft lips and palates is based foremost on the opinion and wishes of the patient in conjunction with possible medical treatments [1]. Because a long therapeutic process leads to physical and mental exhaustion, patients demand a maximum effect with minimum risk, negligible time and low financial cost [7, 8, 11]. A plastic surgeon is frequently the main medical contact of a cleft lip patient. While he or she performs the final aesthetic touches to the patient's appearance, it is necessary to consider other aspects of treatment. The speech therapist's supervision and the mimic's training may improve speech production even in adulthood. Close cooperation with a

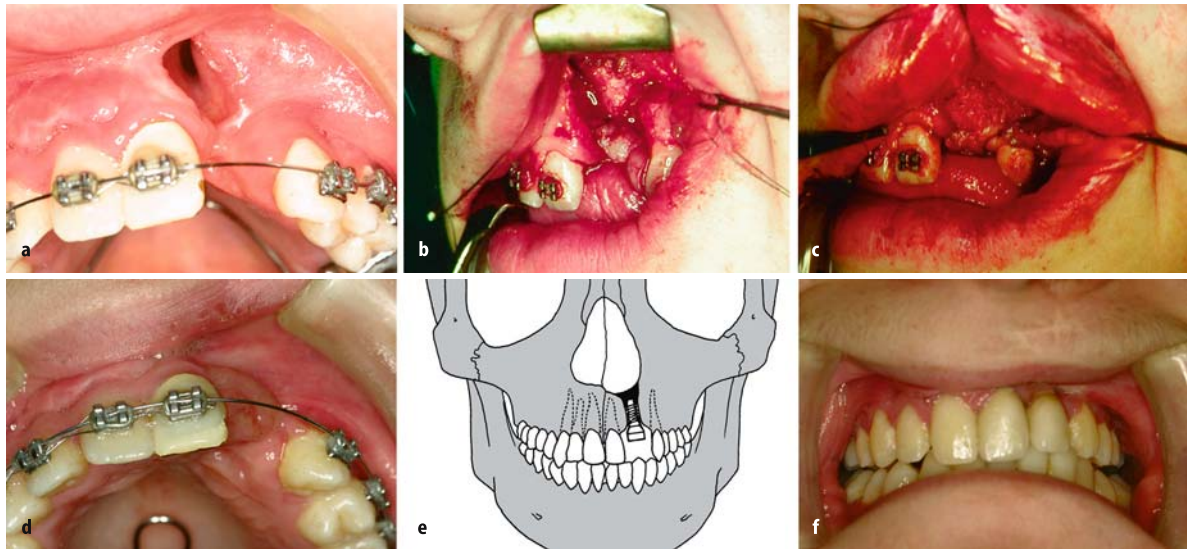

Fig. 24.6. Reconstruction of the maxilla alveolus for subsequent insertion of a dental implant. **a** A patient with alveolus defect and oronasal fistula. **b** Peroperative view to naked gap. **c** Peroperative view to filled gap. **d** A healed alveolus. **e** Sketch of dental implant in maxilla alveolus which was reconstructed by bone grafts. **f** Final result

Fig. 24.7. Patient satisfaction renders the greatest homage to the doctor

psychologist is often helpful in building self-esteem and in social integration with an increased quality of life (Fig. 24.7).

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25 Correction of the Nasojugal Groove

G. Botti, C. Botti, A. Cella, A. Gualdi

25.1 Introduction

A young and pleasant face has a smooth and firm integument lining which covers and blends the different areas of the face in a continuous and harmonious way. The regularity of the skin surface should only be slightly marked by tiny wrinkles and lines which generally tend to deepen with age. In fact, owing to progressive relaxation, soft tissues are prone to move downwards gathering above the skin's fixation areas (ligaments and facial adherences) eventually becoming visible and looking more like furrows. This phenomenon, for example, affects the nasolabial area above the adherences between the dermis and the aponeurosis of the elevator muscles and the orbicularis oris. This line, which may be already present, even though rather vaguely, in childhood, tends to deepen owing to the dermal-adipose fold which forms above it. With age even palpebral and periorbital soft tissues, owing to the pull of gravity, to the movement and deterioration which they undergo, become thinner and descend, causing the formation of the so-called malar bags, as well as the deepening and extension of the nasojugal groove, which is the subject of this article. As we will see though, the latter phenomenon has a slightly different origin compared to the other furrows on the face because it actually does not correspond to a firm adherence but rather to a system of tiny ligaments. One should note that the three main grooves (labiomandibular, nasolabial and nasojugal) which appear or deepen with age are, however, related to the ptosis of the same anterior soft tissues of the face.

The correction of the nasojugal groove is the new frontier of facial aging cosmetic surgery [1]. Aesthetic palpebral defects (dermatochalasis, bags, etc.) and soft tissue sagging in the cheek and neck areas have been appropriately dealt with over the years thanks to techniques at hand. On the contrary, the "circles around the eyes," which are almost always present on an aging face, had been underestimated and neglected for a long time and, as a result, were not corrected because efficacious procedures were unavailable. In other words, the neck bands and jowls are problems that have been basically under control for years but the excellent results achieved in the cervical area, in the lower half of the face and in the eyelids contrast with the poor results obtained in the mid-anterior area and, in particular, in the lower periorbital area, which is marked by nasojugal grooves as well as by local tissue ptosis. So, often, just a face-lift, even if combined with a blepharoplasty, can create situations where harmony is lacking. It could even highlight the areas which have not been adequately dealt with. Only over the last 20 years has the real need for correcting the mid-face defect been felt and consequently appropriate operations have been perfected.

25.2 The Nasojugal Groove

The nasojugal groove, as its name suggests, runs from the nose towards the cheek. As a matter of fact it originates about 1 cm under the medial canthus at the nasal side wall and extends obliquely sidewards and slightly downwards. The part that remains most medial and is about 1 cm long, is often present since youth and we can say that it is almost a kind of, more or less, defined anatomical boundary between the eyelid and the cheek. It would be nice if we could all agree on the univocal use of only one name for this "furrow," which in the Latin world is most frequently called palpebrojugal groove so as to underline its role as a border between the two areas. On the other hand, both in the English language

and in French the term "tear trough" (*valée du larm*) is used, because this is the path that tears actually follow. In general, the Anglo-Saxon scientific world prefers to use the term "nasojugal groove" to indicate the area that starts from the nose and runs in the direction of the cheek.

As mentioned, when you observe a child or an adolescent, you can almost always clearly see, along the medial portion of the orbital rim, a slight depression created by a light adherence and scarce thickness of the soft tissues at this level. In this case it is a normal anatomical characteristic, which can be more or less evident in different individuals. When this groove is very deep, due to a congenital characteristic or when it deepens with age, a kind of unaesthetic frame, popularly called "circle," can be seen around the orbital area. Sometimes it is more evident because of the dark pigmentation of the palpebral skin. The brownish or bluish coloring of the skin above the nasojugal groove has little to do with the furrow itself, but we should rather relate this to an unusually abundant deposit of pigment or to a particularly thin integument which can, due to its transparency, emphasize the underlying darker obicularis muscle.

The lateral part of the nasojugal groove can have different courses. At times it seems to go along the inferior lateral orbital rim (the true nasojugal groove), whereas often it seems to descend inferiorly towards the cheek ligaments. In some cases one can find both kinds of lateral extensions in which the medial portion branches off.

Soft tissue ptosis caused by aging, deepens the grooves of the medial-anterior third of the face. As we have already mentioned, the nasolabial furrow becomes more evident because it gets slowly covered by the skin-adipose fold found above. This crease is made up basically of the cheek fat pad that has slid downwards while the nasojugal groove becomes deeper because of a progressive reduction of an adequate subcutaneous padding. A sort of anatomic relationship between the two lines exists. As a matter of fact the nasojugal groove is positioned, at least partially, at the level of the upper concavity that is above the nasolabial crease.

25.3 Surgical Corrections to the Nasojugal Groove

In order to soften a groove, it is usually necessary to try to fill it out and/or stretch the skin that covers it [2]. The padding can be obtained by either using tissues taken from the surrounding areas or by collecting them from other parts of the body or by using heterologous materials. For as far as the nasojugal groove is concerned in particular, the two operations belonging to the first group are the Loeb technique (using surrounding tissues) which consists of shifting caudally the adipose bags, e.g., herniated intraorbital fat in the eyelids, and the *mid-facial lift*. This latter operation repositions the sagging soft tissues in the infraorbital and malar areas upwards. In the second group, the most frequently used autologous grafts are adipose tissue and composite grafts of fat and dermis. The third group includes injections of "fillers" and specific implants invented by Flowers. All these techniques make the nasojugal groove less evident. The choice of the technique depends on the person's individual needs as well as on the specific experience attained by the surgeon that has used these different solutions. An invasive operation is rarely indicated for young people unless the situation is particularly serious. If this is not the case, it is preferable to limit oneself to filler injections or to a transplant using the person's own fat. On the other hand, it would be worthwhile considering more aggressive surgery for patients who are not so young. For as far as the Loeb operation is concerned, bags need to be of a consistent volume; otherwise the filling material would be literally lacking. One should turn to a mid-face lift especially when a nasojugal groove is present simultaneously with a soft tissue ptosis in the malar/palpebral area. Patients can usually tolerate the Flowers' implant very well despite it sometimes protruding over the orbital rim, but we believe it should be kept for those cases where other techniques cannot be used. These implants are suggested, for example, when there are no bags under the lower eyelid, when the patient is really thin and has no fat available for grafting and there is no indication for a mid-face lift.

25.4 Fat Grafting

The grafting of autologous fat, aspirated previously from another part of the patient's body, has become popular again since the 1990s thanks to remarkable technical improvements that have given the opportunity of achieving more tangible and predictable results compared to those offered by the same operation 10 years earlier. The methods of collecting fat at low pressure, after having infiltrated highly diluted anesthetic solution, and above all, the way fat is processed, and the skills used during the grafting stage, are all factors that have finally made it possible to guarantee that the fat tissues take, at least partially, in a high percentage of cases. For as far as the nasojugal groove is concerned in particular, we need to stress that the orbital rim is in an area of easy taking but, however, complications can arise for exactly the same reason. One must be really careful to carry out the operation with extreme precision avoiding to graft the fat too close to the surface and too abundantly.

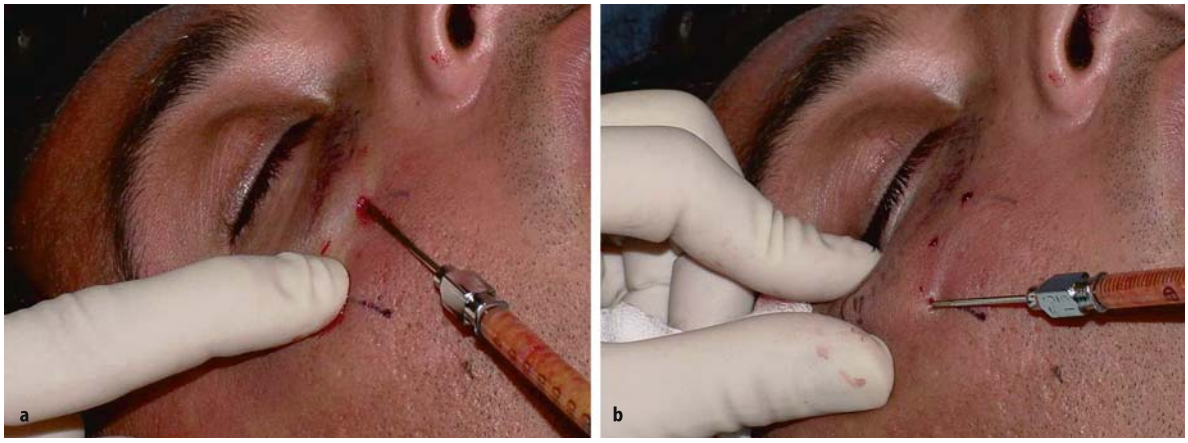

Fig. 25.1a, b. Fat grafting. The adipose tissue must be injected in small amounts under the orbicularis muscle in order to avoid the formation of visible and palpable lumps

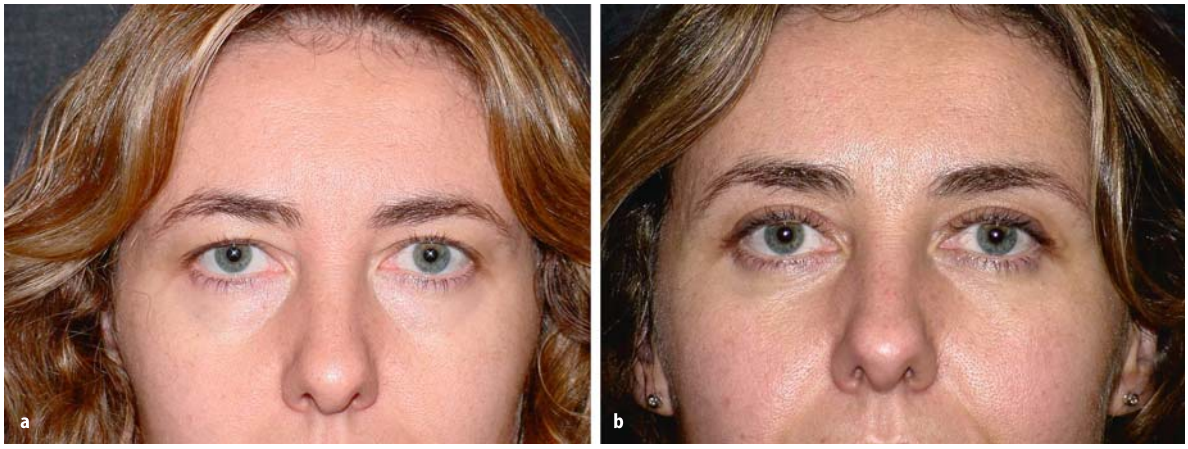

Fig. 25.2a, b. Fat grafting and upper blepharoplasty: before and 6 months later. The nasojugal groove at this point has greatly improved and will remain permanently less visible

Fat may be harvested from any part of the body considering the exiguous amount needed. One should note, though, that the filling of the nasojugal groove is usually carried out when a more general correction of the face takes place. So the filling becomes just a detail of the major operation. Usually 1–2 cc of "purified" adipose tissue for each side of the nose (3–4 cc on the whole) is needed to correct this groove. This tissue is obtained from an amount of collected fat which is 3–4 times more abundant than the tissue needed, and therefore around 15 cc is required. Before proceeding with the liposuction we inject a sufficient quantity of anesthetic solution containing saline or Ringer's lactate and mepivacaine at 0.25% with epinephrine 1,600,000. In order to reduce hematic contamination as much as possible, one should hold and press hard on the area where the aspiration is being carried out using the left hand (vice versa if one is left-handed) so that the blood vessels that are flowing in this area will be temporarily sealed off. The suction is carried out using a 2- to 3-mm-diameter cannula connected to a 10- or 20-cc syringe. One should be careful not to load the plunger with a traction of over 2–3 cc. The fat that has been removed this way is usually quite clear and must undergo further processing to eliminate the fluid parts, the free triglycerides, and the different debris. This "cleaning" can be obtained by simply allowing the fat to settle or by "washing and drying" it. As we have tested these different procedures in hundreds of cases, we have come to the conclusion that the last method is the most suitable. In our opinion, the technique of simply allowing the fat to settle cannot guarantee sufficiently pure adipose tissue. We have nothing against centrifugation, as we do not believe, like some people do, that fat undergoes an excessive trauma but we are convinced that one does not need to resort to such a maneuver in order to obtain adequate grafting material for which specific instrumentation and more time is needed. We have experienced that the taking of centrifuged fat has not proven to be better than fat that has been "washed and dried." In other words, adipose tissue that has just been collected and is "dirty" is placed in a strainer which is

submerged in a saline solution to which insulin may be added (we avoid doing this). The strainer is gently shaken while it is in the solution until the fat which is lying in it appears to be perfectly yellow. The strainer is then taken out of the solution and shaken again or placed on a vibrator so most of the washing liquid and debris found in it are eliminated. Finally, it is put onto a gauze compress that can be rubbed at its base so as to be dried perfectly. At this point, the purified adipose tissue must be poured into 10-cc syringes through their opening after having removed the plunger. The tissue is then transferred using a special fitting, to 1-cc syringes so that tiny amounts of it can be injected into the nasojugal groove with major precision. This area is characterized by a particularly thin tegument and so it is crucial to inject the tissue as deeply as possible in order to prevent visible irregularities on the surface. The correct grafting level is therefore between the orbicularis muscle and the periostium at the SOOF (suborbicularis oculi fat) level, which, however, is particularly thinned out in these cases. The injection can be transcutaneous or transvestibular. In the first case one pierces the skin with a 16G needle, which is then replaced by a 1.5-mm microcannula. This is connected to a 1-cc syringe containing the fat by a Luer-lock coupling. In case the needle has perpendicularly penetrated the furrow (by the infraorbital foramen), one needs to exert pressure softly on the syringe, making the cannula go in and out several times with small movements until obtaining the adequate filling. If instead one prefers to pierce the skin at the level of the lateral extremity of the furrow, the tip of the cannula should be pushed in until the medial extremity is reached, and then whilst withdrawing it, small quantities of fat should be gradually injected (as one would do in the so-called retrograde technique for the heterologous fillers). The transvestibular approach (i.e., going through the internal part of the oral cavity) is just as good, even though considerable attention and sensitivity are needed in order to obtain a smooth filling. It is not necessary to cover the grafted area with dressings but if the injection has been carried out through the skin, covering the hole left by the cannula with a piece of paper tape is sufficient. The patient must be warned that in most cases ecchymosis and moderate edema may appear for 10–15 days and that even in such a minor operation complications can arise. The most frequent one is the partial or total reabsorption of the grafted fat. Considering the modest nature of the operation, one can without hesitation try to correct the possible reabsorption with a second grafting session. A rare complication concerns the outbreak of "adipose pseudo cysts," small irregular fat lumps that appear on the skin surface and that are usually caused by too superficial grafting. In this case one can try to squeeze these small "pearls" against the orbital rim, having previously infiltrated a very small amount of highly diluted steroid, if considered necessary. As an alternative, one can discharge the undesired material by cutaneous stab incisions made above the lesions. Despite our vast experience we have never encountered hematomas and infections, which fortunately are rare just like intravasal fat injections.

The nasojugal groove correction carried out by grafting autologous fat is an excellent solution for the younger patients who might have a congenital defect and for the older ones that only wish to have a targeted "retouch" without visibly altering their facial features too much. Also during a classical face lift, when a mid-face session has not been planned, one can resort to an adipose tissue graft to soften the nasojugal grooves. In conclusion, we are convinced that this minor operation can be, in the majority of cases, the first option for solving the nasojugal groove problem.

25.5 Orbital Fat Pad Sliding

The traditional inferior blepharoplasty technique consists of removing adipose bags with a transcutaneous or transconjunctival approach. Instead, in 1983 Loeb [4] proposed using herniated fat for filling the nasojugal groove. The original procedure has been partially modified over time and today this operation is almost always carried out by a subciliary incision, which is followed by a dissection between the orbicularis muscle and the septum. This allows the fat pads to be clearly seen. The undermining at the SOOF level is extended below the lower orbital rim for about 7–8 mm so as to prepare a pocket alongside the nasojugal groove. At this point the septum along the arcus marginalis (where it converges into the periostium of the orbital rim) is incised in order to allow the fat to discharge. A

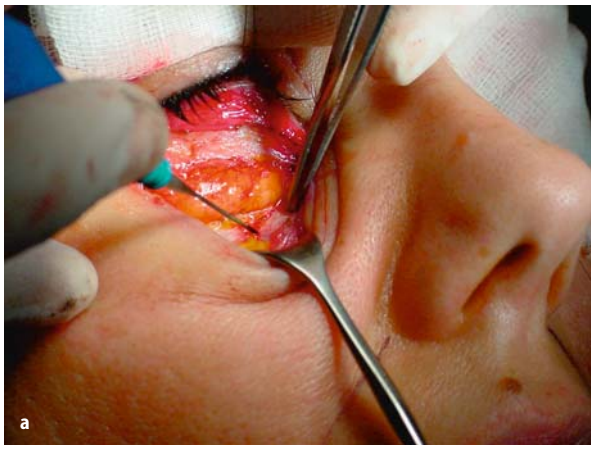

Fig. 25.3a–e. Loeb's technique. The suborbicularis undermining has been extended a bit beyond the orbital rim in order to host the fat flap (**a**)

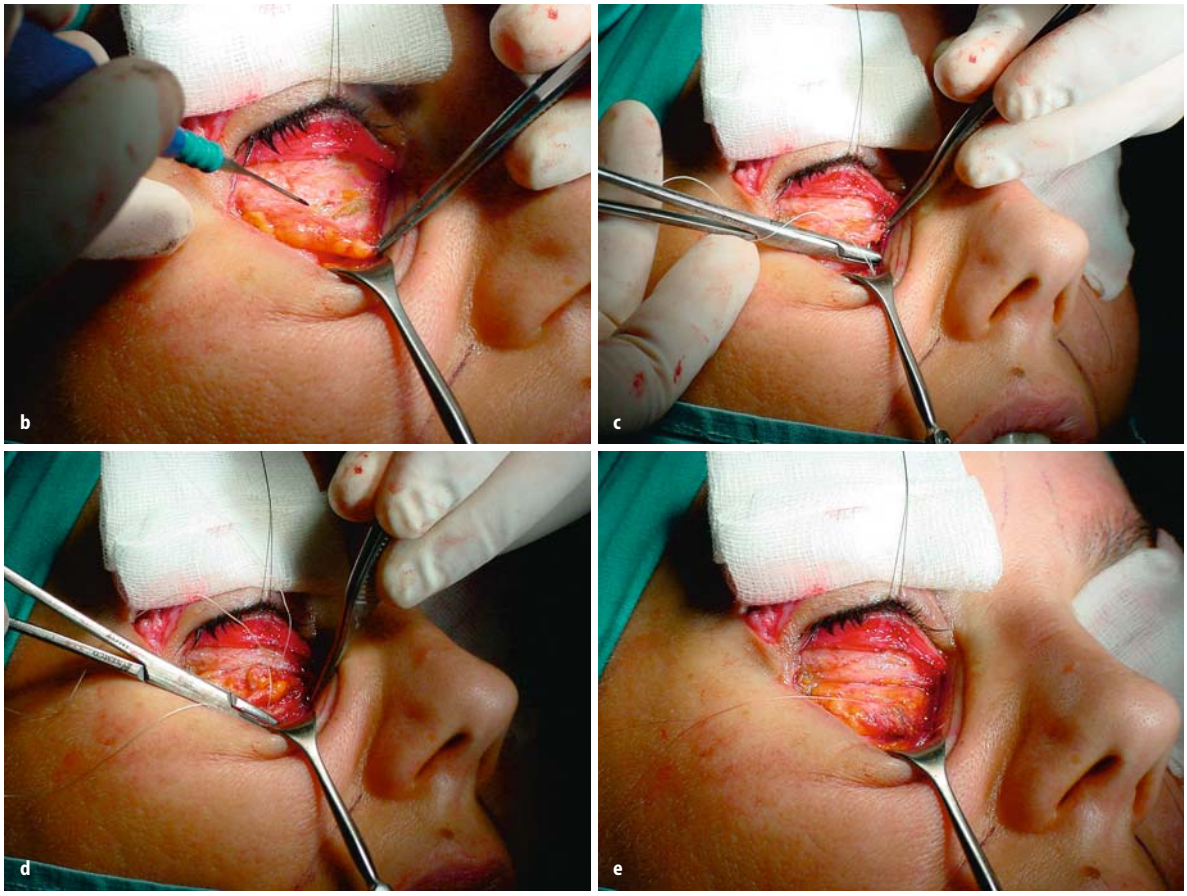

Fig. 25.3b–e. The septum has been incised along the arcus marginalis and above the fat bags (**b**) with the aim of avoiding any palpebral rim distortion. The fat pads have been transposed caudally in order to fill the nasojugal groove (**c–e**)

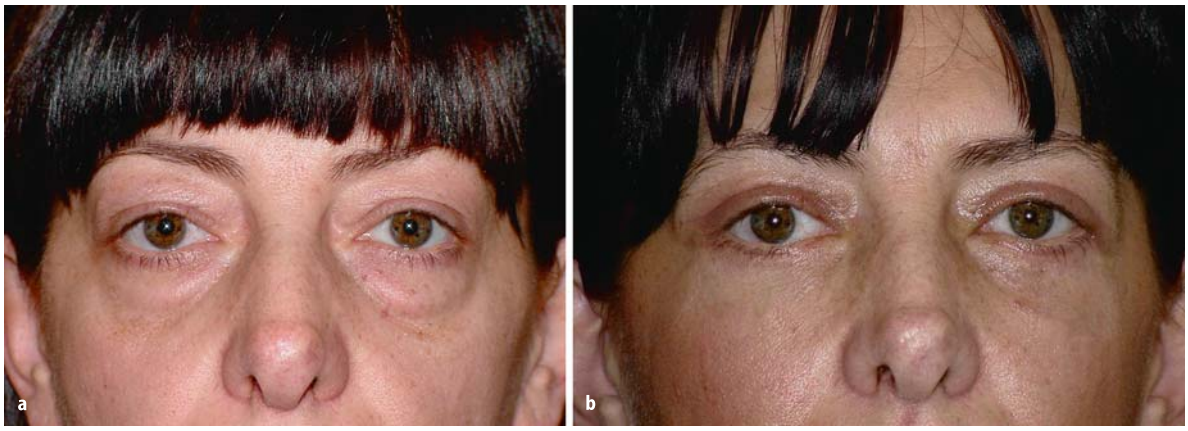

Fig. 25.4a, b. Upper and lower blepharoplasty by means of Loeb's technique: before and 6 months after the operation. The mere transposition of the voluminous fat pads has allowed the deep nasojugal groove to be adequately corrected

second septum incision parallel to the first is made above the bags, to avoid excessive traction on the palpebral rim that otherwise could cause involuntary deformities. The adipose tissue is turned over caudally like a flap, maintaining its vascular connections which guarantee its survival, and consequently the long-lasting results of the operation. In order to keep the adipose flap in its new position, it is sutured to the periosteum or to the soft tissues present in that area. If the nasojugal groove looks too full, the excess fat should be removed and finally the blepharoplasty is concluded using the usual methods. Variations of this technique

include the transconjunctival approach, which is surely more complex but can be easier with the aid of a simultaneous canthotomy, the dissection of a pouch, which might facilitate the anchorage of the adipose flap and finally the fixation of the latter by a transcutaneous suture. The most frequent complications of this operation coincide with those of inferior blepharoplasty, which are well known. Furthermore, over the years we have occasionally observed a moderate resorption of fat that has moved caudally, but in the majority of cases the results remain stable for a long time. We have been using this technique with very satisfying results since it was proposed about 20 years ago. It is indicated for patients who wish to correct bags and/or cutaneous-muscular laxity together with nasojugal grooves by a simple operation which will not radically modify their face. This can be done as long as in the lower eyelids there are adipose hernias that are big enough.

25.6 Flowers' Implants

There are cases where correcting the nasojugal groove with autologous material is difficult, particularly when the furrow is rather deep, the patient is very thin and she or he does not have any fat in the lower eyelid. In such circumstances one could turn to a mid-face lift, which, however, cannot always make up for this defect appropriately. Not to mention that there may not be the correct aesthetic indication either. If all other possible treatments have been excluded, it would be worth considering a heterologous implant and amongst these, Flowers [3] is the best. It is similar to those used to increase the prominence both of the cheekbone and the submalar area and is suitably shaped for filling the nasojugal groove. It is a firm, flat-shaped silicone plaque which is rounded off along the edges and must be inserted below the periostium in the infrapalpebral area. In it there lies a notch in respect of the neurovascular infraorbital bundle. The function of this implant is to soften the depression along the inferior orbital rim and to increase the prominence of the suborbital and submalar areas which, in these cases, are often atrophic. The implant is generally inserted through a subciliary cutaneous incision or, more rarely, via a transvestibular approach (through the mouth). In the former case, at first, the surgeon behaves exactly like in a transcutaneous inferior blepharoplasty. After having incised the skin and undermined between the orbicularis and the septum down to the orbital rim, one transects the periostium and continues the dissection caudally, in contact with the bone surface, being careful not to injure the infraorbital bundle. The subperiosteal pocket, in which the implant will be placed, has to be made with great precision, scrupulously following the presurgical markings. One must be able to see the infraorbital neurovascular bundle clearly, defining its exact position in respect to the nasal wall and the orbital rim. The measurements are marked on the implant, using a template if one wishes to, so as to be able to consequently make a slit in which the above-mentioned bundle is placed. Once the implant has been carved this way, it can be inserted in its site and fixed with a suture, either to the periostium or to the bone inferiorly to the medial canthus. After having positioned the implant, in the majority of cases, the posterior and/or anterior palpebral lamellae should be reinforced with a canthoplasty, in order to avoid iatrogenic displacements of the inferior palpebral rim (round eye, ectropion). In our opinion, inserting the Flowers' implant through the oral vestibule is excessively and pointlessly complex. In those cases where a major prominence in the cheekbone area is also necessary, both the Flowers' prosthesis and a malar implant can be used. We think it is interesting to employ Flowers' implants in those rare cases that have been already mentioned and when it is necessary to increase the prominence of the suborbital area. The results are generally satisfactory, even though we believe it is always advisable to use rather thick implants in order to obtain a clearly visible correction. The rare complications that could arise are those that are common in other surgical operations (infections, hematomas, etc.), as well as implant displacements in case the pouch has not been made with enough precision and deformities of the palpebral border, if one has not, for example, taken steps to compensate any laxity present in the eyelids by means of a canthoplasty.

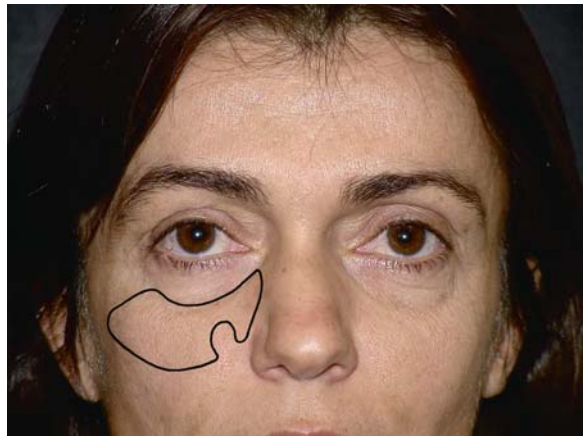

Fig. 25.5. Flowers' implant. The prosthesis outline has been drawn on the area where it will eventually be implanted. Note the notch in which the infraorbital bundle will be inserted

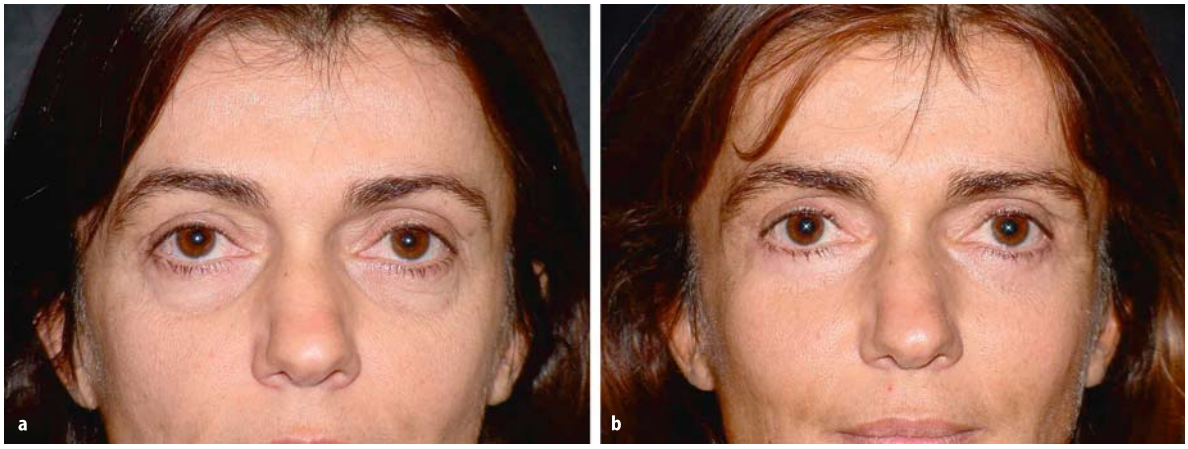

Fig. 25.6a, b. Flowers' implants: before and 1 year after the operation. In this case this technique was chosen because the patient was too thin, did not have sufficient fat in the lower eyelid and did not want a major operation such as a mid-face lift

25.7 Mid-face Lift

The recent tuning up of a reliable and well-standardized mid-face lift technique most probably represents the greatest evolution of facial aesthetic surgery in the last 10 – 15 years. It finally allows problems to be solved concerning the inferior periorbital area for which a proper treatment had not yet been found. The natural and stable way the correction of the nasojugal groove is carried out is to be included among the many effects of this fascinating operation.

Yet, in order to attain such a result it is necessary to completely undermine the periorbital soft tissues at the subperiosteal level reaching the groove itself. An almost vertical traction of the mid-facial flap that has been created must be exerted as well. The operation begins with a subciliary incision. Then follows the section of the orbicularis that is undermined from the septum down to the orbital rim. At this point the dissection continues caudally below the periostium until it reaches the inferior malar border as well as the gingival fornix. Medially the subperiosteal undermining must go to the pyriform aperture, surrounding the infraorbital bundle and reaching the orbital rim superiorly. At this level the periostium must be completely detached from the arcus marginalis along its length, so as to be able to make the thick mid-face flap rise easily over the nasojugal groove. Laterally the subperiosteal dissection must be extended to all the malar area and to the anterior third of the zygomatic arch.

It is very important to incise the periostium along the base of the undermined area; otherwise the flap cannot move. A small incision is then made along the lateral part of the superior palpebral groove, through which a paracanthal tunnel is made between the orbicularis and the periostium, joining the suborbital undermining. Another short incision that allows the superficial temporal fascia to be undermined from the temporal muscle aponeurosis, is then traced in the temporal area of the scalp, about 2 cm in from the hairline. This dissection must be extended inferomedially at the same depth until it joins the mid-face pouch along the lateral inferior orbital rim. Now the anchorage threads must be positioned. The first one hooks the flap full-thickness, about 1 – 2 cm below the orbital rim, and is then fixed to a drill hole in the lower orbital rim and/or to the temporal aponeurosis through the tunnel that has been previously created. The second and third sutures, which are without doubt the most important, hook onto the orbital and periorbital portions of the orbicularis, crossing the periostium adhering to its posterior face. These sutures are fixed, through the paracanthal tunnel, to the superolateral orbital rim periostium (or directly to the bone by means of little holes) and to the most medial part of the temporal aponeurosis. When the mid-face flap is lifted vertically, the thickest soft tissues of the cheek can be moved to the palpebral area. In this way the nasojugal groove is softened as well, and the prominence of the malar area is accentuated. If the nasojugal groove is particularly deep, one or two small perforations should also be made through the inferior orbital bone rim, where the most medial section of the mid-face flap can be anchored. Finally any possible excess of skin, together with a strip of orbicularis, is removed and the wound sutured. This is certainly the most complete, elegant and "physiological" operation amongst the ones available for the correction of the nasojugal groove. However, a discrete training period is needed to be able to achieve good quality results on a regular basis. At the beginning it is difficult to obtain a perfect symmetry between the two sides while simultaneously avoiding excessive and/or non-desirable changes in the shape of the eyes and/or

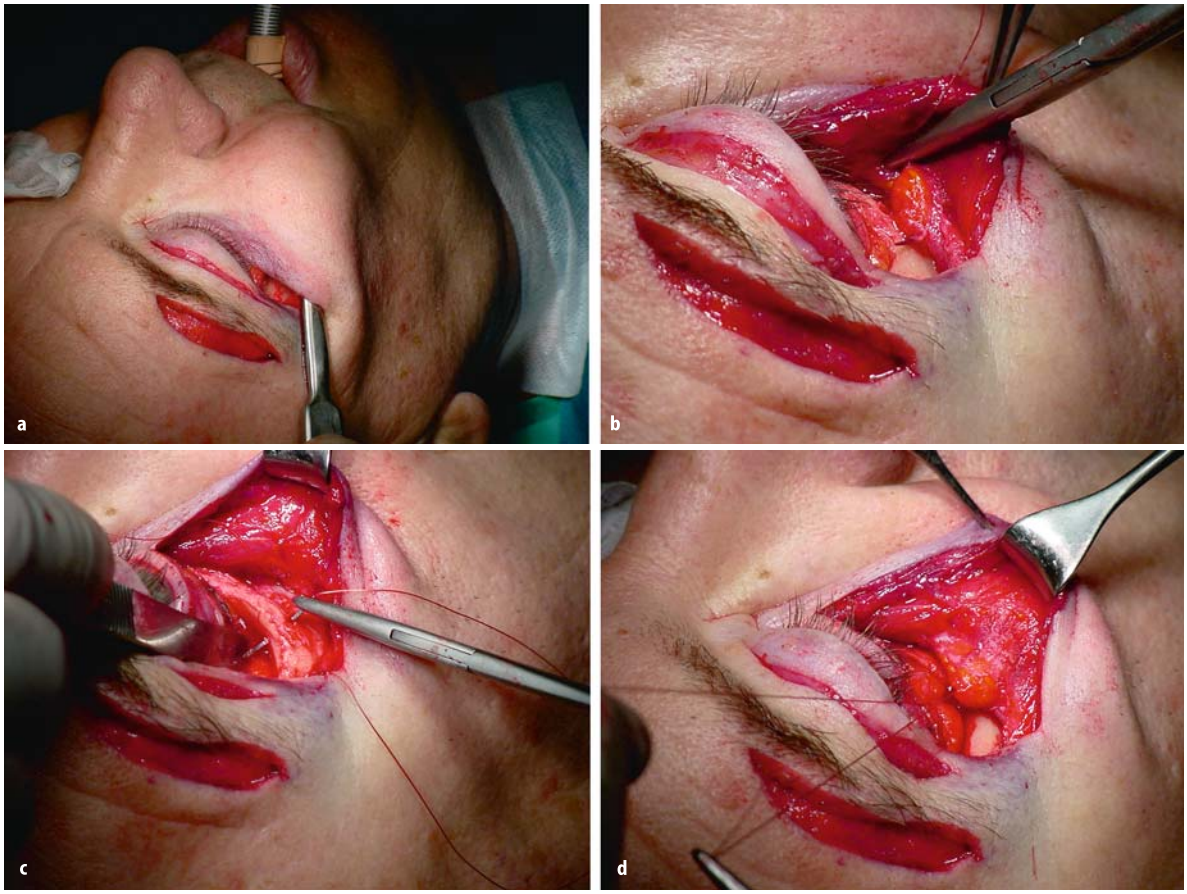

Fig. 25.7a–d. Mid-face lift. In picture **a** a wide sub-periosteal undermining in the infraorbital and malar area is being performed. In pictures **b**, **c** and **d** the anchorage sutures can be seen

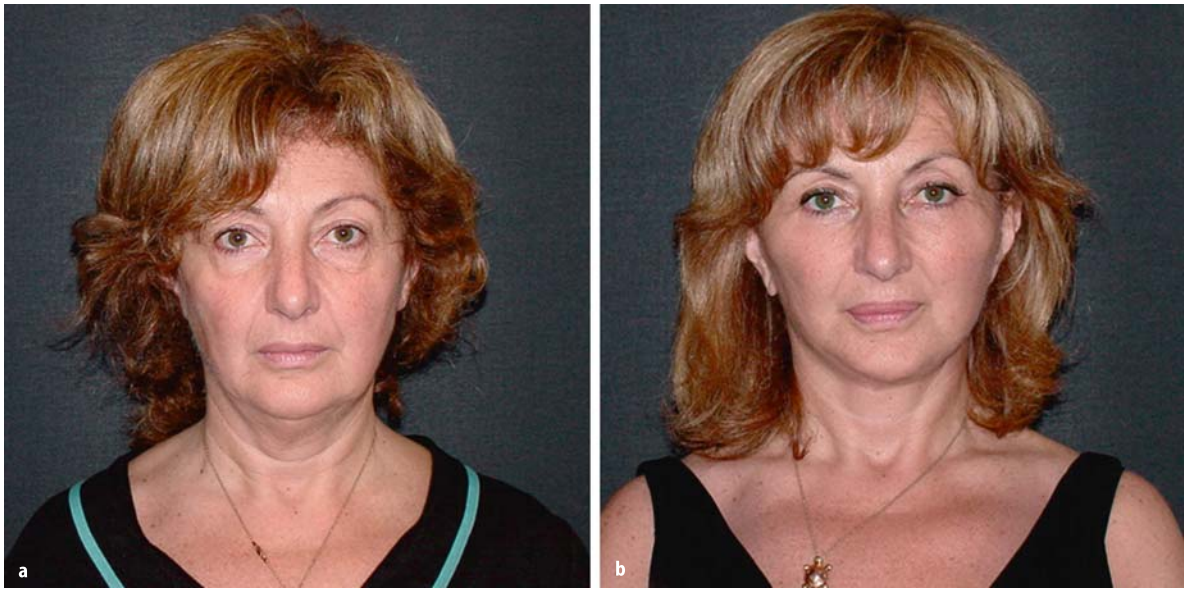

Fig. 25.8a–d. Mid-face lift (and lower-face and neck lift): before (**a, c**) and 1 year later (**b, d**). This operation allows remarkable results to be achieved as far as the nasojugal groove is concerned and the defects corrected in the entire suborbital and malar areas

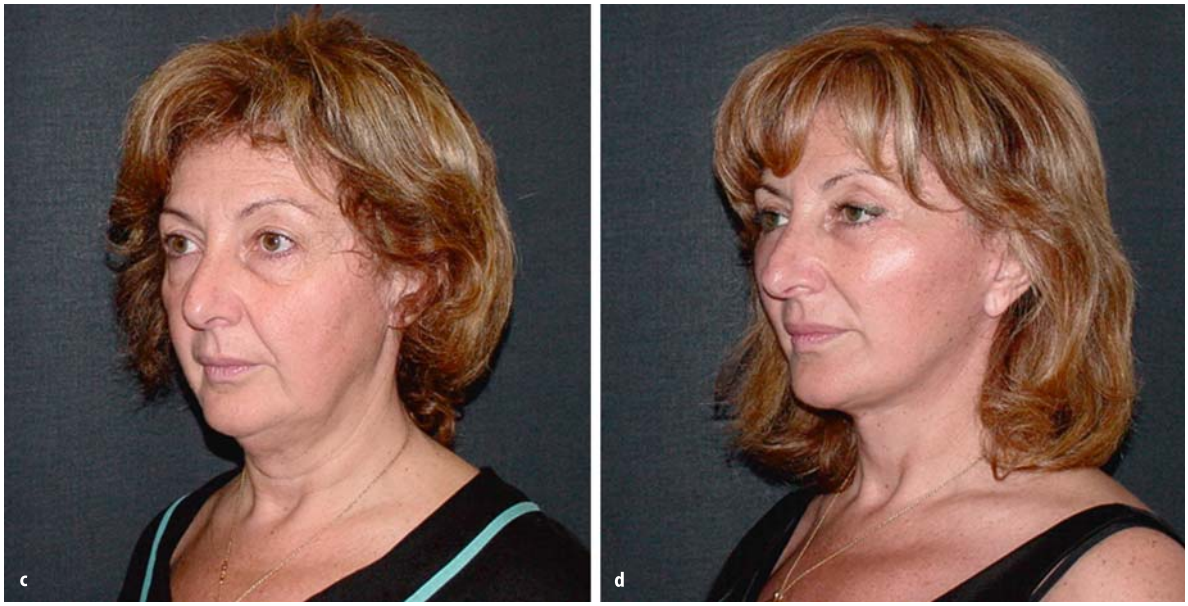

Fig. 25.8 (*Cont.*)

palpebral rim dislocations caused by excisions that are too exuberant compared to the actual skin excess. The patient must also be informed that a long period of time is needed before the edema in the area undergoing subperiosteal dissection disappears.

25.8 Conclusions

We are not hiding our enthusiasm and therefore our preference in regards to mid-face lifts in those cases where they can be carried out. We have worked with commitment for many years to elaborate and perfect this operation. Thanks to it, at the moment, we are able to reposition the whole of the soft tissues in the malar-suborbital area (skin, orbicularis and cheek fat pad), and in doing this, increase the prominence of the cheekbone, reduce the depth of the nasolabial groove and give back major firmness to the eyelids. By lifting the tendons of the lip elevator muscles that enter the periostium of the inferior section of the flap, a slight correction of the oral commissure ptosis is made possible. Furthermore, the new and thicker palpebral walls with their regained tonicity, give the advantage of correcting palpebral bags without having to manipulate anything but only by pushing them back into the orbital area. Thanks to this operation, a nasojugal groove that is too deep can be corrected simply by filling it with the thicker soft tissues of the cheek which have been moved upwards. Therefore, we feel it is the most rational and physiological way to face this problem. Usually a valid alternative to this treatment is fat grafting (also the superficial musculo-aponeurotic system, SMAS, or the temporal fascia collected during a face-lift or a dermis-adipose graft, like the one proposed by Little, could be suitable). The results are certainly less predictable but in most cases it is very effective.

The third option, in our opinion, is the Loeb technique (shifting caudally the adipose "hernias") that can be used every time a blepharoplasty is necessary and when fat is available. Only in a final analysis should a surgeon turn to an alloplastic implant that can, however, offer satisfactory results. The best indication of this procedure remains, in any case, the simultaneous need for softening the nasojugal groove and increasing the prominence in the suborbital area.

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Contemporary Concepts for Correction of Neck Contour Deformities

26

B.F. Connell

Why is neck contour correction needed? Both men and women know a well-contoured neck is an artistic necessity for an attractive and pleasing appearance. The neck can indicate (Fig. 26.1):

- Fitness or obesity
- Vitality
- Strength
- Sensuality
- Beauty or elegance
- Masculinity or femininity
- Health or disease
- Age

Frequently it is not enough to perform only liposuction and tighten skin. Platysma muscle tightening will not overcome deep layer problems. The anatomical problems should be diagnosed and corrected. By utilizing at the same time deeper layer facelift and neck lift techniques including contour correction and support with the superficial musculo-aponeurotic system (SMAS) and platysma muscle, attractive contours can be restored or formed. Some anatomical problems, which can be corrected by precise neck lift, include:

- Excessive skin
- Nipple neck skin
- Platysma laxity

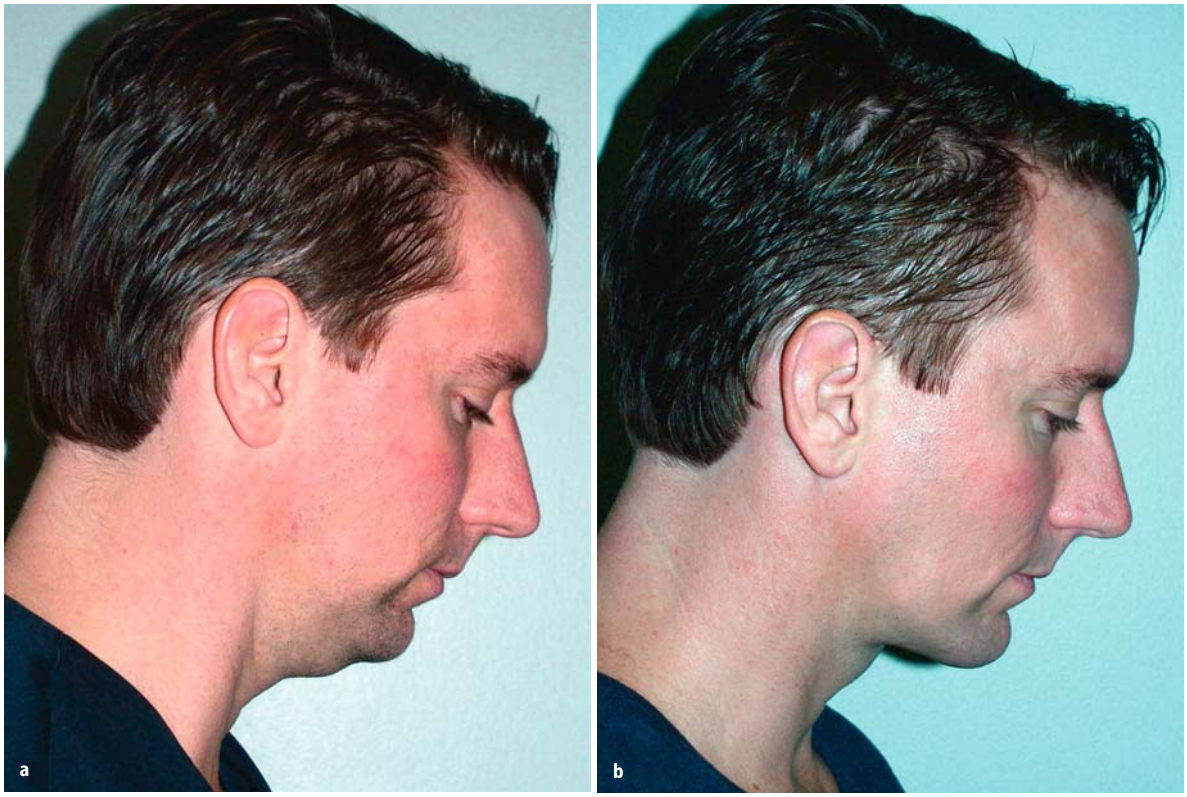

Fig. 26.1. a, b Neck can indicate obesity or fitness

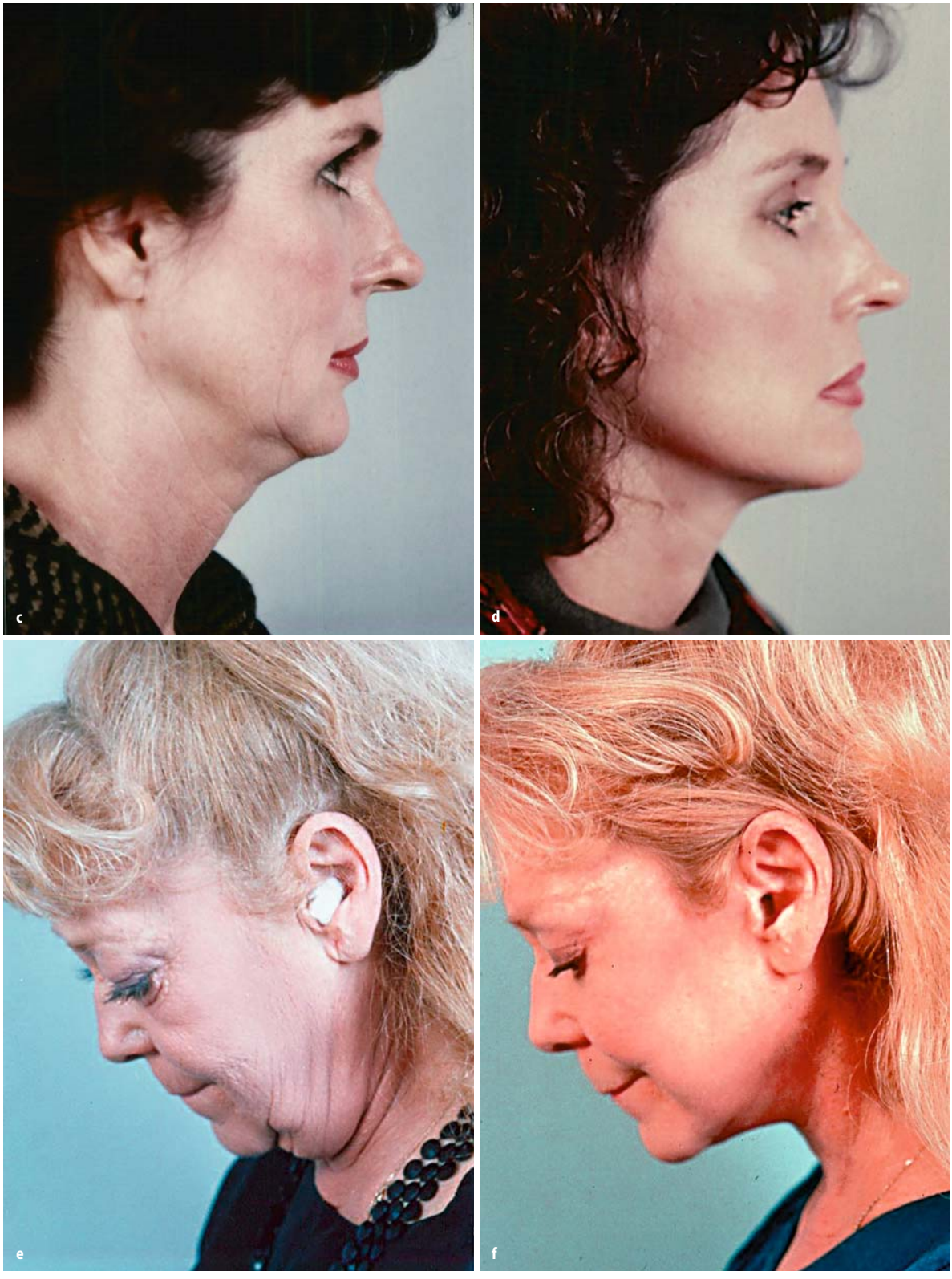

Fig. 26.1. c, d Sensuality or beauty. **e, f** Rejuvenation and vitality.

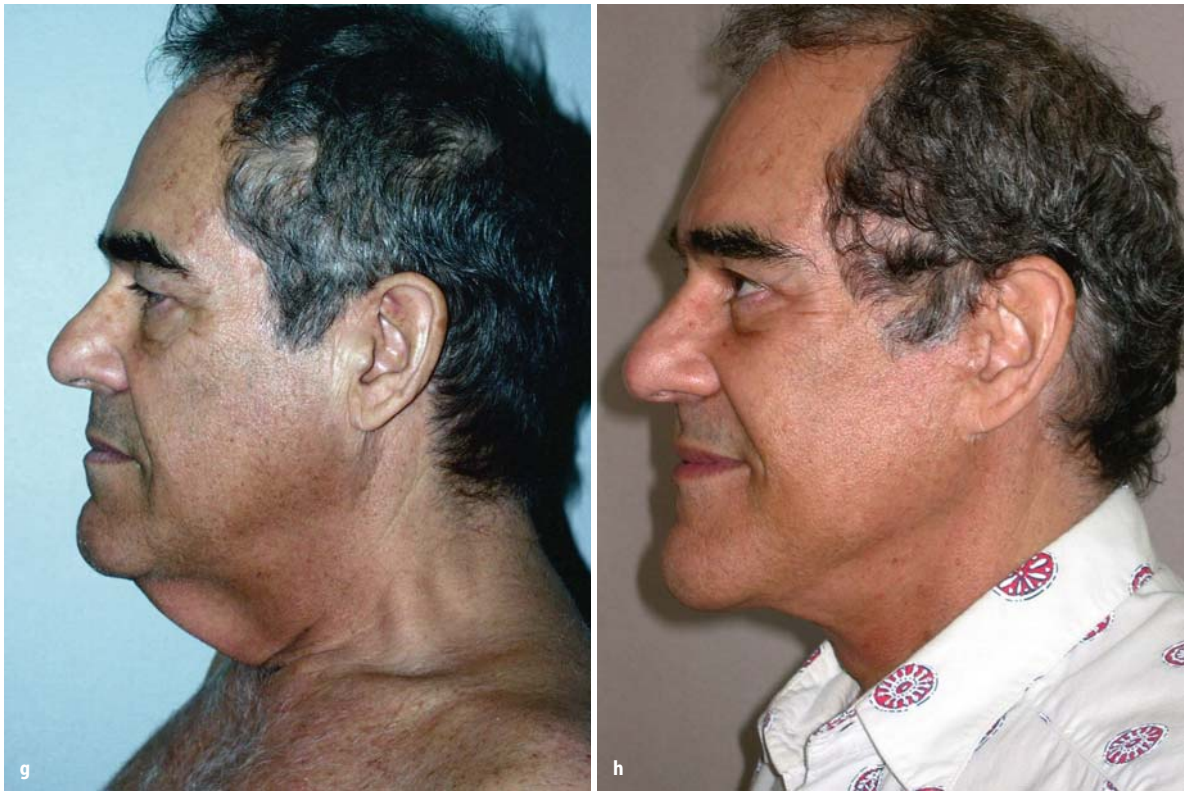

Fig. 26.1. g, h Age, strength, and health

- Subcutaneous or subplatysmal fat
- Large submandibular glands
- Digastric muscle hypertrophy
- Tightening skin over these problems does not correct them

A contour problem frequently overlooked or not diagnosed is the contour problem caused by a large or hypertrophic anterior belly of the digastric muscle. Often when posterior movement of the mandible corrects prognathism, the stretched out anterior belly of the digastric muscle becomes thick and wide and contributes to the postoperative double chin formation. The thick submental muscles become thicker when the projection of the chin is decreased.

After a facelift with subcutaneous and subplatysmal fat contouring there will be some continued liquefaction of the fat. With less fat covering the anterior bellies of the digastric muscles, which were not prominent before, may be postoperatively prominent (Fig. 26.2). Treatment of very large anterior bellies of the digastric muscles is tangential resection of the anterior belly. Often there is a combination of digastric muscle hypertrophy and subplatysmal fat. For younger patients who have no facial sagging skin and sagging subcutaneous tissues, a submental incision alone is adequate for correction. This is indicated for patients who do not have

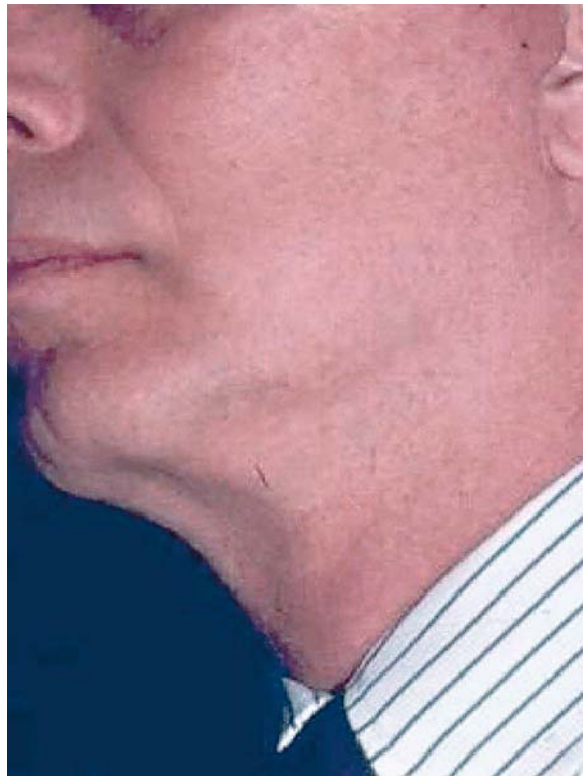

Fig. 26.2. This patient had a facelift and with time the anterior bellies of the digastric muscles were revealed, which could easily be misdiagnosed as platysma muscle bands

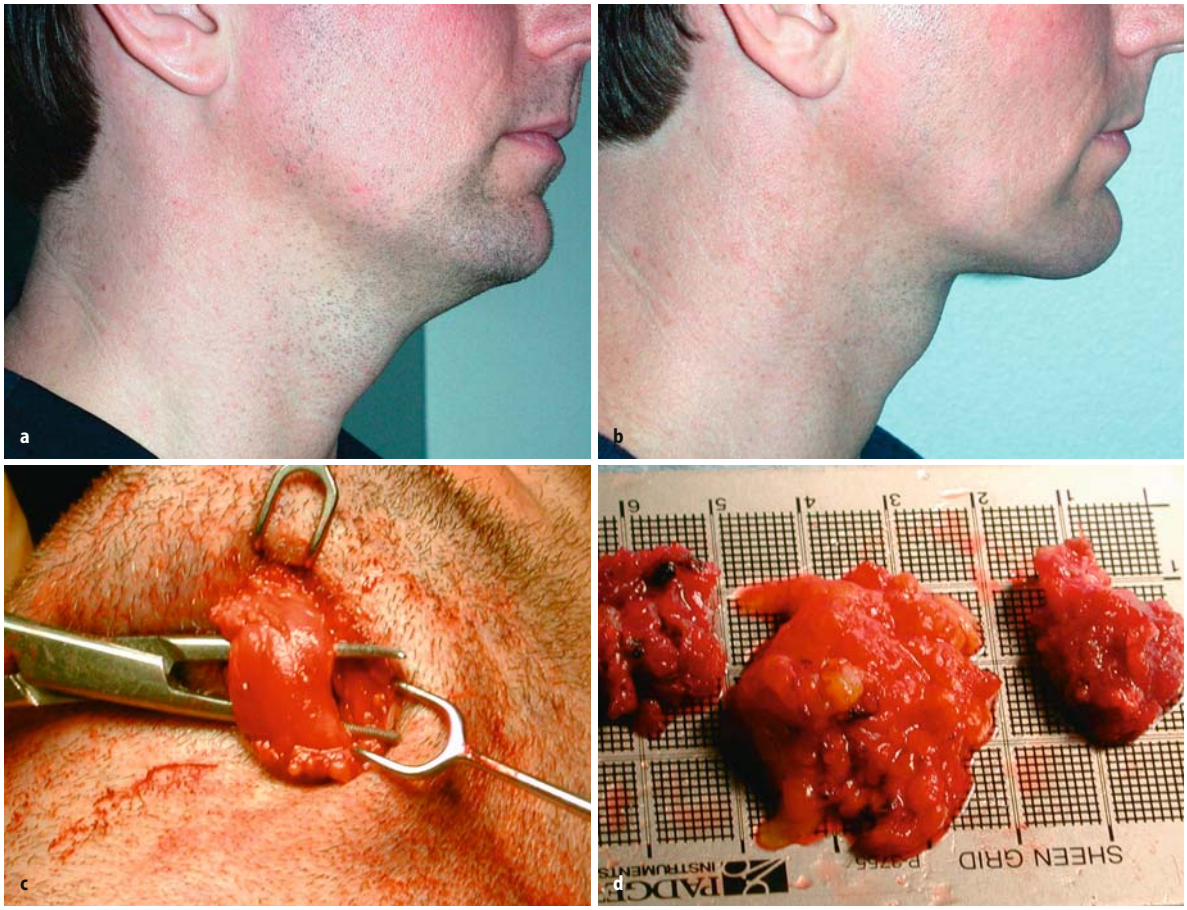

Fig. 26.3. a, b Surgical correction was made by utilizing only a transverse submental incision posterior to the submental crease. Ninety percent of both anterior bellies of the digastric muscle were excised along with removal of midline subplatysmal fat. **c** Platysma muscle elevated by passing the large hemostat superior to the inferior separation in preparation for excision was made by passing the large hemostat inferior to the small upper portion of the muscle and the muscle was then excised by using a needle tip coagulating current to separate the muscle from the mandible and from the sling. **d** On each side of the midline of excised subplatysmal fat is the contracted portion of the anterior bellies of the right and left digastric muscles

short platysma muscles and do not need platysma muscle transection. Treatment for many patients includes (Fig. 26.3):

- Submental incision only
- Release of submental crease
- Release of anterior mandibular ligament
- Excision of excessive subplatysmal fat
- Excision of 95% of anterior digastric muscle
- Midline invagination of platysma muscle
- No platysma transection at cricoid

The patient in Fig. 26.4 had a preoperative diagnosis of a digastric muscle hypertrophy problem, which appeared as a sausage shaped fullness under the skin anterior to the submaxillary gland. The muscle became thicker and protruded more with the neck flexed. When the chin is extended the muscle is elongated and the bulge is decreased. The surgical technique exposes the digastric muscles through a submental incision placed approximately 1 cm behind the submental crease. A midline vertical incision is made through the platysma muscle, which is reflected to expose the subplatysmal structures. After excessive subplatysmal fat is removed, the neck is flexed to see if the bulge persists. If a bulge persists it usually is composed of either subplatysmal fat alone or is combined with large anterior bellies of the digastric muscles. The tangential removal of 95% of the anterior belly is not difficult and is accomplished by passing a curved hemostat under the muscle to be excised. Then the muscle is transected close to the sling at the cricoid cartilage and reflected upward. Then the muscle is separated at the chin with a needle on the coagulating current. After this is repeated on the opposite side the neck is flexed and if the contour is satisfactory there would be no need to remove more muscle. However, if there is still a bulge on one side or the other, additional digastric muscle can be removed (Figs. 26.5, 26.6).

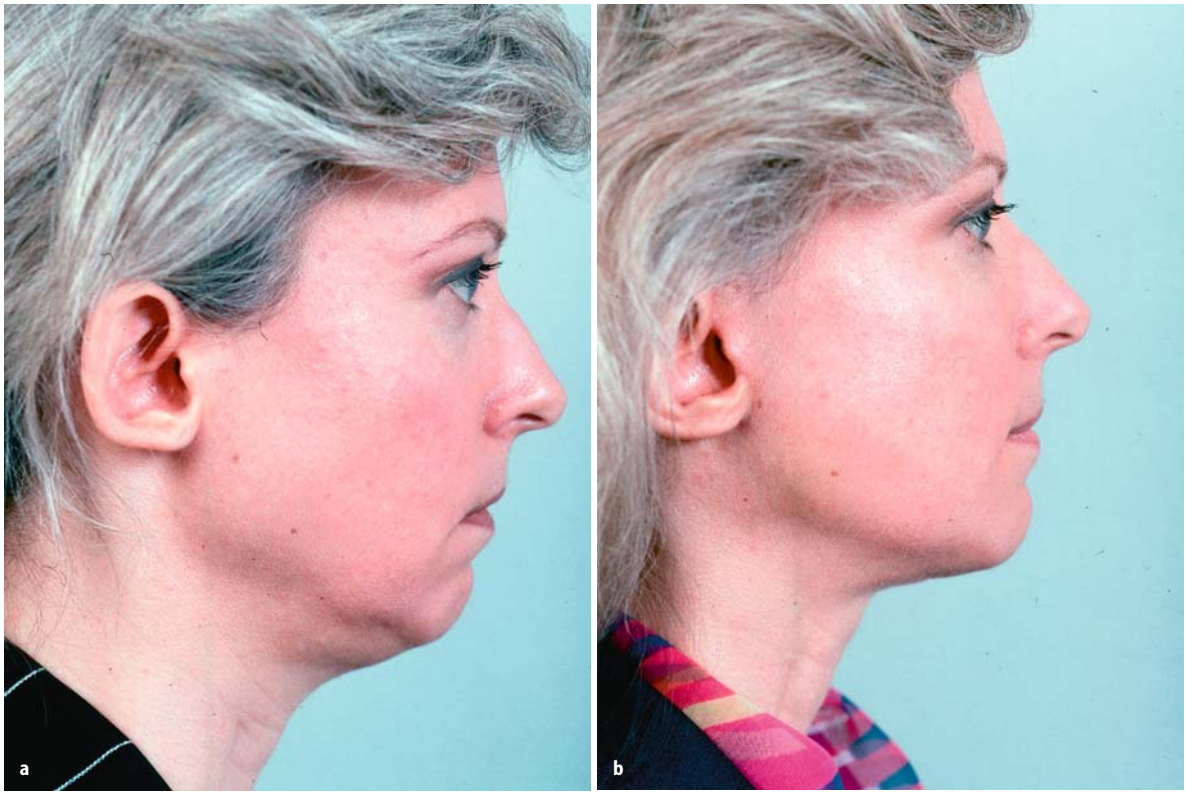

Fig. 26.4a, b. The large anterior belly of the digastric muscle appears as a sausage shaped fullness anterior to the small submaxillary gland. The postoperative photograph taken 2 months after surgery shows a striking improvement following excision of 90 % of the large anterior bellies of the digastric muscles

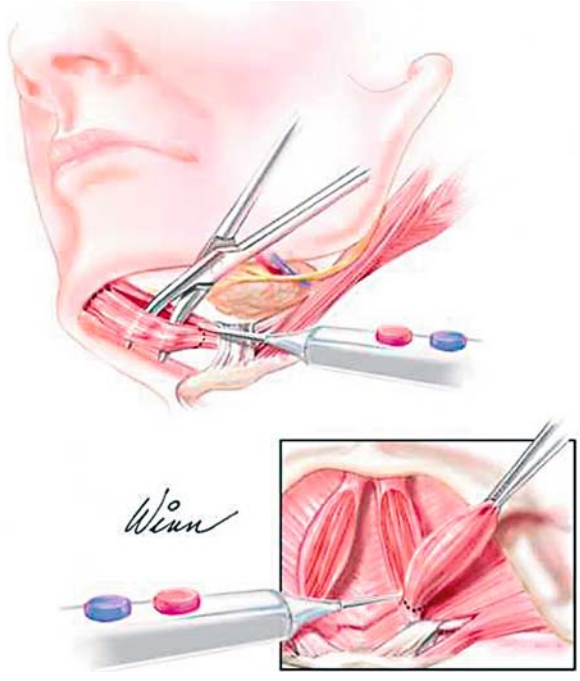

Fig. 26.5. The diagram demonstrates the technique of separation of 90 % of the inferior border of the anterior belly of the digastric muscle in preparation for tangential excision

In regard to planning of the contour correction of neck deformities, the following must be considered.

- Submental incision posterior to the submental crease
- Subcutaneous submental liposuction when indicated
- Neck lift without skin excision
- Neck lift with occipital skin excision
- Neck lift with facelift
- Neck lift with chin implant

Liposuction should not be made with the assumption that all poor neck contours are the result of accumulation of subcutaneous fat. Submental liposuction is indicated for those patients who have a problem of subcutaneous fat. However, for the majority of patients submental liposuction alone is an incomplete solution.

For persons who can have a very good surgical neck improvement without skin excision the question arises as to how is this possible? This is possible because the straight-line anterior neck without a pleasing concave contour can become a pleasing contour by the concavity utilizing all of the excessive neck skin. A straight line between two points is shorter than a curved line and the excessive skin disappears by being utilized to make the curved neckline concavities (Fig. 26.7).

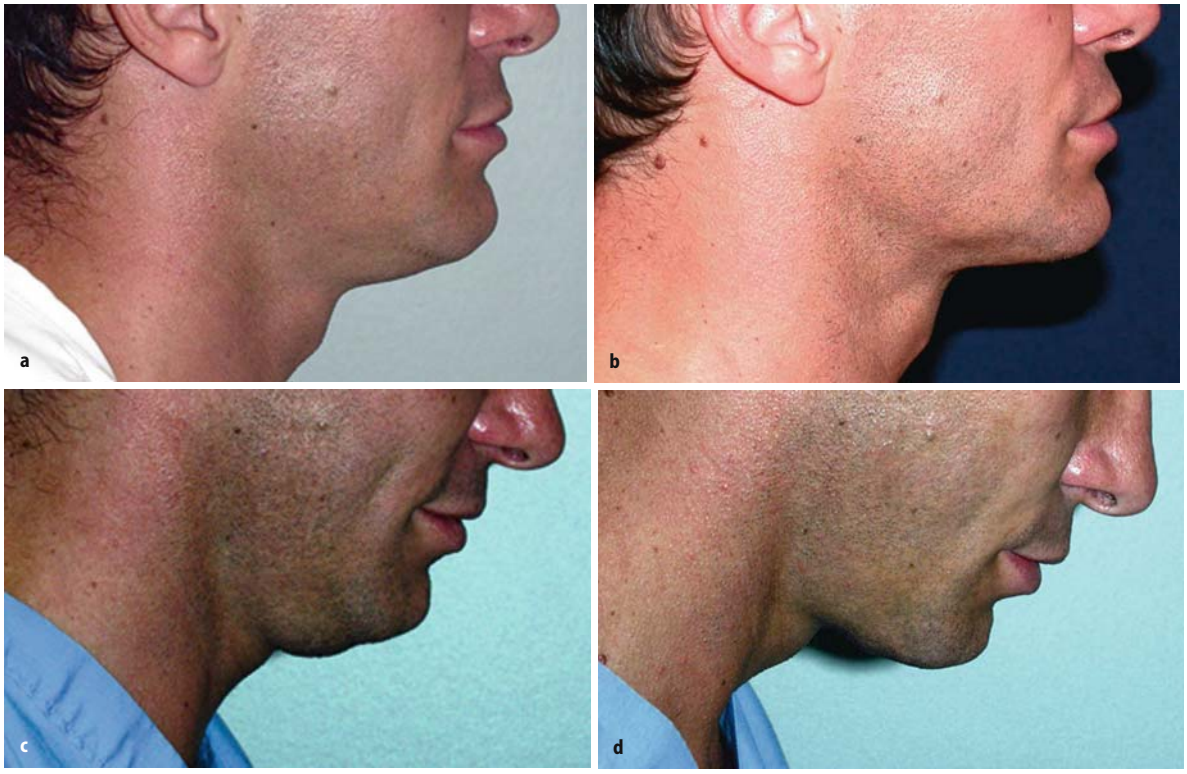

Fig. 26.6a–d. Shows preoperative submental bulge forming a double chin appearance and the appearance a year later following tangential excision of 90% of the anterior belly of the digastric muscle. There was no excessive subplatysmal fat

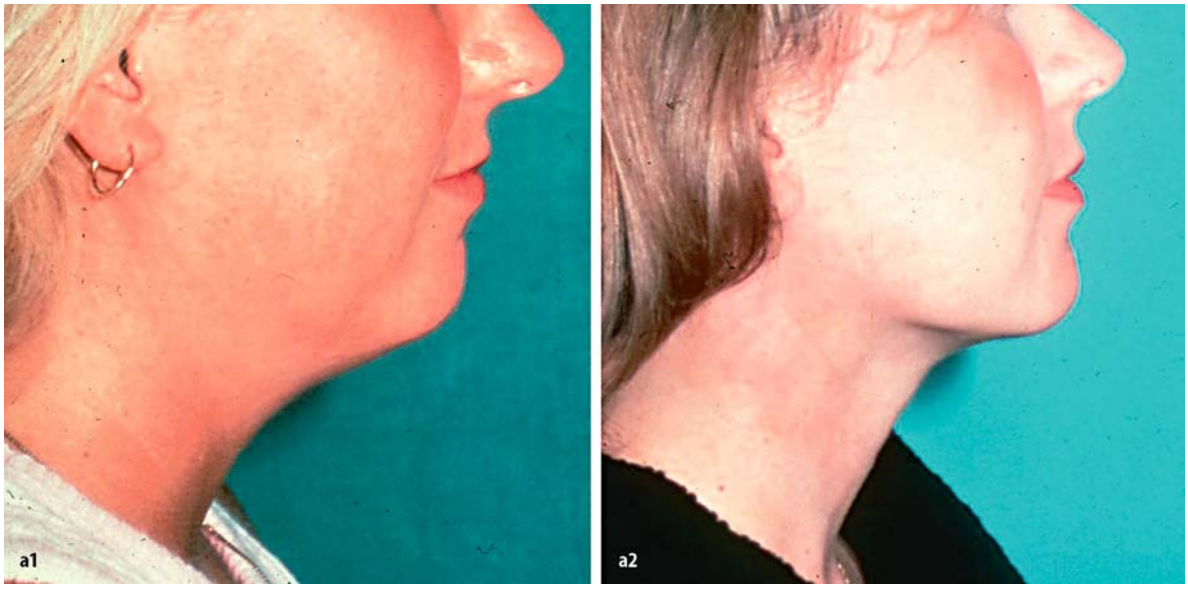

Fig. 26.7a, b. A straight line between two points is shorter than a curved line. Consequently, excessive skin disappears by being utilized to form the curved neckline concavities

A precise neck lift allows the needed precious subcutaneous fat to be preserved and allows the deep layer problems to be appropriately treated. Natural appearing neck rejuvenation sometimes requires a facelift with periauricular incisions if there is much excessive skin or downward descent of the subcutaneous fat, which forms jowls if the tissues of the face have descended into the neck. A youthful neck with an older face makes the face look worse. A precisely performed neck lift allows skin to be excised without skin tight-

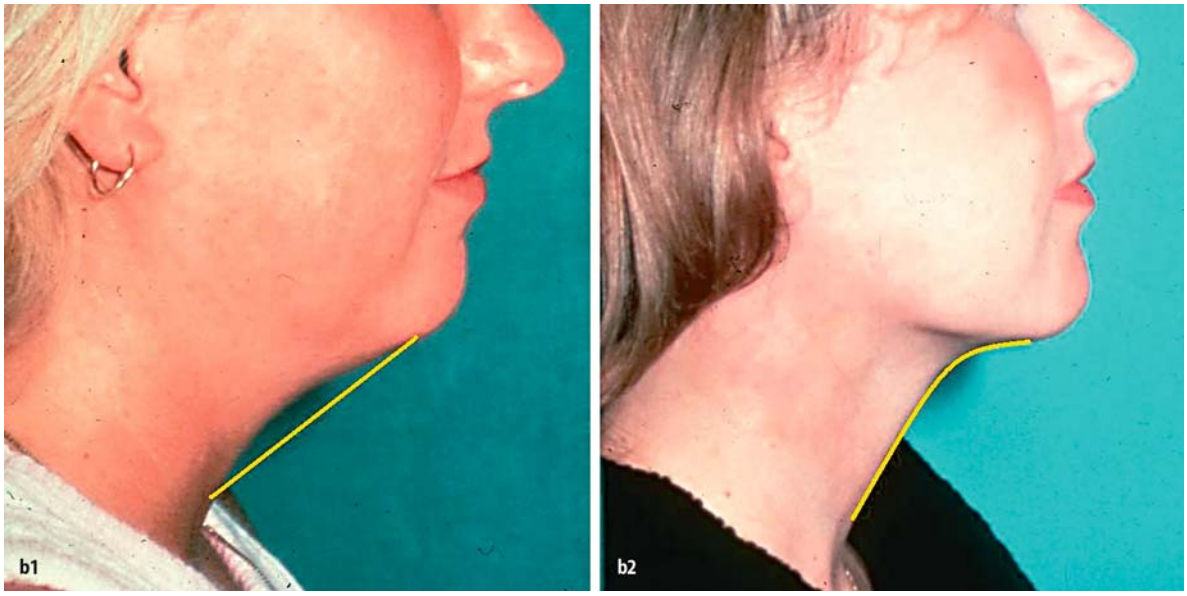

Fig. 26.7b

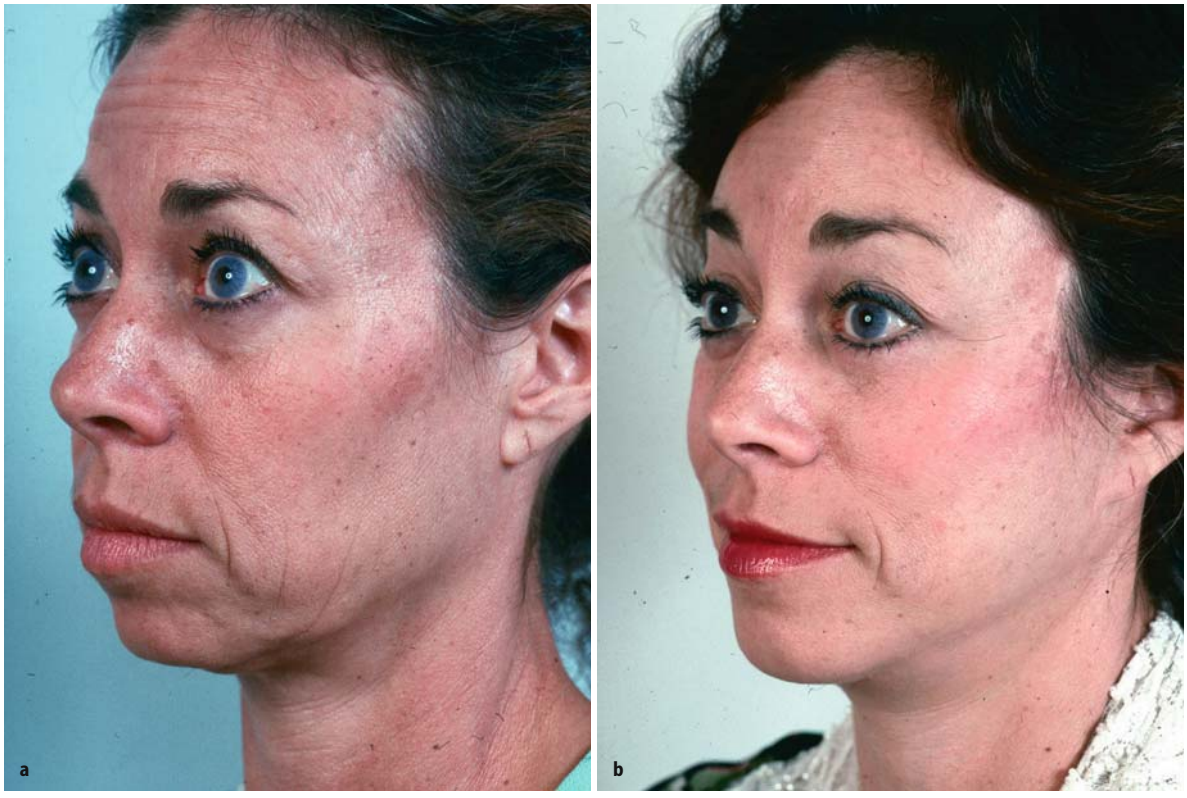

Fig. 26.8a, b. On occasion chin implants can improve results but cannot by themselves produce the very best neck contour

ness and provides a more sustained and natural appearing improvement when deep layer support is utilized. On occasion chin implants can improve the results but cannot by themselves produce the very best neck contour (Fig. 26.8).

Neck lift procedures not used by the author include the submental and neck skin Z-plasty. This procedure may have a visible scar seen when the patient looks from side to side or looks upward. Males may have hairs growing in a different direction within the

flaps and there are always better ways to improve the neck without making anterior neck Z-plasties. A more rapid improvement of excessive neck skin may be made with hidden incisional scars along the occipital hairline.

For cervical lipectomy, the neck fat is found in three layers: preplatysmal, subplatysmal, and deep cervicosubmental located between the digastric muscles. The diagnosis of contour problems due to fat requires the neck be examined with the platysma muscle activated to reveal preplatysmal fat. This fat can be pinched and will remain within the examiner's grasp. Long time submental fullness and poor cervical contour are likely to have subplatysmal fat collections. Sometimes secondary face and neck lift surgical patients who have poor cervical contour may have excessive subplatysmal fat, which was not removed.

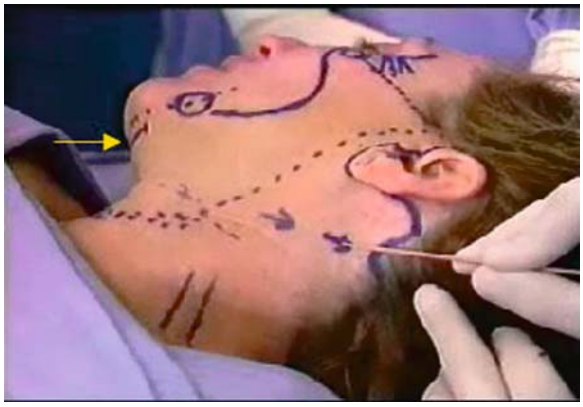

Fig. 26.9. The *yellow arrow* indicates the usual location of the submental incision, which is posterior to the natural crease. This figure also shows the circle where the mandibular ligament is to be released. The upper circle of the malar is the rotation point of the upward shift of the SMAS. The *dotted line* shows the expected location of the transection of the SMAS and the platysma muscle carried down to the level of the cricoid. The *arrows* below the ear show the direction of the expected neck vector for maximum skin improvement

Subplatysmal fat is found as a triangular shaped pad in the submental region and this fat may be exposed by elevating the medial edge of each platysma muscle through the incision in the midline. This elevation reveals subplatysma fat and the anterior bellies of the digastric muscles. When there are enlarged submaxillary glands these can be seen through this incision. Subplatysmal fat between the digastric muscles should not be removed unless the anterior bellies of the digastric are reduced. If there is removal, it should always be convex in contour between the digastric muscles because there will be additional liquefaction of fat postoperatively. When the patient has a lack of concave contours either because the platysma muscle is short or has prominent bands the proper treatment is complete transection of the platysma muscle so that it can rise upward to form the concavity. The transection is made by a subcutaneous incision within the 1 cm anterior to the sternocleidomastoid, which is an area that is avascular except for the crossing of the external jugular vein. As the incision proceeds downward to the level of the cricoid cartilage there is only a small amount of platysma to be transected, which is approximately 2.5 cm or more of vascular muscle that needs to be cut across at the level of the cricoid cartilage. At this location the muscle is thin and if excess fat has been removed the lower and upper cut edges are not visible after surgery (Fig. 26.1c, d). Platysma muscle bands are either hard or soft. Soft bands change very little when the platysma muscle is contracted and are predominantly a problem of skin or platysma muscle laxity. Hard bands become tight and exaggerated upon platysma activation and are predominantly a problem of platysma muscle origin. The treatment of hard bands requires transverse platysma mus-

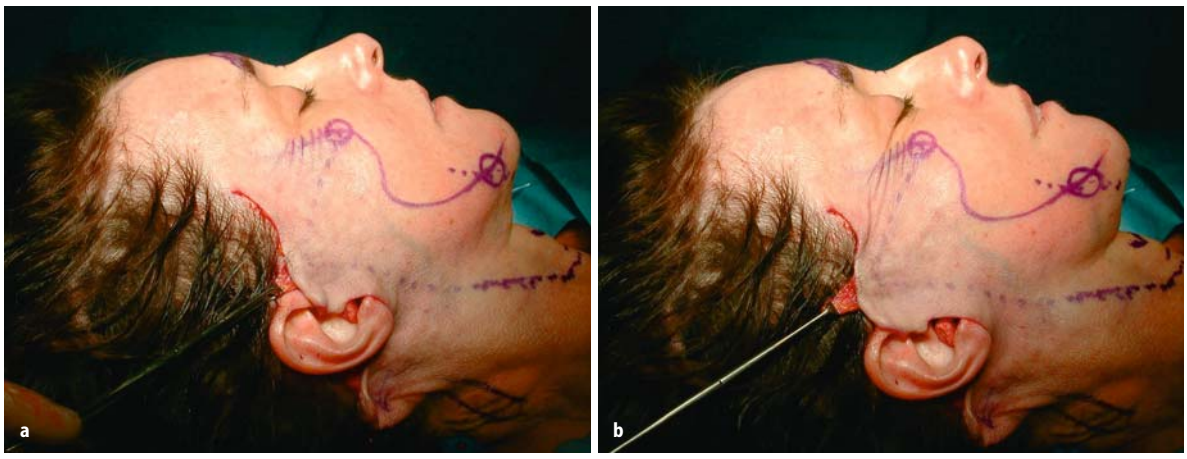

Fig. 26.10. a shows the patient right after elevation of the skin, freeing of the SMAS and transection of the SMAS at the level of the cricoid. **b** shows the effects on shortening the eyelid, elevation of the angle of the mouth, improvement across the midline at the chin and submental area and great improvement at the hyoid utilizing only one vector shift

cle transection. The result of this platysma muscle transection is dramatic, long lasting and superior to suspension or plication techniques. Platysma muscle transverse transection should be performed at the level of the cricoid cartilage or lower and never at the level of the hyoid. Transection higher than the cricoid level may result in visible cut muscle edges, a depression in this area and muscle dysfunction. Platysma transection extent would depend upon the type of bands or the type of short platysma muscle present (Fig. 26.1c,d, 26.9).

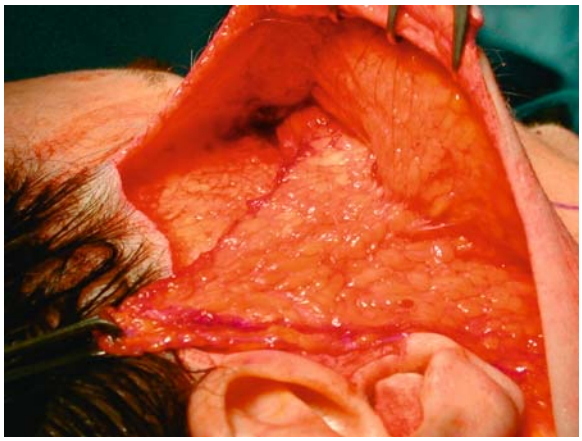

Fig. 26.11. Shift of the SMAS and attached platysma muscle in the precise vector to achieve maximum improvement frequently has an overlap of the temporal fascia of more than 3 cm

Submental support is long lasting and visible at the time of surgery. Excellent submental area rejuvenation requires precise SMAS liberation from the attachment at the malar bone, masseter muscle, parotid gland fascia, and the anterior mandibular ligament attachments (Fig. 26.9). The most frequently used technique for the deep layer support utilizing the SMAS includes a high transection at the superior edge of the zygomatic arch or higher and a transposition of a flap to the mastoid fascia. On rare occasions a superior third flap can be utilized to get the precise vector needed for elevation of the angle of the mouth, flattening of the nasolabial fold and changing the nasojugal groove from the diagonal of old age to the horizontal of youth (Figs. 26.10, 26.11). If preoperatively it is noted that the prominent gland is large and producing an objectionable contour, resection of the protruding portion of the gland can be per-

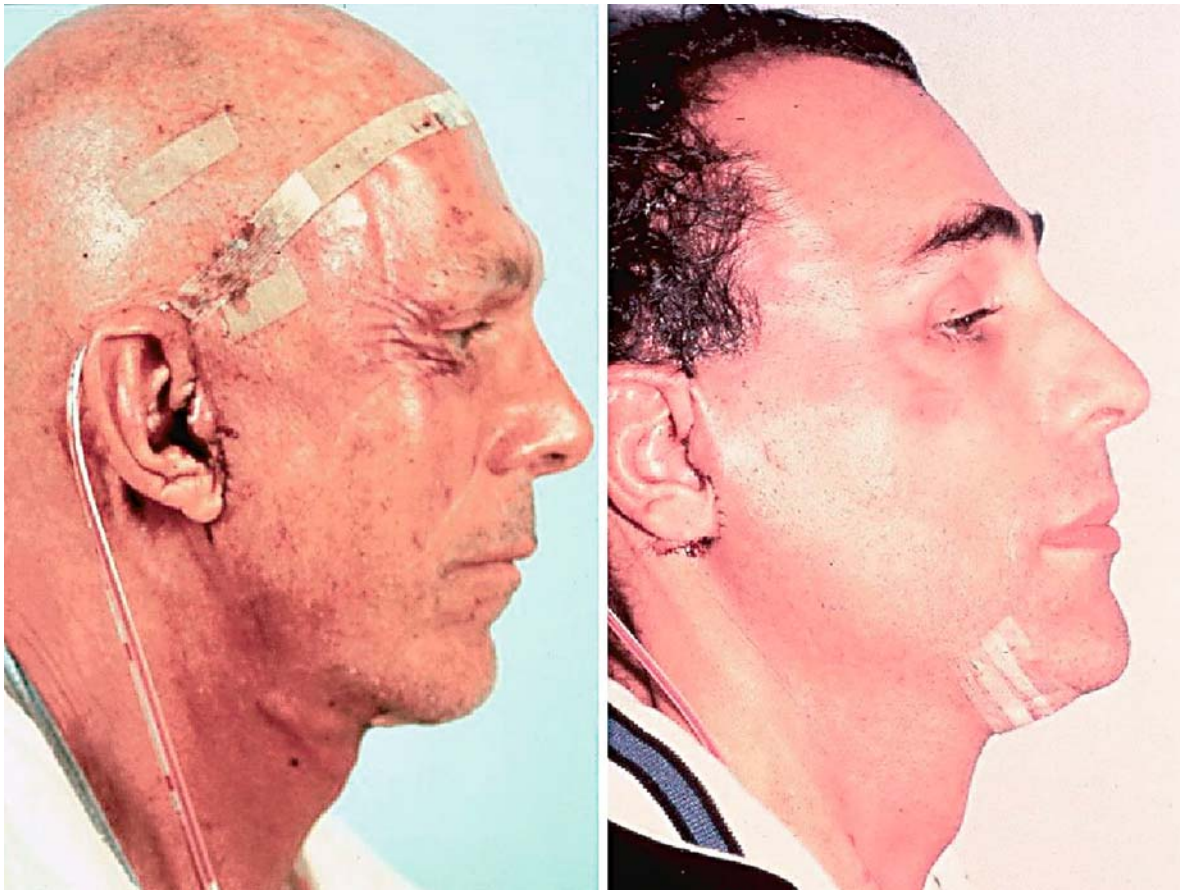

Fig. 26.12. The appearance of the patient the first day after face and neck lift and brow lift. With gentle handling of the tissue by the surgeon and the assistant there is very little discoloration and very little swelling

formed through the submental incision after the platysma muscle is opened in the midline. Why and when is submandibular gland reduction indicated? If large submandibular glands disrupt the attractive neck contour in thin necks or patients who have had prior neck surgery these large glands may be visible.

If submandibular glands are hidden by submental fat, lax platysma muscle and redundant skin, surgical correction of these problems may permit the glands to be revealed and pleasing neck contours disrupted. Preoperative palpation is a very important part of the preoperative evaluation of the neck. For surgical correction the large submandibular glands are exposed through a submental incision between the chin crease and the hyoid. The platysma muscle is opened in the midline and reflected. The capsule of the submental gland is incised in the inferior one-third and the resection of the gland is made inside the capsule.

The submental incision in the midline of the platysma muscle is closed by invagination with one or two layers of interrupted 4-0 nylon sutures. Seldom is excessive muscle excised in the midline. The lateral shift and suturing of the platysma completes the support in the neck.

The most important of the surgical procedures for minimizing scar detectability is excision of skin in such a manner that there is no tension. The support is maintained by the deep layer support. Basic concepts include the realization that skin is a covering layer not a supporting one. Only skin that is truly excessive should be excised. Long-term improvement in neck contour is not possible by only tightening neck skin. Tension of the skin is unnecessary and may cause problems in blood supply and produce wide scars. Excision perpendicular to an improper vector as well as excessive skin excision produces wide scars. Incorrect location of excision may displace the hairline.

The gentle handling of the tissues by the surgeon and the assistant minimizes the postoperative swelling and discoloration (Fig. 26.12).

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Embracing the High SMAS for Facial Rejuvenation 27

B.A. Toth, D.S. Chang

27.1 Introduction

Operations centered on the superficial musculo-aponeurotic system (SMAS) have been the mainstay of facial rejuvenation procedures for nearly three decades. Since its initial description by Mitz and Peyronie in 1976 [6], the SMAS has been successfully used by plastic surgeons as the foundation for different face-lift techniques. Whether a SMAS lift or plication is performed, the basic principle of utilizing the SMAS to restore facial youth has withstood the test of time and has become a reliable technique to achieve facial rejuvenation. Despite the successful use of the SMAS, most plastic surgeons limit their dissection of the SMAS inferior to the zygomatic arch. These operations have not traditionally addressed the changes associated with mid-facial aging. The changes associated with mid-facial aging include: deepening of the nasolabial fold, descent of the malar fat pad with loss of malar prominence, descent of the lower eyelid skin below the orbital rim and deepening of the tear trough. These changes cannot be adequately addressed with an infra-zygomatic operation. Successful use of the supra-zygomatic arch SMAS or high SMAS by Connell [4] and Barton [3] and collaborations with Alpert [1] have encouraged us to make this procedure our mainstay of facial rejuvenation. The high SMAS, above the zygomatic arch, allows for a higher arc of rotation of the mid-face. This translates into a greater rejuvenation of the mid-face by lifting the malar fat pad vertically and softening the nasolabial fold.

27.2 High SMAS Facelift

Traditional facelift surgery results in more of a lateral facial pull (Fig. 27.1a). This vector of pull does not always address the needs of the patient because it fails to address the changes associated with mid-facial aging. The high SMAS facelift technique results in a harmonious and natural lift by allowing the surgeon to achieve a vertical vector elevation of the deep fascial system while allowing for an oblique vector elevation of the skin envelope (Fig. 27.1b, c). The key distinction in the high SMAS facelift is to dissect superior to the zygomatic arch. The SMAS is undermined and then pulled in a more vertical direction. It is then fixed to the deep temporal fascia, rather than the cut superior edge of the SMAS. This technique creates a greater softening of the mid-face yet is

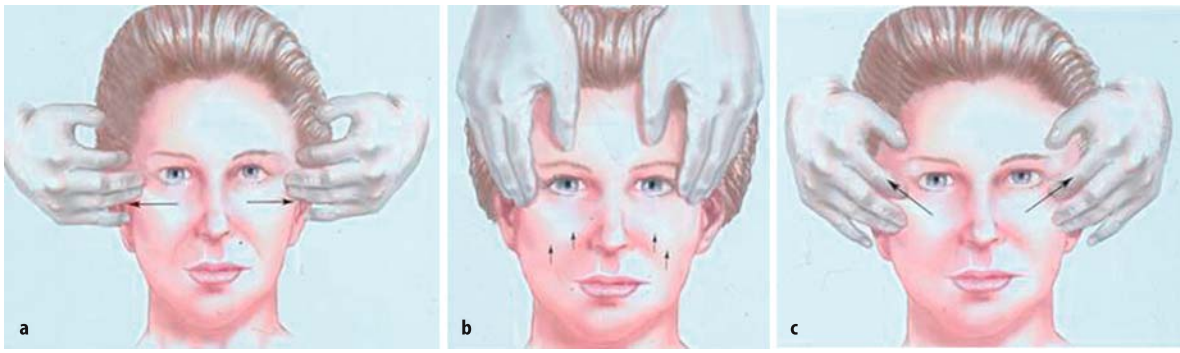

Fig. 27.1. a Lateral vector applied by traditional face-lift operations. **b** Vertical vector applied through high SMAS dissection. **c** Oblique vector of skin redraping

not largely practiced for fear of frontal branch injury. Finally, we think that fixation alone is not an effective anti-gravity procedure. The SMAS must first be dissected and elevated, *then* secured to a fixed structure. In the case of the high SMAS face-lift, the fixed structure is the deep temporal fascia. The large raw surface that is created after elevating the SMAS combined with fixation to a fixed structure produces lasting results.

Previous studies have placed the frontal branch of the facial nerve within the temporoparietal fascia [8] or the superficial layer of the temporalis fascia [2] as it crosses the zygomatic arch. For this reason, surgeons have been reluctant to make a supra-zygomatic SMAS incision for fear of injuring the nerve. However, the neurosurgical literature has described the frontal branch coursing in a plane deep to the temporoparietal fascia immediately above the zygoma [7]. Recent anatomic dissections by surgeons in our own community have verified that the frontal branch runs deep to the SMAS above the zygoma [1]. Plastic surgeons can therefore safely dissect the SMAS above the zygoma without injuring the frontal branch.

It is our philosophy that undermining prior to fixation is essential to a good long term result in any anti-gravity procedure. The high SMAS technique allows for a greater vertical elevation of the deep structures of the face by undermining the mid-face. It allows for fixation to the strong, deep temporal fascia and allows for tightening of the entire face and neck envelope. The result is a greater softening of the nasolabial fold. The malar structures are restored to their more youthful position. In addition, the dissection is extended inferiorly to the platysma which allows for a vertical pull of the SMAS-platysma complex. The result is a tightening of the entire musculofascial corset of the face. Because the SMAS is fixed to the deep temporal fascia, there is no tension on the facial skin. The authors have found this technique to be a safe and predictable technique that produces excellent, lasting results.

27.3 Surgical Technique

We make a standard peri-auricular, retrotragal incision (Fig. 27.2). In the temple, we use a two plane technique and preserve the superficial temporal vessels. Dissection of the SMAS begins at the uper border of the zygomatic arch. The dissection continues to the corner of the lateral canthus with division of the orbicularis oculi muscle. The dissection is then carried out over the parotid and masseter muscle medially and inferiorly to the platysma (Fig. 27.3). Branches of the facial nerve are seen and preserved. The SMAS is then elevated for 2–3 cm *vertically* and fixed to the deep temporal fascia (Fig. 27.4). In the neck, platysmal bands are divided through the facelift incision without making a separate submental incision whenever possible. For severe platysmal bands, a submental incision and midline plication may be necessary. In most patients, however, we are able to obtain good results by dividing the bands

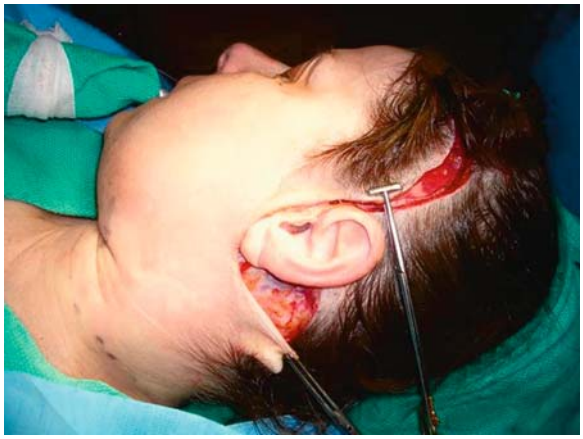

Fig. 27.2. The standard peri-auricular, retrotragal incision

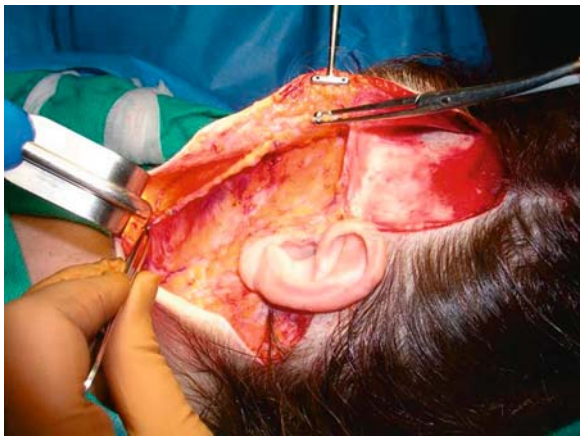

Fig. 27.3. Dissection carried out over the parotid and masseter muscle medially and inferiorly to the platysma

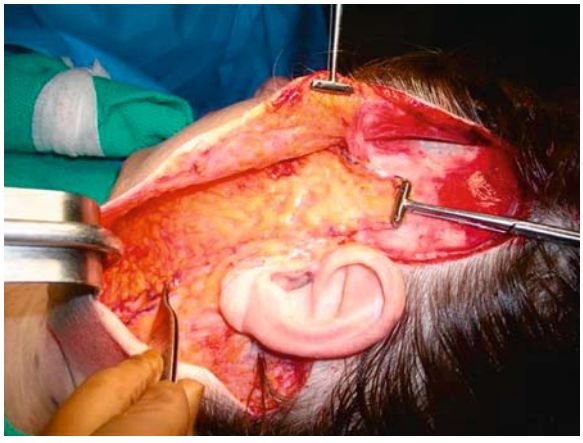

Fig. 27.4. SMAS elevation for 2–3 cm vertically. The SMAS is then fixed to the deep temporal fascia

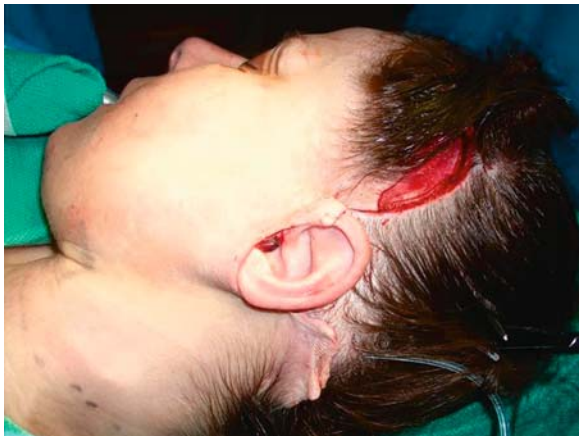

Fig. 27.5. The skin is redraped in an oblique direction and sutured without tension

through the facelift incision. A youthful neck contour is restored by splitting the SMAS-platysma flap and pulling the inferior limb in a lateral direction and fixing it to the mastoid fascia. Once the SMAS has been fixed, the skin is redraped in an oblique direction (Fig. 27.5). The skin is fixed above and behind the ear first without tension. The occipital skin is then trimmed and inset without tension, followed by the temple skin. The pretragal skin is adjusted and inset in a retrotragal position without tension.

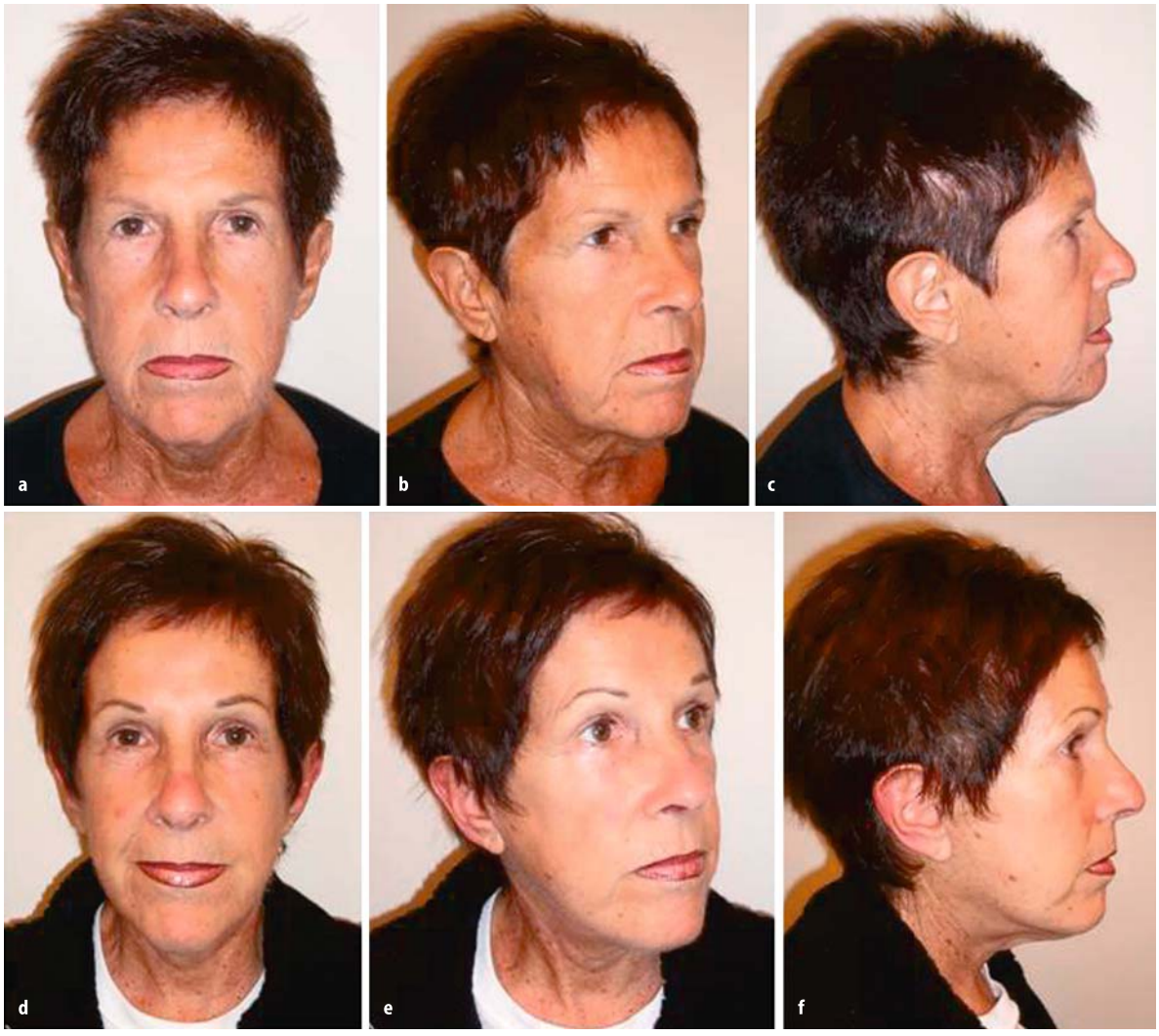

Fig. 27.6. Clinical example of a patient who underwent a high SMAS face lift. Preoperative photos (**a–c**) and postoperative (**d–f**) results at 6 months

27.4 Conclusions

In summary, the high SMAS facelift allows for a primary vertical pull of the SMAS. The vertical vector is fixed directly to the deep temporal fascia. In the neck, platysmal bands are divided and the SMAS-platysma complex is pulled laterally and fixed to the mastoid fascia. The result is a restoration of mid-facial youth and a tightening of the entire musculo-fascial corset of the face while minimizing tension on the facial skin (Fig. 27.6). We find this technique to be a safe and effective method for restoring a youthful facial appearance.

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Barbed Sutures in Aesthetic Facial Plastic Surgery: Evolution of Thought and Process

M.D. Paul

28.1 Introduction

The use of suture suspension techniques in aesthetic facial plastic surgery was a logical pathway to provide less invasive methods of reliably lifting ptotic soft tissues and maintaining the elevated position. With a quantum shift in public interest directed towards procedures that are less invasive, allow for a faster recovery, are associated with low rates of morbidity and complications, and provide natural results, the advance of the technology of barbed sutures seems imperative.

28.2 History

The description of the superficial musculo-aponeurotic system (SMAS) by Mitz and Peyronie in 1976 [1] was a sentinel paper that provided the scientific basis for soft tissue elevation and fixation at a plane deep to the skin and subcutaneous fat of the face and neck. The prior art included subcutaneous dissection and a tension-based "correction" of ptotic soft tissues principally relying on skin for support (a premise that is illogical knowing that the skin had already demonstrated its inability to support the ptotic facial soft tissues). Variations of SMAS plication, undermining, rotation, excision, etc., were described to reposition ptotic facial soft tissues either with or without skin attachment to the flap [2–8]. The introduction of barbed sutures as a method of suspending soft tissues (antiptosis) without dissection was introduced and refined by Marlen Sulamanidze et al. [9, 10]. Others embraced this concept, principally Ruff (personal communication) and Isse (personal communication). The aptos thread and variations were developed and patented by Sulamanidze. These threads are bidirectional and rely on compressing soft tissue from opposite directions towards a central point without tension with the expectation that collagen deposition will maintain the correction. It was Ruff who realized the value in unidirectional barbed sutures with proximal fixation to a stable point (personal communication). The placement of two unidirectional threads with proximal soft tissue anchoring (inverted U shape) avoids the gravitational load exerted by ptotic soft tissues on the barbs. This gravitational load is seen in bidirectional threads that are "free-floating" in the subcutaneous space. Non-barbed sutures have been utilized to elevate the malar fat pad [11].

28.3 Mechanism of Action

Much has been written about the mechanism by which ptotic soft tissues remain elevated with the use of barbed sutures [12–15]. Although a consensus opinion has not been written, the following is an explanation of how this technology works:

If one visualizes the opposite of tissue expansion, then one will visualize tissue retraction. The compression of cells seems to result in a decrease in cell population (apoptosis). The opposite occurs with tissue expansion. Observing muscle wasting in muscles that are not exercised versus muscle growth in those that are exercised, allows one to develop an analogy to tissue expansion and retraction. I believe that the deposition of collagen around the barbs and upon the compressed cells results in reliable soft tissue fixation.

28.4 Clinical Indications

A template for patient selection is mandatory to optimize results in soft tissue elevation, fixation, and longevity.

28.4.1 Acceptable Patient Categories for Barbed Sutures

1. The young patient (typically a female) with minimal soft tissue descent in the brow, midface, jowl, and neck.
2. The patient who is undergoing open surgical procedures (e.g., endoscopic browlift and/or endoscopic midface lift, and/or lower face and necklift, and/or open neck contouring)
3. The patient who has undergone more aggressive procedures as listed in #2 and has minimal to moderate relapse in the midface, and/or jowl, and/or neck 6 – 12 months postoperatively

28.4.2 Unacceptable Patients for Minimally Invasive Barbed Suture Suspension (i.e., No or Minimal Dissection of Soft Tissues with Concomitant Placement of Barbed Sutures)

1. *Patients with severe sun damaged skin*
2. *Patients with thin skin and very little subcutaneous fat*
3. *Patients who are obese and have very heavy ptotic soft tissues*

28.5 Preoperative Planning

Patients are examined and are placed into one of the three categories listed above. Minimally invasive procedures are planned on category 1 and 3 patients. The term "minimally invasive" refers to the placement of barbed sutures with minimal soft tissue dissection.

Patients who are planning to undergo more aggressive open procedures alone or in combination (Category 2/upper, middle, and lower third facial rejuvenative procedures) will, by definition, have significant soft tissue dissection at the subfascial, subperiosteal, and/or subcutaneous planes.

Regardless of which procedure(s) are selected, all patients are marked in the 45 degree upright position. It is helpful to have the patient agree on the vector(s) of planned correction before completing the marking and beginning the procedure(s).

As with any surgical procedures, patients are advised to discontinue the use of aspirin containing medications, non-steroidal anti-inflammatory medications as well as herbal products, diet medications, and large doses of vitamin E to decrease ecchymoses and possible adverse reaction(s) to general anesthetic agents.

Pre-treatment with Botox will help to stabilize the brow by avoiding downward displacement caused by contraction of the depressors of the brow (procerus, corrugator supercilii, depressor supercilii, lateral orbicularis oculi muscles).

Depending on the procedure(s) selected, the technique is performed with the patient under minimal oral sedation with local anesthesia or with the patient under general anesthesia supplemented with local anesthesia with epinephrine to minimize bleeding. In minimally invasive procedures, lidocaine with epinephrine is infiltrated along the proposed pathway of the threads. Regional nerve blocks for V 1, 2, and 3 are helpful as is the use of buffered local anesthesia for increased patient comfort for procedures being performed under minimal sedation. My dissatisfaction with a purely closed approach prompted me to develop both hybrid and open procedures utilizing barbed sutures. The description of the operative maneuver below is the sequence that I employ in a procedure that I have termed The Open Blind Malar Lift [16].

28.6 Four Steps of the Procedure Utilizing the Barbed Sutures (Fig. 28.1)

1. Incisions: temporal and intraoral (Fig. 28.2)
2. Deployment (utilizing the unidirectional barbed sutures)

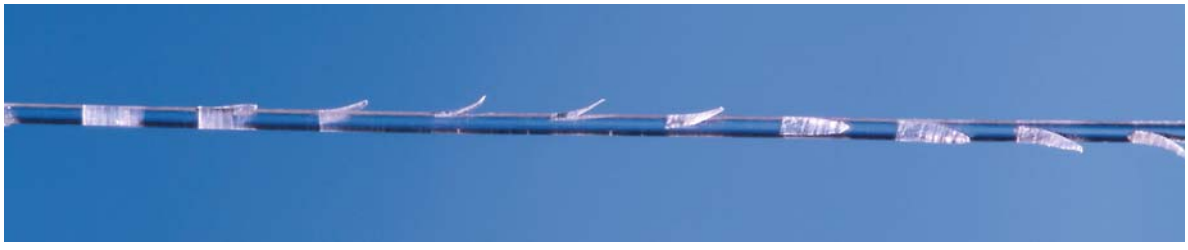

Fig. 28.1. Quill barbed suture

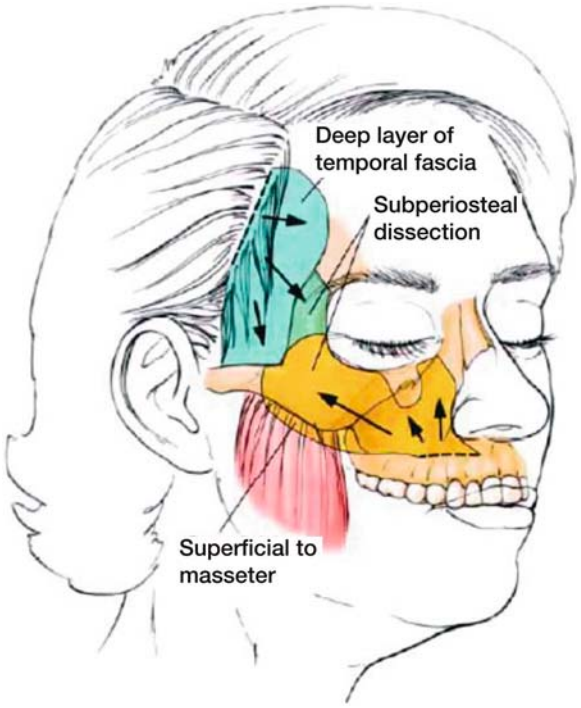

Fig. 28.2. Incisions

a) Begin with dissection down to the deep temporalis fascia through the temporal access incision. Begin a subperiosteal dissection over the malar area and medial third of the zygomatic arch. Make a 1-cm incision over the canine fossa and perform an in continuity subperiosteal dissection joining the temporal pocket.
b) Pass the straight needle above the deep temporal fascia and engage the soft tissue beginning at the lateral orbital rim in a zigzag fashion to incorporate as much soft tissue as possible exiting lateral to the nasolabial crease.
c) Distal to the planned most inferior or inferomedial point of correction (Fig. 28.3)

3. Fix the proximal suture to the deep temporal fascia (Fig. 28.4)
4. Contour the soft tissue creating a "shisk ke bob" effect by stacking the elevated soft tissues. This produces a volumetric augmentation of the malar area (Fig. 28.5)
   a) This is an extremely important step in the process and may be partially completed and modulated in 2 – 3 days in the office in an upright position by leaving the distal end of the suture exposed, covered with a sterile dressing and removed after final soft tissue contouring.

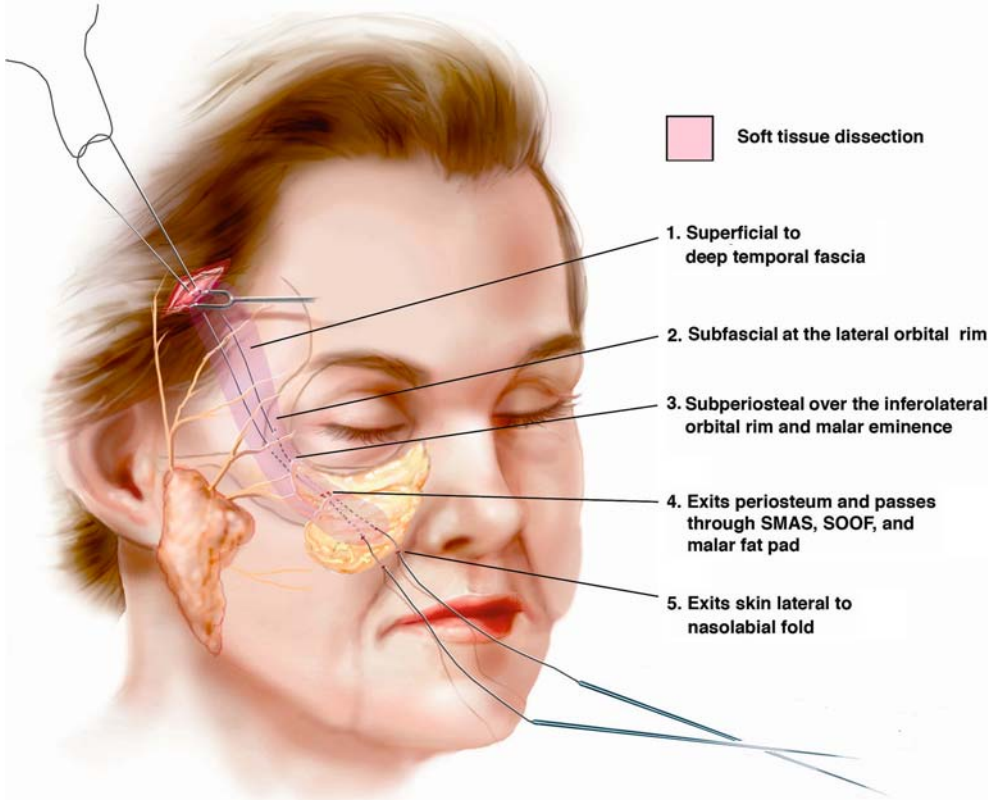

Fig. 28.3. a Soft tissue dissection

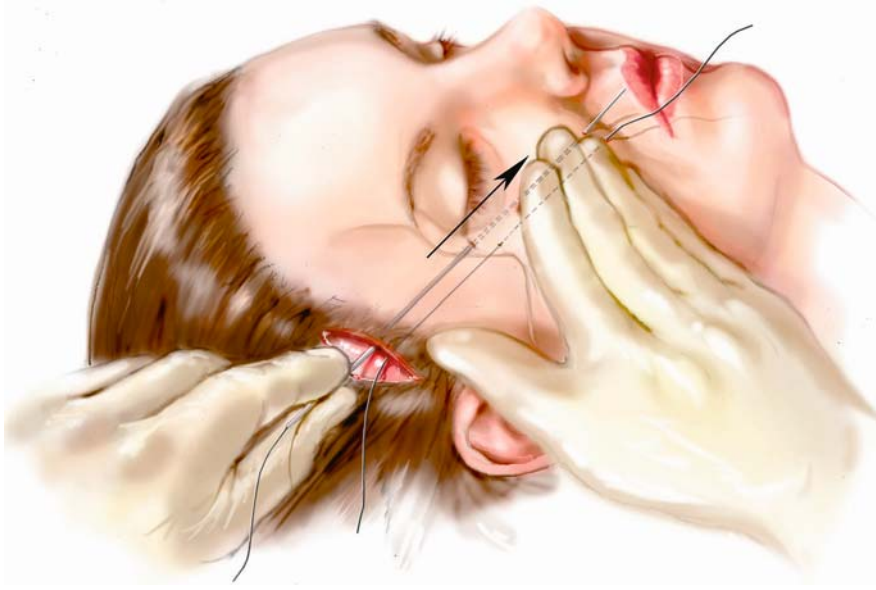

Fig. 28.3. b Deployment of threads

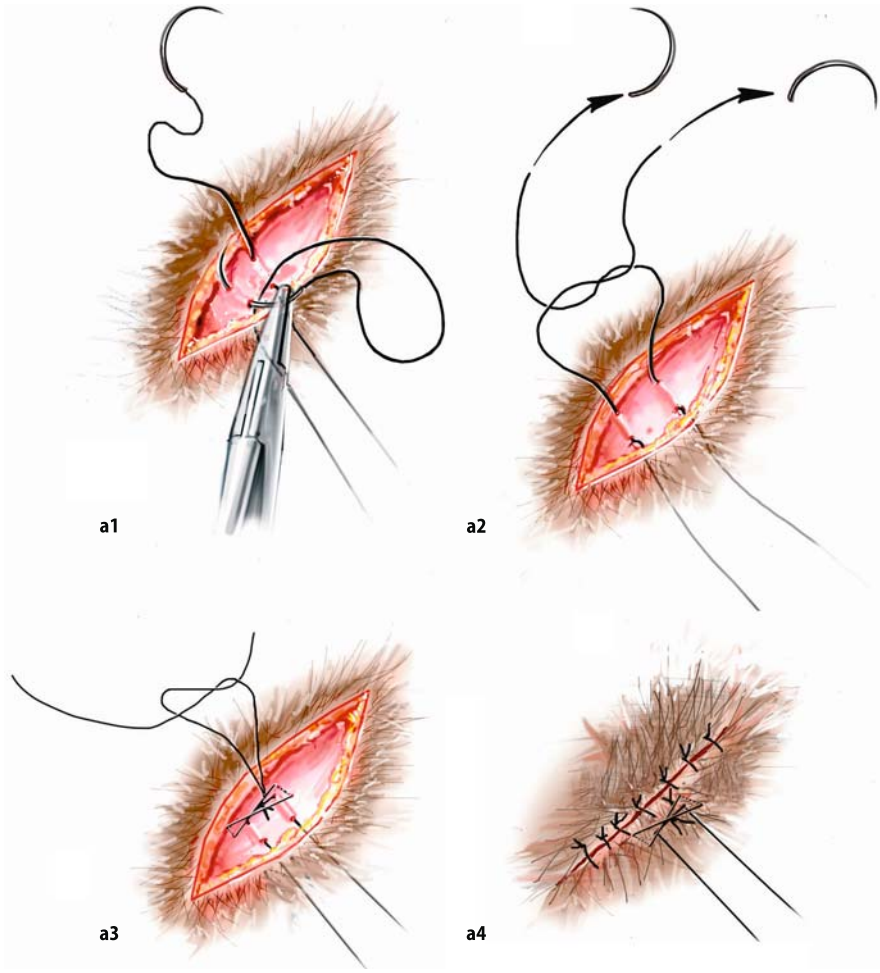

Fig. 28.4. a Proximal suture anchoring to soft tissue with two thread placement

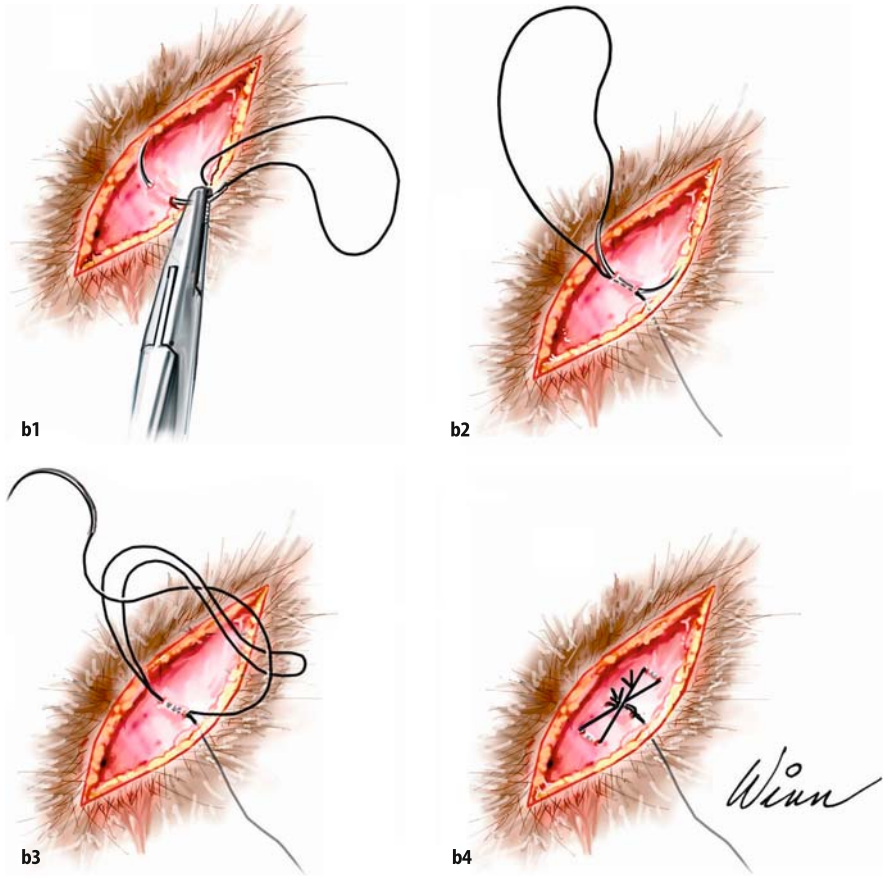

Fig. 28.4. b Proximal suture anchoring to soft tissue with one thread placement

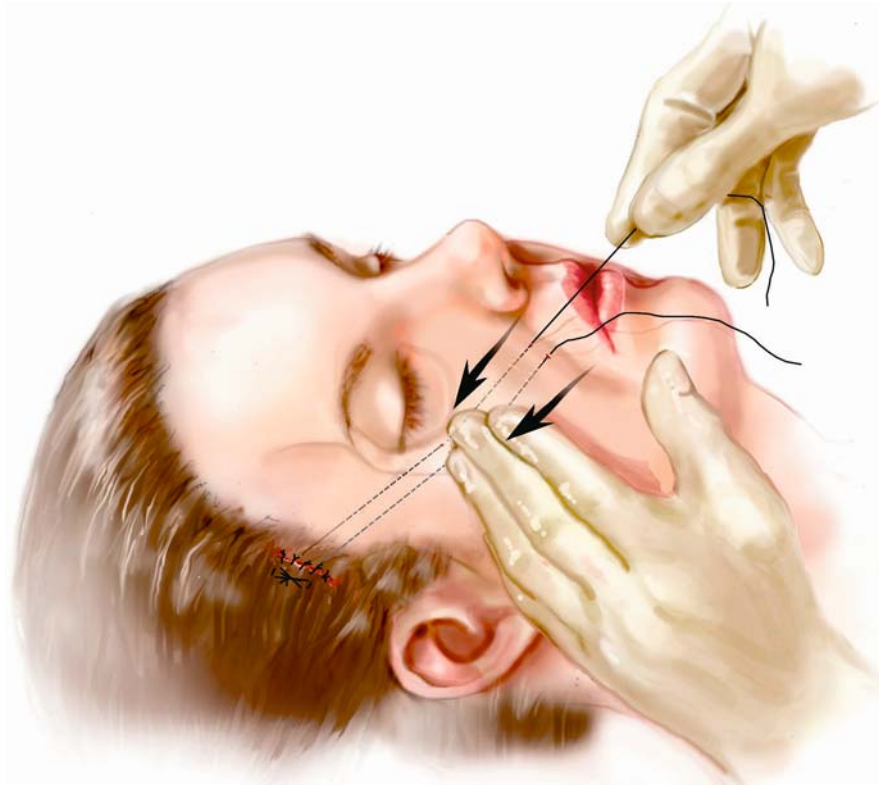

Fig. 28.5. a Soft tissue molding

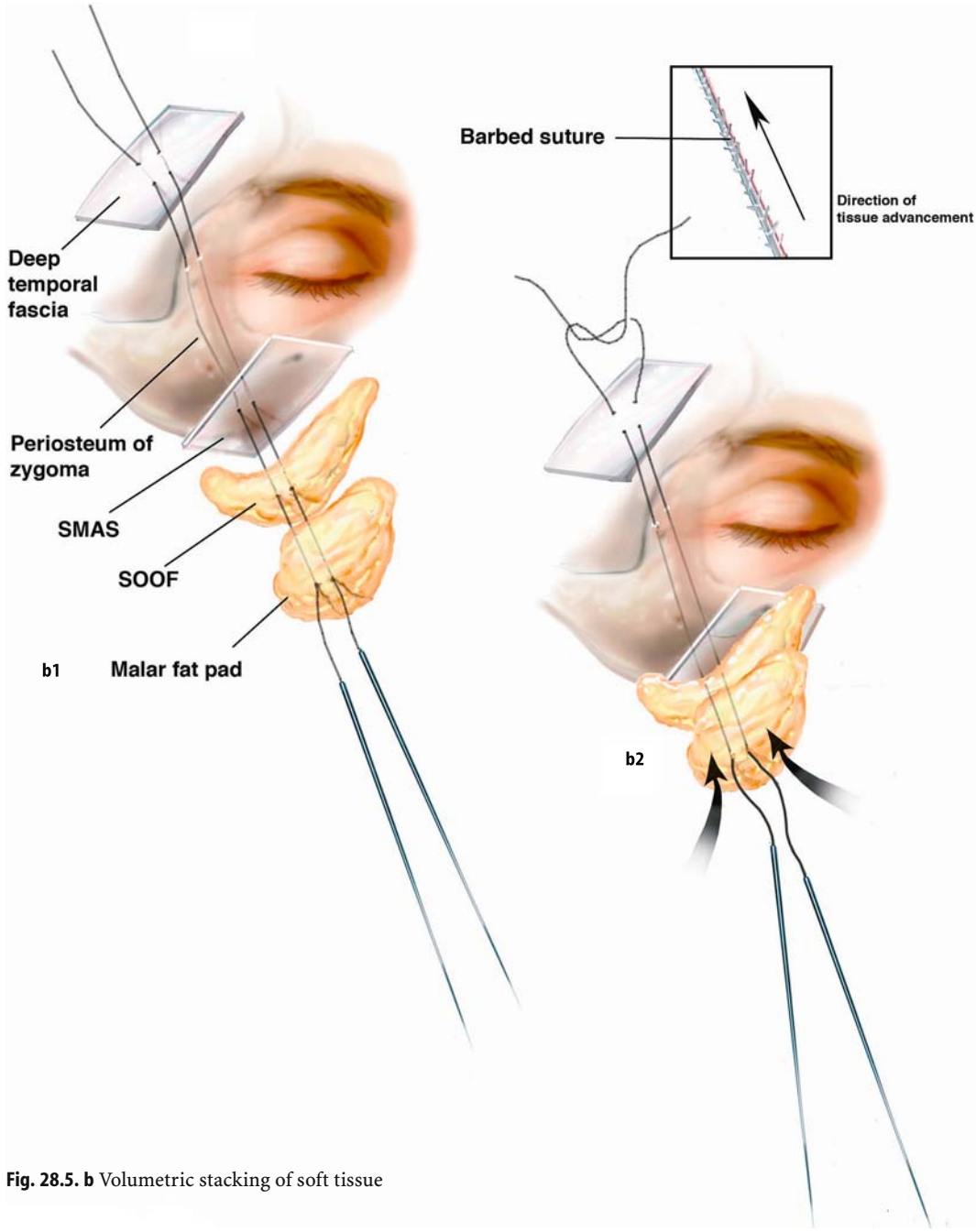

Fig. 28.5. b Volumetric stacking of soft tissue

28.7 Postoperative Care

Maintenance of support for 5–7 days is mandatory to allow reliable soft tissue fixation. Measures to achieve this include: paper tape support, minimal straining, laughing, pressure on the threads, use of a travel pillow to avoid lateral pressure, and a soft diet for a few days. Vigorous exercising should be avoided for 3 weeks. For intraoperative photos see Fig. 28.6a–d, and for pre- and postoperative photos see Fig. 28.7.

28.8 Sequelae and Complications

Minor sequelae are common and include: edema, ecchymosis, proximal tissue gathering (typically resolves in a few days to 1 or 2 weeks), traction lines, and dimpling. The use of intra- and postoperative steroids is helpful in diminishing the edema.

Complications include: thread migration, breakage, infection, malposition, chronic pain, and relapse. Threads can be removed and replaced as indicated.

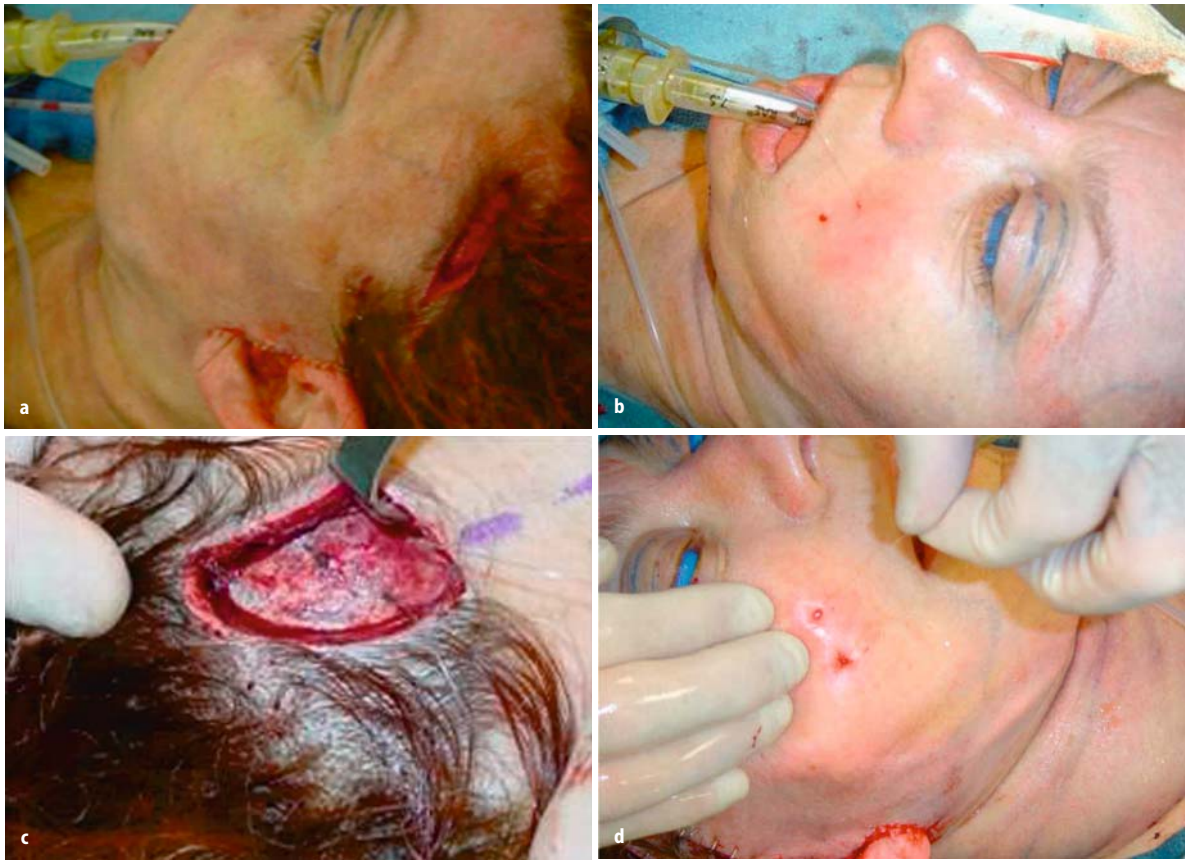

Fig. 28.6a–d. Intraoperative photos: **a** incision, **b** deployment, **c** fixation, **d** contouring

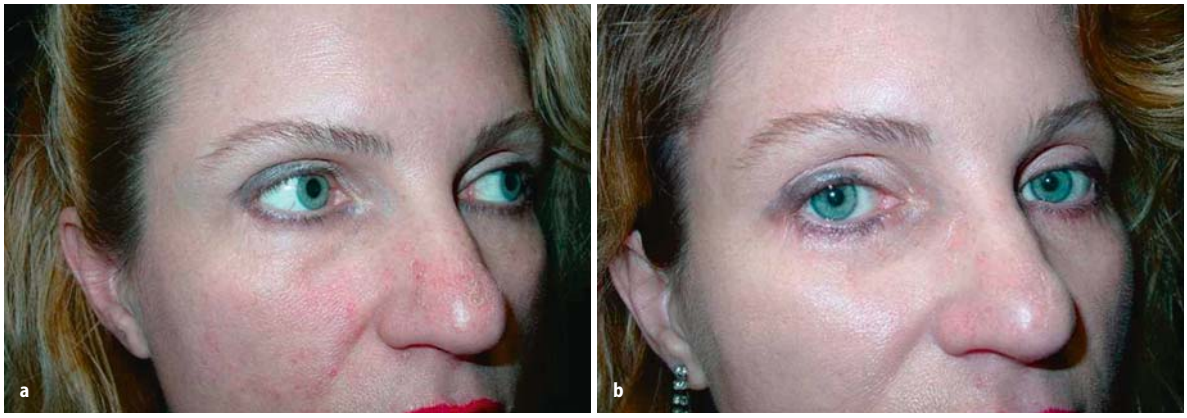

Fig. 28.7a–d. Pre- and postoperative patient photos

28.9 The Future of Barbed Sutures

Many plastic surgeons and facial plastic surgeons have been reluctant to embrace this technology due to concerns about leaving permanent sutures subcutaneously in the face and neck. The use of open procedures has allowed deeper placement of barbed sutures with less risk of exposure, etc. The new generation of barbed sutures (approved by the FDA in the U.S.) are absorbable threads made of polydioxanone (PDO). This will allow placement of several sutures at the subcutaneous and/or deep planes knowing that between 3 and 6 months the sutures will dissolve, leaving neo-collagen to stabilize the elevated tissues. The concern about possibly having to remove the threads will become a non-issue. As the public has asked for faster recovery with attainment of a natural look, the use of barbed sutures will

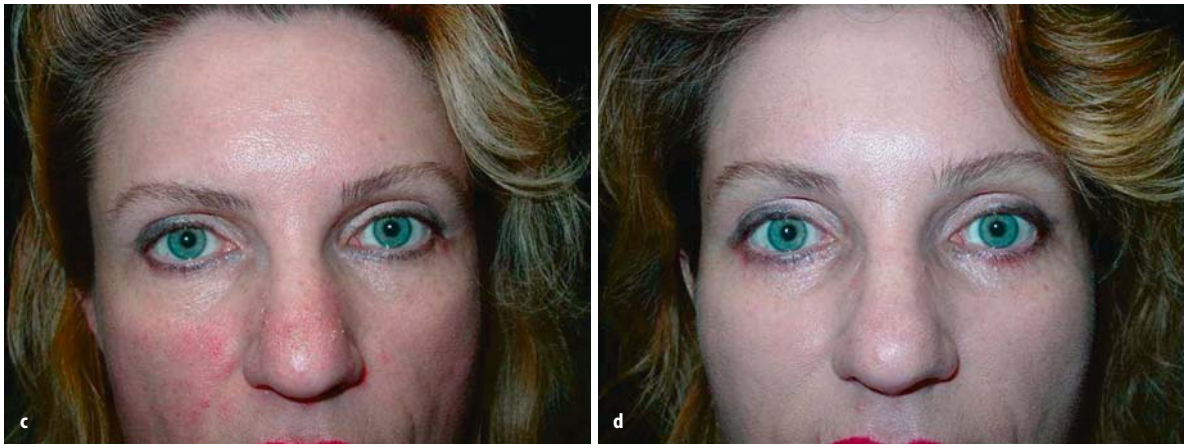

Fig. 28.7 (*Cont.*)

answer this request and will become more reliable as we learn more about the biology of wound healing, understanding how this technology works, and improving the products available to attain reliable improvement in facial rejuvenation. Combining barbed sutures with soft tissue fillers, Botox, lasers, skin care, etc., will provide a palate of procedures that will provide a sum greater than that obtained by adding the individual components. Even in aggressive, open procedures, with recovery times of 10–21 days, this technology allows for a simplified volumetric stacking of soft tissues and vector based correction of the aging face.

Barbed sutures will have other indications:

1. Soft tissue support for body contouring procedures after massive weight loss
2. Soft tissue support for minimal to moderate nipple/areola elevation (mastopexies) and molding of the reduced breast
3. Wound closure (traumatic and planned operative incisions and excisions in many surgical specialties and subspecialities)

Significant work in wound closure has been published by Ruff et al. [17, 18]. A summary of clinical experience was published by Lycka et al. [19] and a descriptive article that also discusses the topics in this paper was published by DeLorenzi et al. [20]. The reader is referred to these papers to further one's understanding of this emerging technology. Harnessing soft tissue support in a reliable way will lead to improved results and, what we all desire, satisfied patients who have obtained the result(s) that they and their surgeon have sought with minimal risk.

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Forehead and Midface Endoscopic Surgery 29

R. Graf, D. Pace, L.R. Araujo, R. Costa Damasio, R. Rippel, L. Graca Neto, T. Al-Yafi

29.1 Introduction

Aesthetic improvements of the upper third of the face have been a challenge for nearly a century. Brow ptosis management has undergone evolutionary changes from the classic coronal open brow and anterior hairline techniques to the more recently described less-invasive techniques such as minimal incision lateral brow lift and endoscopic brow lift [2].

Since the introduction of endoscopic brow lifting in the mid 1990s, endoscopic surgery has become widely accepted as a method for rejuvenation of the upper third of the face, mainly to achieve eyebrows and forehead elevation. It has many indications and it is performed to correct eyebrow ptosis and to treat glabellar rhytids created by corrugators, depressor supercilii and procerus muscles.

Several factors, including natural aging, facial nerve injuries and facial trauma, may cause brow ptosis, although congenital or hereditary factors may also cause this condition. Aging and gravitational forces lead fat and soft tissue of the cheek to drift downward in relation to the underlying bony skeleton. Eyebrow lifting and/or forehead lifting is not a new concept; however, the videoendoscopic technique for these procedures is relatively new.

The midface is a small area in terms of total percentage surface area of the face, but it represents a crucial aesthetic unit of the face. It is bordered by other structures that play major roles in the overall appearance of the face. The midface lift has recently gained significant popularity with many surgeons. It allows the surgeon an opportunity to achieve greater facial harmony with facial rejuvenation procedures by correcting midfacial atrophy, addressing the tear through deformity and correcting the perceived malposition of the malar fat pad [28].

Endoscopic surgery of the forehead and midface is intended to treat forehead wrinkles, elevate the lateral portion of the brow, release the depressor muscles of glabella, free periorbital ligaments, elevate soft tissue of midface and correct asymmetries. To accomplish these goals, one must study the frontal, periorbital and midface anatomy. Advantages include visualization and tissue manipulation through very short incisions with image magnification and treatment of wide areas with short scars.

In the physiology of eyebrow ptosis, the depressor muscles pull down the medial portion and the frontal muscle elevates the medial and central portions of the brows, creating horizontal wrinkles on the forehead and vertical wrinkles on the glabella. On the other hand, there is soft tissue ptosis on the temporal area due to the absence of the frontal muscle laterally to the temporal adhesion zone, with descent of brow tail.

Recent articles report that endoscopic surgery of the forehead and midface shows excellent results. The advantages are a significant reduction of the incision's length with better camouflage of these incisions, precise muscle modification with the aid of magnification, decreased hair loss, and less bleeding and surgical trauma. Besides, it reduces the dysesthesia of the scalp because the deep branch of the supraorbital nerve is injured less [33].

There are several fixation methods, including: absorbable and non-absorbable screws, sutures, cortical tunnel, Endotine and fibrin glue.

Disadvantages include the higher cost related to the sophisticated equipment necessary and the long learning curve needed to achieve proficiency. Counterindications are previous craniotomy or frontal sinus or bone fracture. Complications include relapse, asymmetry, dysesthesia, paresis, hematomas, burns and alopecia.

29.2 History

One of the earliest reports concerning the use of endoscopic techniques in plastic surgery was in 1992 when Core and Vasconez [3] described the endoscopic coronal lift. In the follow-up article published in 1995, they noted that the complication rate in endoscopic brow lifts was not greater than in the open technique [4]. They reported recurrent ptosis in less than 2% of patients. In addition to using external suture stabilization for 3–5 days, they also excised a triangle of skin just in front of the hairline.

In 1994, Vasconez published a new article describing endoscopic forehead lifting [32]. He detailed the use of the endoscope to guide the release of supraorbital and glabella soft tissues. Dissection was on the subgaleal plane and procerus and corrugator muscles were severed. Fixation technique was not clearly described and seemed to be variable.

Since the first reports, multiple variations of the technique have been used, mostly regarding different incisions, planes of dissection and methods of fixation.

In 1993, Marchac [20, 21] described the use of the endoscope to elevate forehead, malar and maxillary tissues, through a subperiosteal plane and fibrin glue fixation.

Isse in 1994 described the subperiosteal endoscopic technique for the forehead, dissection over the deep temporal fascia in the temporal area, supraperiosteal plane in the midface and lower-third, and subcutaneous cervical dissection. He described tissue elevation with vertical and medial vectors with fixation stitches of the forehead to the galea superiorly, and superficial temporal fascia and use of the superficial musculo-aponeurotic system (SMAS) to the deep temporal fascia in the temporal area [9, 10]. Currently, he is using barbed polypropylene sutures for fixation of midface and brow, with excellent results [18].

In 1994, Ramirez described the use of endoscopic surgery for the forehead, mid- and lower face. He used subperiosteal plane for all these areas, emphasizing the need to release the periosteum of the superior gingival sulcus. He also described the biplanar approach at the level of the zygomatic arch.

Since 1995, David Knize [12–16] published several articles regarding the frontal and temporal anatomy, where he identified fully in detail all structures and elements that should be well known to facilitate the performance of the endoscopic technique in order to avoid neurovascular injuries. He described the depressor muscles of the eyebrows: procerus, corrugators (transverse and oblique head) and depressor supercilii, which should be severed. On the other hand, the transverse head of the corrugator muscle should be left intact to prevent widening of the brows.

Many authors have studied fixation techniques on endoscopic surgery over a long-term period. McKinney [23] and Daniel [5] use central and temporal fixation with screws; however, McKinney [24] has used lateral fixation with galea sutures to the deep temporal fascia and bony fixation in parasagittal incisions. He believes that such maneuvers decrease the risks of sagittal sinus and middle meningeal artery damage and alopecia, and allow a longer aesthetic outcome. Casagrande [1] described in 2000 the transcutaneous fixation of midface by needle. De Cordier [6] makes three triangular precapillary incisions that are sutured in a transverse fashion creating additional elevation besides the temporary sutures in the incisions 5 cm posterior to the hairline, which are kept in place for 3–5 days. Jones [11] (2004) compared the use of cortical tunnel suture fixation with fibrin glue. He found sutures were a better method of fixation.

In 2000, Little [19] embraced the idea of volumetric enhancement of the face with special regard to midface elevation.

Mendelson et al. [25–27] described in 2000 new anatomic terms for the periorbital and facial areas, which are zones of adhesion (temporal adhesion), septii (superior and inferior temporal septum, periorbital septum) and real ligaments (zygomatic and masseteric).

Matarasso [22] in 2000 evaluated facial rejuvenation and developed an algorithm for the selection of the appropriate technique, and so, in patients with only forehead rhytids with no associated surgery, he indicates botulinum toxin injections with laser; for patients with glabellar creases with no surgery associated he indicates endoscopic surgery and when there is a blepharoplasty he corrects the depressor muscles through the same incision. Finally, in patients with brow ptosis he performs endoscopic surgery and when there is associated rhytidectomy he makes a temporal suspension through the temporal aspect of face-lift incision.

De Benito [7] in 2003 compared absorbable screws with metallic screws and found better results with the first, showing good fixation without the disadvantages of the last (alopecia, inflammatory reaction, discomfort on scalp and the need for the removal of screws).

29.3 Surgical Technique

29.3.1 Preoperative Markings and Anesthesia

With the patient under sedation, the skin marks are initiated in the temporal fixation zone, and the hair is divided exactly where the incisions will be placed, i.e., one central, two paramedial (1.5 cm medial to the temporal line to avoid injury of the deep branch of the supraorbital nerve, which crosses within 1.5 cm medial to

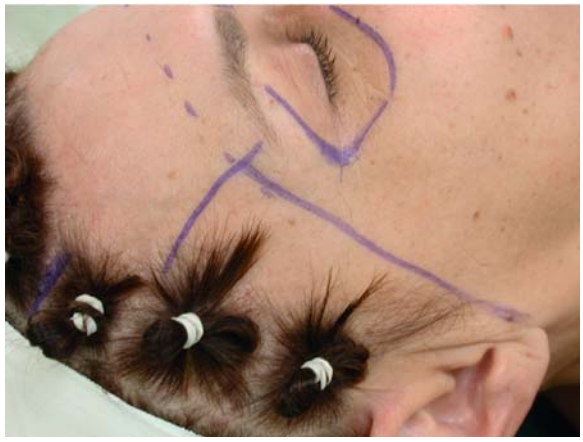

Fig. 29.1. Paramedian incision, 1.5 cm medial to the temporal zone of fixation in order to avoid injury to the deep branch of the supraorbital nerve

this line) and two temporal incisions marked as a continuation of an imaginary line drawn from the nasal ala to the corner of the eye, 2 cm behind the hairline (Fig. 29.1). Xylocaine 1 % and Marcaine with 1:200,000 epinephrine are injected in the areas to be operated on.

29.3.2 Incisions

The anatomy of the orbital and frontal area has a multilayered structure, including skin, subcutaneous tissue, muscles (orbicularis laterally, corrugators, depressor supercilii and procerus medially), galea, periosteum and bone.

Incisions of 1.5 cm each (one central and two paramedian) are made in a vertical fashion to avoid nerve injury and are placed just a few millimeters behind the hairline. The temporal incision is 3 cm long and is placed 2 cm behind the hairline, marked as a continuation of an imaginary line drawn from the nasal ala to the corner of the eye.

29.3.3 Dissection

The undermining of the frontal area is performed at first blindly, with a curved dissector in the subperiosteal plane, down to 2 cm above the supraorbital rim. In the temporal area a blunt round dissector is used, superficial to the deep temporal fascia. Right after this dissection, a 4-mm 30-degree endoscope is introduced, with a protection sleeve with a curved tip to facilitate undermining and visualization (Fig. 29.2).

The subperiosteal plane is used and the dissection is performed under endoscopic vision down to the supraorbital rim, carefully avoiding the supraorbital nerve injury bilaterally. Afterwards, with the endoscope placed in the paramedial incision and face-lift scissors in the temporal incision, the temporal ligament is dissected from its attachment in the lateral orbital rim, including its terminal portion, until the supraorbital septum is visualized. The temporal ligament or temporal fusion line (Knize) or medial temporal septum (Mendelson) is a zone of confluence of superficial temporal fascia and galea, and also deep temporal fascia and frontal bone periosteum. This ligament is present up to the lateral portion of the superior orbital rim.

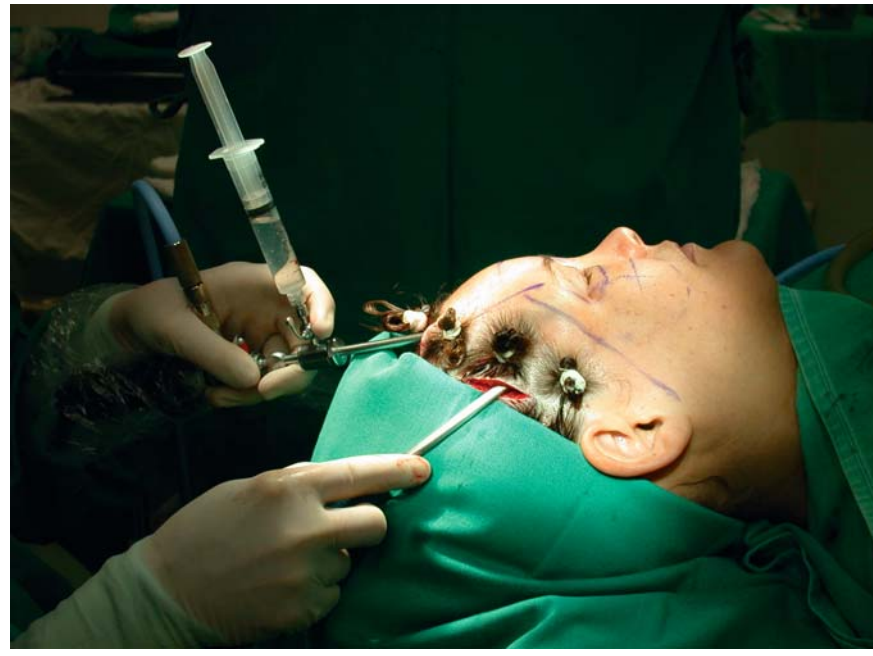

Fig. 29.2. Endoscopic device used through the paramedian incision and dissector through the temporal incision

The dissection continues medially by incising the periosteum in the supraorbital rim (arcus marginalis) until the supraorbital nerve is visualized. The arcus marginalis is an area of thickening of the galea in the superior portion of the orbit and acts as an adherence point to the septum orbitalis.

Next, the dissection is completed in the temporal area with visualization of the sentinel vein (medial zygomatic-temporal vein), which is cauterized to avoid tearing and bleeding of this vessel during endoscopic manipulation when advancing towards the midface. Lateral to this vein there is the medial zygomatic-temporal nerve that can be preserved or severed (sensitive nerve to the surrounding skin). Medial to the sentinel vein, dissection is directed to the infraorbital rim, and lateral to the sentinel vein, dissection is directed towards the midface. At this point, the undermining can be sub- or supraperiosteal. Our preference is the supraperiosteal plane, which is the same continuation above the deep temporal fascia without the need to incise the periosteum at the level of the zygomatic arch. The undermining continues deep to the orbicularis muscle and supraperiosteal in the lower eyelid, releasing the inferior periorbital septum (retaining ligament), responsible for the tear through. The precanthal tendon is released to allow rotation of all periorbital elements superiorly, inferiorly and laterally. Lateral to the sentinel vein, dissection is carried out inferiorly to the midface in the supraperiosteal plane, deep to the suborbicular oculi fat (SOOF) towards the nasolabial fold, undermining deep to the SMAS and superficial to the zygomaticus major muscle. The medial limit for the dissection is the infraorbital nerve, and laterally the motor nerves for the zygomaticus major muscle, and branches of the facial nerve. A blind maneuver is made rotating medially and superiorly, to detach the zygomatic ligament laterally. The motor branches of the facial nerve should be preserved during videoendoscopic facial surgery. The temporal branch of the facial nerve runs 1.5 cm superior and lateral to the supraorbital rim and should remain in the flap throughout the surgery. The zygomatic branches of the facial nerve run between the orbicularis and the zygomaticus major muscle, penetrating the orbicularis oculii muscle through several branches (lateral, medial and inferior).

After the undermining is completed in the midface and temporal area, dissection is directed to the glabella. The endoscope is placed in the central incision in the subperiosteal plane, and 1 cm above the glabella the periosteum is incised with the curved dissector. As a result, the depressor muscles are visualized, from lateral to medial: corrugators (transverse and oblique heads), depressor supercilii and procerus. With a curved grasper, these muscles are divided with a gentle maneuver, beginning from the bony end towards the skin, except the transverse head of the corrugator, in order to avoid widening of the brows. During this point of the procedure, the supratrochlear nerves and vessels are identified and preserved.

The nerves observed in endoscopic surgery are the supraorbital and supratrochlear, which exit from their specific foramen. The correct release of periosteum in the supraorbital rim and division of procerus muscle, depressor supercilii and corrugators, preserving sensitive nerves in the supraorbital area, is one of the most critical steps in endoscopic surgery. Obviously, avoiding injury to the temporal branch of the facial nerve is also very important for a successful procedure.

There are six planes of dissection:

1. Frontal dissection: subperiosteal
2. Temporal dissection: between superficial and deep temporal fascia
3. Upper-eyelid dissection: preseptal and suborbicular
4. Lateral orbital rim dissection: supraperiosteal
5. Lower-eyelid dissection: supraperiosteal and suborbicular
6. Zygomatic-malar dissection: suborbicular and suprazygomaticus major muscle

29.3.4 Fixation

Finally, after all the dissection is completed, the flap can be easily mobilized. Fixation is then started by marking three points of reference in the following order: (1) inferior and lateral malar area, (2) central malar area, and (3) lateral canthal tendon. With the endoscope, a long Keith needle is introduced at the points previously marked. The introduction begins externally and then with the endoscope (to avoid nerve damage), reaching the temporal incision, where 3.0 clear nylon is placed in position and finally the needle is pulled back to the entry point, grasping around 1 cm of the midface flap, going back to the temporal incision, where the suture line is withdrawn from the needle. The third point passes also in the periosteum superiorly, so as to fixate the myocutaneous orbicular flap in a superior position. These three points are sutured in the deep temporal fascia at the level of the temporal incision. Fixation of the forehead is performed with cortical tunnels in the paramedial incisions, fixating the periosteum to the cortical tunnel (2.0 nylon), with the goal of elevating the forehead, mainly in the lateral portion of the brows.

The final step is scalp sutures without skin resection and no tension. Taping over the dissected area is kept in place for a week to decrease the possibility of hematomas and seroma.

29.4 Results

Good to excellent outcomes are expected in the long term, with maintenance of brow elevation, reduction of glabellar creases, lateral rotation of periorbital elements and midface elevation. Swelling disappears in 30–60 days, rarely persisting for more than 3 months (Figs. 29.3–29.5).

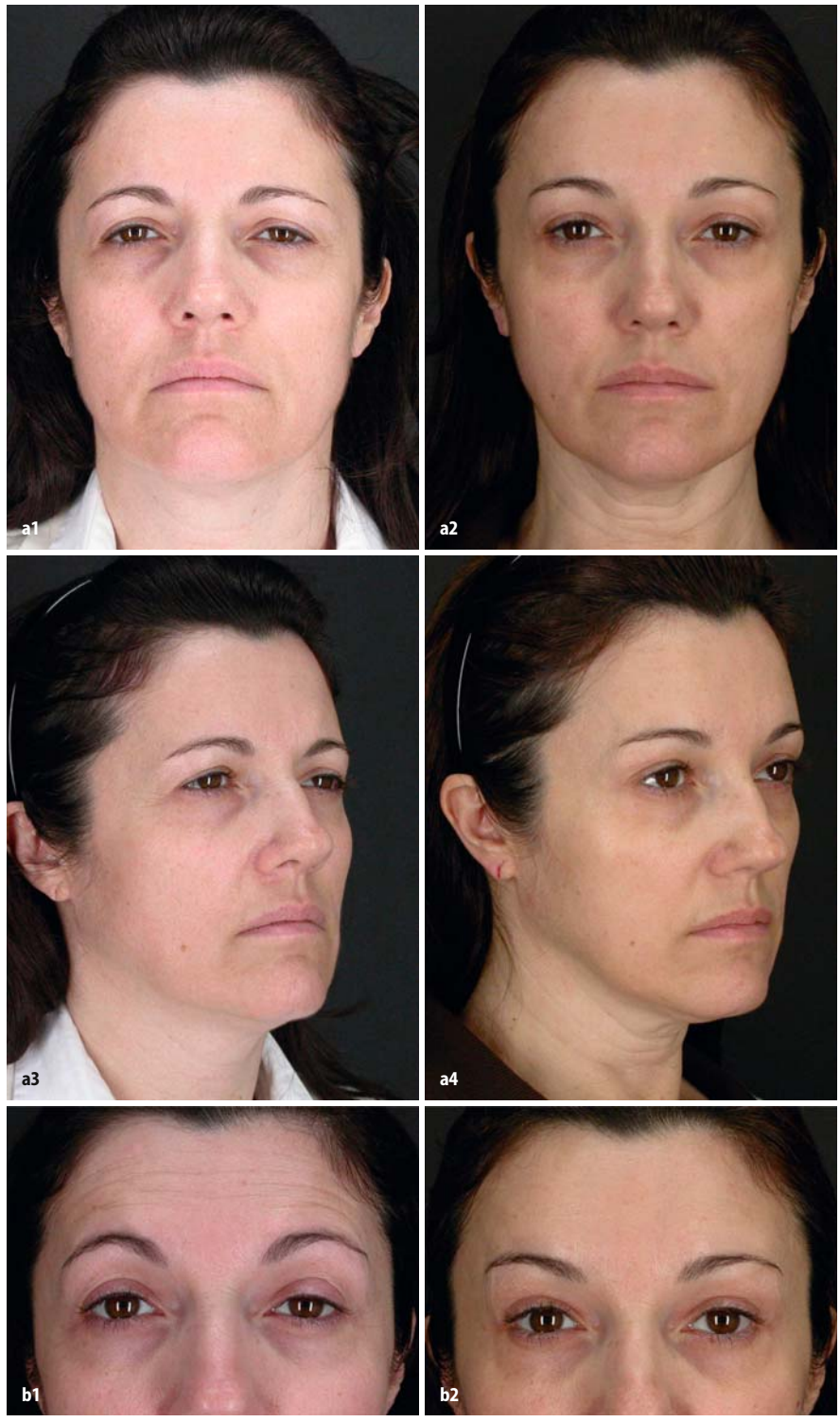

Fig. 29.3. Pre- (*left*) and 1 year postoperative (*right*) photos of a 38-year-old female with forehead and midface lift. Note the elevation of the midface and the eyebrow

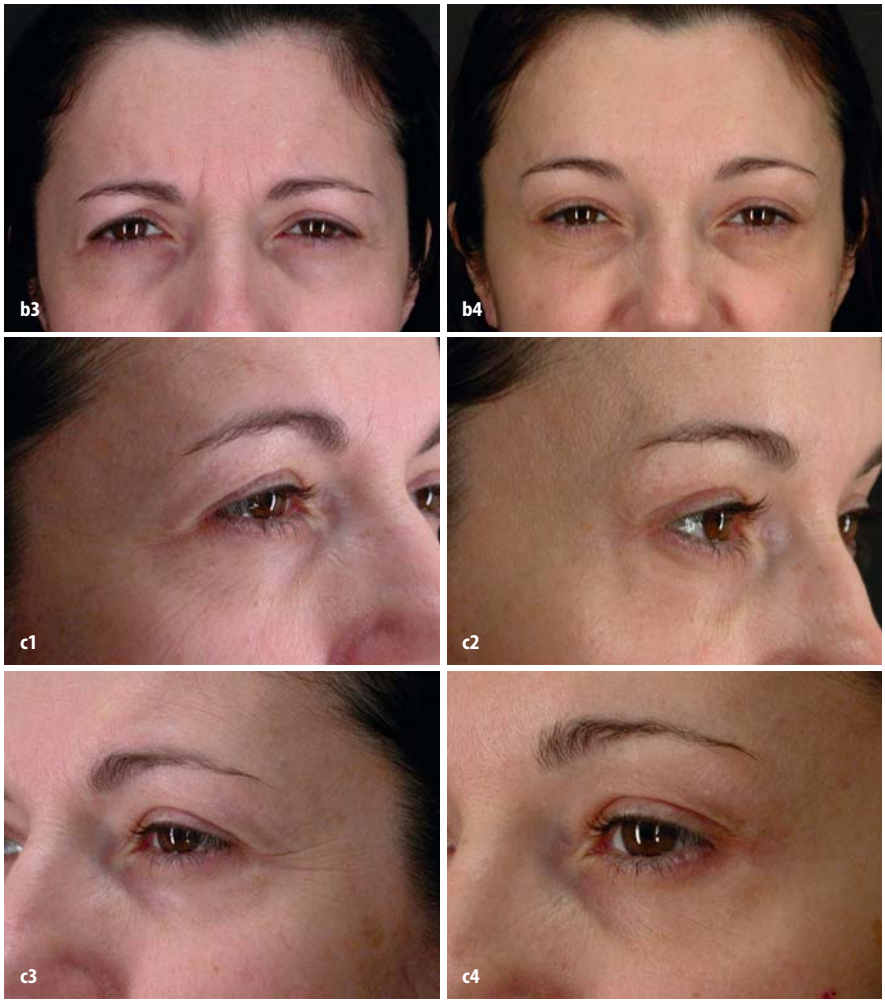

Fig. 29.3. (*Cont.*)

Fig. 29.4. Pre- and 2 years postoperative photos of a 40-year-old female patient after endoscopic forehead and midface lift

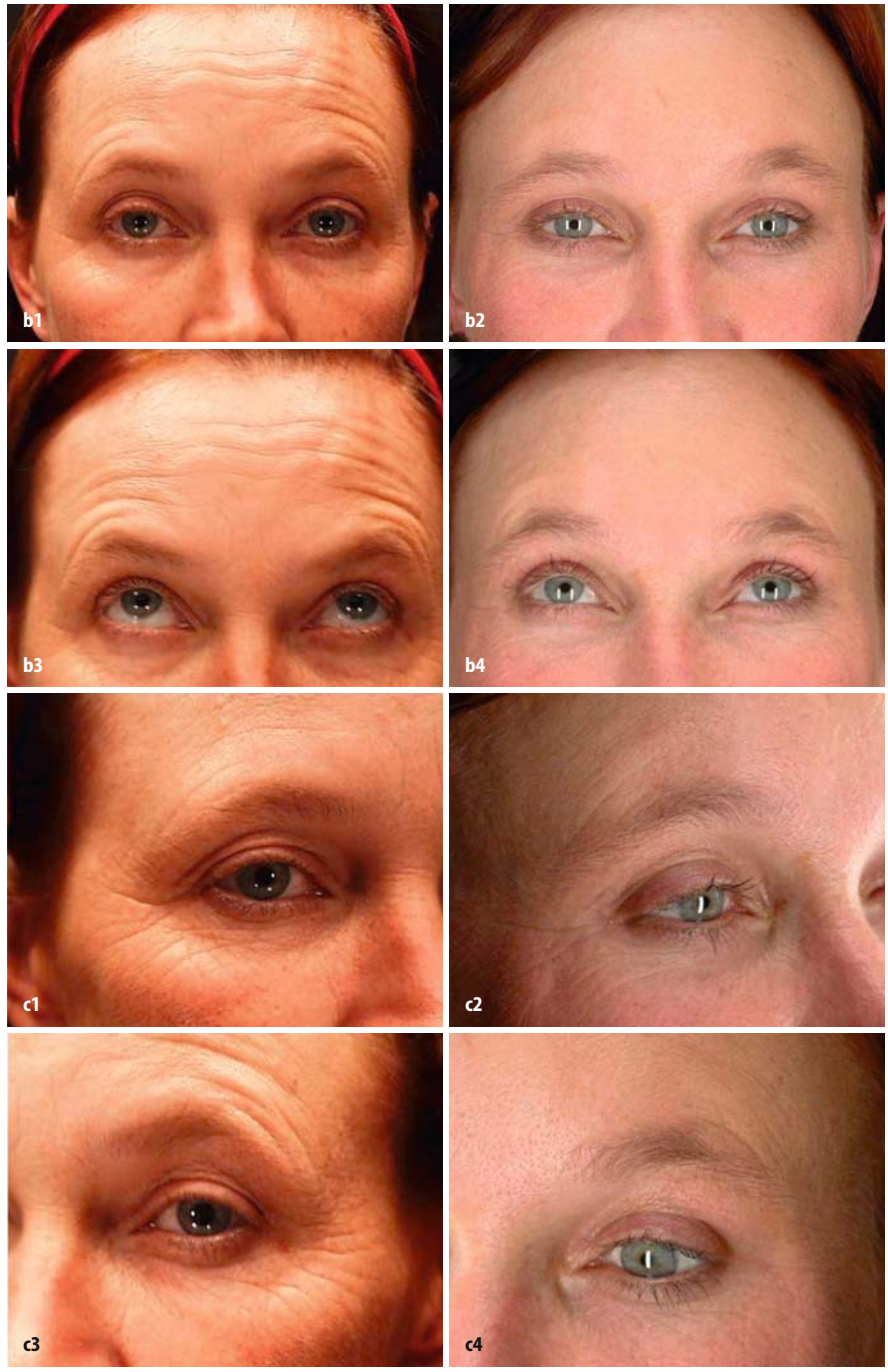

Fig. 29.4. (*Cont.*)

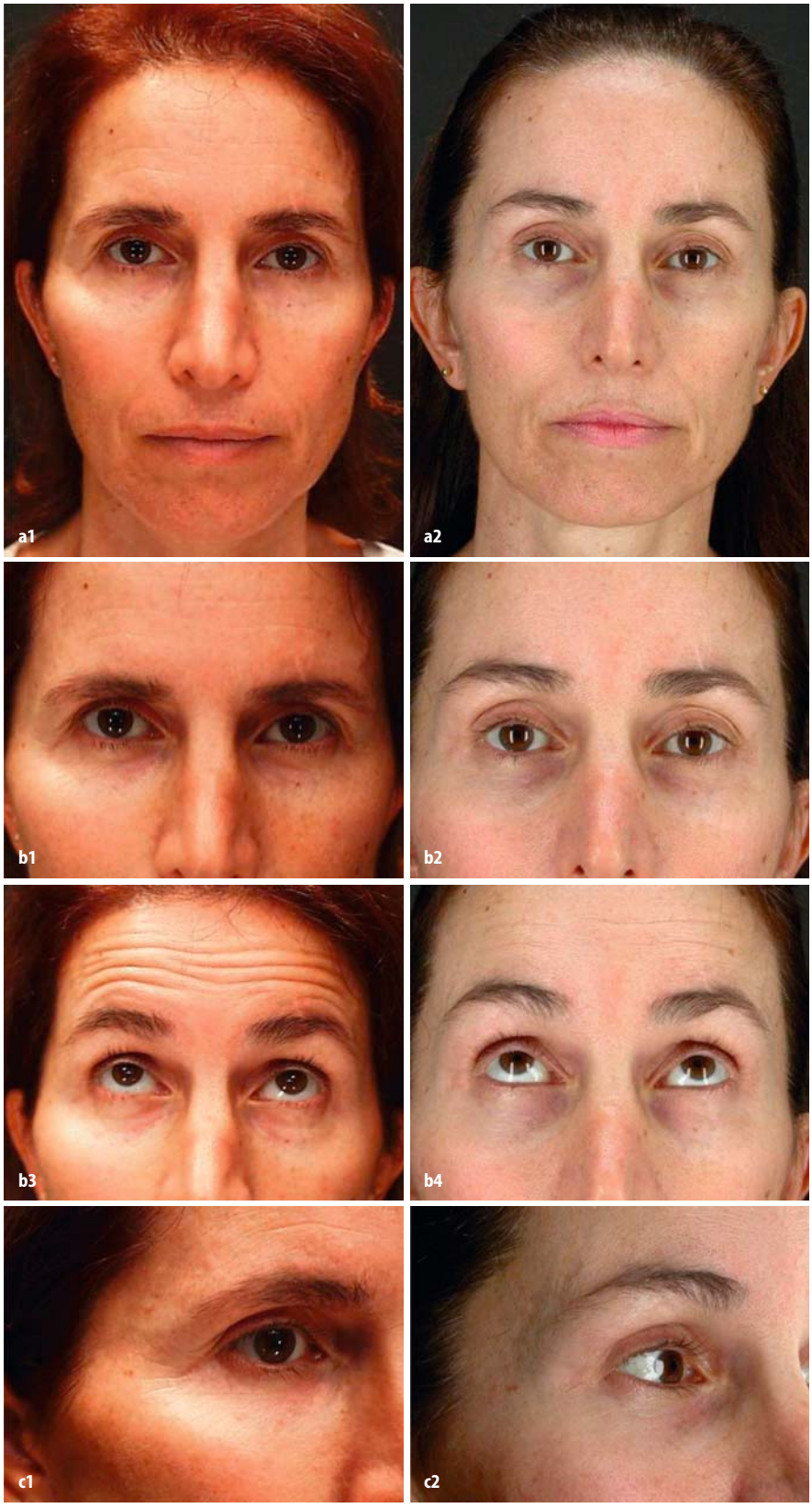

Fig. 29.5. Pre- and 3 years postoperative photos of a 43-year-old female patient after endoscopic forehead and midface lift

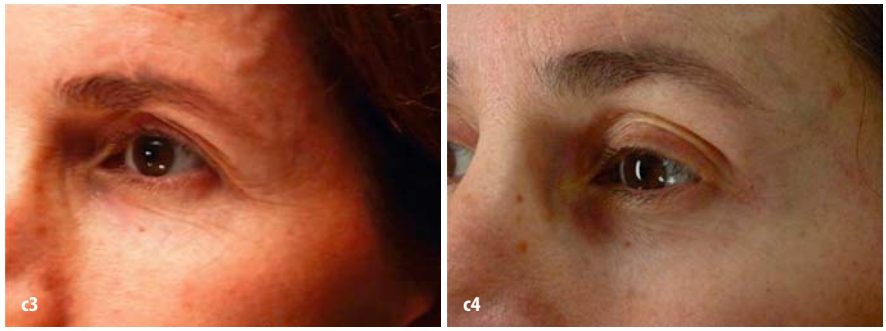

Fig. 29.5. (*Cont.*)

29.5 Complications

Complications are similar to those in other reports [2, 6] of endoscopic forehead and midface lift. Relapse and asymmetry may occur, and sometimes surgical revision is necessary. Dysesthesia and paresis may present due to nerve compression by the endoscopic or surgical manipulation, or even through cauterization. Therefore, only the sentinel vein should be cauterized, and further bleeding should be controlled by external compression and cold saline only. If there is a permanent nerve injury, the nerve on the opposite side should be divided as well to achieve balance. Skin burn may occur if cauterization is extensive, so it should be avoided. Hematoma is rarely described. Alopecia may appear due to overly manipulated tissue or excessive suture tension. Prevention is always the best treatment.

29.6 Conclusions

Endoscopic surgery of the forehead and midface is less invasive with short discrete incisions, where treatment is performed under direct vision and magnification with the endoscope. It is indicated at any age as a single procedure or combined with rhytidectomy, blepharoplasty, chemical peeling, laser and facial fillers. The learning curve may be long, as appropriate training with specific surgical instruments is needed. Study of anatomy is absolutely mandatory and workshops about the technique as well as the observations of experienced peers are very important.

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Endoscopy of the Forehead: A Simple, Effective and Lasting Procedure

30

J.I. de la Torre, L.O. Vasconez

30.1 Introduction

The development of endoscopy of the forehead has provided a simple, lasting and effective procedure to improve the upper third of the face [1]. While the traditional coronal forehead lift invariably results in a long scalp scar, scalp dysesthesia, and alopecia, the endoscopic approach avoids these problematic outcomes. Because endoscopy is a minimally invasive technique and the length of the procedure is short, it can be safely combined with other facial aesthetic surgery procedures to produce a harmonious aesthetic result. With appropriate application, the endoscopic forehead lift has a low rate of complications and beneficial long-term results [2].

30.2 History

Modern improvement to the procedures for forehead rejuvenation had been limited until the early 1990s despite being initially described at the beginning of the last century. Through the use of coronal incisions as well as anterior hairline incisions and direct rhytidectomy, Hunt described techniques to rejuvenate the brow in 1921. Passot originally utilized one of the oldest techniques for brow elevation, temporal brow-lifting, and later included excision of the glabellar region to remove creases and rejuvenate the brow.

During the 1960s and 1970s refinements in the coronal incision and elevation of the frontal flaps for forehead lifting were proposed by numerous authors including Gonzales-Ulloa [3], Vinas [4], Tessier [6] and Ortiz-Monasterio [5]. Kaye [7] and Pitanguy [8] improved dynamic forehead creases by weakening of the frontalis muscle using multiple incisions or strip resections in addition to corrugator excisions. Regnault in 1972 introduced her method "double traction on crow's feet" that avoided subgaleal dissection in the forehead and subcutaneous, face-lift dissection preserving the neurovascular structures in the temporal area [9].

The plastic surgical applications of endoscopy developed slowly when compared with other surgical specialties. The advent of the endoscope combined with the capacity to artificially create an optical cavity led to the birth of endoscopic plastic surgery in the early 1990s. Vasconez et al. described their initial technique at the fall meeting of the American Society of Plastic and Reconstructive Surgeons in 1992 [10]. Subsequent technical refinements and clear delineation of the appropriate indications have made the endoscopic approach increasingly effective and safe.

30.3 Surgical Technique

30.3.1 Incision Placement

Preoperative markings are placed along the midline as well as bilaterally at the level of the pupil. A small triangular skin incision is made in the midline at the prehairline level. The use of three triangular skin excisions has several advantages. The conversion of these incisions into transverse scars at closure allows a small amount of elevation. This design for the skin incisions makes it easier to introduce the endoscope and instruments into the portals and causes less injury to the surrounding tissue. Therefore, it will improve the quality of the scars while keeping them shorter than if the instruments were to be placed through transverse slit in-

cisions. In addition, the triangular incision helps to redefine the apex of the eyebrows in an effort to create the ideal brow contour [11, 12].

This placement is very well tolerated by the patients and it facilitates undermining and endoscopic visualization. This is particularly of value in the case of a very convex forehead [13]. It not only maximizes safety but also the accuracy of the periosteal release and ablation of the brow depressor muscles. These prehairline scars are quite inconspicuous, especially in patients over 55 years of age. In cases of a high forehead or a male receding hair pattern, the minimal access incisions are placed in one of the forehead creases and this has not been found to detract from the scar quality [14]. Designing the skin incisions a few centimeters behind the frontal hairline will complicate the forehead endoscopy and might result in noticeable alopecia.

The two lateral skin incisions are placed where the greatest degree of eyebrow elevation is required. This helps redefine the apex of the eyebrows in an effort to create the ideal brow contour [15, 16].

30.3.2 Anesthesia

General anesthesia is preferred, because multiple additional procedures are usually performed at the same time. The patient is positioned in reverse Trendelenburg with the endotracheal tube directed toward the patient's feet. This provides complete access to the head, and the video monitor which is placed at the foot of the bed, is in the surgeon's line of vision [17]. Local anesthesia is administered (xylocaine 0.5% with 1/200,000 epinephrine) subcutaneously in front of the hairline, subperiosteally along the supraorbital rims and at the radix of the nose. When skin undermining down to the tip of the nose is anticipated, the infiltration is continued to the tip of the nose. The epinephrine not only creates a bloodless operative field, but the lidocaine also reduces the depth of general anesthesia required.

30.3.3 Standard Approach (Fig. 30.1, 30.2)

Once the skin is excised and access is gained to the subperiosteal plane, a hemostat is used to divide the periosteum and then spread in a vertical direction to create an access port. This method spares the nerve endings of the superficial branch of the supraorbital nerve [18, 19]. A periosteal elevator is introduced and subperiosteal undermining is performed between the hairline and supraorbital rims. Elevation is extended laterally in both directions to the transition zone between frontal periosteum and deep temporal fascia. Undermining is not extended posteriorly. A small, rounded, blunt elevator further extends the undermining to the radix of the nose. Unless dissection down to the nose tip is contraindicated, the elevator is turned over 180 degrees so that the curve of the instrument follows the nasal dorsum. By gently rocking this blunt periosteal elevator, one can then safely extend the undermining to the tip of the nose.

Cutaneous retraction sutures are placed above each supraorbital rim at the level of the glabella and supraorbital notch bilaterally. They enable tenting of the forehead soft tissues and create an optical cavity to facilitate maneuvering in the subperiosteal plane [20].

A 300 wide angled endoscope is placed in the central opening with a retractor-elevator. While the assistant is handling the endoscope, the surgeon frees the periosteum in the midline and over the supratrochlear and supraorbital nerves with a blunt periosteal elevator placed in the opposite lateral ports. With a triangle hook knife (Ectra II disposable knife, Dyonics), similar to the one used for endoscopic carpal tunnel release, the periosteum is now released under endoscopic guidance, at the level of the supraorbital rims from lateral to the supraorbital nerves to the level of the lateral orbital rim. Care is taken to avoid extending the periosteal release too far laterally in order to prevent damage to the frontal nerve. Over the lateral third of the eyebrow the hook knife is curved upwards and ends near the midforehead level almost parallel to the transition zone between the periosteum and the deep temporal fascia. No formal undermining or elevation is performed in the temporal region or posteriorly.

Elevation in the subperiosteal plane is a safe and reproducible approach to mobilize the forehead. The interface between bone and periosteum provides an excellent optical cavity. The white bone and bright periosteum increase the light reflection and improve the endoscopic visualization of the dissection [21].

30.3.4 Muscle Resection

The corrugator and procerus muscles are ablated by means of a bimanual maneuver using the left hand to palpate the skin over the glabella and medial eyebrow while the right hand weakens the depressor muscles by grasping them with a biopsy forceps. The precision of this bimanual ablation spares the supratrochlear and supraorbital nerves, and avoids overresection of the muscles. If bleeding occurs due to a vein of the supraorbital bundles, it can be stopped with the disposable suction/coagulator.

Muscle ablation is important in correcting dynamic forehead rhytids, but forehead elevation addresses static rhytids along with brow ptosis. Because the endoscopic approach does not usually involve the resection of skin, transverse wrinkles can be exaggerated follow-

ing forehead elevation. The skin over the inferior half of the forehead is more mobile than that of the superior half. This change in forehead skin mobility is actually the reflection of the anatomical transition of the deep galea plane from a single layer to a multi-layered plane.

When the supraorbital skin is mobilized superiorly, it slides together with its frontalis muscle over the most superficial layers of the deep galea plane. The limited movement of the skin over the upper forehead occurs because there is tight adherence between the one-layered deep galea plane on the undersurface of the frontalis muscle and the periosteum. Therefore, as the mobile lower forehead skin slides in a cranial direction it will at the deep galea transition zone bunch against the upper forehead skin that is quite adherent to the periosteum. On the surface, this will manifest itself as an accentuation of the transverse skin creases, particularly in the cephalad part of the forehead [22].

Once both sides of the forehead have been treated, all instruments are removed from the ports and symmetry is checked: the periosteal release by manually pulling the forehead soft tissues in an upward direction, and the muscle resection by palpating both supraorbital ridges. The cutaneous retraction sutures are then removed, the forehead cavity thoroughly rinsed with a diluted povidone/iodine solution, and a small drain (7 Fr. Jackson-Pratt silicone round drain, Baxter) is introduced through one of the lateral ports. The suction drain is placed in a loop around the extent of the forehead undermining and its lowest part is situated at the glabella. A 3-0 Vicryl (Ethicon) suture approximates the periosteum and subcutaneous soft tissues of the three triangular prehairline incisions and turns them into three short transverse scars. This will result in a slight elevation at the level of the midline and both lateral corneal limbi.

30.3.5 Forehead Fixation

The elevation of the forehead is maintained by a temporary suture suspension. A staple is placed in each of the closed incision sites and a second staple approximately 5 cm posterior to the hairline over each incision. A 3-0 nylon suture is threaded between each pair of staples. The sutures are tightened to obtain the degree of suspension desired. Asymmetry can easily be corrected by adjusting the tension prior to tying down each of the three sutures. Finally, the forehead is taped over its entirety including the glabella and nasal radix and nasal dorsum. This external support stays in place for a period of 3 days.

Additionally, functional elevation of the eyebrow occurs since the pull of the frontalis muscle is unopposed. In contrast to standard rigid fixation techniques, the activity of the frontalis can be used to assist with stabilizing the forehead elevation. Once the frontalis muscle is released from its counteracting forces at the supraorbital insertion, it contracts superiorly [23]. Long-term results indicate that the functional frontalis lift is efficacious in maintaining forehead elevation and it avoids the operated appearance of overelevation of the forehead, which can occur with permanent fixation.

Rigid permanent fixation will provide an immediate postoperative result, which is dramatic, but can often make the brow appear overelevated. This look of surprise is a stigma that is of significant concern to patients seeking upper face rejuvenation [24]. Permanent fixation is advocated for its ability to shape the brow [25]. However, shaping the arch of the brow apex requires tension at the level of the fixation site. In fact, some authors caution that if fixation is achieved under tension, relapse will occur [26]. In addition, the elevated forehead flap incorporates the frontalis muscle that is still involved in forehead animation after the endoscopic lift. If this forehead flap is firmly fixed to the cranial bone, with time the frontalis muscle activity will inevitably loosen the fixation.

30.3.6 Biplanar Technique (Fig. 30.3, 30.4)

An alternative technique, the biplanar forehead lift, combines the standard minimal access endoscopic lift with a limited subcutaneous forehead undermining [27]. Additional local infiltration of the subcutaneous tissues is obtained all along the frontal hairline and over the entire forehead. The incision is placed within the hairline at the border of the denser hair between both temporal regions. Beveling the incision preserves hair follicles and renders the final scar more inconspicuous.

A hemostat is spread to bluntly dissect the forehead in the subcutaneous plane 3 – 4 cm anterior to the hairline incision. This method of dissection spares the nerve endings of the superficial branch of the supraorbital nerves. Standard forehead endoscopy is then used to elevate the subperiosteal plane through the exposed frontalis muscle. As previously described, the optical cavity is created, the forehead periosteum released and the eyebrow depressor muscles are weakened. The three access ports are closed with absorbable suture. Plication of the frontalis muscle is performed using clear nylon horizontal mattress sutures, which span 1 – 1.5 cm. Six of these sutures are placed symmetrically in front of the hairline across the entire width of the forehead. If asymmetry is being corrected, the span of the horizontal mattress suture can be adjusted appropriately. The nerve endings of the superficial branch of the supraorbital nerve and of the supratrochlear nerve are visible superficially on the exposed frontalis muscle and can be easily avoided.

The supraorbital skin remains attached to the lower part of the frontalis muscle; therefore plication of the superior frontalis muscle elevates the eyebrows without the need for the temporary suture suspension. The frontalis plication results in excess skin at the hairline that is resected allowing the forehead flap to be inset and sutured without any tension. The wound edges are approximated with half buried horizontal mattress sutures, and the forehead and nose taped in the area of undermining. No drains are placed in the biplanar forehead lift.

In patients with a high forehead the biplanar forehead lift will avoid further elevating the hairline, and may be used to decrease this excess forehead height. It further affords a more direct impact on the eyebrow and transverse skin creases. Freeing the forehead skin over the upper half severs all the fibrous septa between the muscle and the dermis so as to soften the transverse creases in the area where physiologically they occur most. In addition, plicating the frontalis muscle just cephalad of its mobile lower part and connected supraorbital skin, permits a more accurate correction of the position, shape and possible asymmetry of the eyebrows. For patients willing to accept a prehairline incision, particularly those over the age 55, the biplanar approach may surpass the outcome of a standard coronal lift. Obviously, the older the patient the less noticeable the final prehairline scar will be. Also, plication of the frontalis muscle allows the skin to be redraped and inset without tension, which improves the scar quality.

30.4 Concomitant Procedures

As part of global facial rejuvenation, the endoscopic forehead lift forehead may be accompanied by additional facial aesthetic procedures, including mid-face elevation, neck-lift and eyelid surgery. These ancillary procedures represent an attempt to further meet the ultimate objective of youthful facial harmony [28]. Blepharoplasty is perhaps the most important concomitant procedure performed in conjunction with endoscopic forehead lift. Addressing the upper eyelid enhances the ability of forehead endoscopy to open the periorbital area. Contrary to many recommendations, the upper and lower blepharoplasty is performed preceding the extensive dissection of the forehead lift [29, 30]. Performing the blepharoplasty first avoids periorbital and upper lid swelling that will compound the problem of adequate resection of the upper lid skin. Conservative skin resection of the upper lid is outlined preoperatively with the patient sitting upright. While marking with the right hand, the left slightly elevates the brow to a more youthful position. This avoids overelevation of the brow, which can result in an unnatural surprised look. The lower blepharoplasty is conservative in skin, muscle and fat resection, and always incorporates a tightening and lateral suspension of the preseptal orbicularis oculi.

Additional ancillary procedures may include chin lift, ear lobe reductions, and some lip rejuvenation. The latter may be any combination of upper and lower lip dermabrasion, upper lip shortening and tightening, or upper and/or lower lip augmentation. When endoscopic undermining is extended to the tip of the nose, it offers a slight elevation of the aging, drooping tip; however, in a number of patients formal tip rhinoplasty is required [31].

30.5 Complications

The unsatisfactory results directly related to the endoscopic forehead lift included: surface contour irregularities in seven patients, persistent horizontal forehead wrinkles in three patients, and persistent glabellar frown lines in eight patients.

The rate of hematomas due to forehead endoscopy alone is less than 5%. Most hematomas are minor and can be evacuated at the first postoperative visit. In fact, most of these small hematomas will resolve spontaneously, but drainage shortens the recovery time. The addition of a small forehead drain will eliminate this problem, but is not necessary.

Approximately 2% of all patients with the minimal access endoscopic forehead lift experience a temporary frontal nerve weakness. All frontal nerve injuries were mild and on all occasion resolve spontaneously within 2 months [32].

Overall, 80% of the forehead endoscopies demonstrate no periorbital complications. The rate of complications in isolated endoscopic forehead is 12%, with upper blepharoplasty it rises to 20% and with the addition of upper lid ptosis it jumps to 54%. Typically this includes difficulty closing the eyes, eye irritation, or upper eyelid asymmetry. Of these patients with periorbital complication, 95% resolve with expectant management.

30.6 Conclusions

As the popularity of endoscopy has grown, so has the number of technical variations. There are, however, several key elements to successful forehead rejuvenation using endoscopy: adequate release of the periosteum, ablation of the depressor muscles of the brow, and a suspension technique which is simple and reliable. The endoscopic forehead lift consistently attenuates

transverse forehead wrinkles, reduces the glabellar frown lines, and raises the eyebrows. Further this technique creates a more open and welcoming appearance to the eyes and making the patients look less tired or angry, while avoiding a surprised operated appearance.

Understanding the limitations of standard minimal access endoscopy is as essential as proper execution. The use of the biplanar approach expands the indications for endoscopy of the forehead and with proper patient selection can yield improved results. It is offered to patients with very ptotic eyebrows, deep transverse wrinkles, or a "high forehead."

Overall, the complication rate is quite acceptable and is not markedly increased with the addition of other facial procedures. Endoscopy of the forehead is a safe, effective and long-lasting technique to rejuvenate the upper third of the face.

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31 Baldness Surgery: Megasessions with Follicular Units

C.O. Uebel

31.1 Introduction

Hair restoration has become one of the most popular techniques in male plastic surgery. The use of punch grafts [1] was reported by Orentreich in the 1950s, which proved the presence of hereditary dominant characters when hair follicles are transplanted. This was followed by the tempoparieto-occipital (TPO) flaps of Juri [2], which were improved upon by Chajchir [3] and Uebel [4], and then in the 1980s the micrograft concept of Nordström [5] and Marrit [6] was introduced. A new era began in 1986 [7] when we started to use micro- and minigraft "megasessions." We published details of this method in 1989 [8] and 1991 [9], which we called the micropunctiform technique. Since then other surgeons have presented interesting results using our technique [16]. It is considered a safe and simple procedure which, allied to a natural hairline, is today a much valued option for surgeons and patients.

31.2 Selection of Patients

We know that male pattern baldness (MPB) can start at the age of 16 years, caused by a coincidence of three main factors: hereditary, androgenic hormone and age. It has a progressive nature and has its own growth cycle that becomes more evident after 30 years. In female patients hair fall appears more in the menopause period, but we also see androgenetic female alopecias at earlier ages. We prefer to operate on patients over 24 years old, when they are more conscious about the progressive pathology nature and are really convinced of what they want. In young patients it is important to project the definitive frontal hairline. We normally draw 2 or 3 cm beyond the original hairline, estimating the future frontal and temporal recesses.

For older patients, more than 60 years of age, we recommend a more posterior hairline and sometimes a design like a forelock is suggested.

For patients with dark and thick hair, such as "iron hair," even if we transplant single hair bulbs one by one, it is important to discuss with the patient a modification of their hairstyle, by combing the hair to the front or to the side.

With blond and very thin hair, we have obtained better results, although we need a second replacement to achieve the desired hair density.

31.2.1 Photographic Study

It is important to take pictures from the front and from both oblique views. This is important to estimate the position of the new hairline, the area of baldness and the quantity of hair we want to replace. We take color pictures (ISO 100/210) and digital pictures with a 5.2-pixel camera.

31.2.2 Hairline Design

The frontal hairline is projected irregularly, maintaining the temporal recesses, and a non-straight line is important to achieve a natural and non-detectable result. Over the years we have established some parameters which are important for the frontal hairline. The forehead middle point is normally 8 cm distant from the glabella, varying from 7 to 9 cm depending on the facial

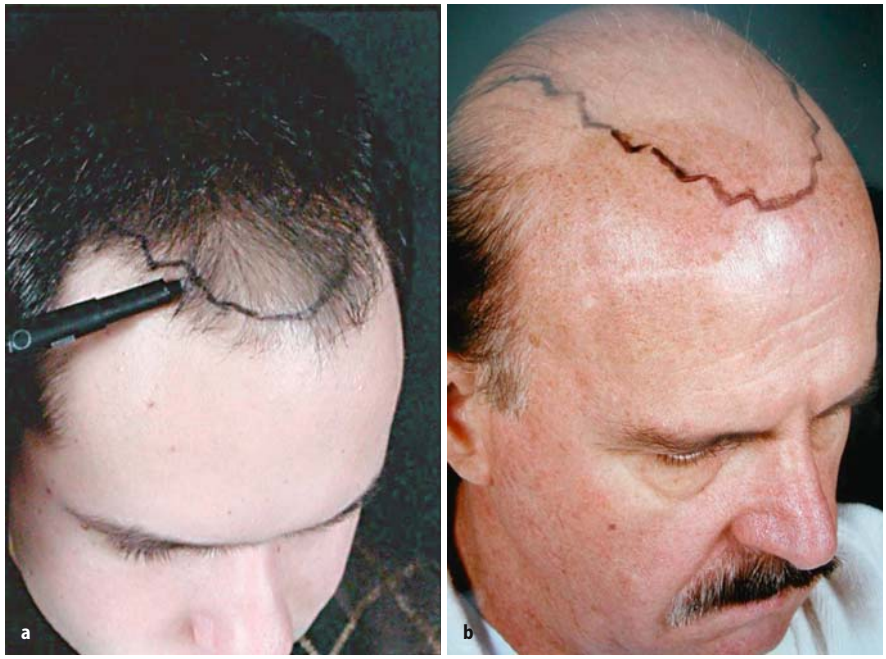

Fig. 31.1. a Young patient with projection of the definitive frontal hairline. **b** Older patient, with a more posterior hairline; sometimes a design like a forelock is suggested

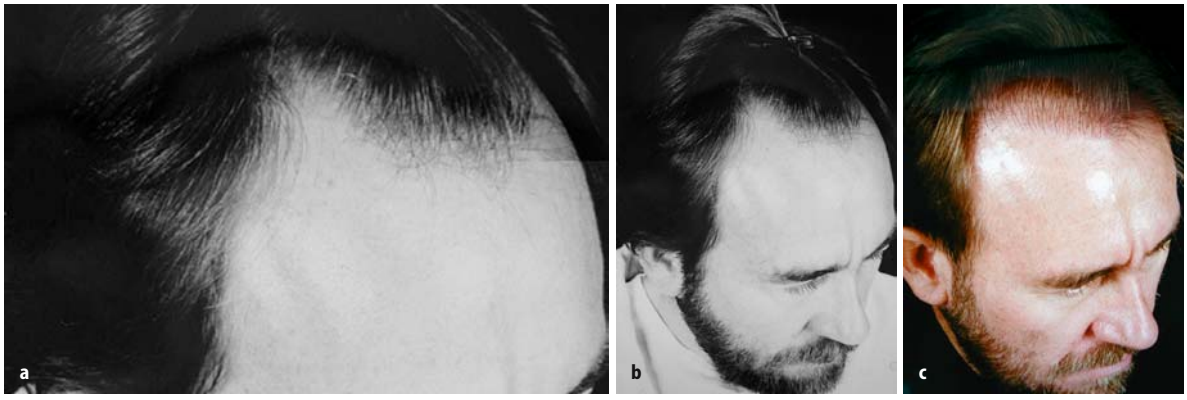

Fig. 31.2. a In patients with dark and thick hair, like "iron hair," it is more difficult to hide the hairline. **b, c** With blond and very thin hair, we obtain better results, although we need a second replacement to achieve the desired hair density

Fig. 31.3a, b. We take color pictures (ISO 100/21°) and digital pictures with a 5.2-megapixel camera

contours of each patient. From the brow lateral canthus, we draw a perpendicular line up to the temporal recesses. This lateral point will connect the middle point in a "vw" irregular line. This procedure is discussed with the patient in front of the mirror. If necessary we raise the thin and effluvium hair to make the surgery more effective and productive.

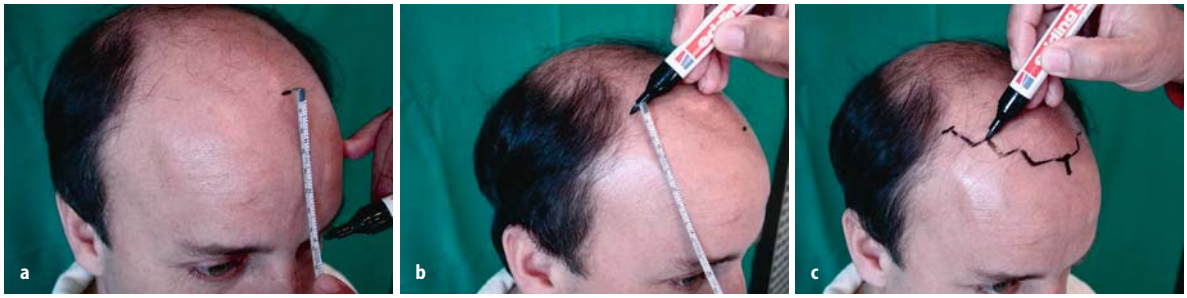

Fig. 31.4a–c. Drawing the frontal hairline and planning with the patient the best design for the hairline

Fig. 31.5a–e. Drawing a hair bearing ellipse according to the size of the bald area, which can be small, medium or large, varying from 10 × 2 cm to 20 × 3 cm, where we can get from 500 to 1,500 follicle units

31.2.3 Donor Area

We harvest the hair follicles from the posterior cervical area, where we have the best density and histological hair quality, normally 6–8 cm from the bottom. We project a hair-bearing ellipse according to the size of the bald area, into a small, medium or large area, varying from 10 × 2 cm to 20 × 3 cm, where we can get from 500 to 1,500 follicle units.

We never measure precisely the amount of hair replaced. Some patients have a lower density per square centimeter than others, so for these it is convenient to harvest a bigger hair bearing ellipse.

31.3 Method – Surgical Routine

31.3.1 Anesthesia

To perform this technique we need to keep the patient in a quiet state. The surgery takes around 2–3 h and so a comfortable position and a calm ambience are desirable. Neither the surgeon nor the patient should be stressed. A well trained team working in harmony is a basic prerequisite for a good outcome. Three items are important:

- Sedation
- Nerve blockage
- Scalp ballooning

We normally use midazolam (Dormonid) 5–10 mg and fentanyl citrate (Fentanil) 1–2 cc to sedate the patient and 20 cc bupivacaine (Marcaine 0.5%) with epinephrine 1:200,000 (Adrenalin) to block the supraorbital nerves and the coronal area 1 cm in front of the hairline.

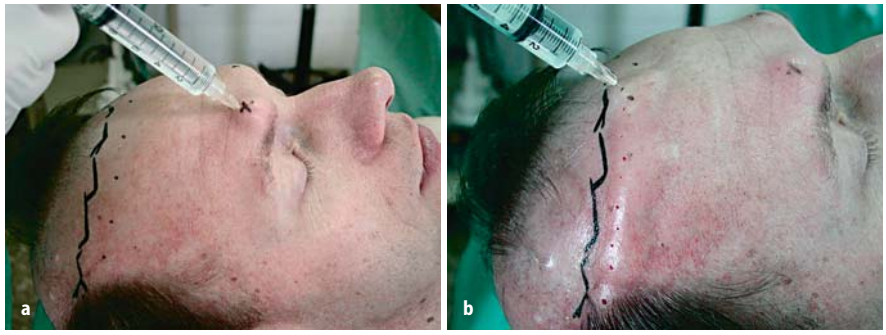

Fig. 31.6a, b. We normally use midazolam (Dormonid) 5 – 10 mg and fentanyl citrate (Fentanil) 1 – 2 cc to sedate the patient and 20 cc levobupivacaine chloride (Novabupi 0.5 %) with epinephrine 1:200,000 (Adrenalin) to block the supraorbital nerves and the coronal area 1 cm in front of the hairline

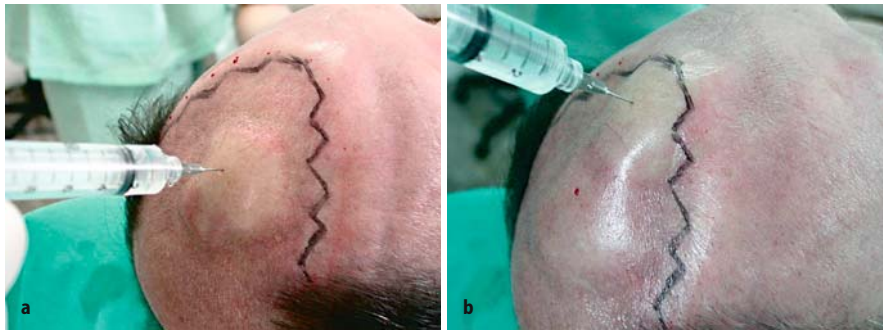

Fig. 31.7a, b. The "scalp ballooning" is performed to increase the edema of the scalp and to obtain ischemia

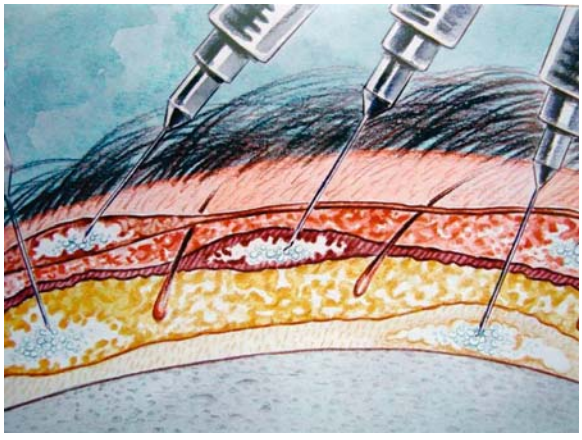

Fig. 31.8. The infiltration is done with 160 cc saline solution with epinephrine 1:160,000, and all the scalp layers are injected up to the derma

"Scalp ballooning" is a procedure that we described in 1991 [9] to increase the edema of the scalp and to obtain ischemia.

The infiltration is done with 160 cc saline solution with epinephrine 1:160,000 and all the scalp layers are injected up to the derma.

The maneuver is important to prevent bleeding during the surgery and to maintain the grafts inside the punctiform incision. We need to wait 5 – 10 min to start and we can repeat the infiltration every half hour if we wish. On the donor site, we make the same blockage with bupivacaine 0.5 %, and a massive infiltration with the saline solution is performed to make the cutting and separation of the future follicular units easier.

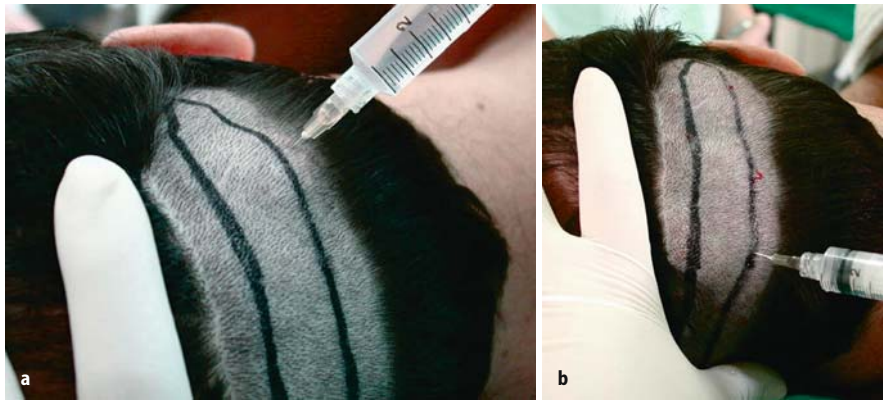

Fig. 31.9a, b. On the donor site, we make the same blockage with Novabupi 0.5 %, and a massive infiltration with the saline solution is done to make the cutting and separation of the future follicular units easier

31.3.2 Harvesting

The hair bearing ellipse is cut with a single #10 blade in an oblique fashion so as not to damage the hair bulbs. The incision is very superficial; we do not cut the galea and we raise the flap from the subcutaneous fat tissue to avoid the occipital nerves and vessels that normally are at the end of the ellipse.

In the past we tried to use multiblades and punches in the donor area, but we observed that we damaged a lot of hair follicles and also made it more difficult to harvest the area in a second replacement procedure. To close the defect, it is very important to avoid stretching, and the undermining of the edges is mandatory. We need to be careful not to damage the occipital vessels and nerves localized at the end of the ellipse.

We place some subcutaneous stitches, and a running superficial cutaneous suture is done to close the defect.

31.3.3 Surgical Instruments

To perform the punctiform incision we use a needle (40×12'), a #11 sharp blade or a microsurgical blade (6500-BD Beaver). An angular microsurgical forceps is

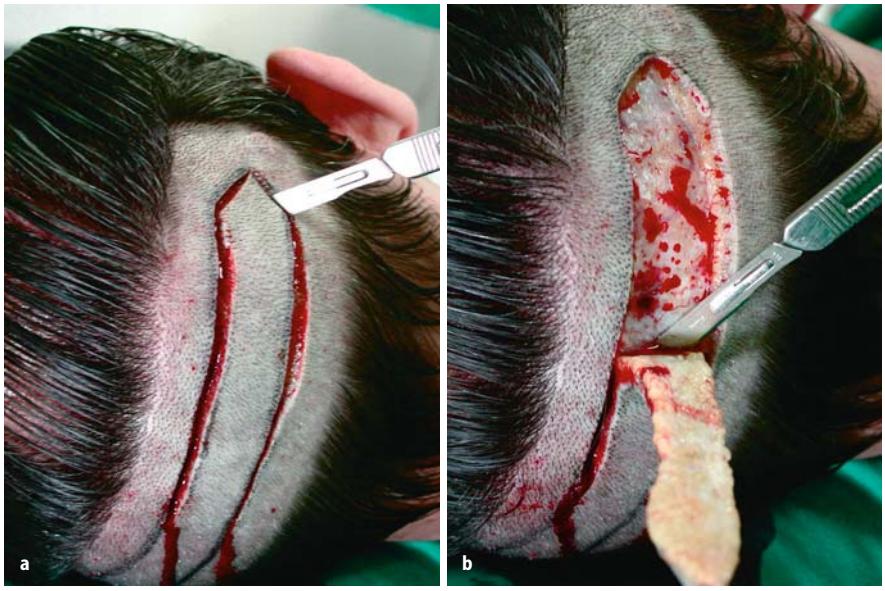

Fig. 31.10a, b. Harvesting the hair bearing ellipse with a single #10 blade at an oblique angle so as not to damage the hair bulbs

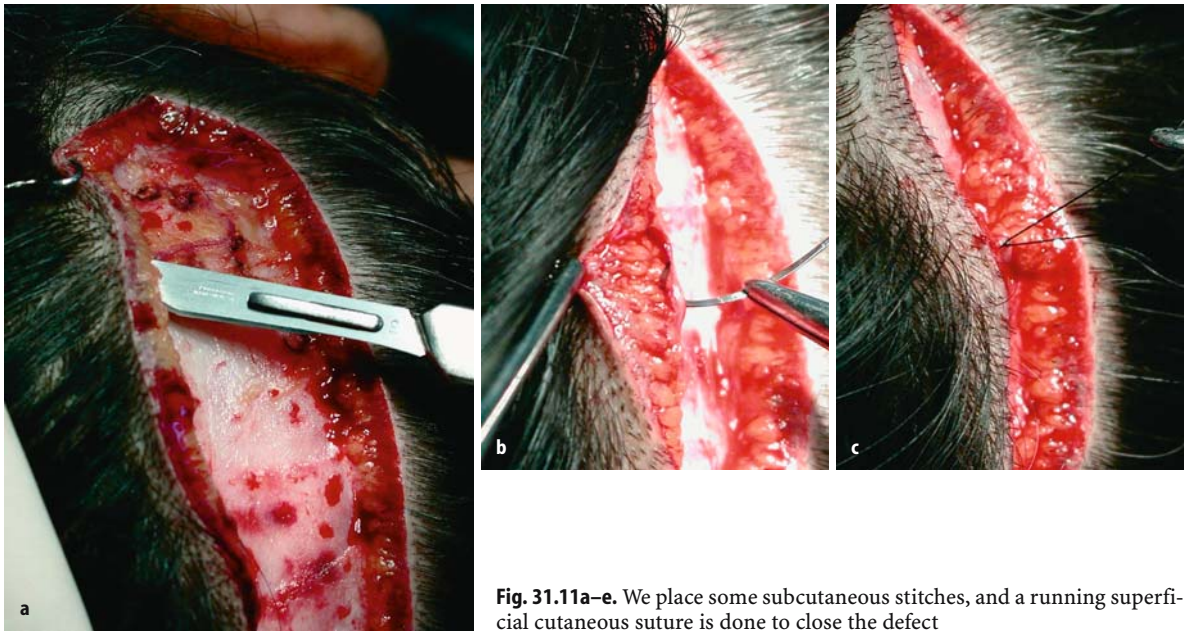

Fig. 31.11a–e. We place some subcutaneous stitches, and a running superficial cutaneous suture is done to close the defect

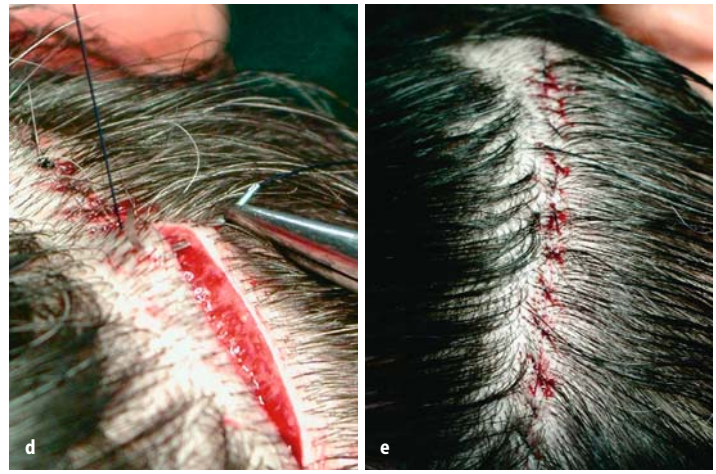

Fig. 31.11d, e

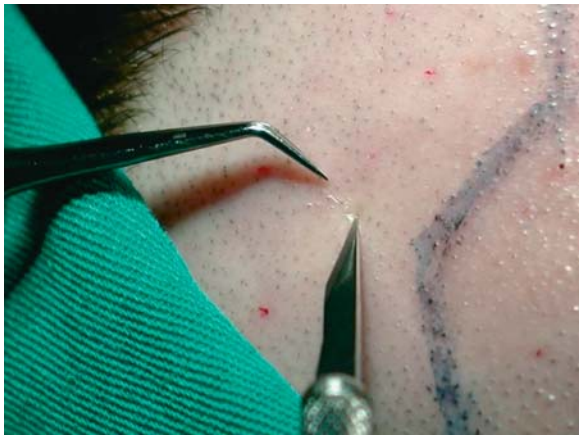

Fig. 31.12. Performing a punctiform incision with a needle (40×12'), a #11 sharp blade or a microsurgical blade (BeaverR 6500-BD)

useful to pinch the follicular units and bring them to the slit. To cut and separate the follicles we use a #22 or a #10 blade, and a hard surface, such as wood or acrylic, is suggested for preparation.

31.4 Surgery

31.4.1 Harvesting the Follicular Units

We cut the ellipse into several slices of 3–4 mm width and trim the fat, maintaining a little bit surrounding the bulbs to allow for nourishment and also for protection during the grasping maneuver.

Some patients have a lower hair density than others with a high connective tissue surrounding the grafts that needs to be trimmed away.

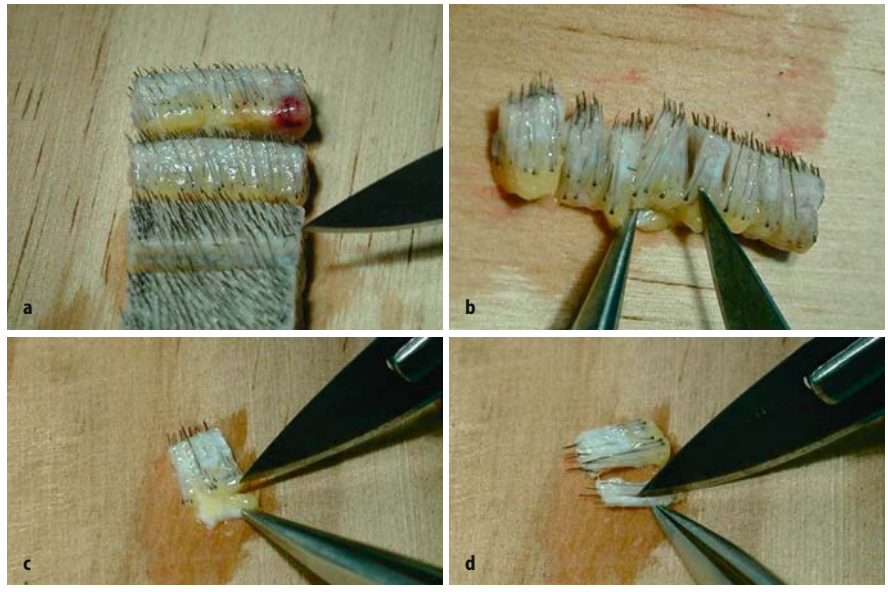

Fig. 31.13a–d. We cut the ellipse into several slices of 3–4 mm width, and trim the fat, maintaining a little bit surrounding the bulbs to allow for nourishment and also to protect it in the grasping maneuver

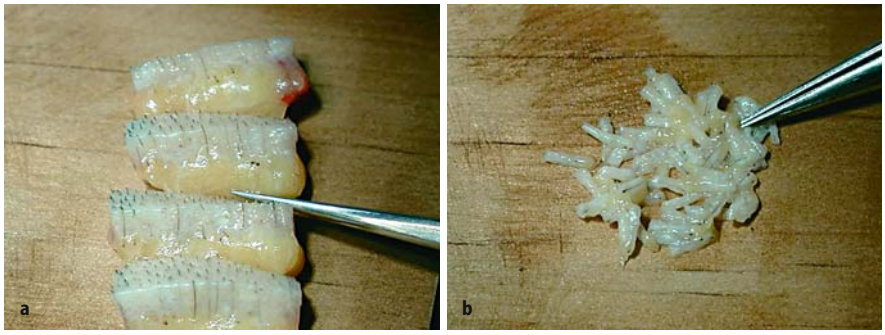

Fig. 31.14a, b. Some patients have a lower hair density than others with a high connective tissue surrounding the grafts that needs to be trimmed away

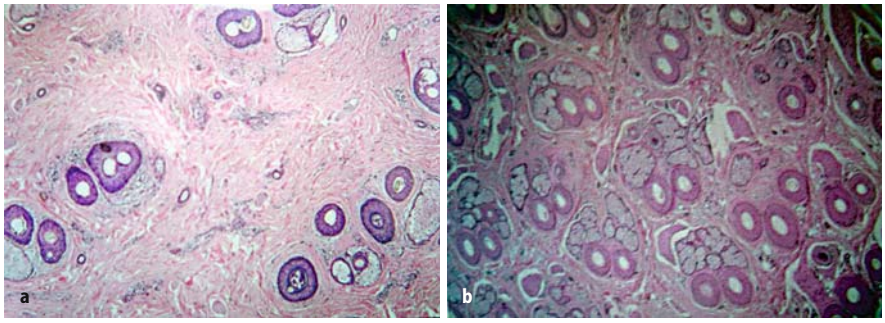

Fig. 31.15a, b. In this transverse scalp section at the sebaceous gland level in the low reticular dermis we see follicles separated by a large fibroconnective tissue. H&E, ×50. Others have a high density of more than 1 follicular unit/mm^2. In this histological study we see a normal density of follicular units. H&E, ×50

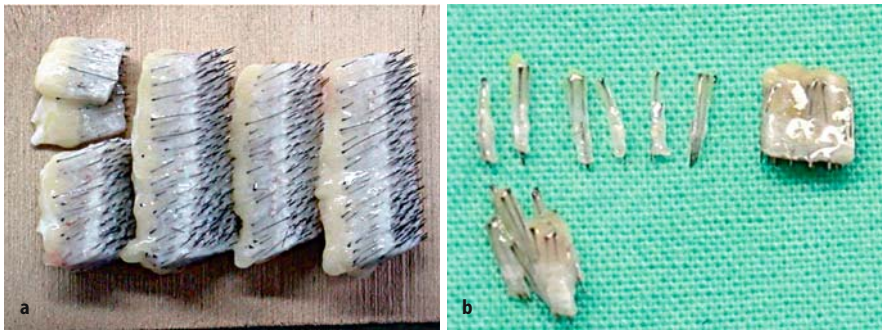

Fig. 31.16a, b. The two groups are: micrografts with one or two bulbs and minigrafts with three or four bulbs

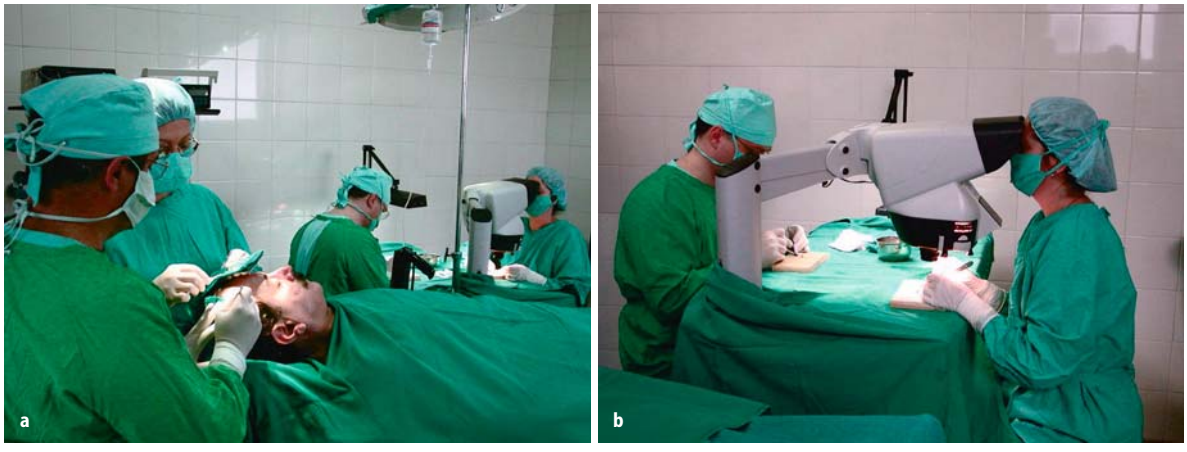

Fig. 31.17a, b. They are separated by the naked eye or by a three-dimensional stereoscopic viewing before they are implanted

In this transverse scalp section at the sebaceous gland level in the low reticular dermis, we see follicles separated by a large fibroconnective tissue (H&E, ×50). Others have a high density of more than 1 follicular unit/mm^2.

In this histological study we see a normal density of follicular units (H&E, ×50). We separate them into two groups: **micrografts** with one or two bulbs and **minigrafts** with three or four bulbs.

These grafts are similar to the follicular units described by Headington [10] in 1984 and furthermore discussed in papers by Kim [10], Bernstein [11] and Seager [12]. The graft is a histological structure of the scalp, as described by Headington. It usually consists of two to four terminal follicles, one to two vellus follicles, sebaceous glands and insertions of the arrector pili muscles. Surrounding this structure is the perifolliculum formed by reticular dermis collagen fibers.

They are separated using the naked eye or under a three-dimensional stereoscopic view.

In the past, we cut the epidermis, but we saw that the buried grafts produced more cysts and granulomas after the 3rd month, when the hair started to grow. In the last 12 years we have preferred to keep the epidermis. The grafts are placed over a humid tissue with saline solution and are brought to the recipient area immediately, it not being necessary to place them in solution or wet dishes.

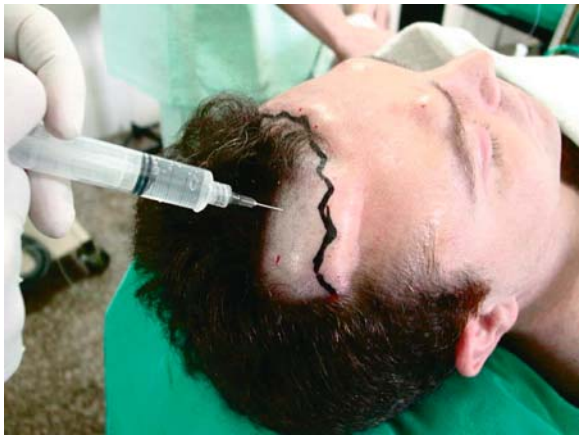

Fig. 31.18. We produce a tumescent infiltration in all layers of the scalp – that is the scalp ballooning – reaching the dermis and producing the "white marbling" signal due to the whiteness of the skin

31.4.2 Implantation of the Follicles

The bald recipient area needs to be swollen and ischemic, it being important to work without bleeding and to maintain the grafts inside the orifices. We produce a tumescent infiltration in all layers of the scalp – that is scalp ballooning – which reaches the dermis and produces the "white marbling" signal due to the whiteness of the skin.

We normally prefer to start from the middle to the front. The punctiform incisions are made vertically in the middle and obliquely further forward, as we reach the frontal head, because these are the natural angles of implantation of the hair on the skull. The incision is 3–4 mm in depth, sufficient to get the graft into place and superficially in touch with the orifice.

We do not cut the galea aponeurotica, but if we do, we have more bleeding and the graft can be totally bur-

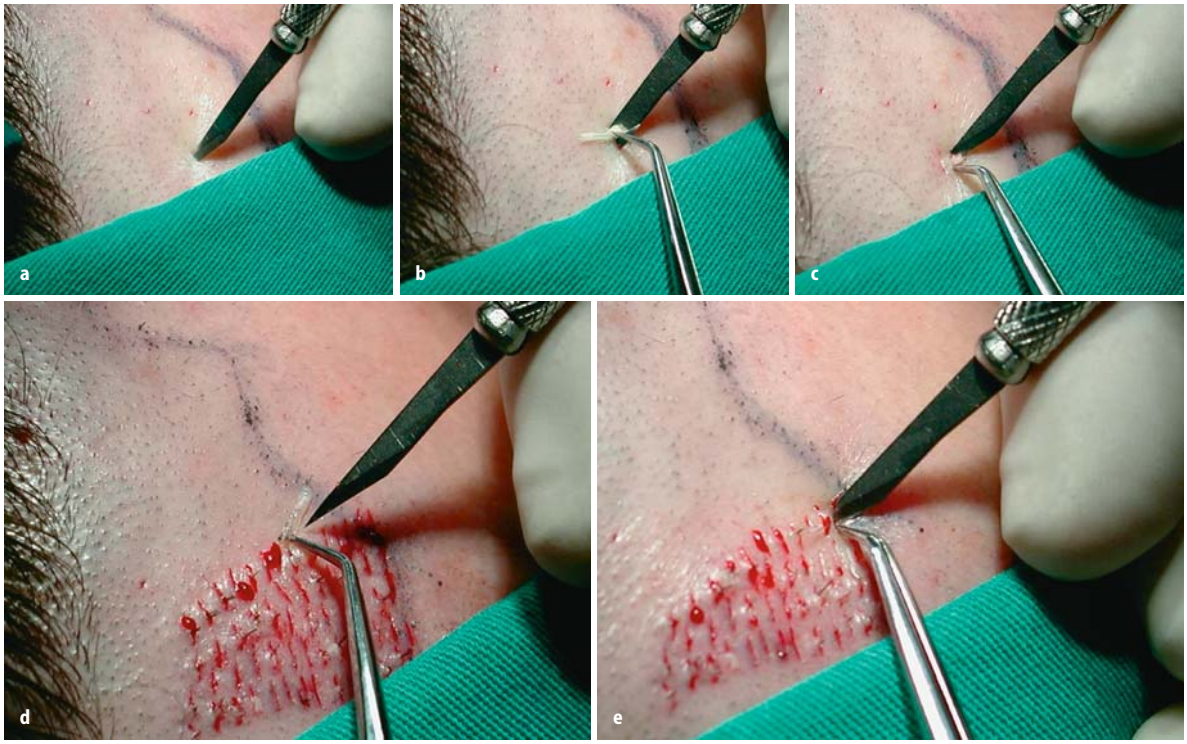

Fig. 31.19a–e. The incision is 3–4 mm in depth, sufficient to get the graft in place and superficially in touch with the orifice

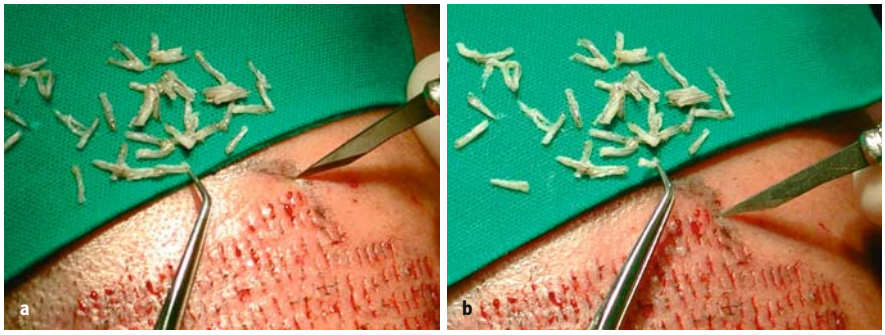

Fig. 31.20a, b. The stick and place procedure is performed with a microsurgical blade, while the follicular unit insertion is done with a microforceps at the same time by an assistant

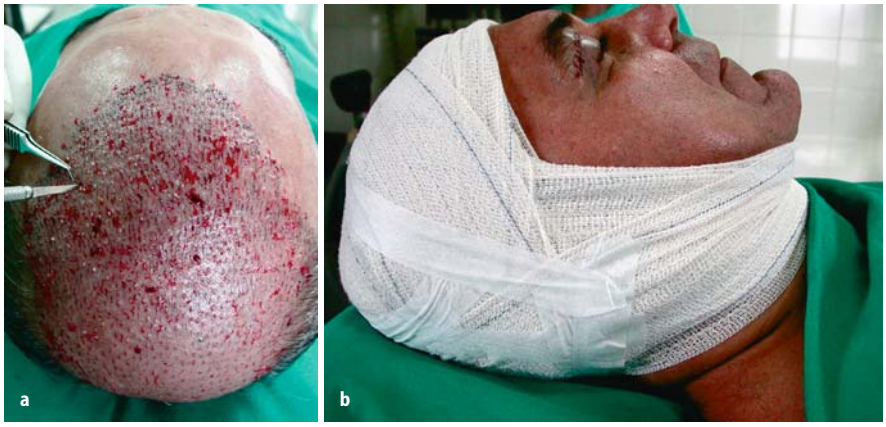

Fig. 31.21a, b. Humid gauzes in saline solution are applied over the implanted area and a bandage is kept on for 24 h to protect the area

ied. When we have made the incision with the #11 blade or the microsurgical blade, the assistant picks the graft from the humid tissue with an angular forceps and gently inserts it into the slit. We then take the blade out and help the insertion. This maneuver, which we call "stick and place," is done simultaneously and is the goal of the technique.

The stick and place procedure is performed with a microsurgical blade, while the follicular unit insertion is done with a microforceps at the same time by an assistant. We repeat the procedure, maintaining a space of 4 – 5 mm between each one, so as not to pump out the implanted grafts. After 15 – 20 min, when the fibrinogen inside the skin becomes fibrin, surrounding the grafts like glue, we go back and reintroduce another graft between them, achieving more density. It usually takes 2 h to replace 1,500 follicular units and we recommend no more than this. It is preferable to make a second replacement after 8 months, when we can implant another quantity of grafts with success. Hair is like a plant – we need to keep a distance of 2 – 3 mm between each graft to enable each one to grow with better vitality. In the frontal hairline we insert only single hair irregularly, producing an appearance important for the final natural look, like a "degradée."

Humid gauzes in saline solution are applied over the implanted area and a bandage is kept on for 24 h to protect the area. The patient takes this "plaster" off at home and takes a shower, cleaning the scalp with an antiseptic soap. After 3 months, the hair will start to grow definitively, coming out appearing very thin and tenuous. We can tell the patient that the final result appears just after 6 – 8 months, and in females from 10 to 12 months, when we estimate all the hair will have come out of the orifices.

31.5 Complications

In 10% of our patients, after the 3rd month, we find some retention cysts. These are common in oily scalps with intensive seborrhea. We recommend to the patient that they rupture the orifice with a sterilized needle or forceps and gently squeeze the cyst. Sometimes there are some follicles that need to be removed entirely. The other cases of cysts occur when we bury the grafts deep under the galea; this causes a tumescent granuloma with redness and pain, which we need to excise using local anesthesia.

31.6 Results

This technique is indicated for both young and older patients, for male and female patients and for incipient and total baldness. It depends on the donor area the pa-

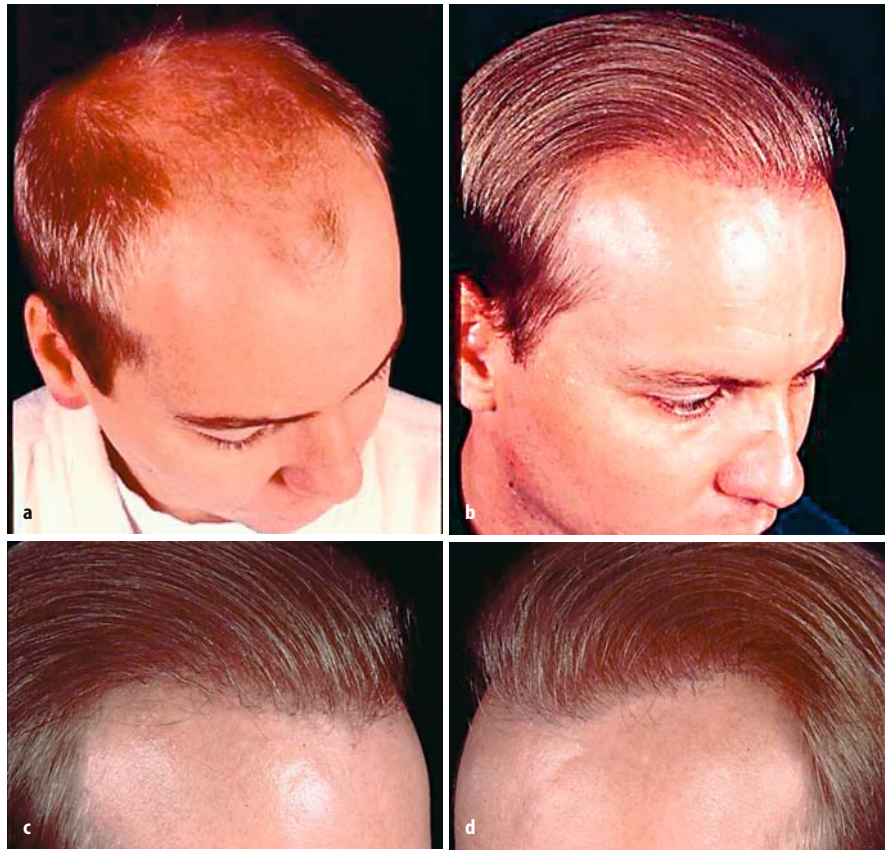

Fig. 31.22a–d. Thirty-four-year-old patient with blond hair. Two years postoperatively

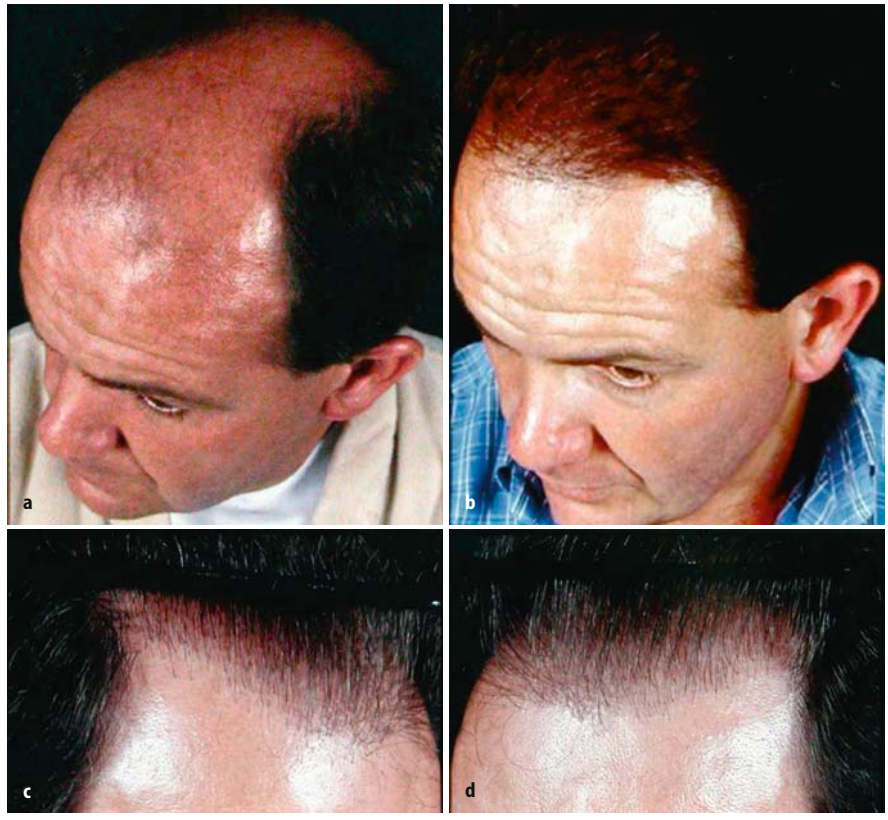

Fig. 31.23a–d. Thirty-eight-year-old patient with black hair. Eighteen months postoperatively and a close-up view of the new hairline

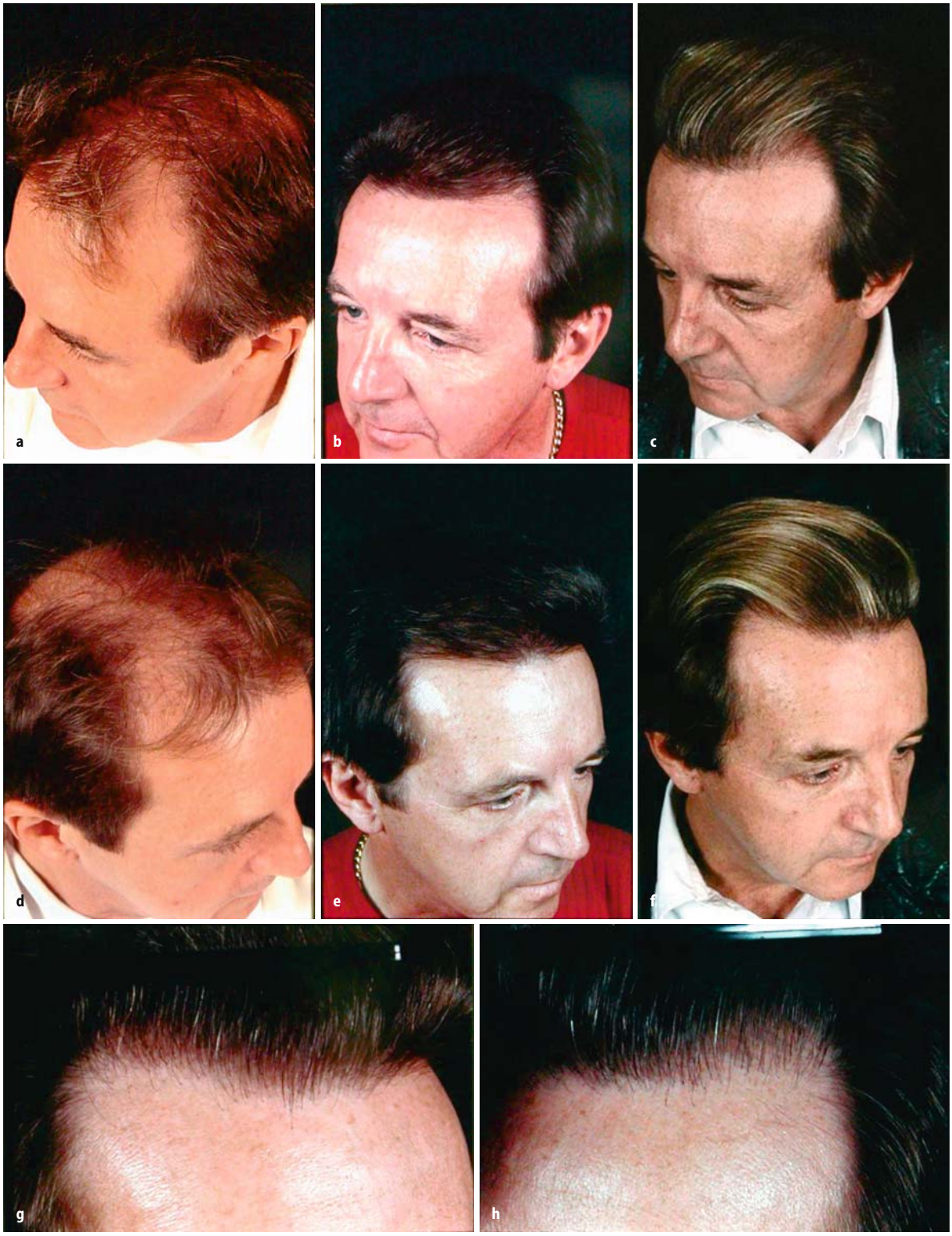

Fig. 31.24a–h. Young patient with an incipient baldness where we increase hair density. After 2 years he improved his hairstyle with some blond matches

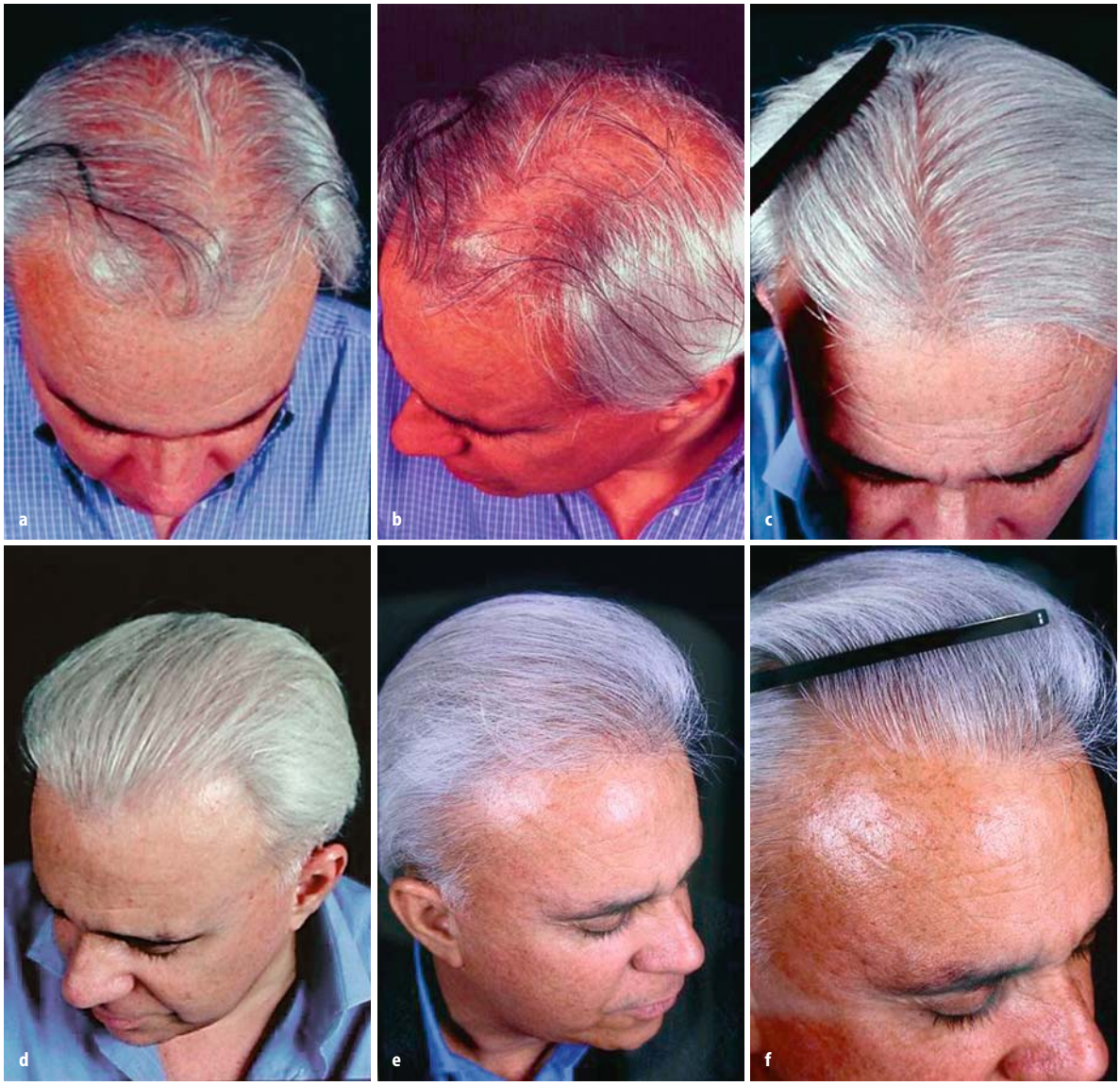

Fig. 31.25a–f. Forty-eight-year-old patient with grey hair. He changed to blue after 4 years

tient has – the density and the quality of the hair to be replaced. We recommend operating on patients over 24 years old, when they should have a better understanding about the progressive nature of baldness and we need to be very honest in telling them that probably in the future they will need a second replacement. One of the best indications is when we want to improve density by putting replacements in between the remaining hair. These patients are the most grateful ones, changing hair styles and trying new colors for their hair. Older patients can achieve a new young look because we know that the new hairline reframes their face with a natural and elegant profile. In women the technique is especially indicated for androgenetic baldness, for secondary face and forehead lifts, for reconstructing sideburns and for improvement of temporary recesses.

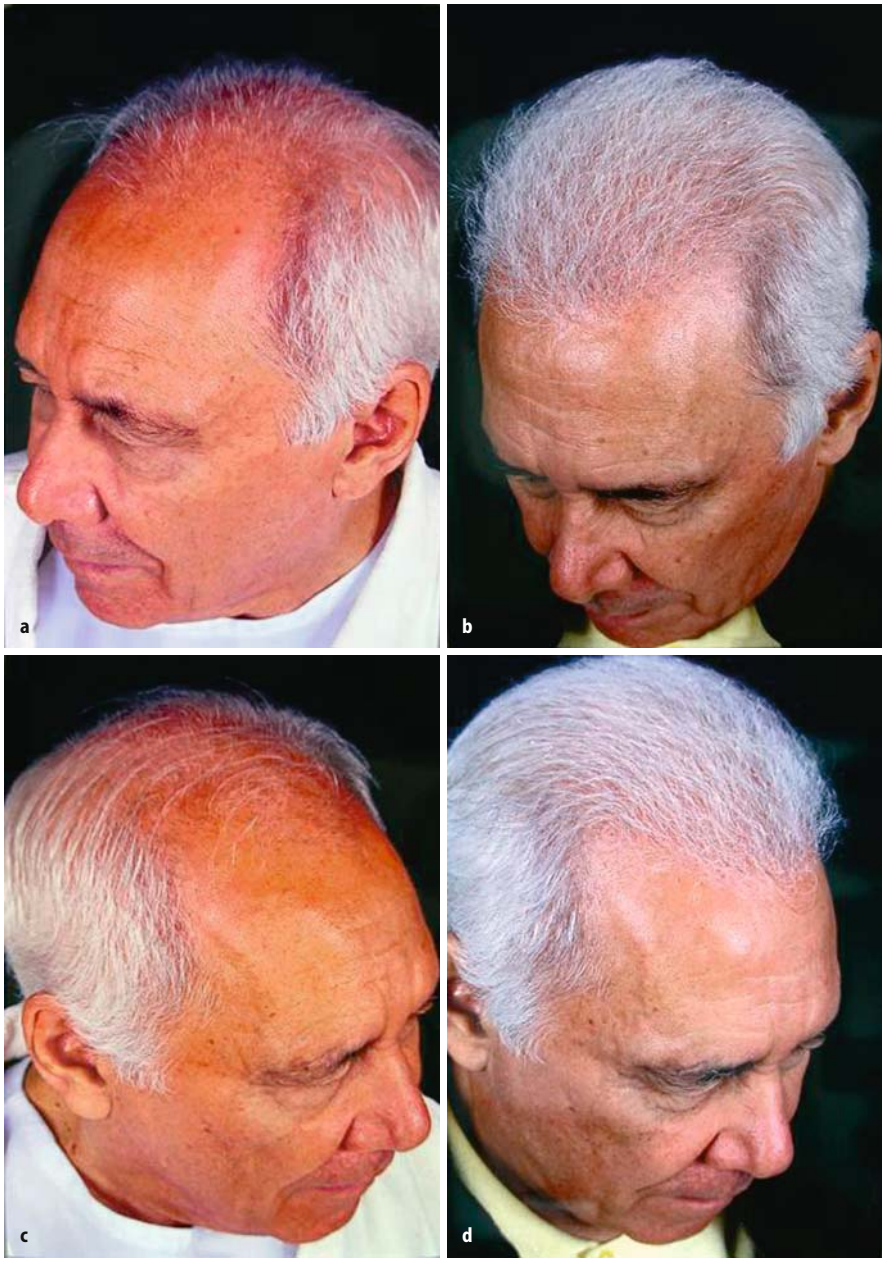

Fig. 31.26a–d. Seventy-eight-year-old patient with white hair. The new hair reframes the face and he looks younger

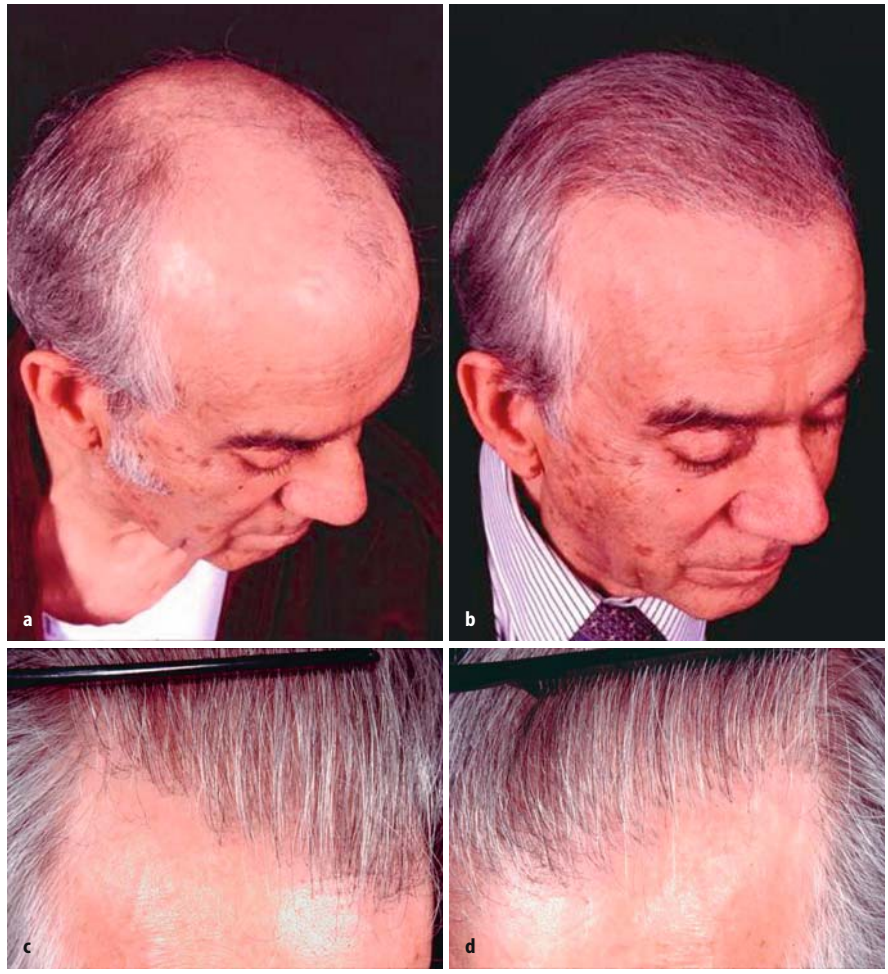

Fig. 31.27a–d. Eighty-year-old patient with grey hair showing a good quality of implanted follicular units

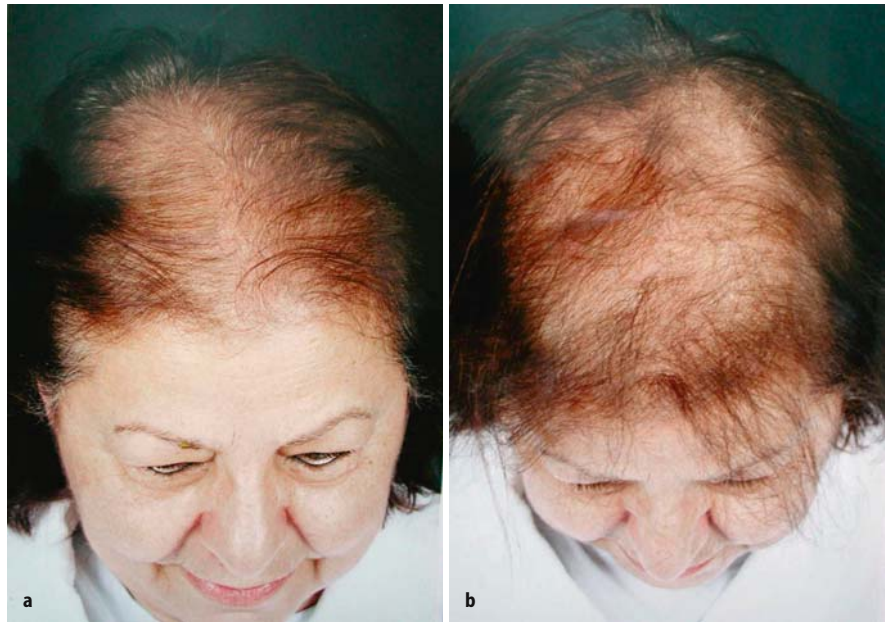

Fig. 31.28a–d. Seventy-nine-year-old female patient with androgenic baldness. After 2 years we have achieved a good hair density

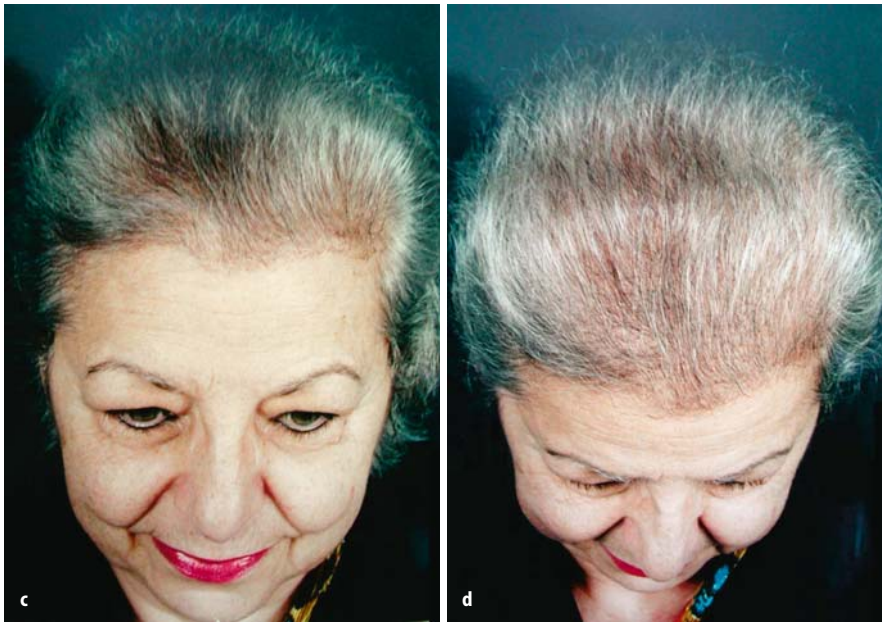

Fig. 31.28c, d

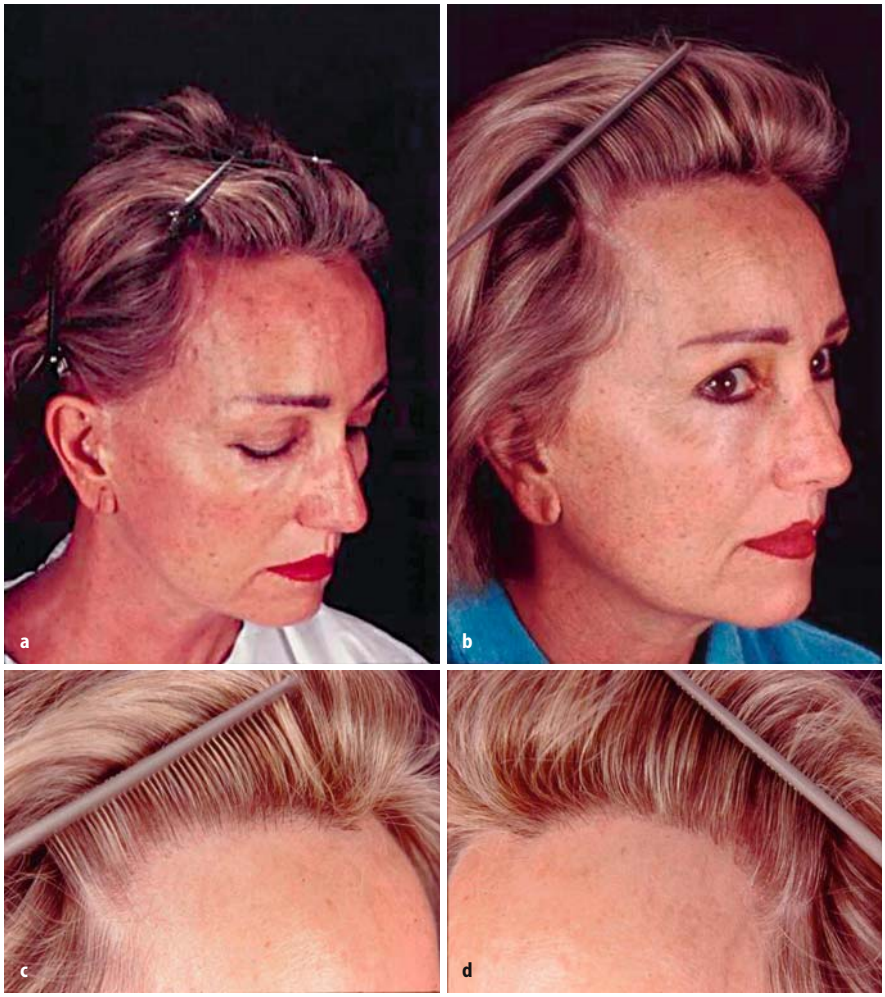

Fig. 31.29a–d. Female patient with a secondary forehead lift and absence of sideburn. Close-up view shows the new temporal and frontal hairline

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32 The Cantilever Rib Graft in Nasal Reconstruction

G.F. Shubailat

32.1 Historical Review

Rib grafting for reconstruction of the nose has been reported by many workers [1–5]. The cantilever rib osseocartilagenous graft that was rigidly fixed with a microscrew was first reported by David and Moore [6] in 25 cases, 19 of which were children with congenital craniofacial deformities. Daniel [7] presented his technique for monobloc osseocartilagenous autogenous rib graft rigidly fixed with double ultramicro screws at the radix on a cancellous platform. Shubailat [8] reported the technique used in 48 cases, 45 of which were secondary to 1–9 previous operations.

32.2 Technique

The transcolumellar open approach is always used. Careful conservative dissection of the skin off the usual dense fibrosis allows exposure of the damage. Fibrosis and previously placed cartilage, bone or alloplastic materials is cleared to uncover the exact nature of the pathology. If a small septal perforation is present, an attempt to repair it in three layers is performed. Larger perforations are left alone. Through a 5-cm incision over the 10th or 11th rib, an osseocartilagenous rib graft is harvested and fashioned with a bone-to-cartilage ratio of 70:30% (Fig. 32.1). A platform is prepared in the radix with a glabellar rasp (Fig. 32.2). With a 1.5 drill bit, a hole is drilled 8–10 mm from the proximal edge of the bony graft. With a countersink instrument a trough is made to house the screw head (Fig. 32.3). The graft is fitted into position and through a 2-mm stab incision, the drill is guided through the hole and deeper into the nasal bone platform. A 2-mm tab is next introduced, followed by a microscrew 2 mm in diameter and 14–16 mm long to attain rigid fixation (Figs. 32.4, 32.5). The domes of the lower lateral cartilages, if present, are fixed with Vicryl to the cartilaginous part of the graft. Alar, tip and columellar strut grafts may be added as the circumstances dictate. Remnants of the upper lateral cartilages are fixed to the side of the graft to reconstruct the inner valve. Any depressions on either side of the rib are filled with crushed or diced cartilages wrapped in Surgicel (Fig. 32.6), described by Erol as the Turkish delight graft [9].

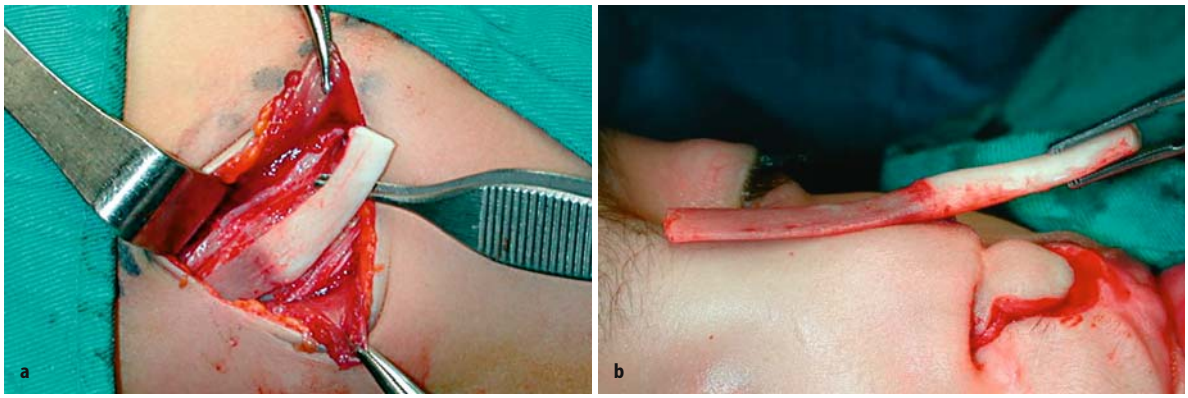

Fig. 32.1. Osseocartilagenous rib graft

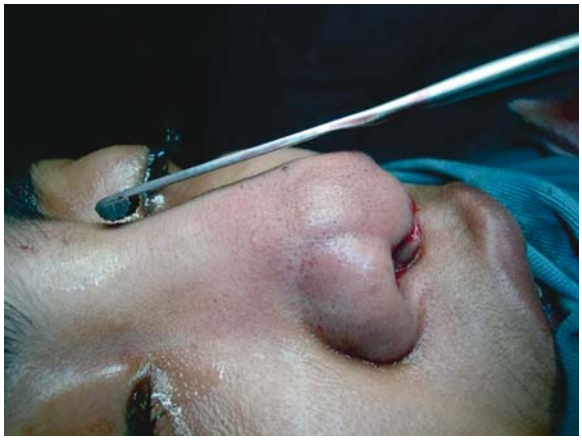

Fig. 32.2. Creating a bony platform

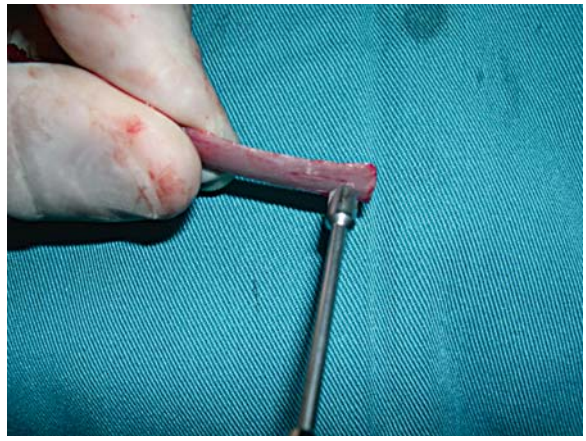

Fig. 32.3. Drill hole and countersink

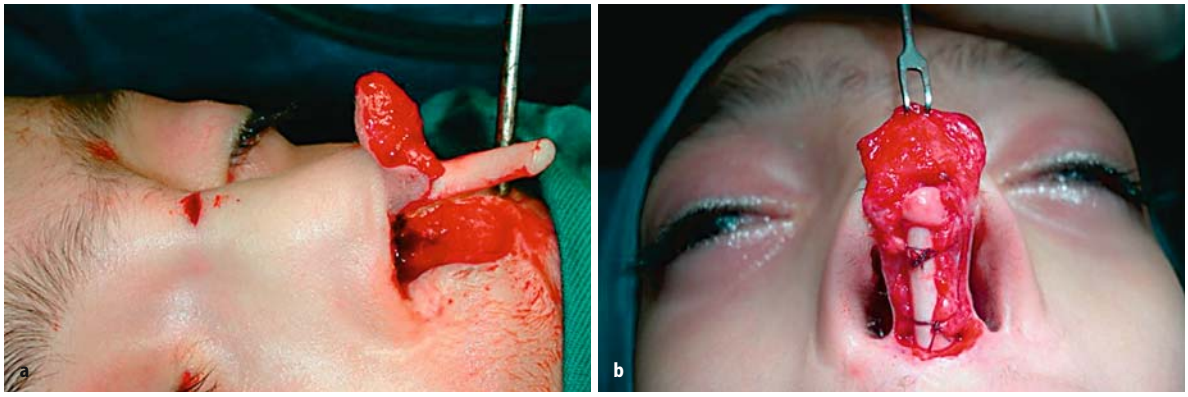

Fig. 32.4. Cantilever and columellar strut grafts

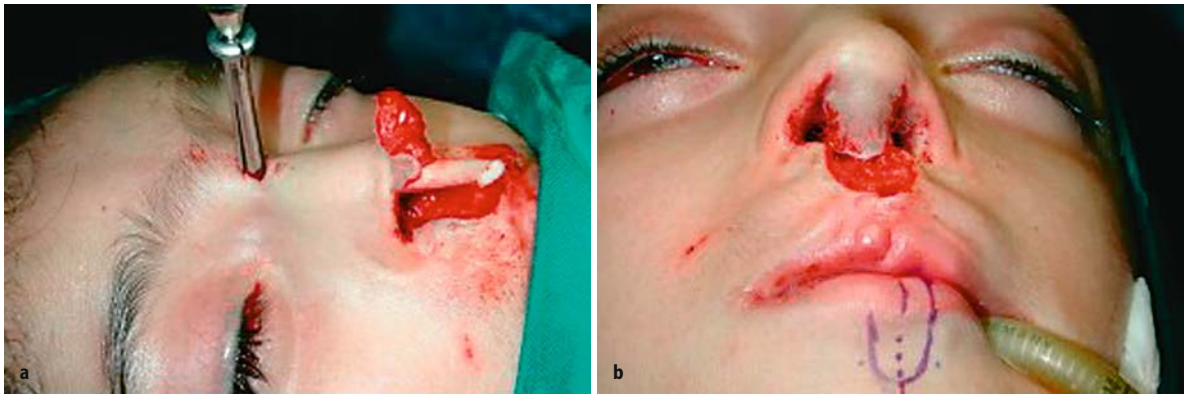

Fig. 32.5. Microscrew fixation and columellar reconstruction

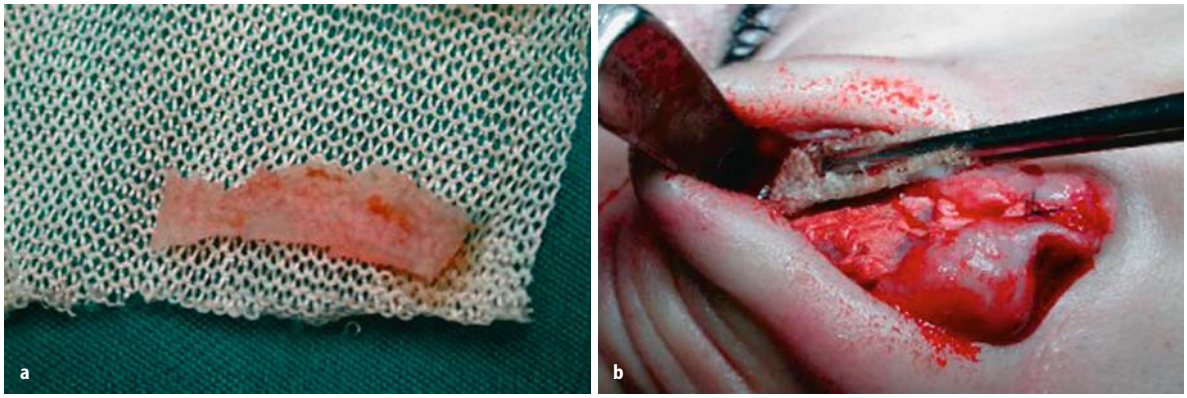

Fig. 32.6. Crushed graft filler

32.3 Materials and Results

In the period 1992–2006, 58 salvage rhinoplasty patients using this technique were operated on, of whom 71% were females and 29% were males. Age ranged from 8 to 55 years. Fifty-three patients had had one to nine previous rhinoseptoplasty procedures. One patient was a child who had complete cleft palate repair and no septum was present. Cantilever rib was used, and columellar skin was reconstructed by sliding up an upper lip flap. The defect in the upper lip was reconstructed with an Abbe flap (Fig. 32.7). In four patients, severe trauma rendered the nasal skeleton irreparable with local material and necessitated a rib graft. There was no warping and bony union was solid within 1 year in all cases. Due to expected limited bony resorption in ten cases, the head of the microscrew showed under the skin and was only removed after bony union was confirmed clinically and radiologically. In three cases infection of a dorsal hematoma was encountered. Drainage and daily washouts with hydrogen peroxide and Betadine with the appropriate antibiotic therapy controlled all the cases without having to remove the screw. None had any perforations of the pleura or peritoneum and the resultant scar was most acceptable.

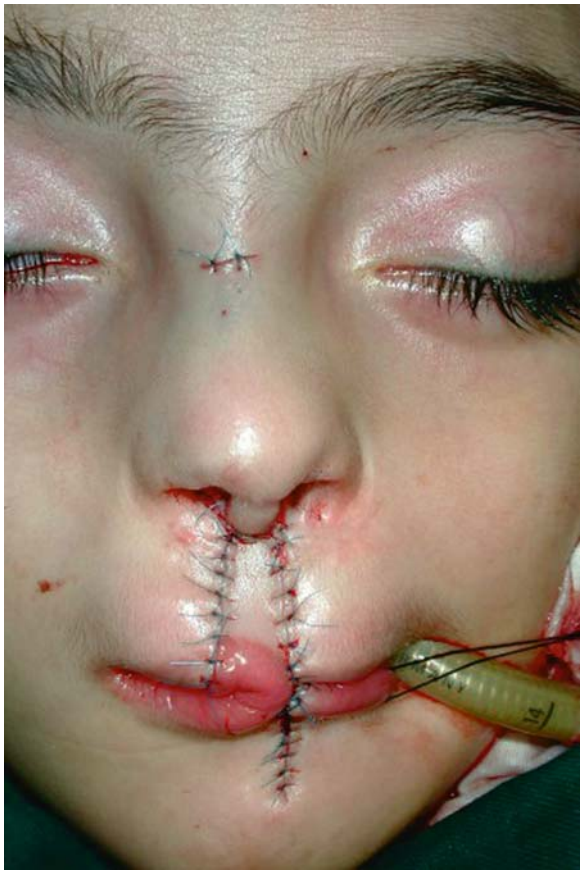

Fig. 32.7. Abbe flap

32.4 Discussion

The aims of nasal surgery are to obtain rigid dorsal support, maintain tip projection and restore function. In the last 14 years, 1,290 rhinoplasty procedures were performed, 30% of which were secondary to 1 to 9 previous nasal operations. In 58 cases (4.5%) that were classified as salvage cases, autogenous septal and conchal material was insufficient to attain the goals. Osseocartilagenous rib grafts taken from the 10th or 11th rib and fixed rigidly with a microscrew was our method of choice. It carried a very low complication rate with long term satisfactory and consistent aesthetic and functional results (Figs. 32.8–32.12).

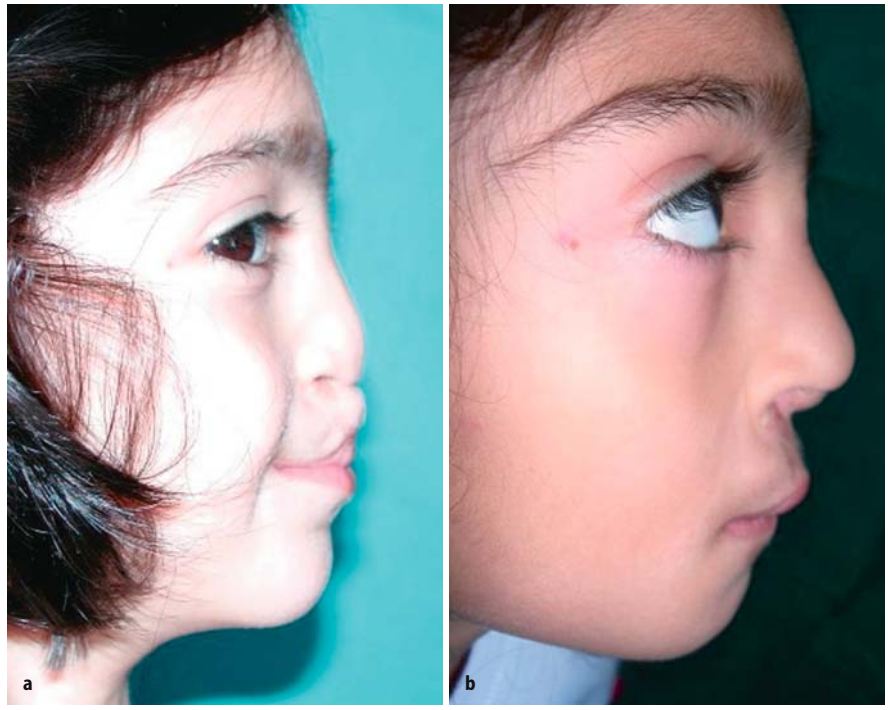

Fig. 32.8. Cleft palate deformity. Pre- and 3 years postoperatively

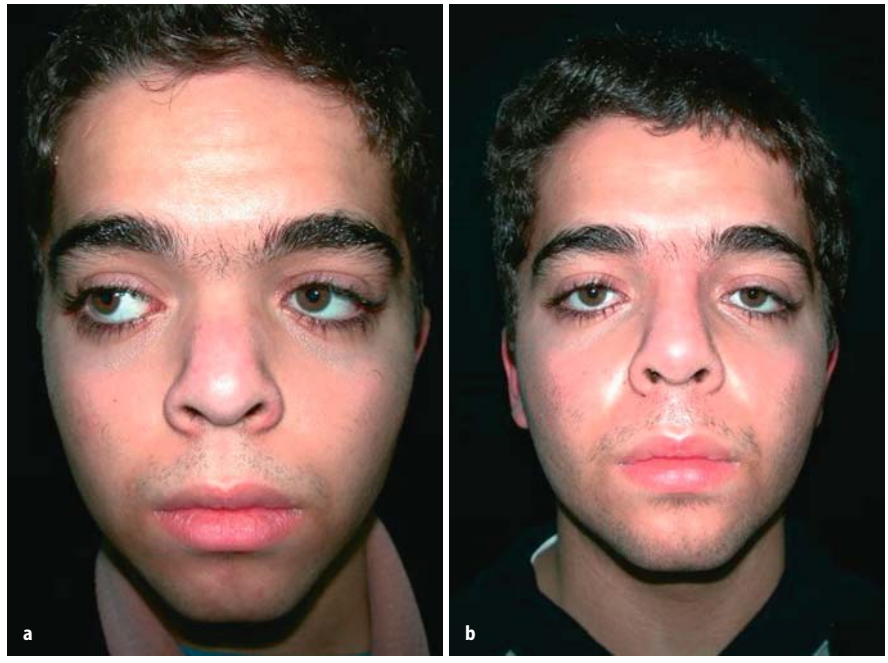

Fig. 32.9. Achondroplastic, pre- and 2 years postoperatively

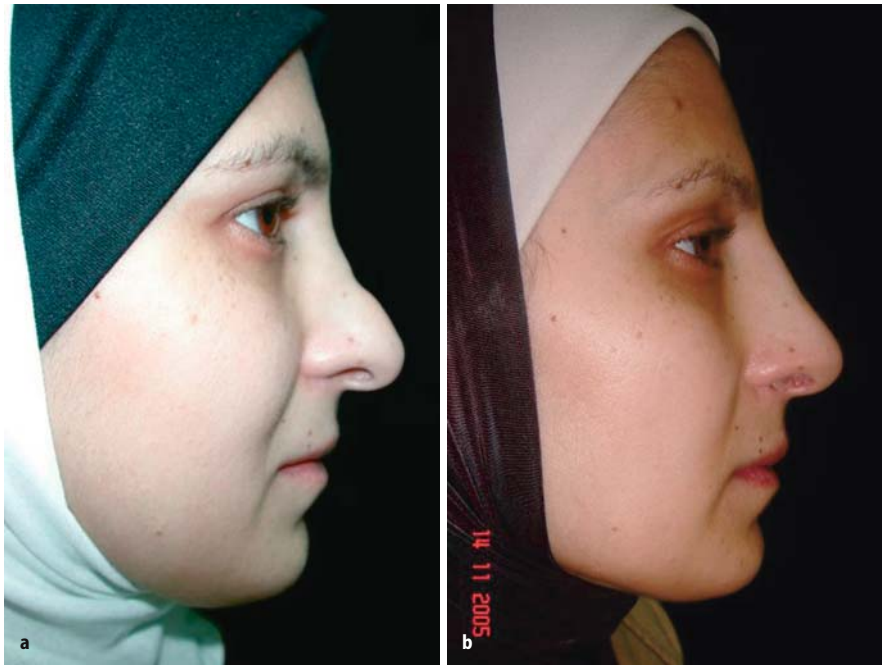

Fig. 32.10. Tertiary rib graft, pre- and 4 years postoperatively, lateral

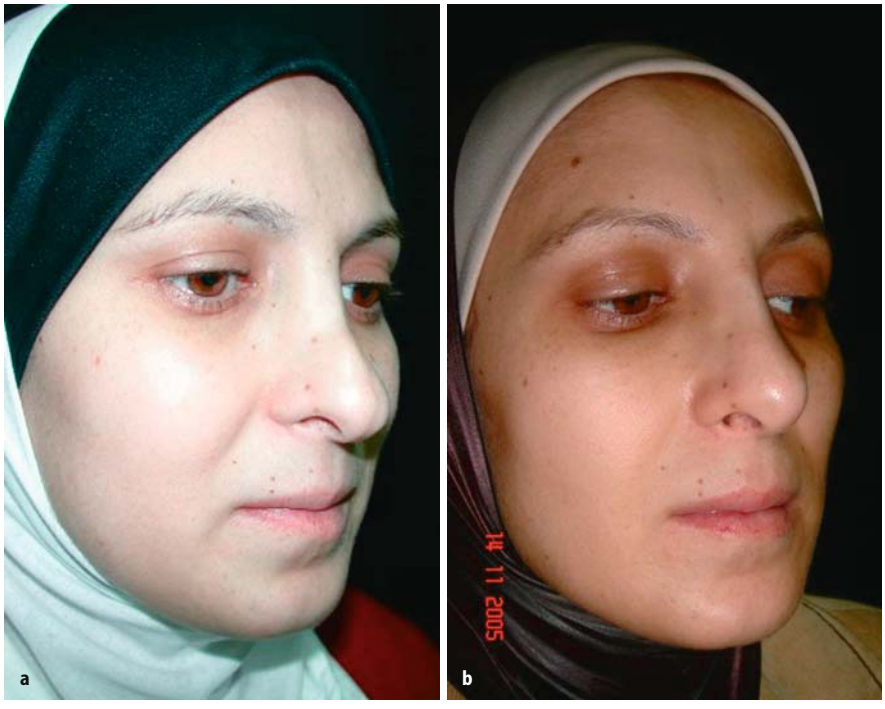

Fig. 32.11. Tertiary rib graft, pre- and 4 years postoperatively, oblique

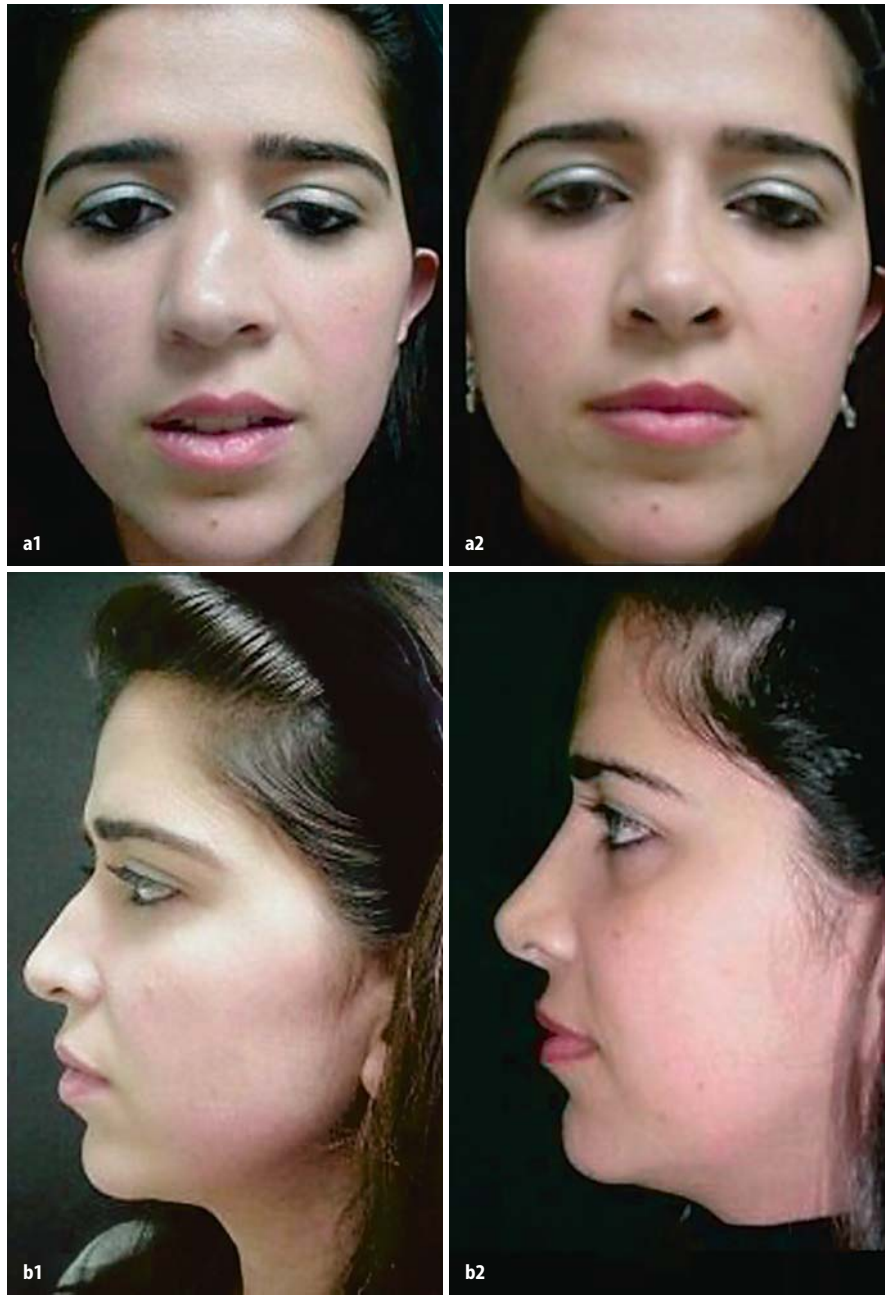

Fig. 32.12. a Post-traumatic primary rib graft, pre- and 6 years postoperatively, Frontal view. **b** Post-traumatic primary rib graft, pre- and 6 years postoperatively, lateral view

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33 Nasal Tip Surgery in Primary Rhinoplasty: My Two Different Approaches with the Closed Technique

E. Muti

The approach to a rhinoplasty should start from a precise preoperative diagnosis through a clinical examination, a preoperative photographic study of the proposed corrections, which are discussed with the patient, to surgical planning to achieve the desired result. Before starting the operation the surgeon should clearly have in mind three main points:

- The exact anatomical feature from which to start (what's in his hands)
- The desired point of arrival (what he wants to obtain)
- What are the means of obtaining the desired result

To obtain the preoperative diagnosis it is necessary to imagine the shape of the anatomical structures through careful inspection and palpation; this is easier in thin skin noses than with thick skin, in post-traumatic noses, in secondary rhinoplasties and in cases of malformation.

With the exact starting point clearly in mind, the surgeon must evaluate by means of a photographic study which structures should be corrected: the dorsum line, the nasofrontal angle, the nasolabial angle, the tip shape and projection and the dome position.

Nevertheless, the means of obtaining the desired results often becomes clear only during surgery thanks to direct inspection of the nasal structures.

The chosen photographic correction is drawn on the patient at the start of the operation, and checked again at the end of the operation (Figs. 33.1 – 33.4).

The nasofrontal and the nasolabial angles, the dorsum and the tip are all crucial points in rhinoplasty, *but* all nose surgeons agree that the most difficult and unforeseeable step in a rhinoplasty is without any doubt the correction of the nasal tip. The nasal tip shape and projection depend on the shape of the "cartilaginous arch," which is determined by the lateral crus, the medial crus, and the junction between them: the "dome" or "cupola" [3, 4, 8, 10].

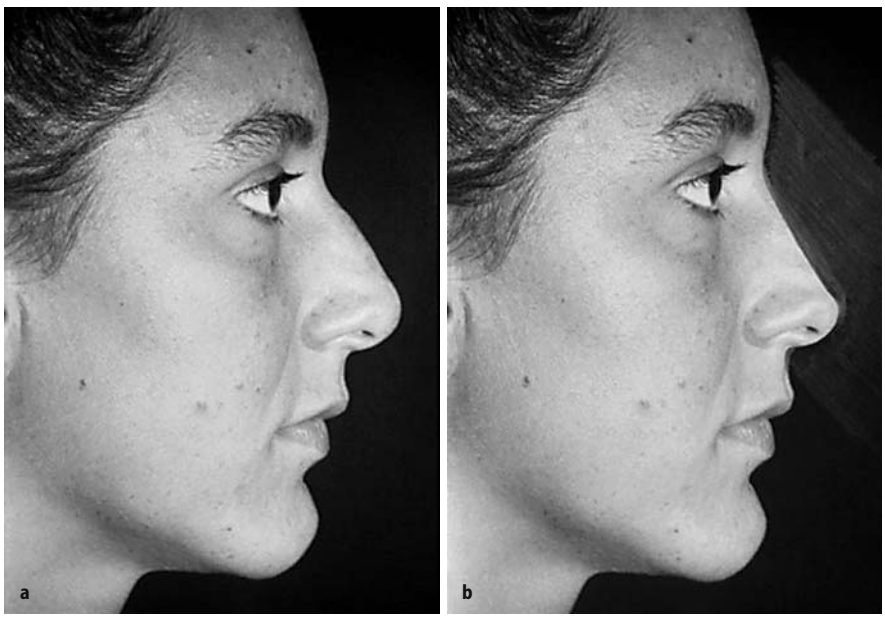


Fig. 33.1. The preoperative photographic profile correction

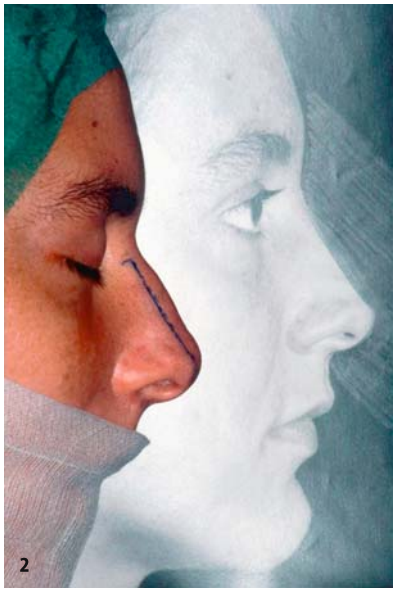
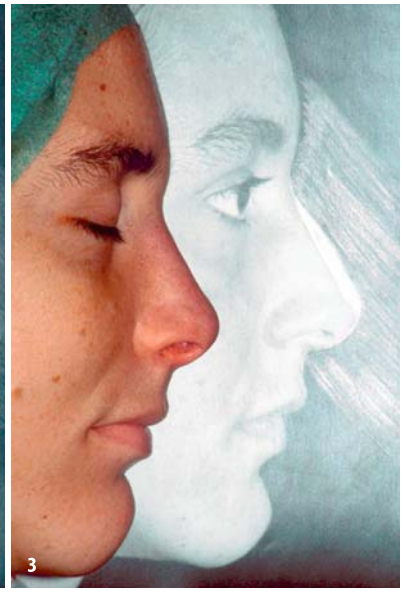
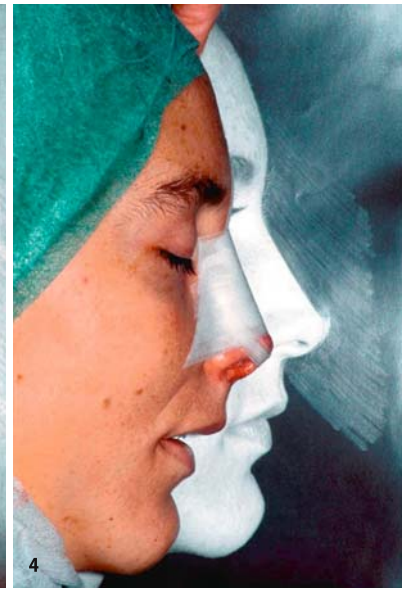


Fig. 33.2. The photographic correction is drawn on the patient's nose at the start of the operation





Figs. 33.3, 33.4. At the end of the operation, the result is checked for correspondence with the programmed one

According to the treatment of this arch, I distinguish two different types of rhinoplasty:

Type 1 rhinoplasty: without dome interruption (such as Joseph's technique and its derivatives) [1–3, 6–10]
Type 2 rhinoplasty: with dome interruption (such as Goldmann's techniques and their derivatives) [4, 5, 11, 12]

33.1 Type 1 Rhinoplasty

This is applicable and always chosen if the "cartilage arch" is considered "congruous" at the preoperative planning stage. That means when there is a correct balance between the length and position of the alar crus, a good position and sweep of the domes according to the desired correction, a cranial strip resection of the alar crura, more or less reaching the dome, is enough to obtain the desired result (Figs. 33.5, 33.6). In such cases we chose this more conservative technique, without interruption of the cartilage arch at the level of the dome, because it is an easier and faster procedure, allows the normal tip structure to be maintained and preserved, and has a very low risk of tip asymmetry [10]. The cartilage resection is performed through an intracartilaginous incision, and a subperichondral undermining of the cartilage to be resected, leaving the remaining cartilage intact and adherent to both (external and internal) surfaces, with a stable position. This technique was performed in Case 1 (Figs. 33.7–33.12).

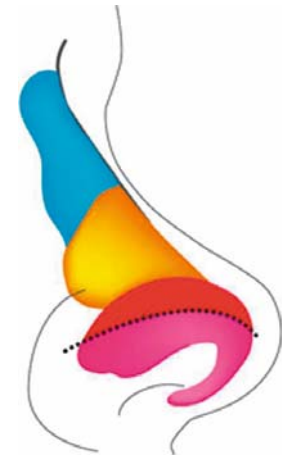


Fig. 33.5. In *red* the cranial strip of the alar cartilage to be resected

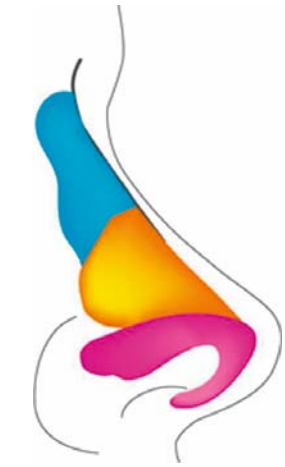


Fig. 33.6. The remaining alar cartilage, without interruption of the arch, left attached to the skin and the internal surface

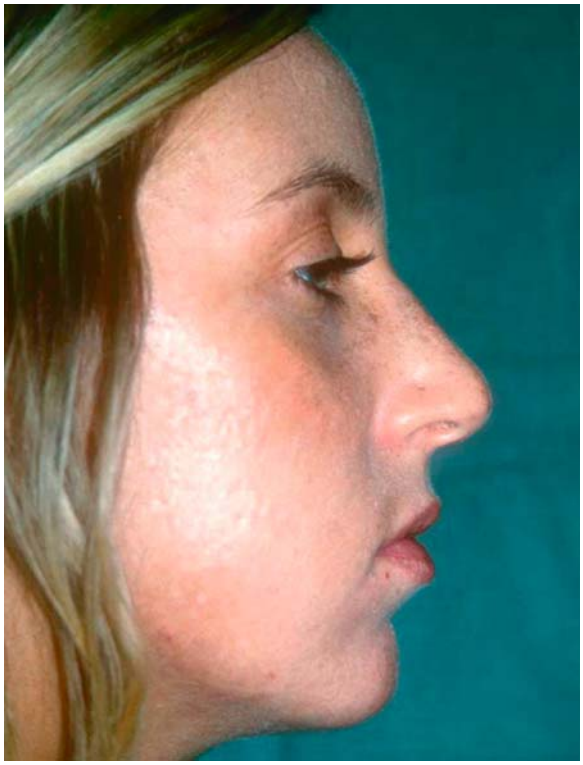


Fig. 33.7. Preoperatively: a small nose with slight cranial expansion of the lateral crus

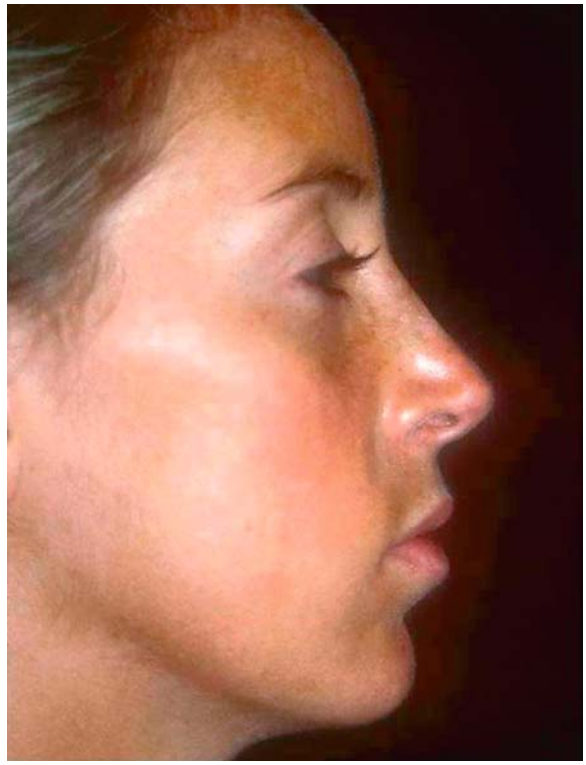


Fig. 33.8. Postoperatively: the result obtained with the described conservative technique. Five years after surgery

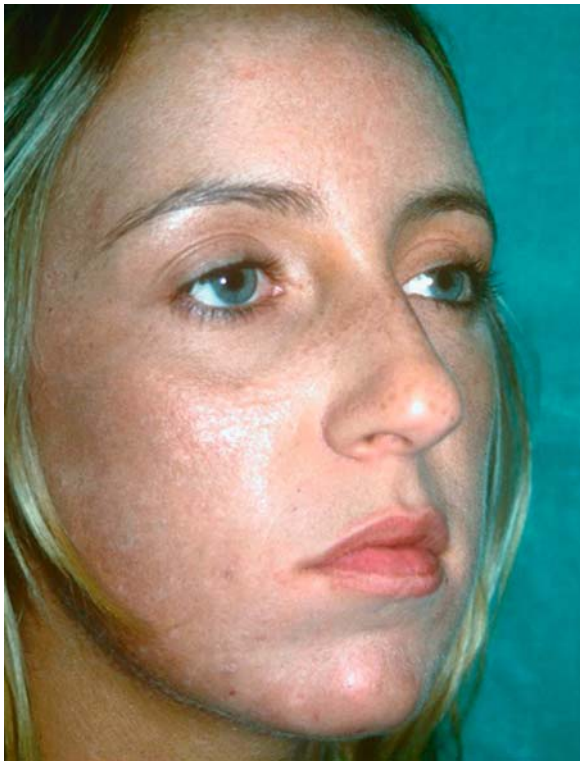


Fig. 33.9. Preoperative appearance

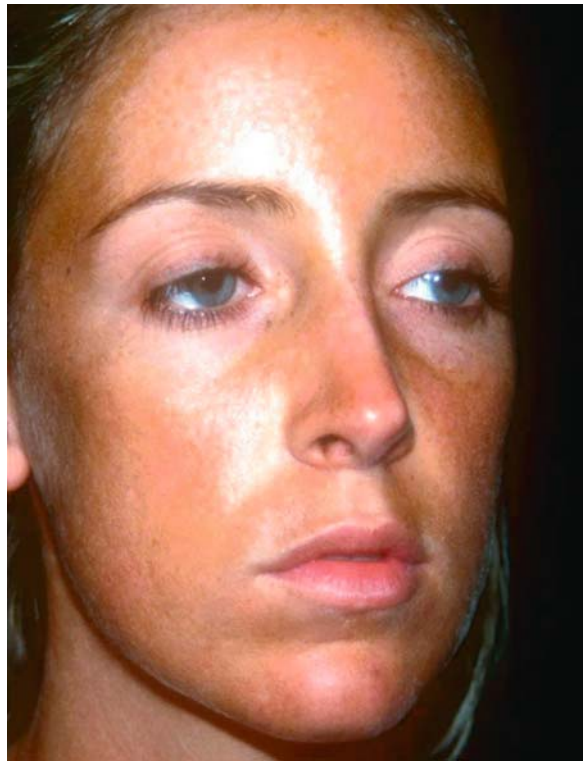


Fig. 33.10. Postoperatively. The tip acquired a good definition and projection

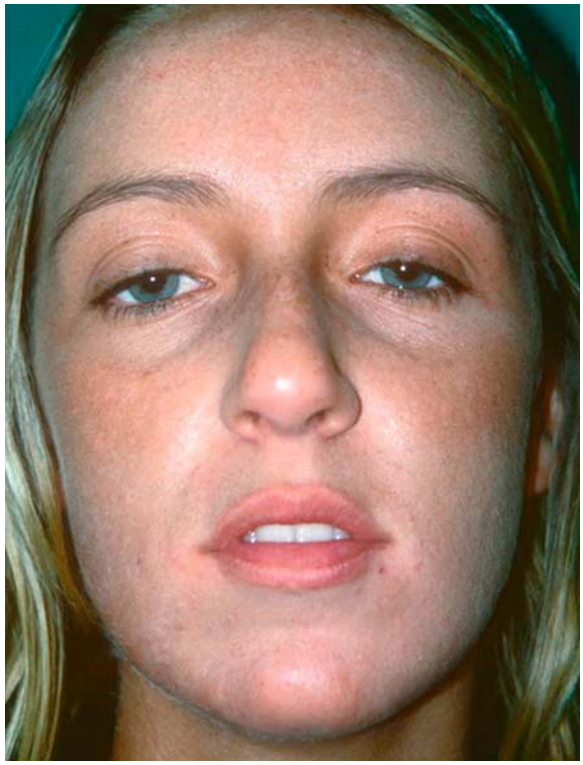


Fig. 33.11. Preoperative appearance

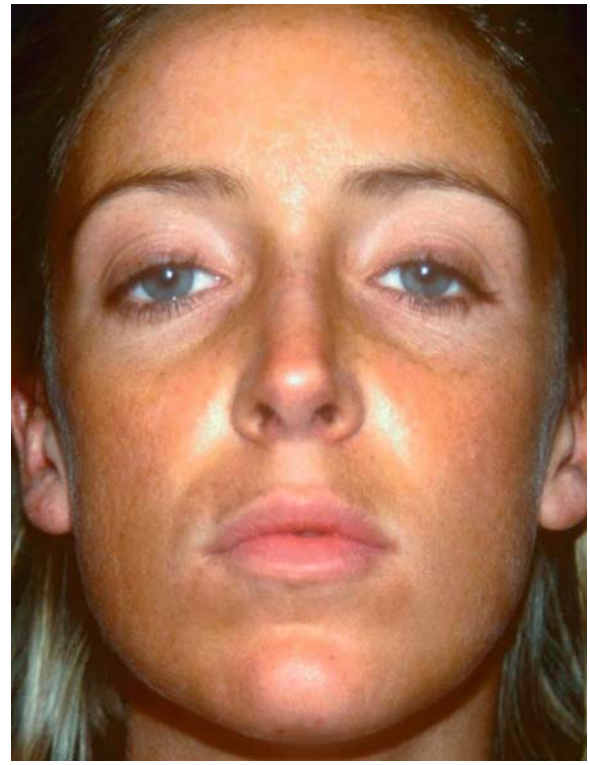


Fig. 33.12. Postoperative appearance

33.2 Type 2 Rhinoplasty

Nevertheless, in several cases, in my opinion and in my hands, dome interruption becomes necessary in order to achieve the desired correction [10] of the tip of the nose, that means, when the cartilage arch is incongruous with it; for example, when there is a lateral crus length in excess, as in "tension tip," in which a more or less large triangle of lateral crus, laterally to the dome, must be resected, sometimes leaving intact the most marginal part of the lateral crura (Fig. 33.13); the same could be done in "hooked noses," as in the case of Figs. 33.14 – 33.19. When

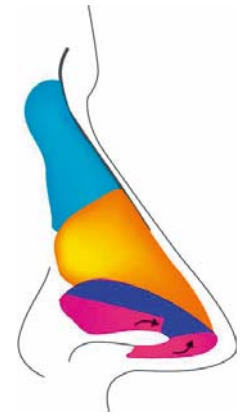


Fig. 33.13. In *blue* the resected alar cartilage: a cranial strip and a caudal triangle of the lateral crus; this triangle will be more or less wide depending on the length of the lateral crus in relation to the desired retroposition of the nasal tip

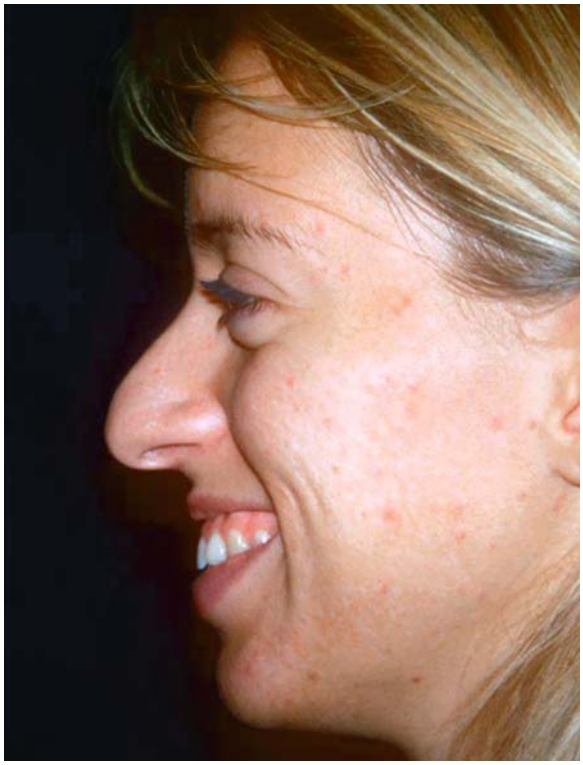


Fig. 33.14. A tensioned nose, with long lateral crura given a push forward and downward to the nose tip

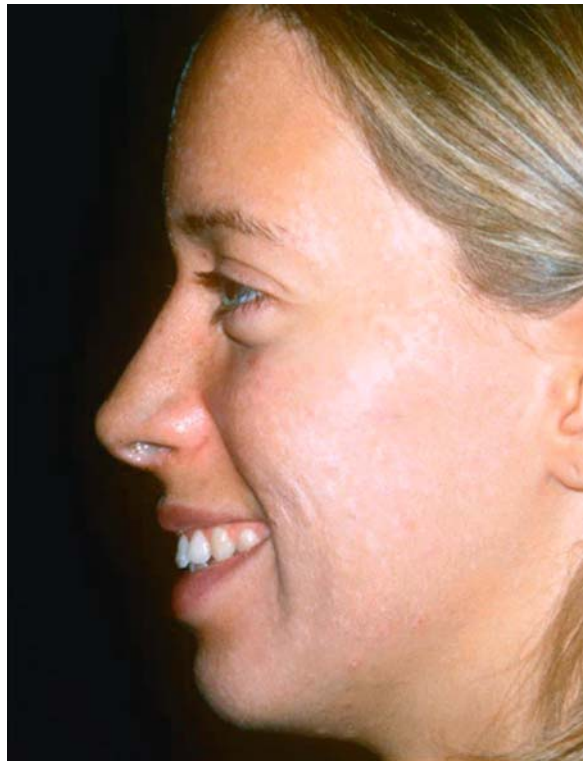


Fig. 33.15. Postoperatively. A nice dorsal line with a good tip projection is achieved. The quadrangular cartilage was properly lowered, the lateral crus reduced in width and length (as shown in Fig. 33.13), interrupting its push and allowing tip rotation

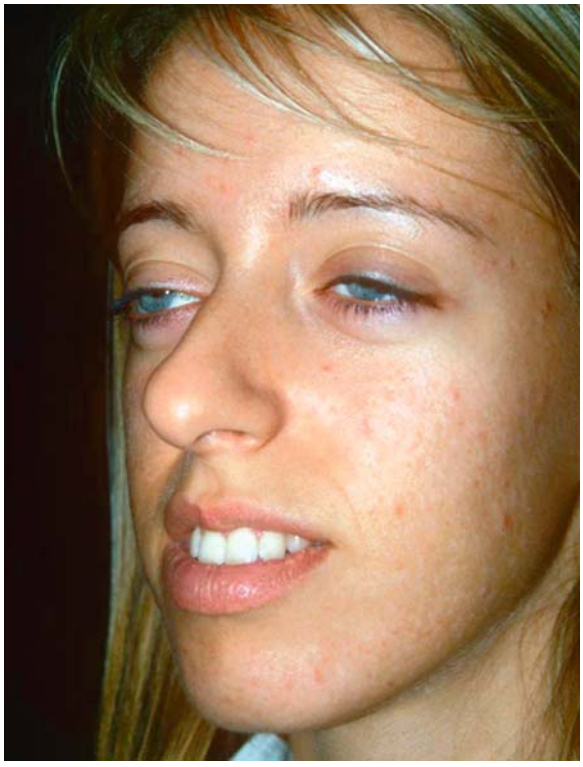


Fig. 33.16. Preoperatively. The excess tip projection is evident

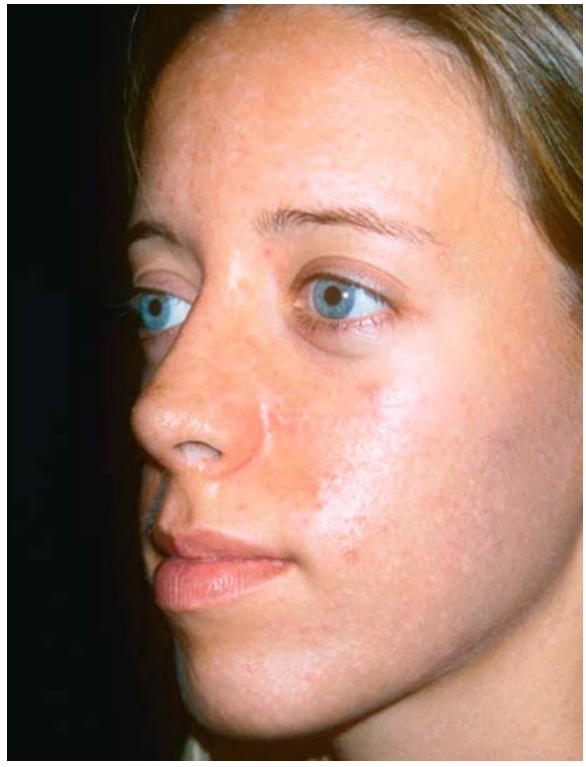


Fig. 33.17. Postoperative appearance

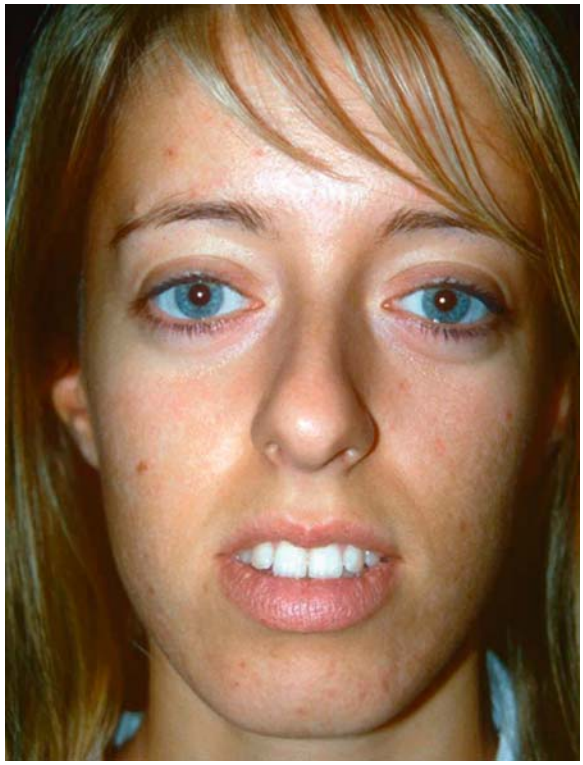


Fig. 33.18. Preoperative appearance

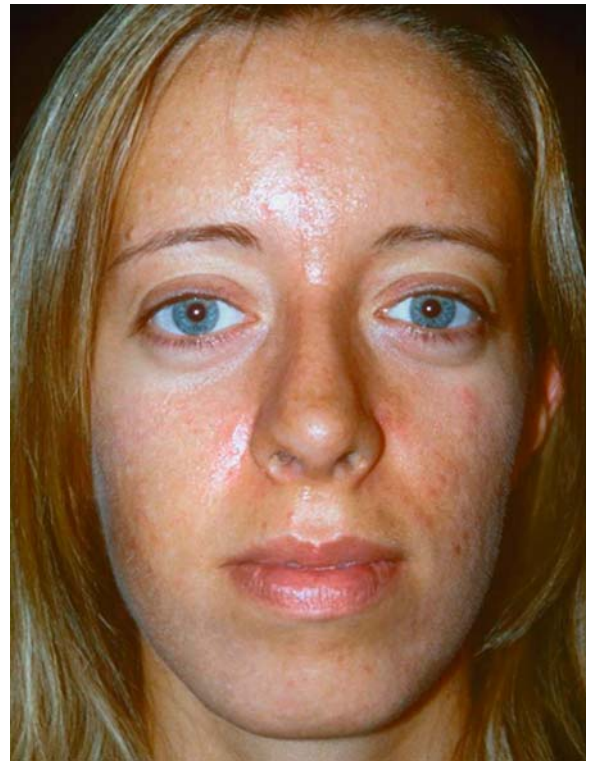


Fig. 33.19. Postoperative appearance

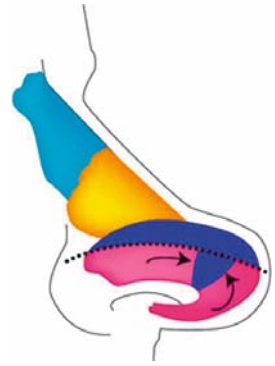


Fig. 33.20. The alar cartilage in a bulbous nose. The amount of cranial resection is wider

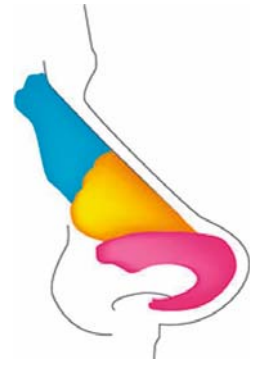


Fig. 33.21. The reduced alar cartilage after resection

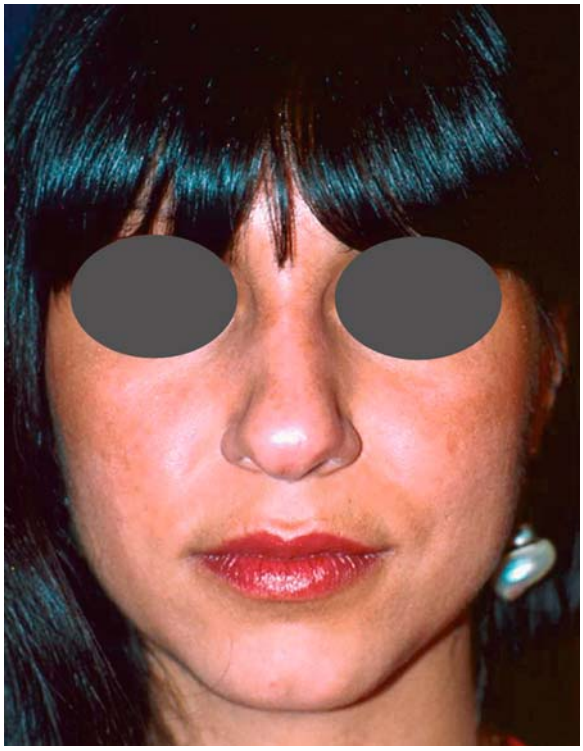


Fig. 33.22. A bulbous and slightly deviated nasal tip

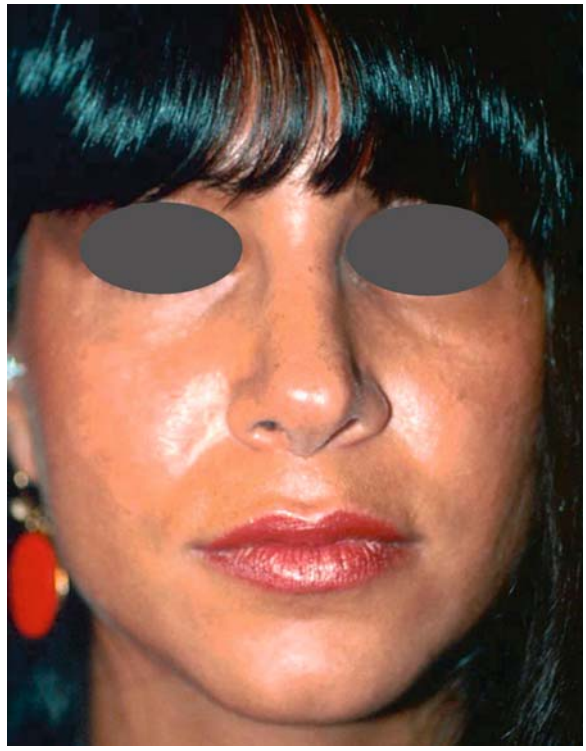


Fig. 33.23. Postoperatively. In a wide face with a bulbous nose it is better to maintain a good tip support and not too narrow a nasal tip point, preserving the dome's curvature and not shortening the lateral crus too much

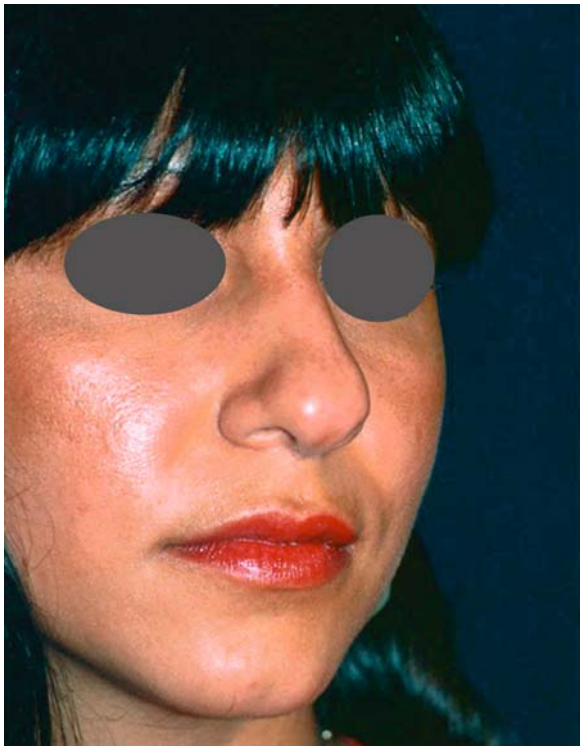


Fig. 33.24. Preoperatively: In such cases the retention of the interdomal soft tissue is often indicated, and sometimes it must be evaluated whether a stitch between the medial crura, caudally to the dome's junction, is necessary to approximate the domes in the medial line

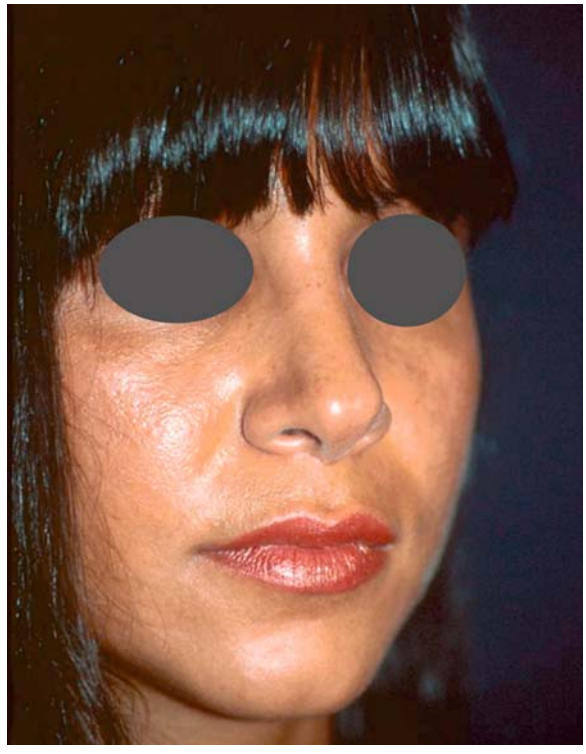


Fig. 33.25. Postoperatively: the two light points are evident and symmetrical

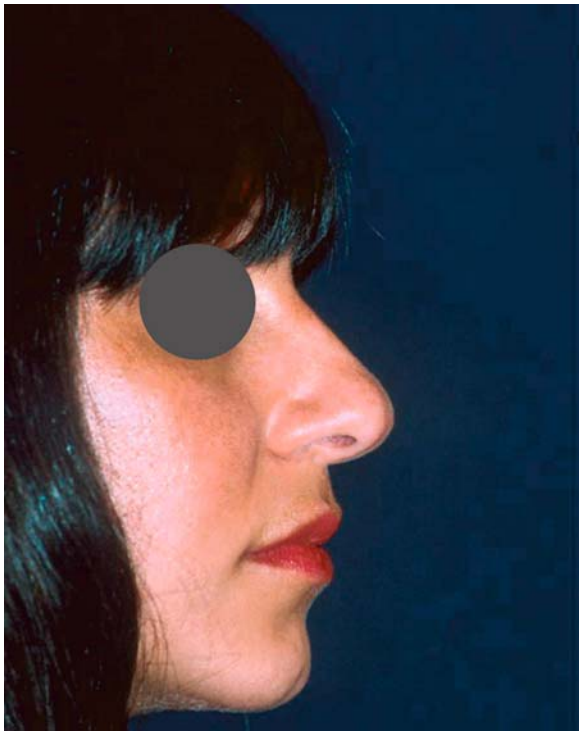


Fig. 33.26. Preoperative appearance

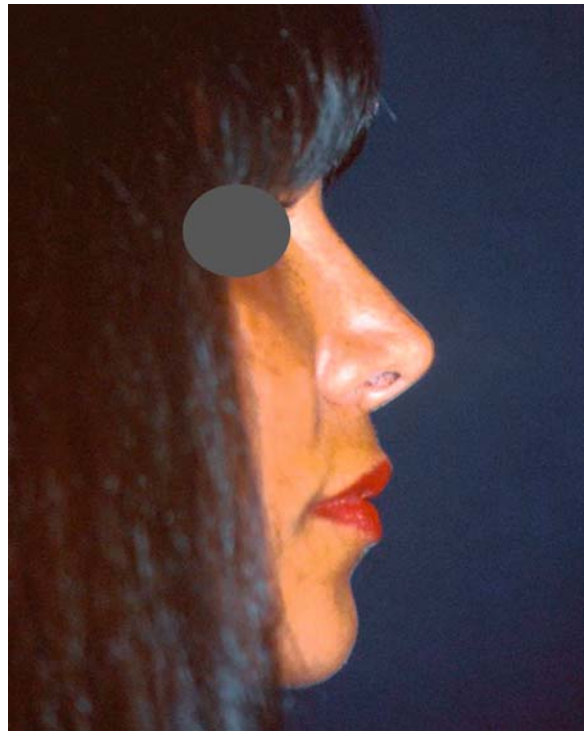
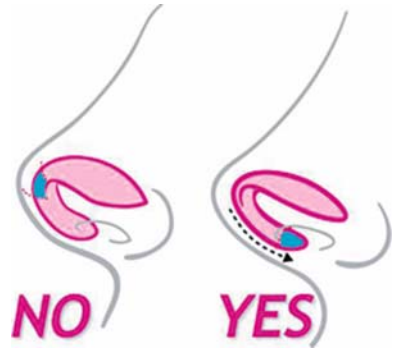
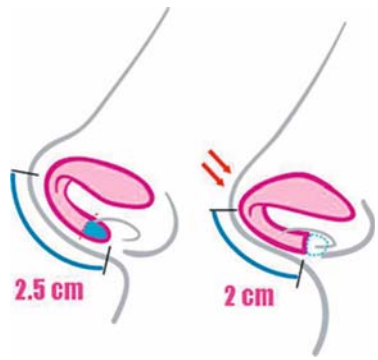


Fig. 33.27. Postoperatively. In my opinion the reduction of the lateral crus avoids the overlapping of them over the quadrangular cartilage and therefore the frequent complication of pseudo-supratip swelling in cases like this





Figs. 33.28, 33.29. In a case in which we considered the medial crura too long, it was preferable to resect a piece of cartilage at the level of the feet of the medial crura as shown in this figure

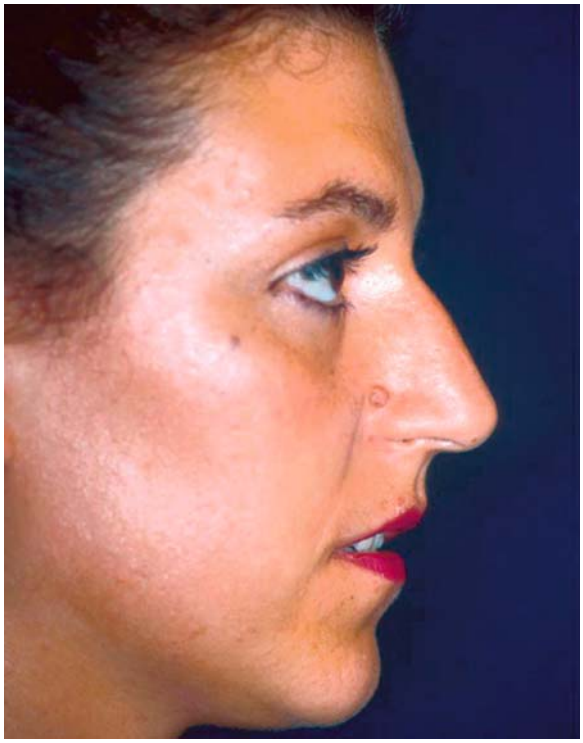


Fig. 33.30. Preoperatively: projected tip, with both crura too long in relation to the programmed correction, in which the previous maneuvers have been performed: reduction of the lateral crura and medial crura length as described previously

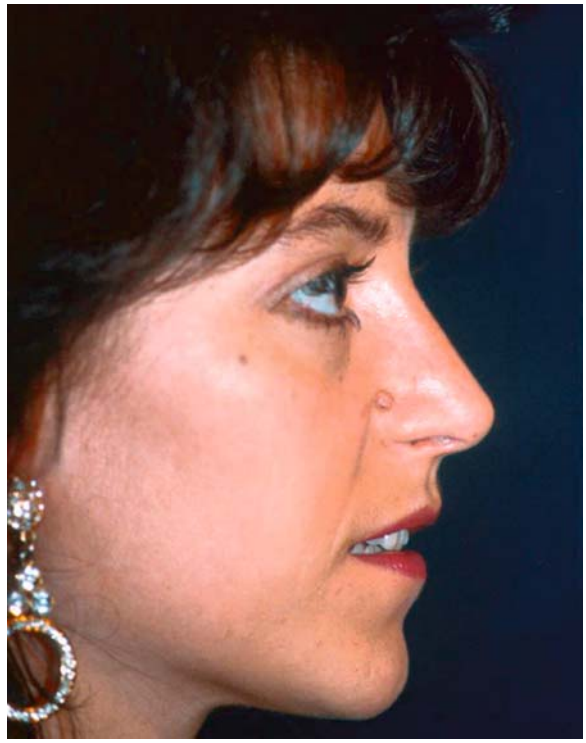


Fig. 33.31. Postoperatively. The cartilage arch is reduced completely, maintaining a natural appearance

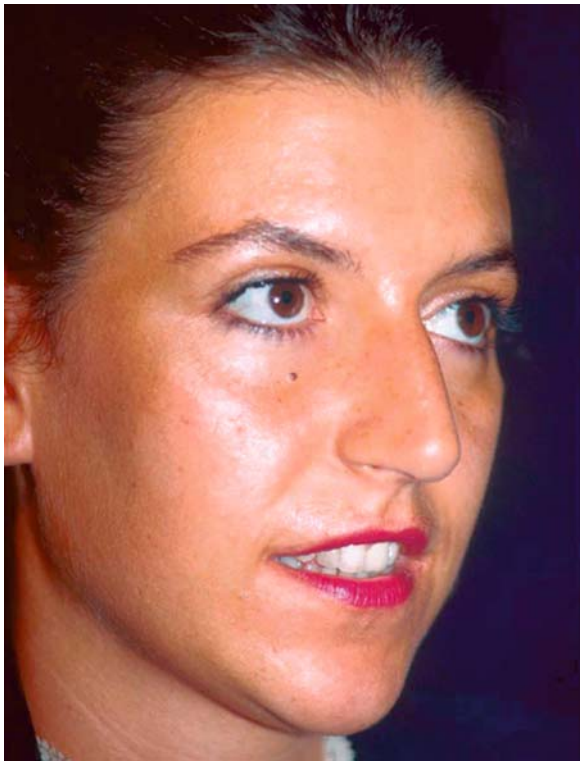


Fig. 33.32. Preoperative appearance

Fig. 33.33. Postoperative appearance

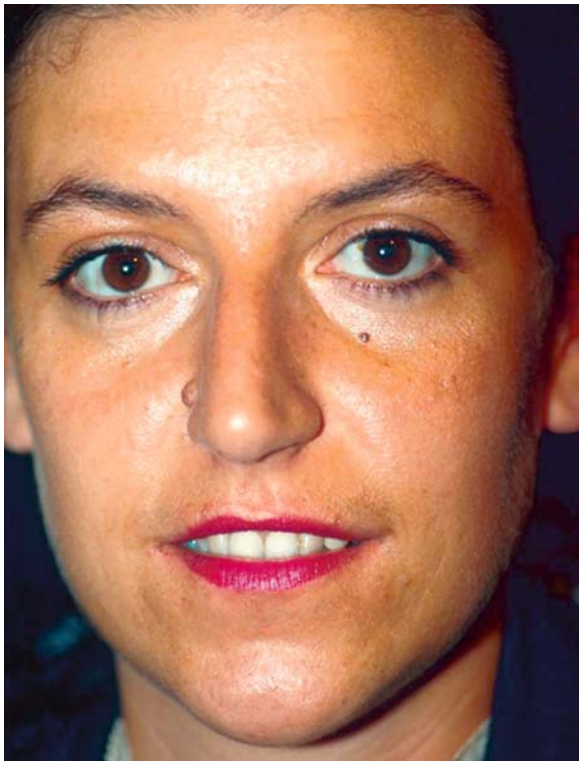


Fig. 33.34. Preoperative appearance

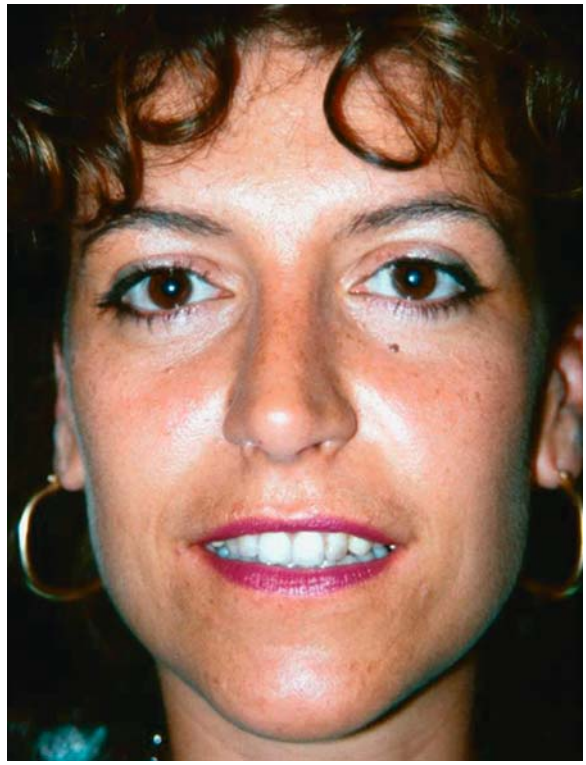


Fig. 33.35. Postoperative appearance

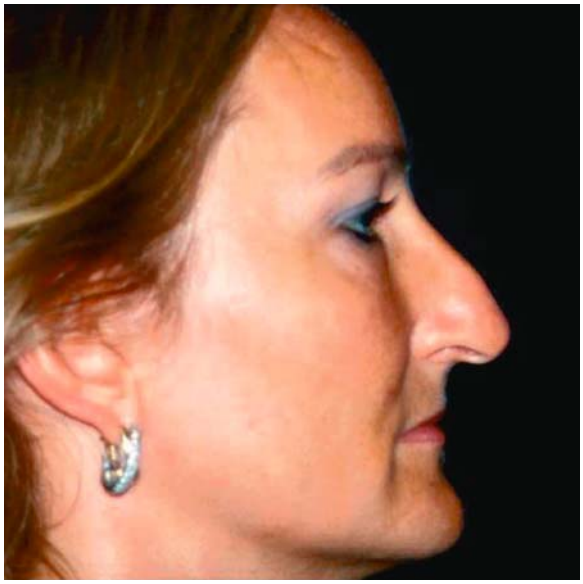
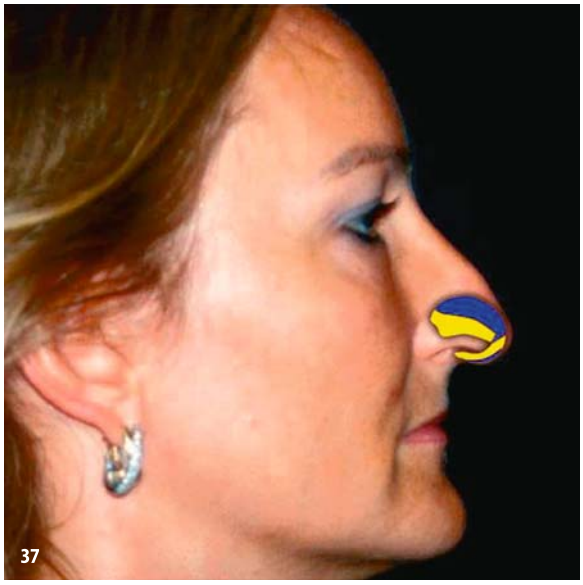
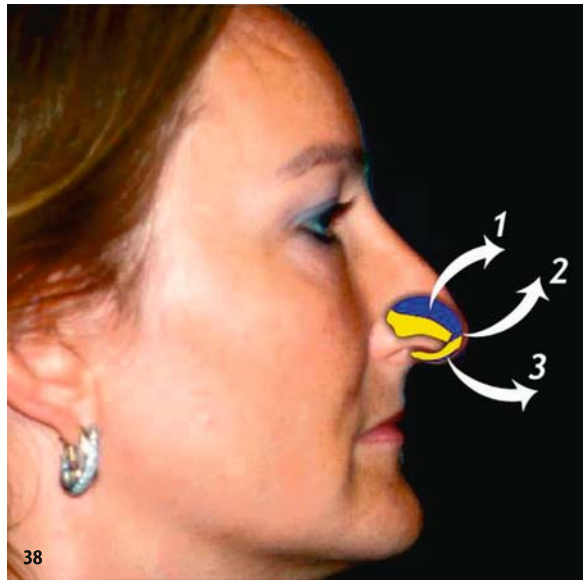


Fig. 33.36. Preoperative appearance: the same, and some other corrections, will be done in this case





Figs. 33.37, 33.38. Postoperative appearance: cranial strip resection of alar cartilage, triangular resection of alar crus length, marginal resection of medial crus, to modify the columellar drooping shape

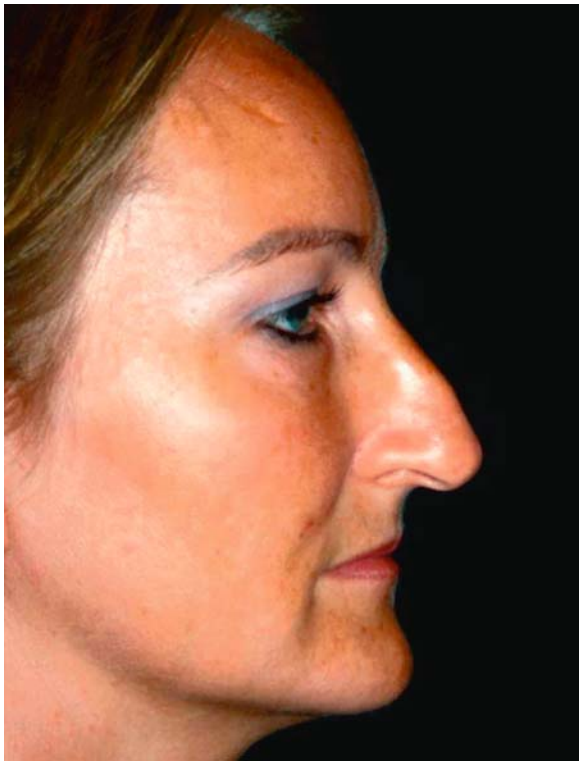


Fig. 33.39. Preoperative appearance

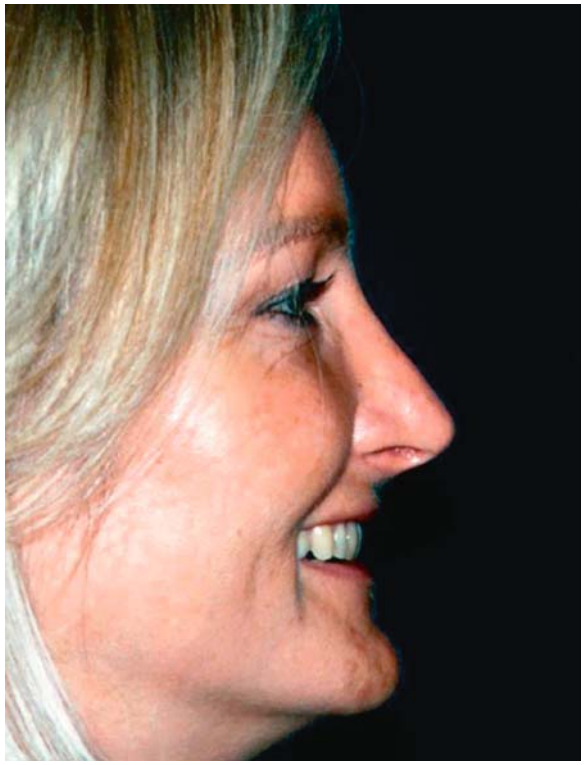


Fig. 33.40. Postoperative appearance. Correction of the nasolabial angle: suturing together the feet of the medial crura, and lengthening the nasal tip depressor muscle

Fig. 33.41. Preoperative appearance

Fig. 33.42. Postoperative appearance

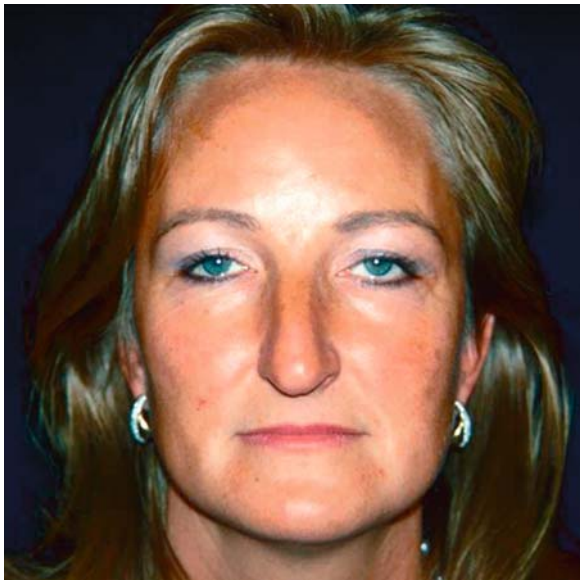


Fig. 33.43. Preoperative appearance

Fig. 33.44. Postoperative appearance

Fig. 33.45. Preoperative appearance: again a case with both crura long in relation to the programmed correction (from [10])

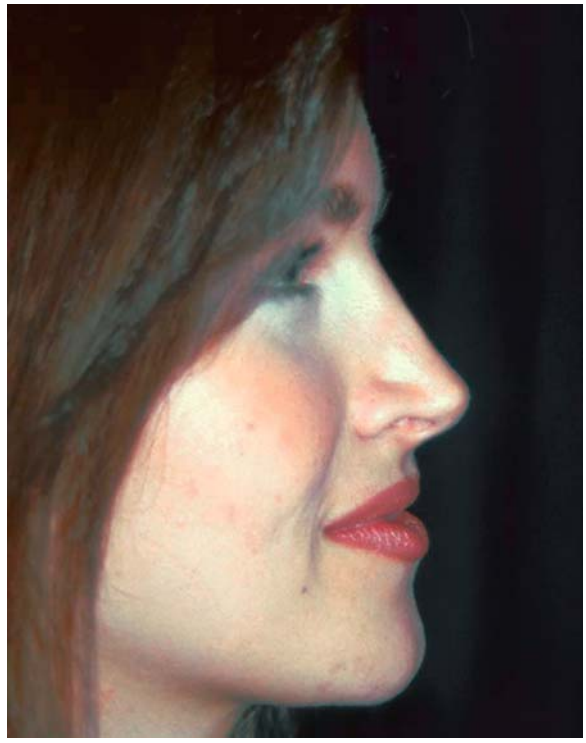


Fig. 33.46. Postoperative appearance: All the maneuvers previously described to reduce the lateral and medial crura's length have been applied (from [10])

Fig. 33.47. Preoperative appearance (from [10])

Fig. 33.48. Postoperative appearance. The principal objective of a rhinoplasty is to increase the beauty of the face without distorting the personal expression (from [10])

Fig. 33.49. Preoperative appearance (from [10])

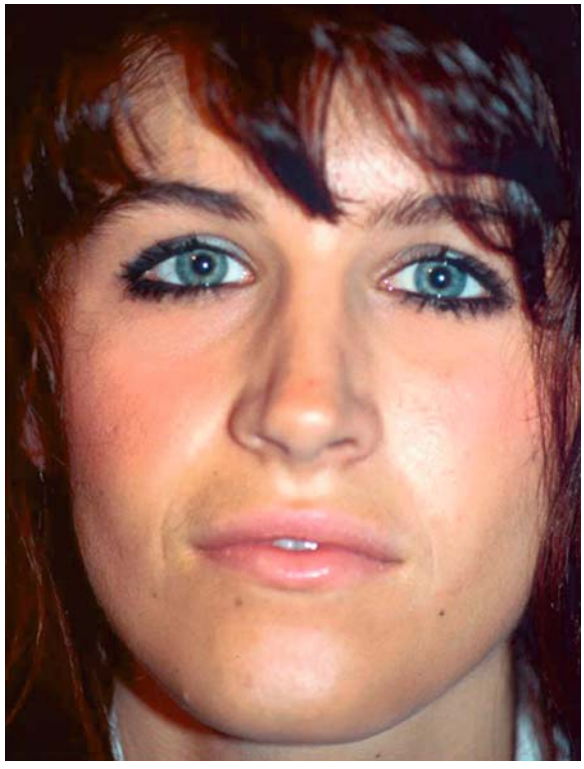


Fig. 33.50. Postoperative appearance (from [10])

the dome is too large, as in "bulbous nose," a larger triangle of lateral crus is resected (Figs. 33.20, 33.21), as in the example in Figs. 33.22 – 33.27; when both the medial and lateral crura are too long, as in "projected tip," we prefer to reduce the length of the medial crus, shortening it at the level of its feet (Figs. 33.28, 33.29); as has been done in the example in Figs. 33.30 – 33.35. The same is done in "too big noses" and again when there is dome diastasis or asymmetrical domes or when major correction is needed (Figs. 33.36 – 33.44) (Figs. 33.45 – 33.50).

The interruption of the dome with a reduction in length of the lateral crus exposes the patient to the risk of developing asymmetry and dislocation of cartilaginous fragments even if we try to fix them with sutures in order to restore the continuity of the cartilaginous arch. In order to avoid such problems, it is necessary to place the first medial incision on the dome exactly where we want the tip projection and the "light points." To identify the exact point of incision of the dome, we mark the light point with fine needles through the skin

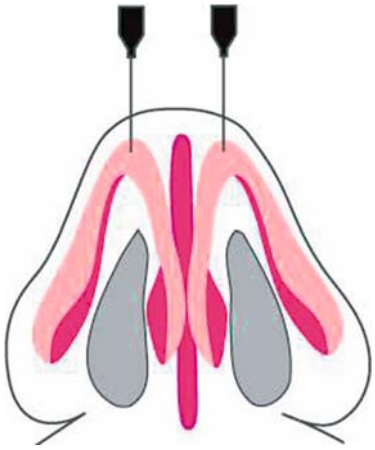
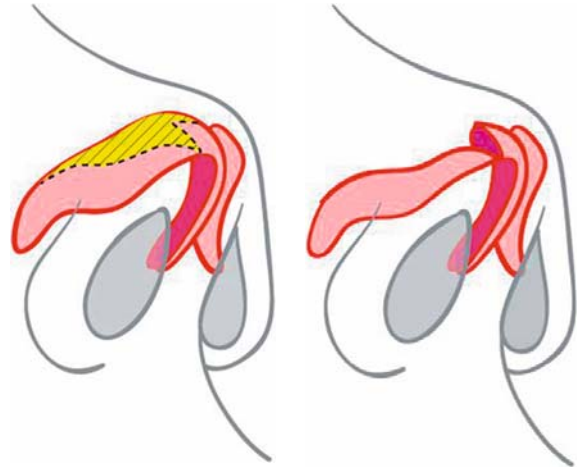


Fig. 33.51. Marking the light point through the skin with fine needles

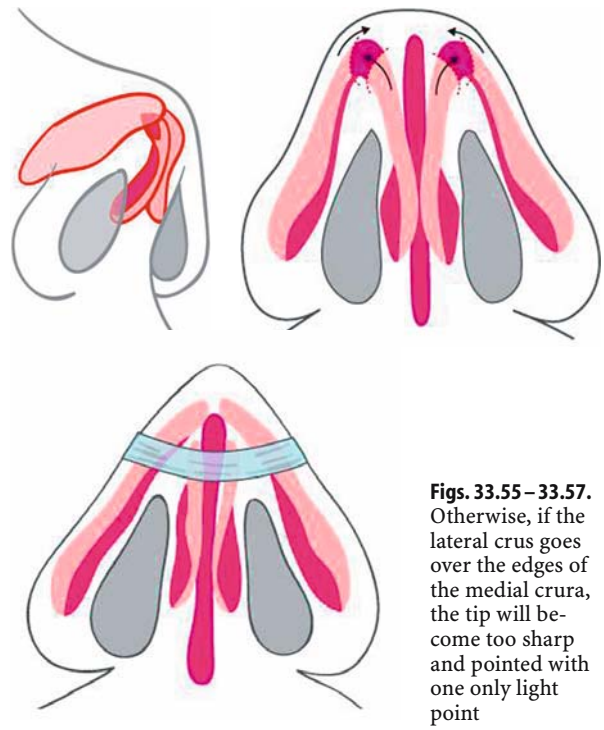
Fig. 33.52. The lateral crus is shortened by excising a triangle of cartilage laterally to the domes

(Figs. 33.51, 33.52), and great care should be taken with the final position of the free edges of the medial and lateral crus: the lateral crus should slide under the medial one (Figs. 33.53, 33.54); otherwise, if the lateral crus covers the free edges of the medial one, the nasal tip becomes too sharp and pointed, with only one light point (Figs. 33.55 – 33.57); and if we have this situation on only one side, we have an asymmetry with the appearance of a deviated nasal tip.

In conclusion, **rhinoplasty type 1**, without dome interruption, is always preferable in primary rhinoplas-



Figs. 33.53, 33.54. The tip's edge of the lateral crus must slide and remain under the dome



Figs. 33.55 – 33.57. Otherwise, if the lateral crus goes over the edges of the medial crura, the tip will become too sharp and pointed with one only light point

ties, and it should be the first choice for the youngest surgeons. Nevertheless, in the various situations described above, the interruption of the dome, in my opinion, becomes necessary, or at least useful to obtain the desired result. In these cases the surgery becomes longer, more difficult, and the surgeon should pay careful attention to detail to avoid complications such as tip distortion, tip asymmetry or lack of tip support. For that reason, **rhinoplasty type 2**, with dome interruption, requires more experience and a knowledge of some tricks and refinements.

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34 Refinements in Nasal Tip Surgery

K.P. Pshenisnov, G.I. Patlazhan

34.1 Introduction

The shaping and final positioning of the nasal tip complex is the most critical and sophisticated stage of rhinoplasty. Increased control and predictability of this part of the procedure is achieved by preserving the anatomical structures of the nose using suturing techniques that are reversible and incremental [2, 8]. Limiting visible onlay tip grafts also fits the concept of nondestructive techniques in modern open rhinoplasty. At the same time some of the well described maneuvers can result in consequences or can even cause complications of the procedure. For instance, dome definition sutures and extensive correction of the lateral alar convexities can lead to pinching of the tip and external nasal valve narrowing with breathing problems [3, 4]. Decreasing the tip projection by resection of dome segments should be followed by the use of camouflage tip grafting [7], which causes the same problems as application of the other grafts in the tip and supratip areas (distortion, dislocation, contour visibility, etc.).

The purpose of this study was to work out a complex of techniques to improve the results of open structure tip rhinoplasty.

34.2 Sliding Technique for Lowering Tip Projection

The first technical improvement described in this chapter is the method of decreasing tip projection without distortion of rim strip integrity. Using the idea of a tripod, shortening all three legs should result in backward and upward movement of the tip. Using the proposed technique, it is possible to achieve lowering of the tip projection via mobilization of the lower lateral cartilages from the middle of the lateral crus to the level of the juncture between the medial crus and the infralobular segment (Fig. 34.1A). Sliding the dome segment towards the medial crus reduces the length of both lateral and medial crura, causing a lowering of the tip projection. Integrity of the lower laterals is restored by suturing of duplicated components of the medial crus (Fig. 34.1B). This helps to increase the stability of tip support even without insertion of a columella strut.

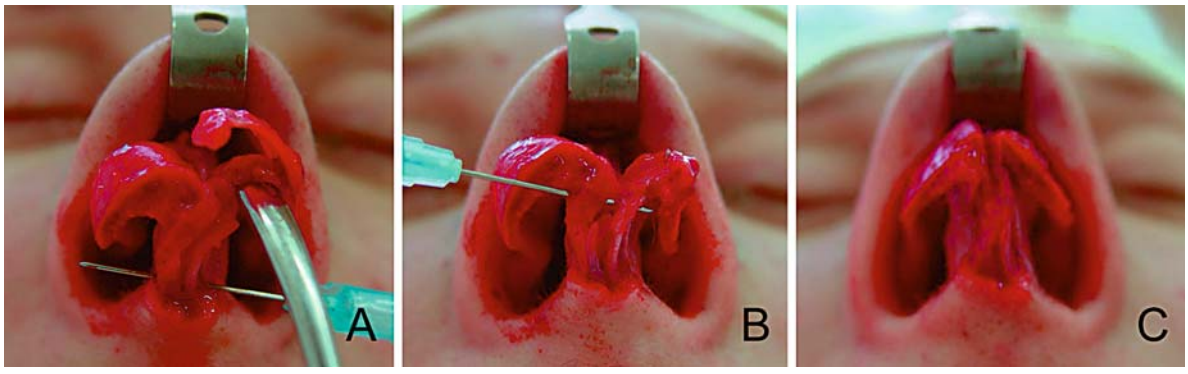

Fig. 34.1. Sliding technique for lowering of nasal tip projection. **A** Crosscuts of medial crura. **B** Temporary fixation of medial crura after sliding of crosscut parts. **C** Dome recreation with sutures

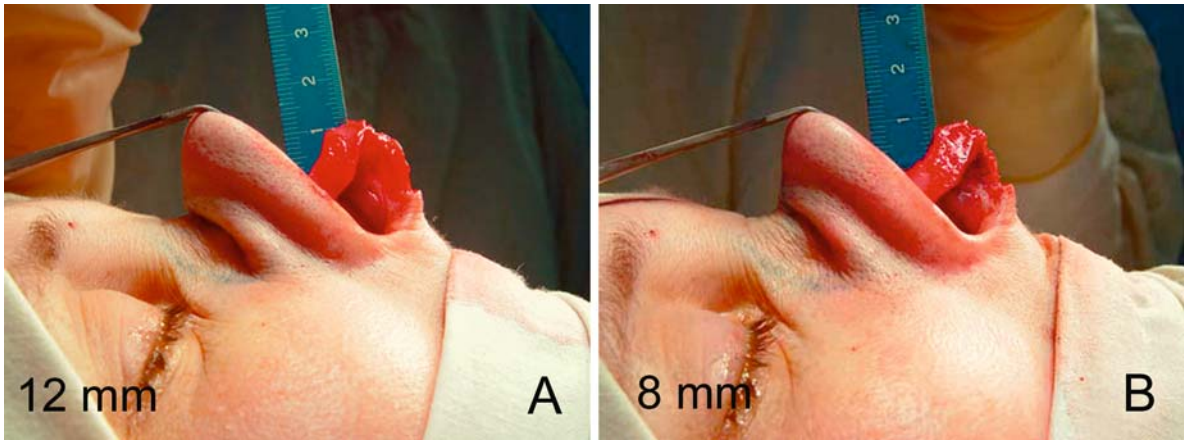

Fig. 34.2. Intraoperative measurements of dome projection. **A** Before lowering of tip projection. **B** After lowering of tip projection

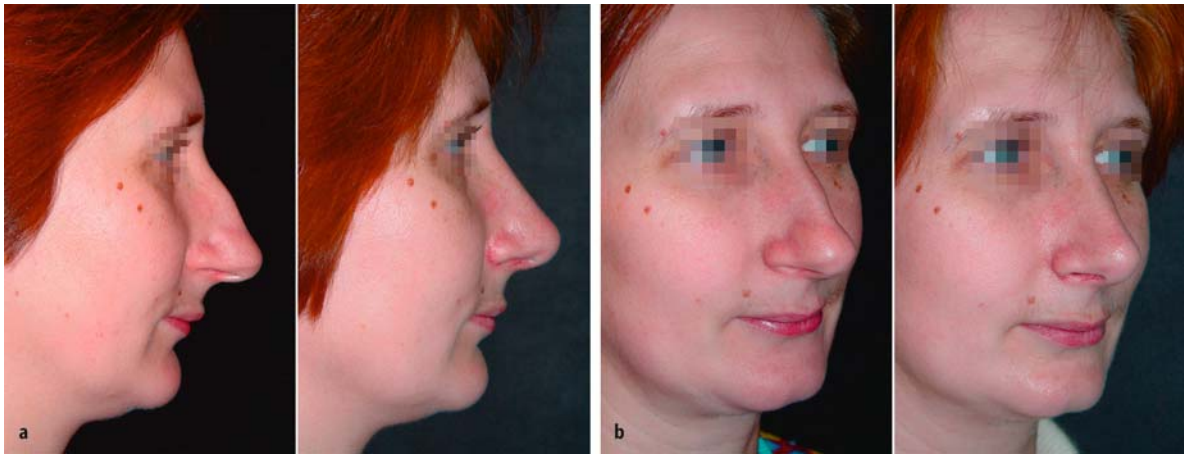

Fig. 34.3. Clinical example of tip projection lowering with the sliding technique. **a** Side view of the nose before (*left*) and 6 months after surgery (*right*). **b** Three-quarters view preoperatively (*left*) and postoperatively (*right*)

Recreation of domes from the lateral crus is achieved using conventional suturing techniques with application of transdomal and interdomal stitches (Fig. 34.1C). Coaptation of soft tissue flaps to the mobilized lower lateral cartilages can be completed using side-to-side resorbable mattress sutures. The results of cartilage modifications and the appearance of the nose are shown in Figs. 34.2 and 34.3.

A similar cartilage overlapping technique was proposed by G. Aiach to correct an overprojecting tip, to correct a plunging tip that requires a cephalic rotation and for correction of excessive width of the domes [1]. We independently presented this method in 2002 at the 16th ISAPS Congress in Istanbul, Turkey [6].

34.3 The Second Interdomal Stitch

Another technical maneuver for nasal tip creation we advocate is a second interdomal stitch (SIDS). Reducing nasal tip width usually begins with resection of the cephalic portion of the lateral crura. This is according to the algorithm of placing sutures in the lower lateral cartilages and between them; the first stitch is between the medial crus and the next one is between the domes (interdomal stitch – IDS) [3, 8]. The following delicate sutures usually applied are transdomal ones (TDS), reducing the flare of the lateral crura, creating tip defining points and slightly adjusting tip projection. At the same time, TDS as well as dome spanning sutures (DSS) can result in convexity of the lateral crural complex, pinching the tip and narrowing the nasal vestibule, so causing breathing problems [4]. Lateral crural struts that were recommended to correct this problem are hardly ever applied because they need abutment with the rim of the piriform aperture [1, 4]. Instead of this we use the stitch between the newly created domes (SIDS) after application of TDS. The newly formed force vector between the upper dome segments causes the following effects for predictable symmetric nasal tip modification: (1) stabilization of tip and dome defi-

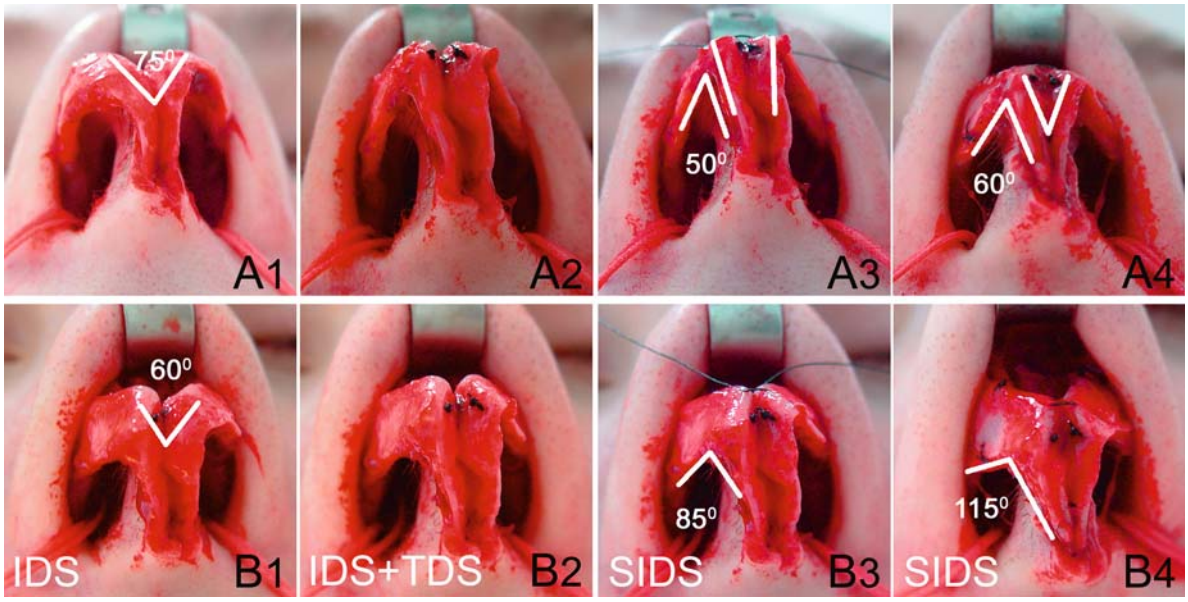

Fig. 34.4. Nasal tip remodeling dynamics with sutures from the basal (*upper row*, **A**) and front views (*bottom row*, **B**). *1* Angle of divergence before suture application (**A**) and after using IDS and TDS on the right side (**B**); *2* nasal tip framework appearance after IDS and TDS application; *3* angle of the external nasal valve before the SIDS tightening; *4* angle of the external nasal valve modification after the SIDS tightening

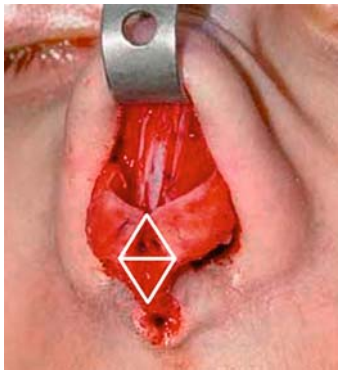

Fig. 34.5. Virtual equal side triangles over a framework background for tip-defining points created with the second interdomal suture

nition points; (2) manipulation by the angle of divergence and domal angulation; (3) production of a tension force that strengthens the lateral crus; (4) elimination of inversion of the lateral crus; (5) control of the proper position of supratip and infratip breakpoints; and (6) opening of the external nasal valve (Fig. 34.4). In cases of convexity SIDS serves as a lateral crus spanning suture with much more predictable outcomes. As the result of suture application, one can find a cartilaginous framework (Fig. 34.5) fitting the ideal tip characteristics after skin redraping.

Tebbetts [8] systematized suturing techniques for nasal tip remodeling. In his hands medial crural fixation sutures served to establish interdomal width, to adjust dome projection and to control the angle of the crus and the degree of flaring. Gruber [3] used interdomal sutures just posterior to the dome to achieve symmetry and stabilization of the tip cartilages. In the cases reported by Tardy [7], this type of suture sets interdomal width and usually serves as a platform for tip graft. Daniel [2] popularized domal equalization suture between cephalic ends of dome segments. It served to narrow the tip sufficiently and insure symmetry of the domes. At the same time this stitch location did not result in a tension force on the lateral crura that strengthened it and opened the external nasal valve.

The 2nd interdomal suture (SIDS) described in this paper is placed anterior to the previous ones and brings together the cephalic domes with the lateral crura, resulting in additional valuable effects on nasal tip geometry and function.

34.4 SMAS Flap

The nasal profile restoration is especially important in patients with excessive nasal septum resection and loss of cartilaginous dorsum support, in patients with posttraumatic nasal deformities and in patients with long nose after drooping tip lifting. To correct nose contour defects surgeons traditionally use different grafts. But the number of well-known complications – distortion, twisting, resorption, and skin atrophy – has led to a reduction of the indications for subcutaneous graft placing. The search for more reliable materials for contour nasal restoration is therefore continuing.

The goal of that part of our study was to work out the method of surgical correction of nasal dorsum defects

especially in the tip and supratip areas using the superficial musculoaponeurotic layer flap (SMAS flap).

There are four soft tissue layers between the nasal skin and the cartilaginous framework: subdermal fat, SMAS, subaponeurotic fat layer and perichondrium [8]. The superficial musculoaponeurotic layer presents with collagen bunches that surround the nasal musculature and form superficial and deep fascial layers for each muscle. As a result all these structures act as one functional unit – the musculoaponeurotic system of the nose. The basis of the worked-out soft tissue flap is the distal part of the superficial musculoaponeurotic system of the nose with a location above the lower lateral cartilages. The pedicle of the mobilized tissues is directed to the caudal part of the transverse nasal muscle. The blood supply of the flap is achieved via the dorsal nasal artery and external nasal branch of the anterior ethmoidal artery. The branches of the lateral nasal artery serve as the main source of the nasal tip blood supply. They are located in the subdermal fat layer above the SMAS.

Open rhinoplasty begins with subcutaneous soft tissue mobilization above the lower lateral cartilages up to the level of the upper lateral cartilages. The SMAS layer is left underneath the skin envelope. Then the SMAS flap is undermined over the lobules of the lower lateral cartilages. Average dimensions of the flap are as follows: length – 18 – 30 mm, width – 8 – 15 mm, thickness – 1 – 2 mm (Fig. 34.6). The flap transfer is possible under the angle of rotation up to 90 degrees. Small subcutaneous irregularities in supratip area, interlobular bifidity, and retractions in that zone as a result of scarring after previous surgery are possible to manage successfully with the SMAS flap.

We performed 103 rhinoplasties with tissue mobilization within the tip area in two surgical planes: subcutaneously and with SMAS undermining. In 37 cases the SMAS flap was used for nasal tip and dorsum remodeling, whereas in the other 66 cases there were no indications to use it. In these patients we also studied the possibilities for flap rotation and transposition.

34.5 Case Report

Patient K., a 22-years-old female, complained of nasal deformity – hump, supratip depression and entire nose asymmetry. In childhood she had sustained nasal trauma with bone fracture and subsequent repositioning. At the age of 18 she underwent a closed septorhinoplasty with excessive resection of the septal cartilage that caused loss of cartilaginous dorsum support. Secondary open septorhinoplasty was performed. The remnant of the septal cartilage was harvested endoscopically with dimensions of 23×11×2 mm. But it was not sufficient to fill the supratip depression. The SMAS flap was undermined with dimensions of 22×15×2 mm. Two cartilage flaps from cranial portions of the lateral crura with dimensions 16×6 mm were also elevated. The remaining portion of the lateral crura was 6 mm in width. Hump resection and lateral osteotomies were performed. To fill the supratip depression we turned the alar cartilage flaps around the midline overlapping the upper lateral cartilages with the suture positioning. Next the SMAS flap was rolled up above the cartilage flaps. Tip support was restored with a strut graft; dome sutures and a Sheen graft were also applied. The nasal appearance was significantly improved (Fig. 34.7).

In the 5 years of follow-up we have not observed any nose deformities connected with SMAS flap atrophy. There were no secondary procedures after usage of the above-mentioned flap. In all patients we obtained good functional and aesthetic results.

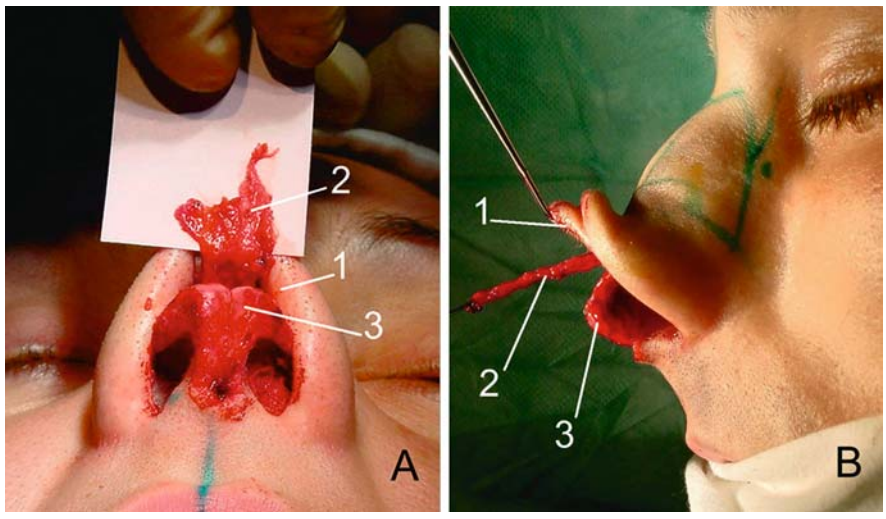

Fig. 34.6. SMAS flap undermining on basal (**A**) and side (**B**) views. *1* Elevated skin envelope; *2* SMAS flap; *3* lower lateral cartilages

Fig. 34.7. Patient K before (*left*) and 2 years after (*right*) open rhinoplasty using SMAS flap to fill supratip depression

Grafts from the temporal fascia and fascia lata were widely used especially in secondary rhinoplasties [2]. The SMAS graft rhinoplasty from the masseterico-parotid area harvested during a simultaneous face-lift was also described [5]. Fascial transplants are very pliable but unfortunately rather unstable. It is well known that the classical open rhinoplasty technique implies dissection in the subaponeurotic layer striving for tissue exposure underneath the perichondrium and periosteum. At the same time in clinical practice skin undermining in columella and tip areas is usually performed subcutaneously with the SMAS layer remaining adherent to alar cartilages. This layer is recommended to be cut off to expose the cartilage of lateral crura and prevent soft tissue fibrosis in the tip area. Thus the utilized material can be turned into the flap. Tip skin blood supply is based on subdermal plexus and the accurate SMAS dissection does not compromise skin vascularization. At the same time precisely elevated skin can better contract and fit the newly formed cartilaginous frame. The previously described ligament flap also included the musculoaponeurotic system of the nose (Yukio Shirakabe 2006, personal communication). This study was presented recently by Dr. Shirakabe (from Tokyo, Japan) at an ISAPS course in Cape Town, South Africa, in 2006 and was dedicated to tip projection adjustments in Oriental patients. Unfortunately we did not receive approval for publication of this data in the journals we sent it to.

34.6 Conclusions

A worked out complex of techniques is a useful modality to improve the results of open structure tip rhinoplasty. The second interdomal suture strengthens the lateral crura and opens the external nasal valve. A sliding technique for lowering of the nasal tip projection preserves the integrity of the domal segment. Application of the SMAS flap diminishes the necessity of cartilage and fascial graft usage, reducing the risk of sequelae connected with them. Two-layer soft tissue separation enables the nasal skin to shrink better and allows adequate redraping of the newly formed cartilaginous framework.

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The Breast VI

Breast Reconstruction with Deep Inferior Epigastric Flap: State of the Art and Practical Aspects

35

A. Mendonça Munhoz, R. Gemperli, M. Castro Ferreira

35.1 Introduction

Breast reconstruction with autogenous tissue is a standard technique and a well-established procedure in many advanced breast cancer centers. Among the technical alternatives, abdominal flaps have been selected as the option of choice to produce the most natural results [1–10]. In order to maintain blood supply to the skin and the subcutaneous tissue, part of one or both rectus abdominis muscles must be harvested in the myocutaneous flaps. Regardless of the cosmetic benefits, some questions have been raised concerning the rectus abdominis muscle resection [1–6]. In recent years, the progress in microsurgical technique as well as a better understanding of skin anatomy has proved that muscle tissue itself is not required as long as perforator vessels are preserved. Thus, the introduction of the concept of perforator flaps associated with the development of the deep inferior epigastric perforator flap (DIEP) has brought new modifications to the conventional abdominal flaps [1, 3, 5–10].

During the past decade, many combinations of operative techniques for DIEP flap harvesting have been published [1, 3, 5, 6, 8]. To date, there is no consensus concerning the best procedure and the main advantages of the technique should include simplicity, safety and reproducibility. Reproducibility is one of the main principles of the scientific method, and refers to the ability of a test or experiment to be accurately reproduced. Probably, these goals are not achieved by any single procedure and each technique has advantages and limitations.

35.2 Patient Selection and Preoperative Care

The ideal candidates are active younger non-obese patients with moderate-size breasts. The amount of flap volume is evaluated in the infraumbilical region, and care is taken to make certain that adequate tissue will remain to accomplish abdominal closure. Patients should be nonsmokers or have discontinued smoking a minimum of 6 weeks prior to surgery. Relative contraindications are comorbid medical conditions limiting the ability to accept a prolonged anesthetic and operative time. Pfannensteil and lower midline incisions are not formal contraindications. Preoperatively, the location of the abdominal perforators should be identified and marked utilizing a hand-held Doppler.

35.3 Surgical Aspects

A two-team approach is necessary to reduce the operative time. The skin is incised down to the rectus abdominis muscle and external abdominal oblique fascia. Skin and subcutaneous tissue are lifted off the external oblique muscle up to the lateral border of the rectus abdominis muscle. When the lateral row of perforators from the deep inferior epigastric vessels are encountered they are carefully evaluated with the aid of loupe magnification and microsurgical instruments (Fig. 35.1a, b). The sensory branches normally go together with a arterial perforator, and care must be taken not to mistake the nerve for a venous branch when selecting the flap's perforators. It is important to identify two perforators with the same vertical orientation. Incorporation of aligned perforators enhances blood supply while limiting the amount of rectus abdominis muscle that is divided. If arterial and venous perforators with diameters greater than 1.0 mm are present, then the flap can be designed around these perforators. If no adequate lateral perforators are present, then the dissection is carried to the medial row. The procedure can be transformed to a muscle sparing free TRAM (transverse rectus abdominis myocutaneous) flap if enough

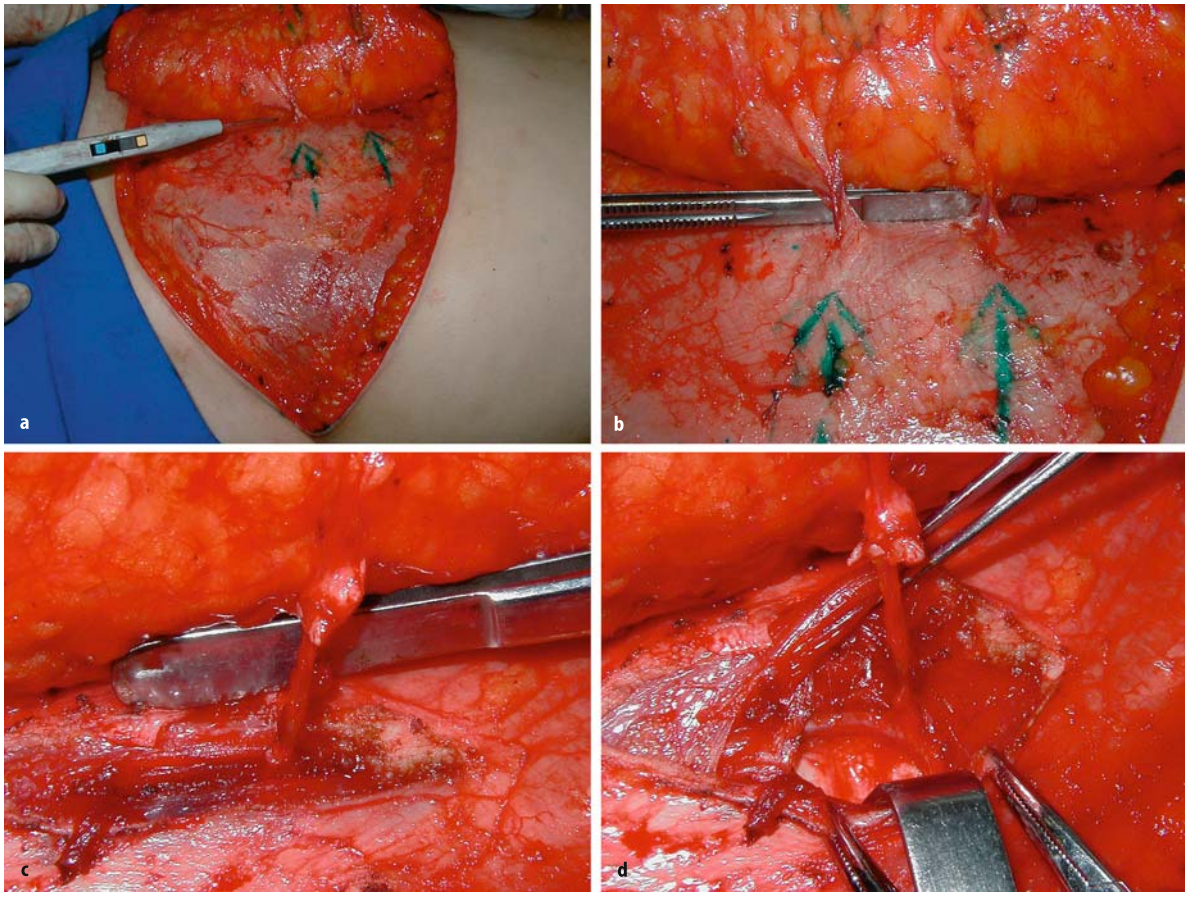

Fig. 35.1a–d. The skin is incised down to the rectus muscle and external abdominal oblique fascia. Skin and subcutaneous tissue are lifted off the external oblique muscle up to the lateral border of the rectus abdominis muscle. When the lateral row of perforators from the deep inferior epigastric vessels are encountered they are carefully evaluated (**a, b**). Once a perforator vessel is selected, the subcutaneous fat around it is immediately dissected through the fascia. The anterior rectus sheath through which the perforator passed is opened, and the vessel is dissected from the rectus muscle fibers through a longitudinal direction split (**c, d**)

perforators are not identified in this last region. Once a perforator vessel is selected, the subcutaneous fat around it is immediately dissected through the fascia. The anterior rectus sheath through which the perforator passed is opened, and the vessel is dissected from the rectus muscle fibers through a longitudinal direction split (Fig. 35.1c, d). At this time, the motor nerve of the rectus abdominis muscle is left intact to avoid muscular denervation. Small vascular branches are ligated with surgical clips, and the dissection is continued to the underlying deep inferior epigastric vessels. The plane posterior to the rectus muscle is dissected and the deep inferior epigastric vessels exposed. Regarding the course of the intramuscular perforator vessels, two different paths are observed [8]. A rectilinear course is observed in the intermuscular septum reaching the subcutaneous tissue. In this pathway, the distance from the flap to the deep inferior epigastric vessels is shorter and runs more perpendicularly through the muscle fibers. The muscle is split in a longitudinal direction without muscle resection and the perforator vessels can be freed by blunt dissection. An oblique perforator vessel runs in more than one intermuscular septum to reach the subcutaneous tissue. The distance from the flap to the main pedicle is longer and sometimes some muscle resection is needed to free the perforator vessels. The dissection is more tedious, requiring extensive longitudinal splitting of the muscle. The inferior epigastric vessels are then dissected from the muscle with the aid of a small lighted retractor. If additional vessel length is desired, the fascial incision is extended and the vessels are identified at the muscle's lateral border. This exposure allows the vessels to be traced to their origin from the external iliac artery and vein if required. The umbilicus is incised circumferentially down to the fascia, and the entire skin and subcutaneous flap are raised carefully to prevent damage to the perforator vessels. The flaps are transferred to the thorax, and then sutured to the anterior chest wall. A conventional end-to-end anastomosis is performed with

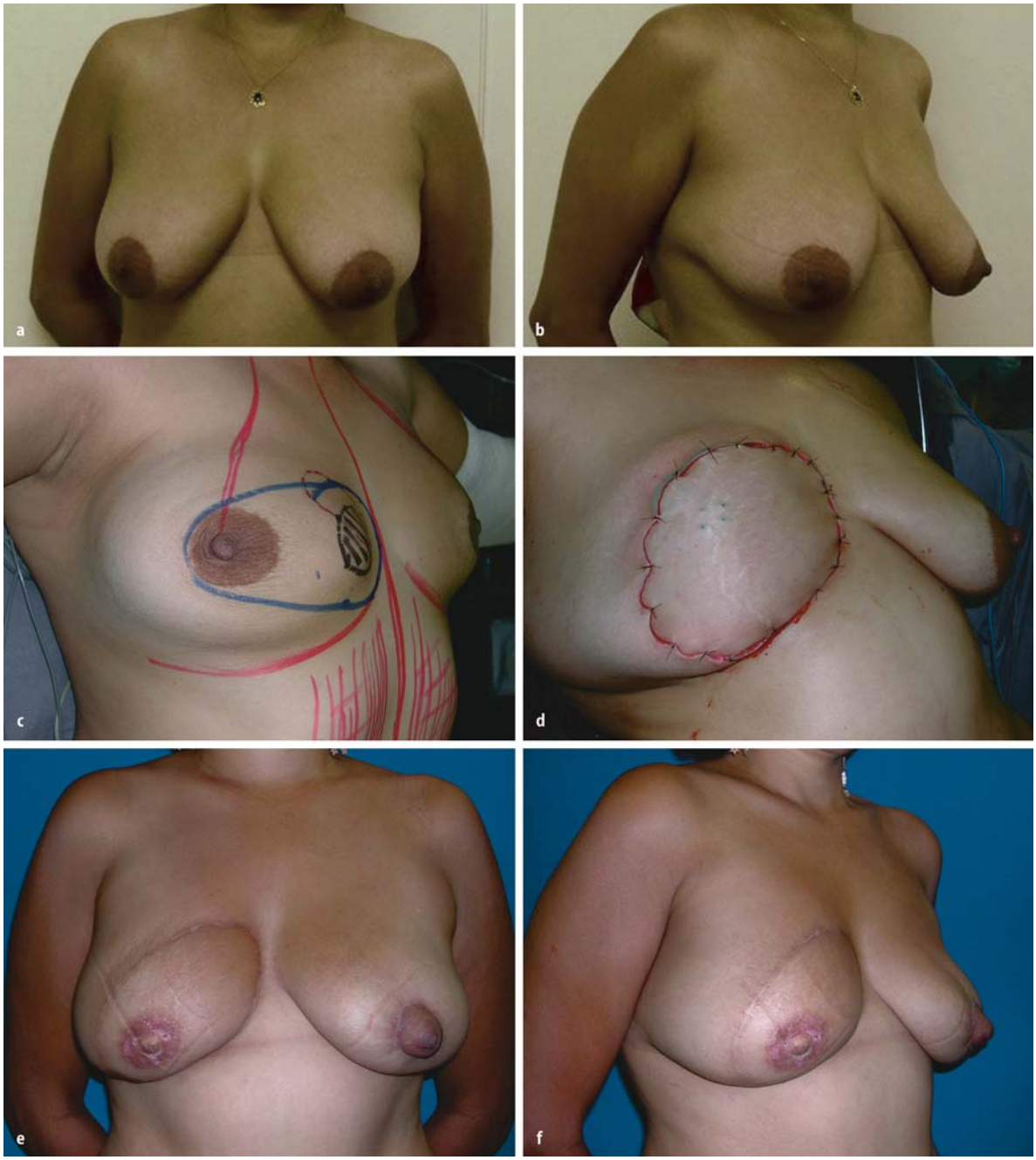

Fig. 35.2a–f. A 46-year-old patient with 4 cm invasive ductal carcinoma of right breast (**a, b**). The reconstructive markings showing tumor location and the amount of skin resection (**c**). The patient underwent a right mastectomy and immediate DIEP flap reconstruction (**d**). Two years postoperative appearance with a good outcome after contralateral mastopexy and nipple-areola reconstruction (**e, f**)

10/0 interrupted nylon sutures under surgical microscope enlargement. Both the rectus abdominis muscle and sheath are preserved and no tension during abdominal wall closure is observed which permits primary closure. The skin and subcutaneous tissue of the upper abdominal wall are undermined, and skin closure is performed as a conventional abdominoplasty (Fig. 35.2a–f).

35.4 Future Perspectives

A successful reconstruction demands a collaborative team approach and a careful assessment helps establish a comprehensive surgical plan that will achieve better results. In fact, perforator flap breast reconstruction

continues to be an area of innovation and progress, with recent efforts focused largely on reducing donor site and recipient vessel morbidity, improving postoperative recovery and reproducibility. An increased comprehension of cutaneous circulation in conjunction with the trend toward more minimally invasive surgery has led to the development of new interest in surgical alternatives. Occasionally insufficient venous drainage can be observed with the DIEP flap subsequent anastomosis of the deep inferior epigastric veins. Thus, preservation of the superficial inferior epigastric vein allows for an additional anastomosis to be made to a second recipient vein with resolution of venous congestion.

The concept related to extravenous drainage and perfusion has also motivated new research and innovative techniques. The infraumbilical soft tissues can also be harvested on the superficial vascular vessels to form the SIEA flap [2]. This procedure requires no dissection of the muscular tissue of the abdominal wall or its motor innervation. Despite the abdominal wall being totally preserved, the superficial vessels have a variable anatomy and may be minuscule or not present in up to 35% of cases [13].

Another important issue is related to recipient vessels. Reconstruction time, flap pedicle length and recipient vessel diameter are main option criteria. Additionally, the surgeon's experience, contralateral breast size and history of radiation therapy are related factors [9, 14]. In immediate reconstructions, the axillary vessels have already been exposed following axillary dissection. However, in late reconstructions these vessels may be inadequate due to scar formation and fibrosis [11, 12, 14]. In some situations, the use of axillary vessels may impair medial flap movement due toinsufficient pedicle length [9, 12]. Thus, the internal thoracic vessels may be a good alternative if they have not been previously manipulated and the deleterious radiotherapy tissue effects are absent [4, 9, 14]. Despite these advantages, its use is not free of morbidity. Costal rib resection, postoperative pain and thoracic contour deformities have been noted [4, 9]. Thus, the use of internal mammary branches as a recipient site can be a further refinement [9]. The main advantages are sparing the internal mammary vessels for a possible future cardiac surgery, avoiding thoracic deformities and decreasing the operative time by limited dissection. Despite these positive aspects, the perforator branches present some limitations if the technique is not potentially applicable in all patients. In immediate reconstruction, preoperative planning is fundamental to preserve the main perforator branches during the mastectomy. In late reconstructions the procedure is not demonstrable and several factors are involved such as previous surgery and radiation therapy [9].

Regardless of the absence of large prospective trials, clinical evidence continues to increase indicating that muscle preservation with perforator flaps reduces donor site morbidity. Additional comparative studies evaluating the SIEA flap and the internal mammary perforator branches as a recipient site are necessary to elucidate the potential advantages of these new procedures.

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Back from the Future: Reappraisal of the Pedicled TRAM Flap in "Standard" Patients

P. Berrino, S. Cicchetti

36.1 Introduction

Since Hartrampf's original description of the pedicled transverse rectus abdominis myocutaneous (TRAM) flap [1, 2], this procedure has undergone a gradual evolution: the development of microsurgical techniques, involving the sacrifice of only a small segment of rectus muscle or even preserving it [3–8], could overcome many of the drawbacks of the standard operation (donor site morbidity, fat necrosis caused by poor blood supply, etc.) [9–11]. However, according to the literature, no general consensus exists with respect to one technique or the other, either in terms of outcomes, complication rates or costs [12–19].

In this paper the authors, familiar with both pedicled and microsurgical procedures, review the experience over a 23-year period, in order to verify the results in three large groups of patients.

36.2 Materials and Methods

From January 1982 to June 1992, pedicled TRAM flaps were used in 232 cases; from July 1992 to January 2000, 352 patients were operated on: 249 of them had pedicled TRAM flap breast reconstruction, while in 103 women a free TRAM flap was used (either traditional, muscle sparing or DIEP). Patients were selected for the microsurgical flaps in the presence of a high risk for flap perfusional problems (smokers, obese women and those needing large flaps).

From April 2000 to December 2005, 79 patients received pedicled TRAM flaps (79 unilateral, 3 bilateral).

36.3 Surgical Technique: Pedicled TRAM Flap

Since it was used in the majority of patients in this series, the technique of pedicled TRAM flap harvesting is described as follows.

The patient, with the flap design marked as explained elsewhere [20], is positioned supine on the operating table, with the arms along the body.

The upper border of the flap is incised to the deep dermis. The fat layer is incised in a bevelled fashion, so that an adipose extension is transferred with the flap, which will create a smooth upper cleavage. Undermining proceeds upwards above the sternal apophysis and laterally well above the costal margin.

At the mastectomy site the area where the flap will be inset is prepared by excising the skin according to the preoperative design. The upper skin flap is undermined in a pre-fascial plane to the subclavicular area, so as to create a space where the deepithelialized and the adipose portions of the flap will be placed. The lateral and the inferior edges of the incision are not undermined in order to have a better definition of the new submammary crease. At the medial third of the inferior incision the tunnel is created, which reaches the abdominal undermining.

The medial and the lateral borders of the rectus muscle which will be harvested are identified. Two longitudinal lines are drawn over the central third of the muscular belly. Inferiorly both lines reach the upper margin of the flap. Along these two lines the anterior rectus sheath is grasped with an Adson forceps and it is incised using the electric knife. The sheath can be easily elevated off the muscle fibers, while it is adherent to the fibrous intersections (fimbriae). The fascia is gently separated from the muscular belly using a bipolar forceps. The elevation of the fascia proceeds both laterally and medially until the edges of the muscle are exposed.

The inferior border of the skin ellipse is then incised, and the two wings of the skin ellipse flap are detached

from the fascia. The contralateral portion of the flap is first elevated in the prefascial plane beyond the midline, over the medial border of the rectus muscle, until the medial row of perforators is seen. The inferior portion of the flap is elevated off the fascia until midway between umbilicus and pubis. The navel is then cut in a triangular shape, its pedicle is freed, and it is then passed under the flap.

On the side of the muscular pedicle, the skin is elevated off the fascia, until the lateral row of perforators is encountered. The fascia is incised vertically along the lateral and medial rows of perforators. The muscle is then cut vertically; dissection proceeds until the deep inferior epigastric vessel is encountered and the inferior pedicle is securely clipped and cut.

The incision in the muscle is turned upwards and it reaches the medial margin of the muscle at the level of the lower (umbilical) fimbria. The apex of the V-shaped fascial and muscular incision is midway between umbilicus and pubis. In most women the arcuate line is at this level, or lower; therefore no weakening of the abdominal wall is created where the risk of hernia or bulging is higher.

The dissection of the muscular pedicle can then proceed either preserving a lateral strip of muscle or harvesting the full width of the muscle. The more conservative muscle harvesting is preferred when the flap is small and very reliable from the perfusional point of view. The latter dissection preserves the integrity of the vascular plexus and it is to be preferred in the majority of patients.

The dissection proceeds cranially until the superior pedicle is seen. The lateral border of the muscle is freed from the fascial envelope well above the costal margin to allow an unconstricted rotation of the pedicle. The eighth intercostal nerve must be located and severed; otherwise it will maintain innervation and motility of the upper part of the muscular pedicle, which will show during sit-ups. With the flap completely dissected but still in its original location, the portion exceeding the preoperative design is resected by scissors, bleeding is stopped and vascularity is checked. Normally a good peripheral bleeding is seen, with a prevalence of venous outflow. The appearance of the flap immediately improves after resecting the contralateral portion. The flap is transferred through the tunnel to the mastectomy site. The muscular pedicle must show a tension-free rotation, without any remaining fibrous attachment pulling laterally. The skin island is temporarily stitched at the mastectomy opening with a staple, and attention is given to abdominal closure.

The fascial defect is repaired first by separate figure-of-eight stitches using 2/0 nylon, then by a continuous running suture.

When the full width of muscle is harvested, the portion of the muscle which has been preserved below the lower intersection is moved superiorly when the sheath is repaired, thus contributing to abdominal competence and strength. The fascial defect is not repaired above the costal margin, in order to avoid any stricture around the muscular pedicle. A resorbable mesh is then positioned on the abdominal sheath and it is sutured under some tension. This protects the underlying fascial repair in case of strong movements or tension in the early postoperative period.

The patient is placed in a semi-sitting position and the skin is sutured in two layers, using a 3/0 resorbable suture and an intradermal 3/0 nylon suture. The navel is exposed through a triangular opening and sutured in the new position using 5/0 nylon. Although no plication of the rectus fascia is done in order to relocate the navel in the midline, the length of the umbilical pedicle is sufficient to expose it through a midline opening. Two drains are positioned to collect fluids in both halves of the abdominal undermining.

The flap is shaped by moving the temporary staples until a satisfactory shape is obtained.

36.4 Results

In the group of patients who underwent pedicled flap transfer from 1982 to 1992, there was no total flap necrosis; major necrosis (involving more than 15% of the flap surface, or extensive liponecrosis) occurred in 7% of patients and a 11% minor necrosis rate was seen. In the group of patients who had pedicled flap transfer from 1992 to 2000, no major necrosis was recorded and a 5% minor necrosis was observed. In the free flap group a total flap loss occurred in three cases and one marginal necrosis was seen; seven patients were reoperated on for anastomosis revision. The incidence of abdominal wall bulging was 8% in both groups.

Aesthetic results were absolutely comparable in all groups of patients.

In the group of patients operated on from 2000 to 2005, no flap loss and no major necrosis were recorded; however, there was a 5% minor flap necrosis and a 5% rate of abdominal wall weakness.

36.5 Discussion

This paper reviews the experience of the senior author, analyzing how his choice of breast reconstruction with autogenous tissues has evolved over a 23-year time course.

In the first period of this experience (1982–1992), pedicled flaps were used in all women and a 7% major

necrosis and a 11 % minor necrosis rate were recorded, which allowed the detection of patients at high risk for partial flap necrosis. In the second period (1992 – 2000), patients were strictly selected according to their risk of having perfusional complications and only "standard" patients received pedicled TRAM flaps, while patients considered at high risk (obese, smokers, patients needing large flaps) had free flap transfer. This determined a drop in the total amount of flap vascular complications, with a 5 % rate of minor necrosis in the pedicled group, which is acceptable for the "standard" patient. In smokers, obese women and patients needing large flaps a 3 % total failure risk was considered an adequate price to pay to avoid a 20 – 25 % risk of flap perfusional problems.

From 2000 on, there was a reappraisal of the pedicled TRAM flap, offered to all the "standard" patients requiring autogenous breast reconstruction. High risk patients were offered other procedures (implants, local flaps) and microsurgical techniques were reserved only for an extremely selected subset of patients, after discussing all of the possible alternatives.

The reasons for this choice can be summarized as follows:

1. Nowadays economic factors have increasing importance and each surgeon should choose a procedure taking into account not only the clinical outcome and the risk of complications, but also the resource costs. According to the Italian National Health System, where autogenous breast reconstruction is usually performed on a delayed basis, microsurgical techniques are considered more cost expensive than conventional procedures, requiring longer operative time and postoperative stay. In our series the pedicled TRAM flap breast reconstruction required a mean operative time of 205 min, a mean hospital stay of 2.3 days and 2 – 4 secondary stages on an outpatient basis (except contralateral operations). According to our experience, microsurgical procedures required a mean operative time of 310 min and a mean hospital stay of 6.6 days (to guarantee a continuous flap monitoring), with higher costs than the pedicled flap, but with comparable results.
2. Maximal care in avoidance of complications played a major role in cost reduction. Vascular related complications were minimized by not extending the flap further from the lateral margin of the contralateral muscle. A knowledge of microsurgical muscle-sparing techniques allowed the operator to adopt a very conservative approach even with the pedicled flap, which was always raised with maximal care in preserving the fascia at the level of the arcuate line, where the risk of hernia or bulging is higher.
3. Preoperative selection of patients was very conservative: risk factors such as long-term smoking history and heavy obesity were considered absolute contraindications, posing serious problems even with the use of free flaps (risk of abdominal skin necrosis).
4. The introduction onto the market of increasingly sophisticated devices and the evolution of techniques of implant-based breast reconstruction has expanded the possibilities for the reconstructive surgeon to obtain results comparable with those of autogenous tissues in selected patients, which caused a drop in autogenous tissue breast reconstruction from 80 % to 35 % in our series.

36.6 Conclusions

In the experience of the senior author, the latest innovation in autogenous tissue breast reconstruction is a way back to the past, with the use of the pedicled technique in "standard patients," which allows a reduction of costs in terms of operative time, hospital stay and immediate complications, and with an excellent outcome.

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Decision Making in Breast Reconstruction with Implants in Irradiated Patients: An Algorithm

37

M. Scheflan, E. Gur, T. Friedman

37.1 Introduction

Radiation therapy is used increasingly for breast cancer as an adjuvant therapy in breast conserving surgery and following mastectomy in local advanced breast cancer. Studies have shown a better locoregional control with postmastectomy radiation also in patients with early breast cancer [1–3]. In general, indications for radiotherapy in breast cancer patients have become more liberal and widespread.

Breast reconstruction with implants in irradiated patients is challenging. Alloplastic breast reconstruction in patients previously treated by irradiation has potentially more complications and poorer aesthetic results when compared to non-irradiated patients [1–6]. The injurious effect of radiation often results in varying degrees of fibrosis and loss of elasticity, disrupting the vitally needed soft tissue envelope for breast reconstruction around a device and interfering with the wound healing process and possibly reducing local mechanisms that deal with infections [5, 6]. Occasionally, pigmentation, induration and atrophy of the soft tissue is present clinically with or without telangiectasis.

Since the first introduction of breast implants by Cronin [7] and tissue expanders by Radovan [8], important advances in device design, dimensions, fill, texture and envelope have evolved as did our comprehension of the device/soft tissues interaction and its critical influence on final results [9–13].

Current studies still demonstrate higher complication rates in irradiated patients compared to non-irradiated patients after breast reconstruction with implants. This is therefore why plastic and reconstructive surgeons shy away from using implants in irradiated patients and prefer an all autogenous breast rebuilding in most postradiotherapy patients [3–6].

This oversimplified approach, in our opinion, misses many postmastectomy irradiated patients who are good candidates for implant reconstruction.

Subgrouping our irradiated patients into two clinical groups, and selecting a procedure and an implant accordingly, has shown that most postmastectomy irradiated patients are actually good candidates for implant reconstruction. "Simple" breast reconstruction with shaped implants has the advantages of a lesser procedure with good color match, relatively intact skin sensation, less scarring, no donor site, and a more rapid recovery with low morbidity.

Depending on the quantity and quality of the irradiated soft tissues remaining on the chest wall after mastectomy at the time of either immediate or delayed breast reconstruction, we have used different surgical approaches and three types of devices:

1. Shaped (anatomical) devices: Inamed's style 410/510 or Mentor's contour gel
2. Shaped adjustable devices (anatomical): Inamed's style 150 or Mentor's Becker 35
3. Shaped tissue expanders (anatomical): Biospan from Inamed or Mentor

Proper selection of surgical procedure is the first and most critical decision in irradiated patients. Device selection is second.

Patients are carefully examined for clinical evidence of radiation sequelae on the chest wall, including pigmentation, induration atrophy and telangiectasis.

Patients with clinical evidence of radiation damage and/or inadequate soft tissue coverage are advised to undergo a latissimus dorsi myocutaneous flap transfer with an implant or expander.

In patients who had previous radiation therapy but with no clinical evidence of pigmentation, induration, adhesion or atrophy, a "simple" implant reconstruction is undertaken.

In both groups, the implant is selected using one of the three types of devices mentioned above: shaped (fixed volume, **permanent** silicone gel implant), shaped adjustable ["soft expander/implant" double lumen (silicone/saline), **permanent** implant] or shaped expander ("hard expander," **temporary** saline device).

37.2 The Shaped (Anatomical) Implant

We prefer anatomical implants for breast reconstruction after mastectomy for the same reasons we use them in thin patients for breast augmentation. Shaped silicone gel devices demonstrate a gradual upper pole takeoff in patients with minimal soft tissue padding such as postmastectomy patients as opposed to round silicone gel implants that accentuate the infraclavicular hollow and implant visibility.

Furthermore, a wider variety of heights, widths, projections and volumes are available with shaped devices, necessary to meet the individual soft tissue characteristics of the patient.

Shaped devices with fixed volumes are used whenever the soft tissue envelope is adequate to contain the desired final shape, dimension and volume of the reconstructed breast. For the reconstructions discussed in this chapter we have used primarily the Styles 410 and 510 devices by Inamed and the contour gel shaped implants from Mentor.

37.3 The Shaped Adjustable Implant

Shaped adjustable, "anatomical" implants are permanent devices with dual chambers: an **outer chamber** with 45% high cohesive silicone gel and **an inner chamber** with 55% saline.

The inner chamber is adjustable through a filling tube attached to a remote valve [14–17]. This permanent anatomical shaped adjustable implant is a "soft" expander; while unable to stretch and a thick, adherent and indurated envelope, it is effective in stretching soft, elastic and supple tissues, even if previously radiated skin without clinical evidence of radiation damage. This property of "soft expansion" may also be useful in treating an evolving capsule contracture, by overexpanding the device to contra-act, compress or "break" the capsule from within. It may be used efficiently in breast reconstruction following skin sparing mastectomies as well as after modified radical mastectomy in immediate and delayed settings. Leaving the distant port permanently, when using this device, is an option which helps manage subtle volume adjustments in patients with weight changes and breast tissue aging. Moreover, early capsule contracture may be treated with temporary overexpansion, and long term volume adjustment capabilities decrease reoperation rates. The expansion process in irradiated patients reconstructed by an adjustable "soft" expander is slower with more sessions and more volume of saline fills, when compared with non-radiated patients.

Upper pole muscle coverage of the shaped implant provides a subtle, gradual transition from chest wall to implant, and a well vascularized protective barrier between the skin incision and the implant. Subcutaneous lower pole placement enhances projection, lower pole roundness and fold definition.

Adjustable expanders and implants are expanded once a week or two beginning at 2 weeks following surgery.

Moderate overexpansion of the implant is indicated to gain more stretched skin/muscle envelope or promote ptosis when indicated.

If at the end of the reconstructive project, the valve proves objectionable to the patient – it may be removed under local anesthesia, and the filling tube shortened and "corked" with a solid silicone plug (Inamed style 150 – Fill Tube Plug Kit) or pulled (Mentor Becker 35). In general, we prefer to leave the port permanently, as it helps manage moderate capsule contracture or subtle volume adjustments.

37.4 The Shaped (Anatomical) Expander

Shaped expanders are temporary devices able to stretch and expand indurated and inelastic chest wall tissues following mastectomy and radiation. These devices constitute the mainstream "workhorse" soft tissue manipulators of breast reconstruction after mastectomy. The use of a temporary shaped expander is indicated for patients where there is no clinical evidence of radiation damage but the soft tissue envelope is too tight to overcome the tension exerted by either the fixed shaped or adjustable implant and a more aggressive expansion is needed. After completion of the expansion process the device is exchanged with a permanent implant.

37.5 Patient / Procedure Selection

Patient selection following radiotherapy is the key to a successful reconstruction. "Simple" implant only re-

construction is used only in patients with adequate soft tissue coverage and no clinical evidence of radiation damage (i.e., pigmentation, induration, atrophy and telangiectasis).

On the other hand, in patients with clinical evidence of radiation damage (pigmentation, induration, atrophy and telangiectasis), the addition of a muscle/skin flap using the latissimus dorsi is recommended.

In more severely irradiated chest walls, with tight, indurated, pigmented thin, adherent and deficient soft tissue coverage – an all autologous breast reconstruction using the pedicled TRAM, free DIEP or SIEP flaps is recommended.

Another group of patients designated to have an autologous reconstruction is women with excess of skin and fat in the lower abdomen who wish to undergo an abdominoplasty procedure simultaneously with their breast reconstruction and are reluctant to have implant reconstruction.

37.6 "Simple" Reconstruction: Surgical Technique

The desirable width, height, projection and volume of the reconstructed breast are measured on the contralateral breast and the chest wall. Device options, choices, dimensions and volumes are decided upon at that stage.

In immediate reconstruction, the specific skin sparing mastectomy pattern is planned in collaboration with the patient and the general surgeon. Following mastectomy, the pectoralis major muscle is partially released from its low rib cage and sternal origins to allow controlled forward and upward displacement of the muscle.

Laterally the pectoralis minor muscle is dissected off the rib cage together with serratus anterior muscle as a

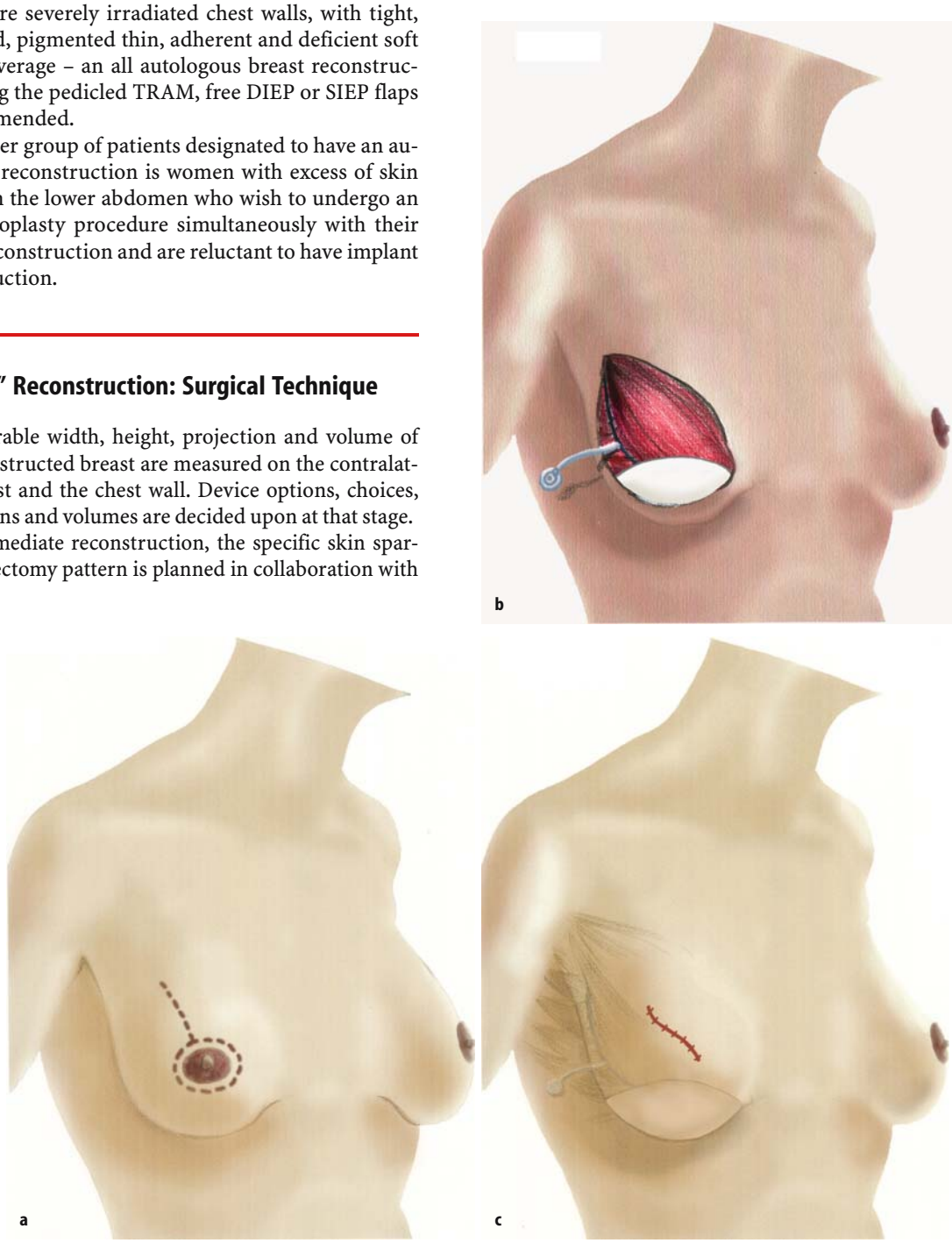

Fig. 37.1. The implant is placed with its upper two-thirds covered with muscle and the lower third subcutaneously

lateral chest wall based flap to an extent that may accommodate the desired base width of the implant. The lateral pectoral muscle edge is then sutured to the medial edge of the serratus muscle flap. The implant is placed with its upper two-thirds covered with muscle and lower third subcutaneously (Fig. 37.1). When the lower mastectomy skin flap is draped up over the implant, the muscle is anchored to the undersurface of the flap, using "Marionette" sutures, to prevent cephalic displacement of the pectoral muscle and guaranteeing muscular, vascular barrier, padding and good soft tissue coverage between incision and implant.

It is at this point that the final decision is made regarding which of the three device options is to be implanted in that particular patient.

Ideally, whenever the characteristics of the soft tissue envelope may accommodate a placement of the desired final shape, dimensions and volume device, a fixed shaped implant is placed with its upper two-thirds covered with muscle.

When only partial breast volume replacement is possible due to inadequate muscle and/or skin, a shaped adjustable device is chosen. The distant port is positioned subcutaneously at the mid or posterior axillary lines or below the new inframammary fold, inferior to the inner lower quadrant of the breast close to the midline, and the inner chamber is gradually filled to allow tension free closure.

In patients where tissue characteristics or individual anatomy do not enable the placement of either previously discussed devices, an empty, shaped temporary tissue expander is placed under the prepared muscle and skin envelope.

In delayed breast reconstruction settings, the same principles regarding implant choices are applied with the exception that the inframammary fold is created and enhanced when indicated. This is done by undermining the skin and fat of the upper abdomen below the future fold and over the anterior sheath of the rectus abdominis muscle (3–8 cm), advancing the tissue on to the lower pole of the breast, to allow cradling the lower pole of the implant which mimics a natural well defined fold and ptosis effect (Fig. 37.2). The flap is secured with non-absorbable sutures to the periosteum of the 5th or 6th rib at the desired height and in symmetry with the other inframammary fold.

The addition of non-irradiated abdominal sliding, skin and fat flap to the lower pole of the reconstructed breast acts as a transfer of soft vascularized tissues to the chest wall area and cradles the device for a more natural appearing breast with an enhanced inframammary fold [18].

Nipple reconstruction is usually performed at a second stage only after a satisfactory aesthetic and functional symmetry has been accomplished. Areola reconstruction is performed by color tattoo around the nipple 6–8 weeks later. In patients who required secondary procedures, such as device exchange, scar revision, enhancing the inframammary fold, adjusting the envelope or lipostructure of the upper pole of the breast, nipple reconstruction is performed at that stage whenever possible or at a third, separate procedure.

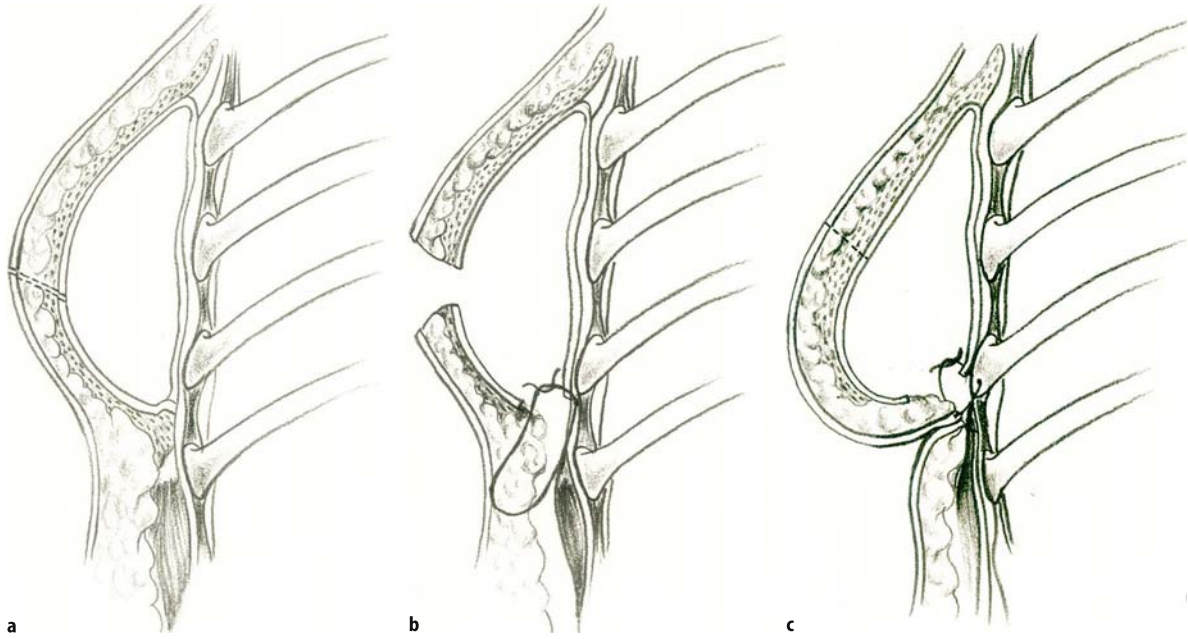

Fig. 37.2. Abdominal advancement flap to enhance the inframammary fold. By undermining the skin and fat of the upper abdomen and advancing the tissue onto the lower pole of the breast, the flap is secured with non-absorbable sutures to the periosteum of the 5th or 6th rib at the desired height and in symmetry with the other inframammary fold

37.7 Latissimus Dorsi Myocutaneous Flap Breast Reconstruction and Implant in Irradiated Patients

The latissimus dorsi myocutaneous flap was one of the first methods of breast reconstruction described [19–22]. The use of a latissimus dorsi flap has proven to be an excellent solution to postirradiation tissue contracture.

The reconstruction technique specific disadvantages are donor site scarring, seroma formation, and minute power reduction in shoulder extension and internal rotation. We have chosen this option in the subgroup of patients with moderate to severe clinical evidence of radiation sequelae as described above.

The markings are performed with the patient in the upright position. A skin island, which fits the specific needs of the patient [the largest available ellipse-shaped skin paddle (10–18×4–8 cm), allowing primary closure of the donor site with minimal tension] is marked along the posterior bra line, depending on the individual patient's morphology. The lateral corner of the skin ellipse is planned to reach the lateral border of the reconstructed breast and the medial tip of the ellipse will be shifted to the medial border of the reconstructed breast, a rotation of almost 180°. Care should be taken to measure the distance from the pivot point (muscle insertion at the intertubercular groove of the humerus), to the lateral and medial tips of the flap to allow the arc of rotation necessary for the particular patient.

Improved aesthetics are achieved when the latissimus skin island is placed in the lower pole of the breast with its lower border to the inframammary fold.

The bi-pedicled skin flap that often thus results between the old mastectomy scar and the new inframammary incision must retain adequate vascularity. We try, whenever possible, to leave wide intact bridges of skin on the medial and lateral ends between the latissimus skin island and the old mastectomy scar to allow perfusion to support the random skin and fat flap. The tissues above the mastectomy scar are elevated with the pectoralis muscle attached.

In immediate reconstructive setting, mastectomy with or without axillary sampling or dissection is performed simultaneously with the latissimus flap harvest.

The specific skin sparing mastectomy incision (pattern, location, size and orientation) is planned and discussed with the general surgeon and the patient.

In specific situations, such as postlumpectomy patients, when the tumor is close to the upper pole skin or in other indications for skin resection higher on the breast, the latissimus skin island is placed at the mastectomy skin defect and not in the inframammary fold, resulting in a somewhat less desirable aesthetic outcome.

The flap dissection begins from lateral to medial to avoid inadvertent elevation of the serratus anterior muscle with the flap. The flap is dissected to or near its insertion at the humerus. Its insertion is transected only when necessary to extend the arc of rotation, while the vascular pedicle is identified and preserved.

Rarely, and only in athletes with large muscle mass of the latissimus, the motor nerve is transected in order to prevent deformity and swelling in the breast and the axilla during rest and in motion.

Sacrificing the latissimus dorsi muscle for breast reconstruction bears minimal aesthetic and functional donor site consequences for the patient.

After flap dissection, a tunnel is created at a most cephalic point (high anterior axilla) and the flap is rotated 180 degrees and forward to the mastectomy site. The skin island may fit various sizes and orientations of defects on the chest wall.

The donor site is closed in layers using deep permanent and long absorbing sutures in the subcutaneous layer. A drain is placed for up to 1 week. The patient is turned to the supine position for the insetting and shaping of the flap. The latissimus muscle is draped and fixed with absorbable sutures to the entire margins of the anteriorly prepared pocket to provide a well vascularized layer over the device.

In the immediate breast reconstruction setting, the muscle is redraped in the same manner but the skin island fits into the incision/defect created with the mastectomy.

We believe that using the latissimus dorsi myocutaneous flap along with an appropriate breast implant in irradiated patients, even with the present clinical evidence of irradiation injury, produces excellent aesthetic results in most patients and is associated with low implant related complications. This is due to the addition of well vascularized soft tissue, which improves skin texturing and adds padding; this in return helps reduce the chances of infectious complications, skin necrosis or implant extrusion.

37.8 Complications

From 1998 to 2006 we have operated on 109 women, 115 breasts, using implants. Seventy-five breasts were previously irradiated. Major complications of the "simple" implant reconstruction included periprosthetic infection leading to temporary explantation in 4% of the irradiated patients as opposed to 2.5% of the non-irradiated group. Four percent of irradiated breasts which originally had implant/expander reconstruction required a secondary transfer of a latissimus dorsi myocutaneous flap due to inadequate provision of soft tissue coverage in the first procedure [17].

Minor complications were treated conservatively and included superficial surgical wound infection and local wound dehiscence in 12% of irradiated patients and 10% in non-irradiated patients, and mild seroma in 4% versus 2.5% of patients. Surprisingly, capsular contracture rates were similar in both irradiated and non-irradiated patients. Capsule contracture occurred in 8%, with an equal degree of severity according to the Baker classification. Fifty breasts were reconstructed using a latissimus dorsi flap and an implant. Flap related complications developed in about 15% of the patients; among them donor site seroma was the most common at 12%. Visible wrinkling due to muscle atrophy was noticed in 2% of the patients; while neither flap nor skin island necrosis occurred in any of our patients. Implant related complications included capsular contracture (6%) and port dislocation (2%). The total revision rate was 6%, implant exchange rate was 3% and minor wound dehiscence appeared in 3% of the patients.

37.9 Conclusions

Since the introduction of autogenous breast reconstruction, there has been an overall trend towards reconstructing all irradiated patients without implants. While continuing to use autologous tissue in selected patients, we have found many of our irradiated patients suitable for implant reconstruction.

For women who have had radiotherapy but show no clinical signs of radiation damage and who have an adequate soft tissue envelope, we will perform a "simple" implant reconstruction choosing one of the three different devices as discussed above. For patients with moderate to severe clinical evidence of irradiation damage we choose the latissimus dorsi with an implant following the same rationale of device selection.

We will perform autogenous reconstruction in patients where there are no other options, when other options have failed, on patients with proper available tissue in the abdomen or buttocks (IGAP, SGAP), or when the patient refuses an implant reconstruction or wishes to undergo abdominoplasty combined with her breast reconstruction and realizes the magnitude of the procedure with its potential complications and recuperation period.

We have found that in well selected patients, reconstructing the breast with the latissimus dorsi myocutaneous flap combined with an implant results in a similar aesthetic result and a lower complication rate when compared to autogenous reconstruction. That is the reason for the clear and steady shift in our practice from autogenous to the latissimus dorsi myocutaneous flap and an implant breast reconstruction in irradiated patients.

Our experience with implant reconstructions in irradiated patients following the selection process discussed above yields a high aesthetic and functional result with no significant increase in complication rate or morbidity.

In contrast to previous reports, implant reconstruction plays an important role in postirradiation patients including those with clinical evidence of radiation damage.

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38 Advanced Oncoplastic Breast Surgery: Evolution of Surgical Strategies

A. Mendonça Munhoz, R. Gemperli, M. Castro Ferreira

38.1 Introduction

Modern breast-conserving surgery is firmly established as a safe option for most women with early breast cancer [11, 13]. The standard treatment is to accomplish a satisfactory aesthetic result with minimal postoperative complications [1, 3–7].

Recently, increasing attention has been focused on immediate reconstructive procedures [1, 3–9, 14]. This modern concept, usually termed "oncoplastic surgery," is mostly applicable in the surgical treatment of malignant diseases [1, 6]. Fundamentally, by means of customized plastic surgery techniques the surgeon ensures that oncologic principles are not jeopardized while meeting the needs of the patient from an aesthetic point of view. Thus, the challenge for the surgeon is to perform a resection wide enough to provide the most favorable oncologic control but not to remove so much breast tissue as to leave a deformed breast. Conceptually, the oncoplastic concept integrates the surgical techniques of plastic surgery and surgical oncology. Additionally, in some circumstances oncoplastic techniques allow a more radical tumor excision, which potentially reduces margin involvement. The capacity to remove a wider margin may be significant in certain groups of patients such as those with ductal carcinoma in situ and larger tumors that would usually be treated by radical surgery [1]. Several important basic points are crucial to obtaining a pleasing outcome: the right surgery to resect the cancer, immediate reconstruction using the appropriate technique, and management of the contralateral breast. All of these require careful planning with respect to the correct undermining and placement of the incisions [6]. Despite this appropriate management, the aesthetic outcome depends on various factors, including the size and location of the defect and the size of the original breast [1, 3–6]. Additionally, there is common agreement that the surgical deformities are best treated immediately following tumor resection. This is because it is more complicated to correct soft tissue deformities, particularly after radiotherapy [4, 8, 14]. In essence, oncoplastic surgery refers to a number of techniques by which tumors of breast are removed while the remaining tissue or local/distant tissues are transposed to achieve a satisfactory aesthetic outcome. The oncoplastic techniques include:

- Simple volume displacement
- Reduction mammaplasty techniques
- Replacement of tissue by local flaps
- Replacement of tissue by distant flaps

To date, there is no consensus concerning the best procedure for conservative breast reconstructive surgery. The main advantages of the technique should include reproducibility and low interference with the oncologic treatment. Probably, these goals are not achievable by any single procedure and each technique has its advantages and limitations [6].

38.2 Simple Volume Displacement

A range of methods of parenchymal displacement techniques have been described [1, 2, 9, 12]. Basically, all techniques are based on advancement, rotation or transposition of an area of breast tissue to fill the defect. In its simplest form this may involve mobilizing the parenchymal tissue from the area around the excision up to whole breast plate mobilization. Simple reshaping is performed by widely undermining nearby skin and the breast gland off the chest wall. The breast defect is then closed, full thickness, by peeling the remaining breast gland off the pectoralis muscle, and then shifting together by advancing the breast over the

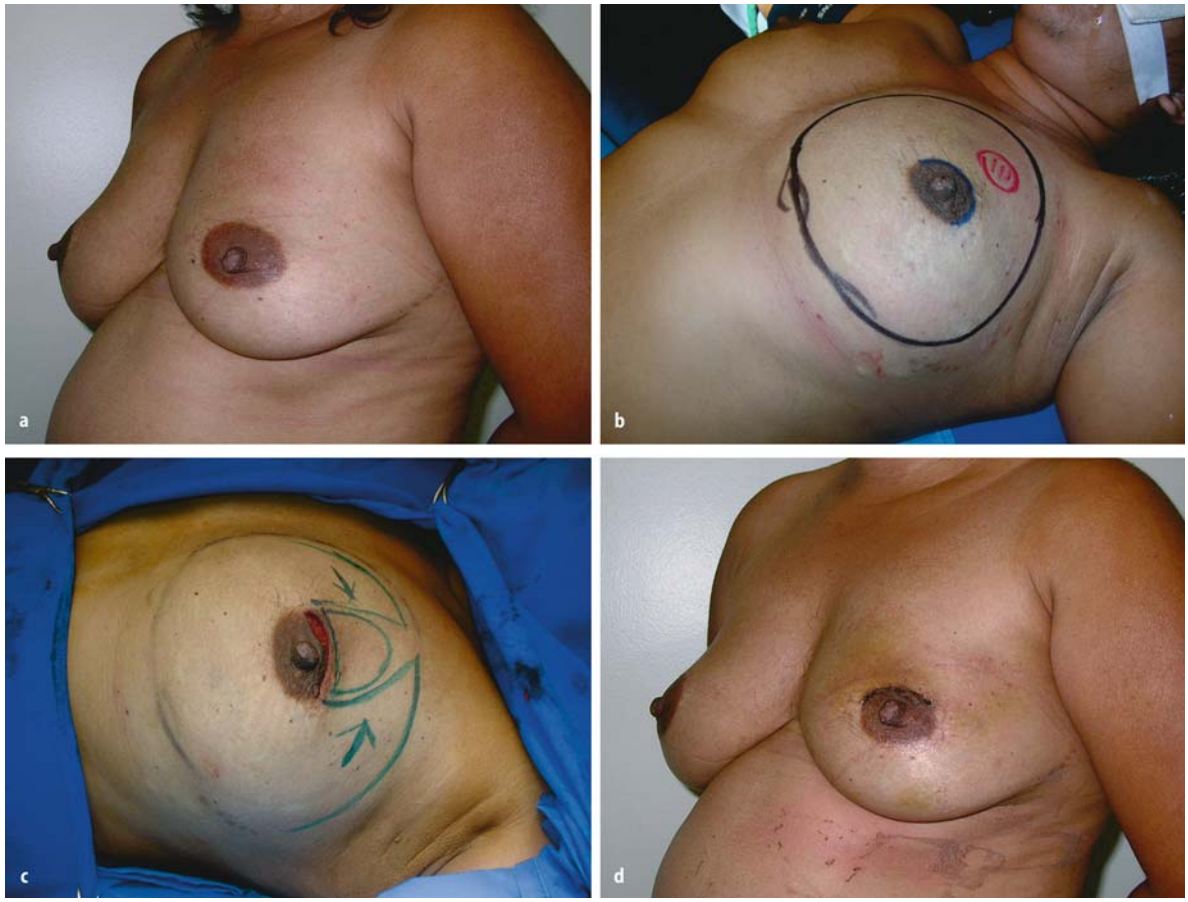

Fig. 38.1a–d. A 37-year-old patient with 0.5 cm invasive ductal carcinoma of the left breast (**a**). The reconstructive markings show tumor location (**b**). The patient underwent a left superior quadrantectomy followed by local glandular flap advancement; a total of 85 g was removed from the left breast (**c**). Two months postoperative appearance with a good outcome (**d**)

muscle. The remaining breast gland heals with a long-term cosmetic outcome that is an improvement over that observed with traditional conservative breast surgery with primary closure (Fig. 38.1).

38.3 Reduction Mammaplasty Techniques

Although satisfactory results may be achieved with all techniques, reduction mammaplasty leads to better overall results in patients with previous macromastia [4]. In larger breasts, it is possible to perform a remodeling mammaplasty using customized reduction techniques immediately following tumor excision. However, this approach frequently requires surgery to the opposite breast to achieve an acceptable symmetry. Despite this fact, the bilateral procedure presents a positive aspect once it allows us to examine the contralateral breast tissue for occult breast lesions [4, 10]. In addition, in patients with large breasts the postoperative radiotherapy may be ineffective since dose homogeneity is far more difficult to achieve. In these cases, radiation fibrosis, prolonged pigmentation and a poor cosmetic result are often related [4, 8, 14]. The mammaplasty technique is best indicated in patients with large volume breasts. This includes patients with small or moderate breast defects where there is enough breast tissue to perform the reconstruction [4, 14]. According to the breast volume, presence of ptosis and tumor size/location, we can choose the appropriate technique for each case. In previous reports [1, 4, 7, 8, 14], there has been no consensus regarding the best mammaplasty technique. Each presents particular advantages for their indications, tumor location limitations, vascular pedicle, additional skin and glandular resections due to compromised margins, and resultant scar [4]. Because of rich breast tissue vascularization, the majority of techniques have based their planning on preserving the pedicle of the nipple-areolar complex (NAC) after tumor removal. Thus, the location of the pedicle may be superior, inferior, or mixed and usually results in an in-

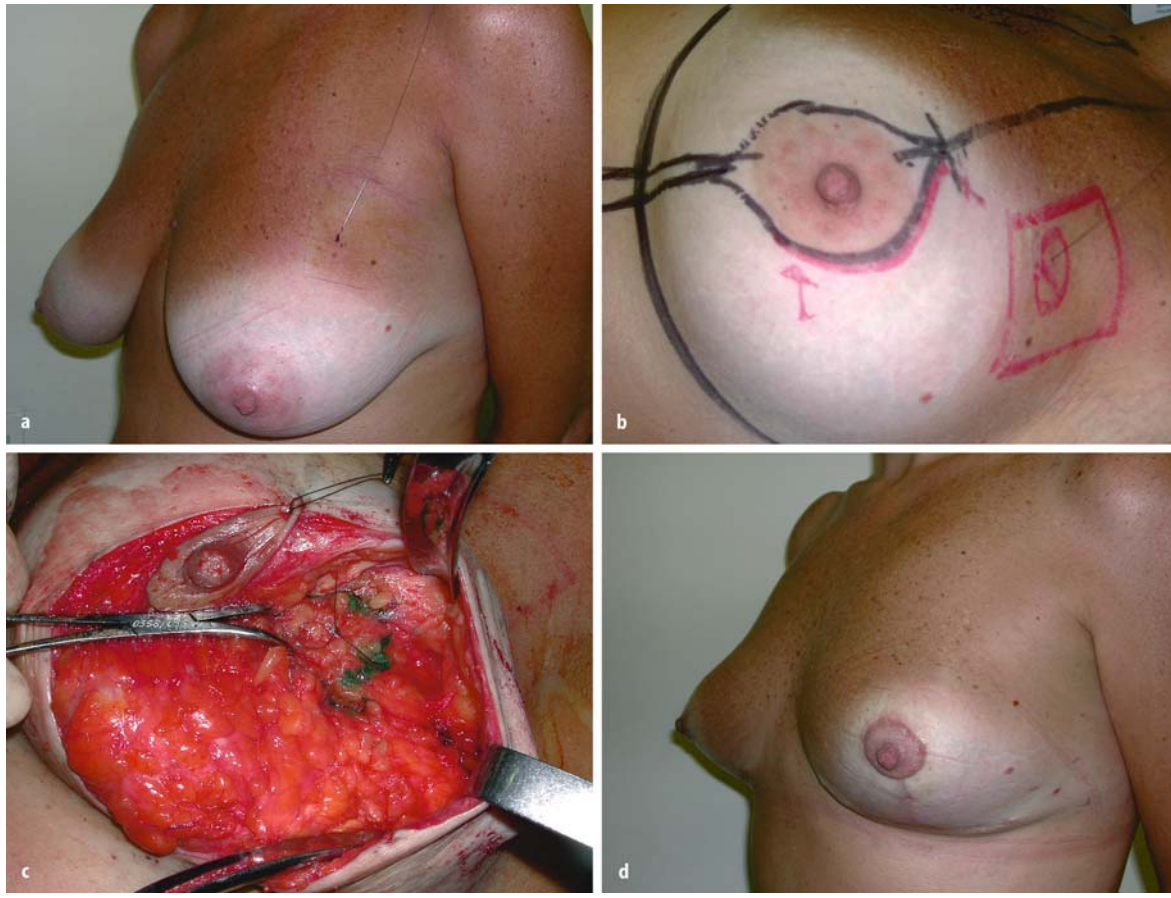

Fig. 38.2a–d. A 42-year-old patient with 0.8 cm invasive ductal carcinoma of left breast (**a**). The reconstructive markings show tumor location and superior pedicle reduction mammaplasty technique (**b**). The patient underwent a left superior-lateral quadrantectomy followed by a reduction mammaplasty reconstruction; a total of 115 g was removed from the left breast (**c**). Four months postoperative appearance with a good outcome (**d**)

verted T scar pattern. Despite the main advantages, reduction mammaplasty presents some limitations once the techniques involve a rearrangement of glandular tissue and make reexcision difficult [4, 7]. This aspect is important in the situation where positive margins are observed. For this reason, coordinated planning with the oncologic surgeon and radiologist is crucial. Likewise it is important to identify the glandular specimen and also to place surgical clips at the tumor margins before the reduction mammaplasty is performed [4, 7] (Fig. 38.2).

38.4 Replacement of Tissue by Local Flaps

Volume displacement and reduction mammaplasty are suitable only when enough breast tissue remains [4]. If there was not sufficient tissue, another option would be to introduce adjacent tissue into the defect [1, 3, 5]. This can be in the form of a flap from the lateral thorax. In terms of aesthetic results and surgical morbidity, local flaps have some advantages. The skin texture and color are similar, the technique is simpler, and the patient has a shorter recovery period [5]. Basically, all techniques employed a rotation or transposition flap of skin and subaxillary fat into the breast defect [2, 5]. According to the defect location, the pedicle flap may be based superiorly or inferiorly and with the axis located dorsal to extensions of the submammary fold. In spite of its main benefits, the technique has some disadvantages. Since the flap is not an axial flap, flap vascularization to the most distant parts is difficult to predict. This situation can predispose to partial necrosis [5]. Thus, it is prudent to evaluate dermal bleeding in the tip of the flap and shorten it if necessary. In comparison to other oncoplastic techniques, lateral flaps have positive aspects once the technique does not alter the normal architecture of the breast and the original tumor site location [5] (Fig. 38.3).

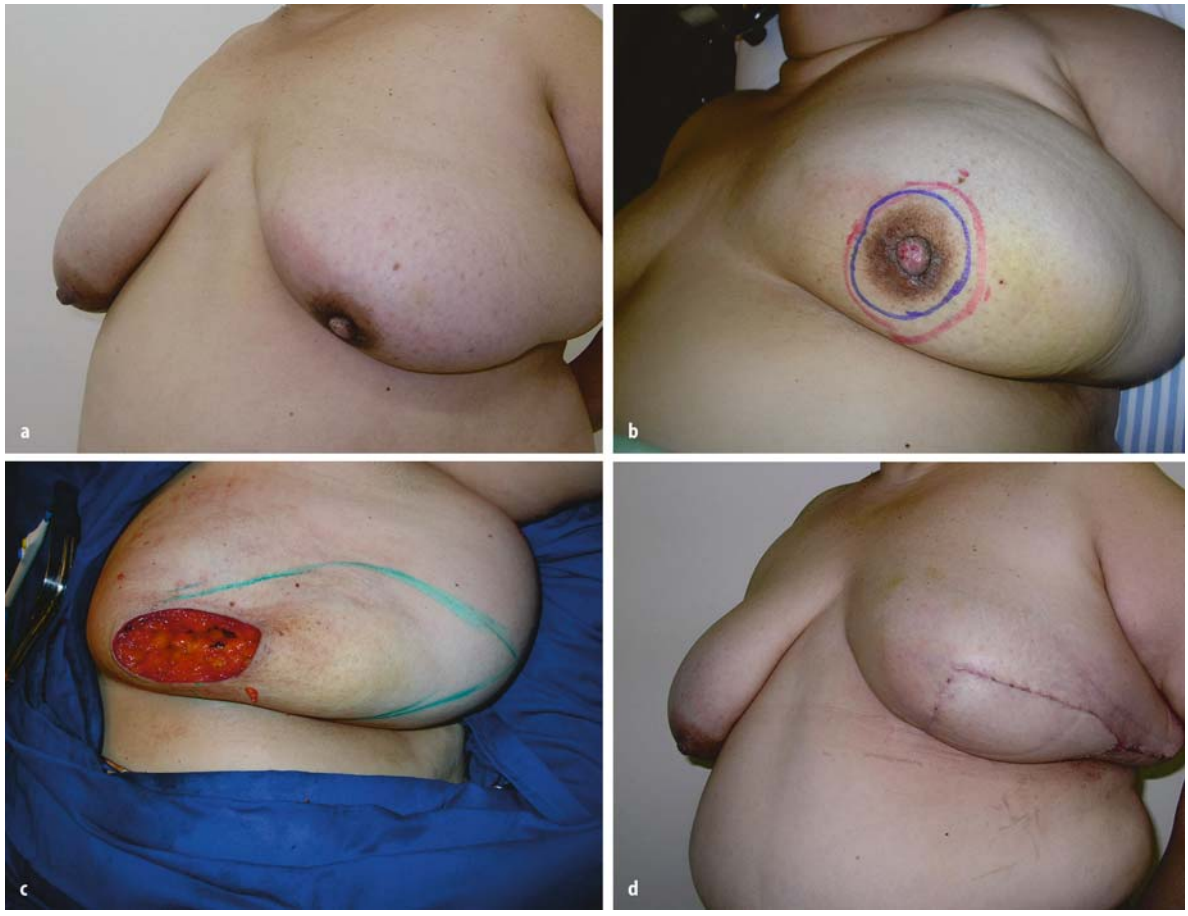

Fig. 38.3a–d. A 51-year-old patient with 2.1 cm invasive ductal carcinoma of left breast (**a**). The reconstructive markings show tumor location (**b**). The patient underwent a central quadrantectomy followed by lateral flap reconstruction; a total of 195 g was removed from the left breast (**c**). Five months postoperative appearance with a good outcome (**d**)

38.5 Replacement of Tissue by Distant Flaps

Replacement of breast tissue by distant flaps is indicated only for severe defects where there is not enough breast tissue or local flaps to perform the reconstruction [1, 3, 5]. Basically, the most common use of these techniques has been in patients who underwent an extensive tissue resection. These include patients with small or medium volume breasts and severe medial defects [3, 5]. Of the main techniques, we can mention the latissimus dorsi myocutaneous flap, the TRAM (transverse rectus abdominis myocutaneous) flap and the perforator flaps. The latissimus can include muscle, fat and skin, depending on the defect to be reconstructed [3]. Usually, the skin island is drawn into a horizontal position and the width of the paddle is measured according to the skin previously resected. The inferior and superior flap extensions are subjectively estimated to match the volume of glandular tissue removed [3, 9].

For the TRAM flap the transversely oriented elliptical skin island is usually based over the rectus opposite the side of the breast surgery, and low on the abdomen to camouflage the scar. Potential limitations are related to the muscle resection and donor site morbidity [15].

Distant flaps can also be achieved by harvesting only the skin and fat overlying a muscle. Defined by perforator flaps, it is possible to dissect out the main perforator and leave the surrounding muscle undamaged. The advantages of preserving the muscular tissue include a quicker recovery time and a reduction of the risk of muscular weakness. Disadvantages of perforator flaps include the fact that they are more technically demanding. The most commonly used perforator flaps include the DIEP (deep inferior epigastric perforator) and TAP (thoracodorsal perforator flap) [15]. Although the abdominal flaps (TRAM and DIEP) are a reliable procedure for qualified surgeons, patient selection is critical to avoid complications. Once the abdominal flap is indicated, it is reasonable to perform a complete resection of the breast tissue such as a skin-sparing mastec-

tomy and total reconstruction. The breast can be easier to shape and the radiotherapy can be avoided, resulting in a more favorable outcome.

38.6 Future Perspectives

Successful breast cancer treatment demands a collaborative team approach, requiring dynamic communication between a diverse group of specialists. In fact, a careful preoperative assessment helps to establish a comprehensive surgical plan that will achieve better results [6]. In this multidisciplinary field, oncoplastic surgery has begun to grow as a new subspecialty. As more surgeons adopt the oncoplastic concept, more techniques will be developed, advancing the subspecialty of breast surgical oncology. Modern concepts indicate that plastic surgery techniques should be integrated with the primary oncological operation, thereby reducing unsatisfactory results, patient dissatisfaction and the need for delayed secondary procedures.

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The Knife Marker

39

M. Costagliola

In plastic surgery, the preoperative marking is always a problem, a not very difficult one but an irritating one nevertheless. *Before the start* of the operation (preoperative phase), we can use a marker. *But when the patient is under anesthesia*, and the surgeon is in sterile dress, everything has been tried:

- Tooth picks
- Picks
- Pen nibs
- Stylets
- Brushes
- Pencils
- Tooth forceps
- And also sterile markers, which can be used once and thrown away

But I do not think anyone has found these to be very satisfactory. So the problem of finding a good marker for use during the operative phase remains to be solved.

My first idea was to use the same instrument to mark and cut. So, I transformed the the superior extremity into two parts, like a scholar's pencil. But the result was not good because it was too sharp.

My inspiration came when I saw a tailor's chalk. It is one of the tools of the trade used by tailors and dressmakers and it is used to draw lines on cloth and fabric quickly, easily and precisely. The chalk has a flat rounded shape and this shape reminded me of the flat end of a normal scalpel. And it is much easier to draw with a flat rounded object than with a pointed object.

After several trials, we came up with the model seen in Fig. 39.1: there is a tiny hole at the extremity of the

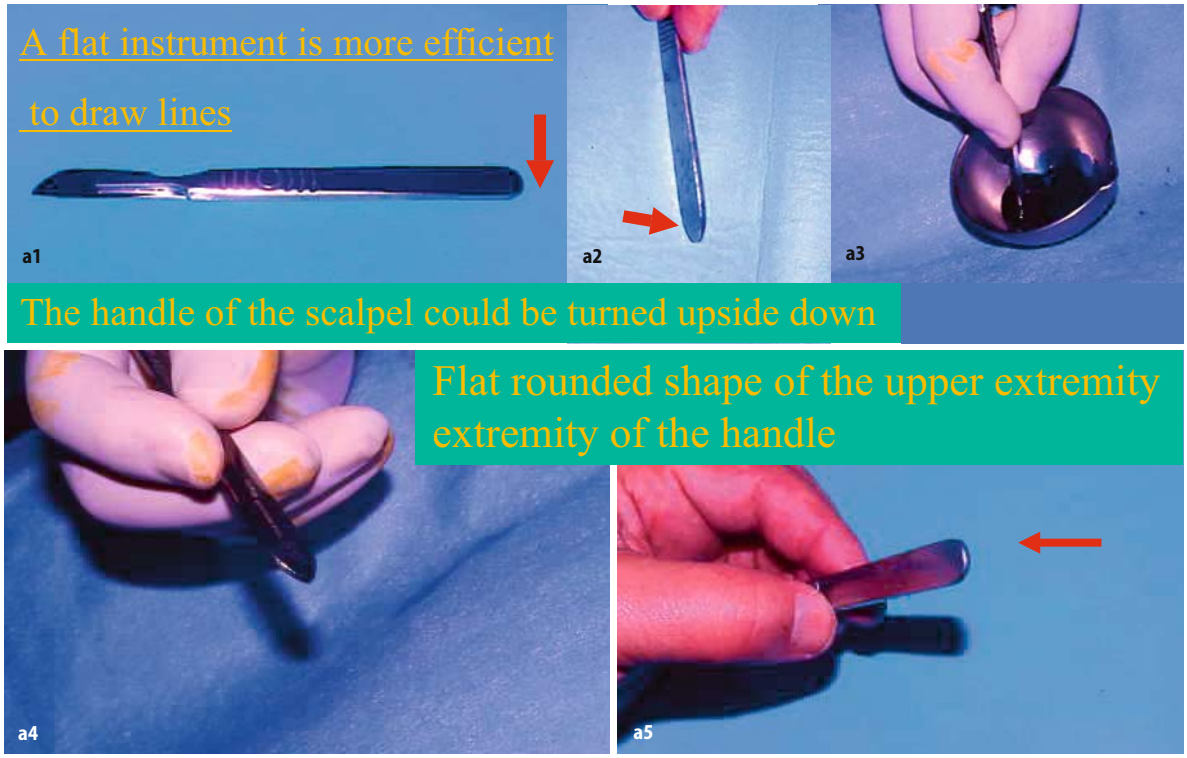

Fig. 39.1. The knife marker

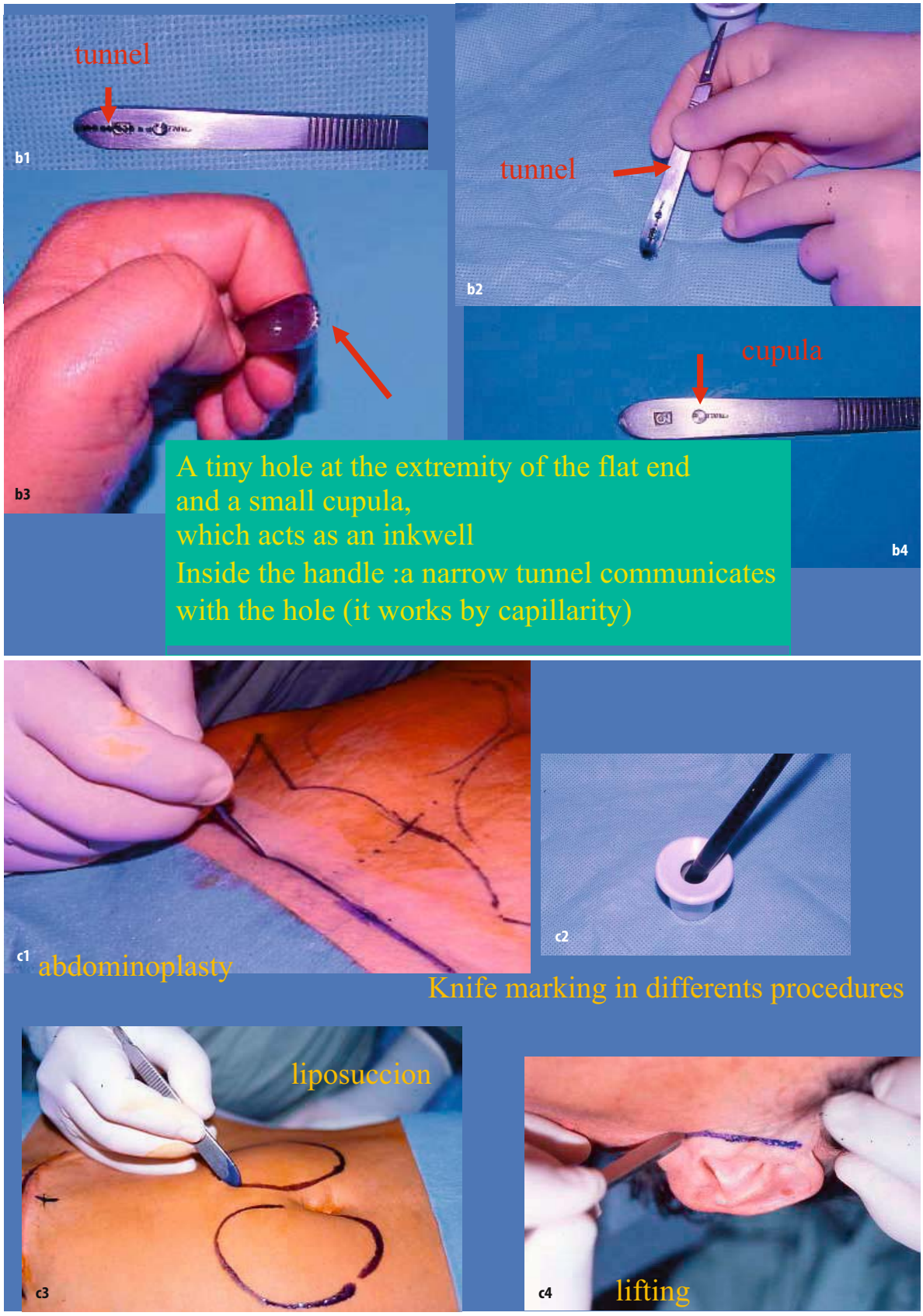
tunnel
b1
tunnel
b2
cupula
b4
b3
A tiny hole at the extremity of the flat end
and a small cupula,
which acts as an inkwell
Inside the handle :a narrow tunnel communicates
with the hole (it works by capillarity)
c1
abdominoplasty
c2
Knife marking in differents procedures
liposuccion
c3
c4
lifting

Fig. 39.1 (*Cont.*)

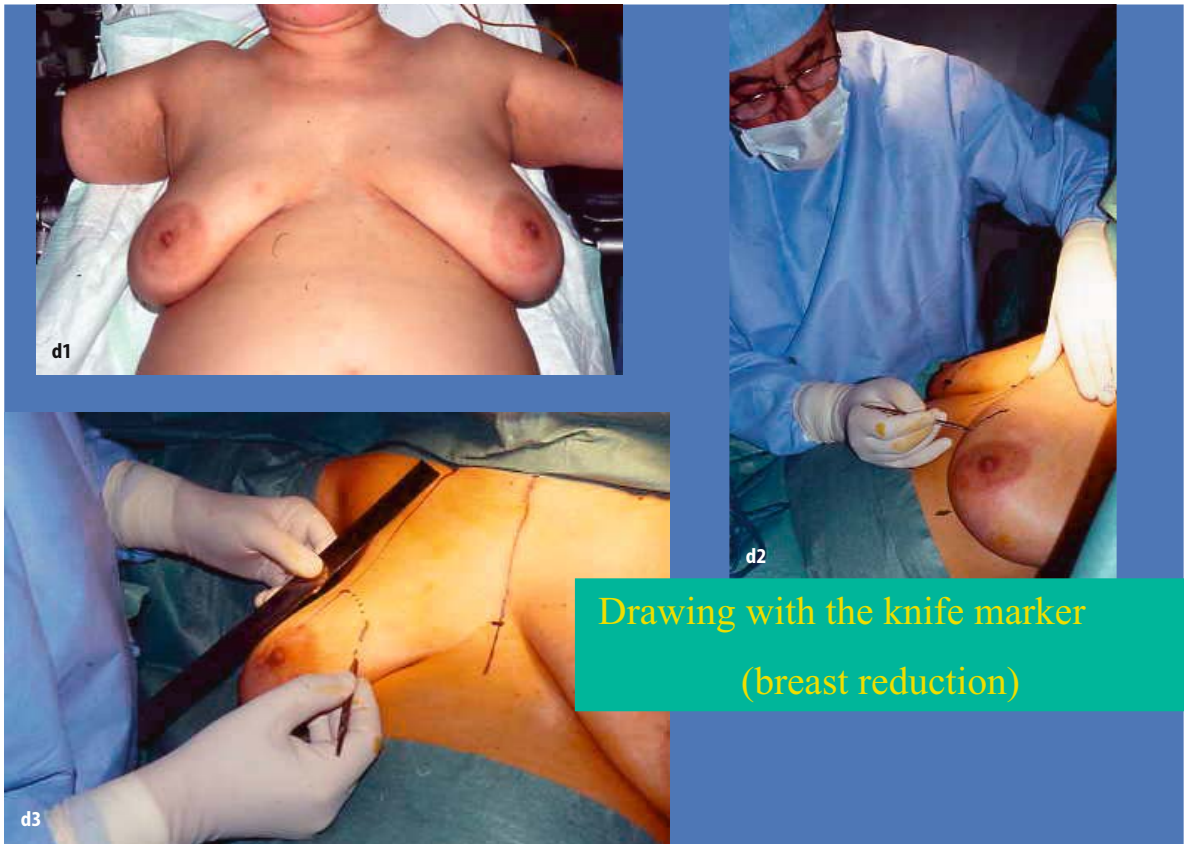

Fig. 39.1 (*Cont.*)

flat end and a narrow tunnel communicating with an inkwell (a small cupula or tank). The ink then flows by capillarity.

We therefore have a perfect "two in one" instrument: a marker combined with a scalpel: the Knife Marker. It is easy to use and to mark out the incision line or the lines of the flap, then to turn the instrument round and start cutting. The name of this device in French is "*le bistouri traceur*." This tool is not specific to breast surgery; it can be used in a variety of plastic surgery procedures.

40 Breast Reduction with Ultrasound Assisted Lipoplasty

G. Di Benedetto, A. Di Giuseppe

40.1 Introduction

Ultrasound energy can be applied to the adipose component of the breast parenchyma to reduce the volume of the breast mound in hypertrophic breasts. This technique has its main application in patients with fibrofatty and fatty breast parenchyma who are accurately selected before breast reduction and fixation with ultrasound-assisted lipoplasty is performed.

Ultrasound energy was initially used by Zocchi in 1988 to emulsify fat. He created a special tool consisting of an ultrasound generator, a crystal piezoelectric transducer, and a titanium probe transmitter. First applied to body fat to emulsify fat cells only, the other supporting, vascular, and connective components of the cutaneous network were spared; this technique was more recently used [1–12] in breast tissue, in both hypertrophic and ptotic breasts, to achieve breast reduction and correction of mild to medium ptosis.

The main effect of ultrasound energy is to decrease the fatty component of the breast tissue and to lift the breast, with visible scars. The advantages, disadvantages, and complications related to the procedure are discussed in detail below.

40.2 Patient Selection

The ideal candidate is the juvenile breast, in which there is normally fatty parenchyma, or the breast with

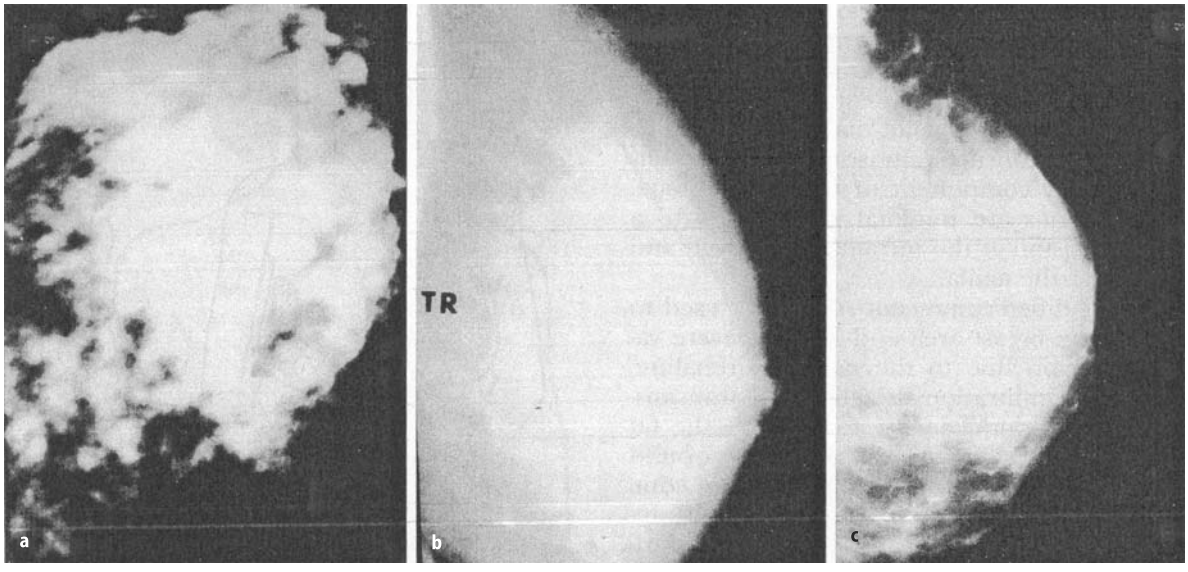

Fig. 40.1. Preoperative mammographic evaluations are used to identify candidates for ultrasound-assisted lipoplasty and breast reduction. **a** Typical fibrotic glandular tissue; this patient is not a candidate. **b** Typical fatty breast; this patient is an ideal candidate. **c** Fibro-fatty mixed gland; the patient is a candidate for lipoplasty of the posterior cone and upper and lower quadrants

postmenopausal involution breast parenchyma, both of which have good skin tone and elasticity.

The study of the patient who will undergo a breast reduction with ultrasound-assisted lipoplasty includes a mammographic study (Fig. 40.1), a breast clinical history and an evaluation of breast ptosis and the consistency of the breast parenchyma.

Each patient receives preoperative mammograms (anteroposterior and lateral views) for correct assessment of the nature and consistency of the breast tissue (fibrotic, mixed, or fatty parenchyma). The presence of fibroadenomas, calcifications, or other suspect masses on radiological images is double checked with a senologist (breast cancer specialist) and a radiologist with a high degree of competence in breast tissue resonance [13]. Patients with suspect mammograms (calcification), a history of breast cancer or mastodynia and patients who may be at risk for potential sequelae are not considered ideal candidates for the treatment.

Breast measurements are taken to assess preoperative and postoperative breast size and to determine the position of the nipple in relation to the clavicle and sternum, as follows. Breast sizers are usually used to evaluate preoperative and postoperative dimensions of the patient's brassiere (Fig. 40.2). A classic breast drawing is used to check the following preoperative and postoperative distances: from the midclavicular notch to the nipple, from the nipple to the submammary line, from the midclavicular notch to the submammary line, and from the nipple to the sternum (Fig. 40.3).

40.3 Technique

The steps for ultrasound-assisted lipoplasty are as follows [14]: (1) preoperative planning; (2) patient set-up; (3) tumescent infiltration; (4) ultrasonic treatment; (5)

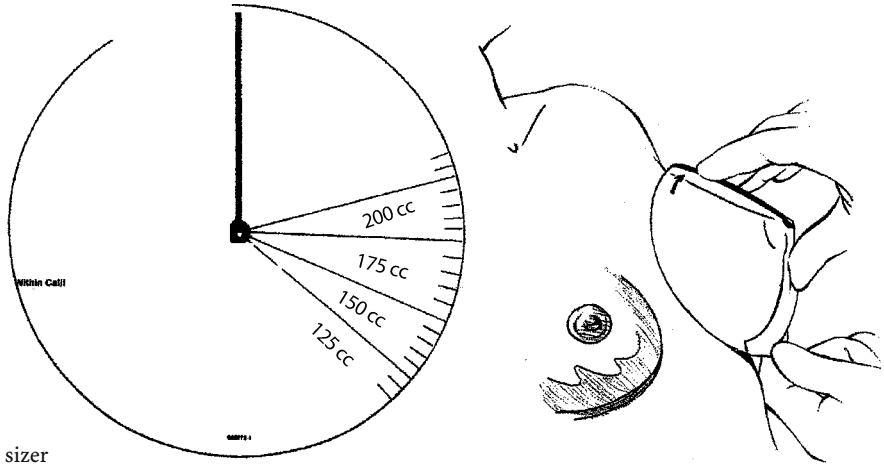

Fig. 40.2. An example of a breast sizer

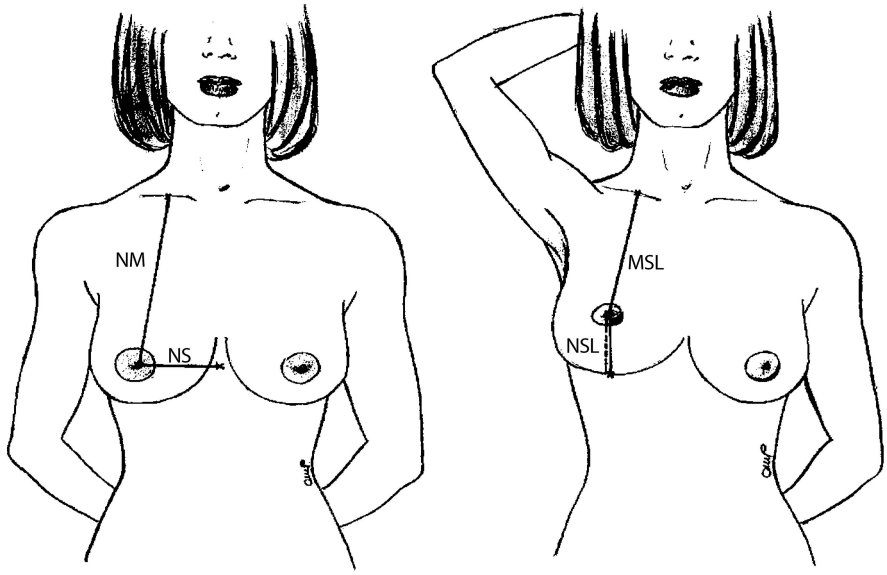

Fig. 40.3. Preoperative and postoperative measurements are taken of the following distances: *left* the distance from the midclavicular notch to the nipple (*NM*); the distance from the nipple to the sternum (*NS*); *right* the distance from the nipple to the submammary line (*NSL*); and the distance from the midclavicular notch to the submammary line (*MSL*)

suction of the emulsion; (6) manual remodeling; (7) subcutaneous stimulation with ultrasound (when required); and (8) postoperative care.

Ultrasound-assisted lipoplasty can be used as a unique method of fatty breast reduction [15] and fixation or as a temporizing measure to reduce breast volume and tighten breast skin, until a secondary operation with a less pronounced scar is feasible (such as periareolar double-skin breast mastopexy).

Often, in our experience, it is easy to obtain a mean amount of fat emulsion of 500 cc from each breast, after infiltration of 700 cc of Klein's modified solution for tumescence, followed by energic skin stimulation of the subcutaneous tissue, to allow skin redraping.

Two stab incisions (2 cm long) are necessary to allow the titanium probe to enter; the skin is protected from friction injuries with a specially made skin protector. We prefer to place these incisions at the axillary line and 2 cm below the inframammary crease (Fig. 40.4). With these two incisions, we can easily reach all of the breast tissue, working, as usual, in a criss-cross manner.

After preoperative marking (Fig. 40.5), fatty breast tissue is emulsified in the lateral and medial compartments, in the upper quadrants, and in the inferior aspect of the periareolar area (Figs. 40.6, 40.7). All of the periareolar area (a 5-cm circular area around the nipple-areola complex) is preserved, because this is where most of the glandular tissue is localized.

The deep portion, mostly fat, can be emulsified as well to allow natural rotation of the breast, to regain the natural breast shape, and to increase the elevation of the breast from its initial position, taken from the midclavicular notch (Fig. 40.7, left). Up to 4 cm of breast elevation can be obtained, after proper reduction and stimulation, to allow skin retraction and correction of the ptosis.

Routinely, a standard, 35-cm-long titanium probe is utilized. This probe has a diameter that tapers from 5.1 mm in the proximal portion to 4 mm in the distal portion.

The amount of breast tissue reduced is determined using the emulsified breast fat (including the tumescent solution infiltrated at the beginning of the procedure). The amount of aspirate ranges from a minimum of 300 ml for breasts undergoing mild reduction and

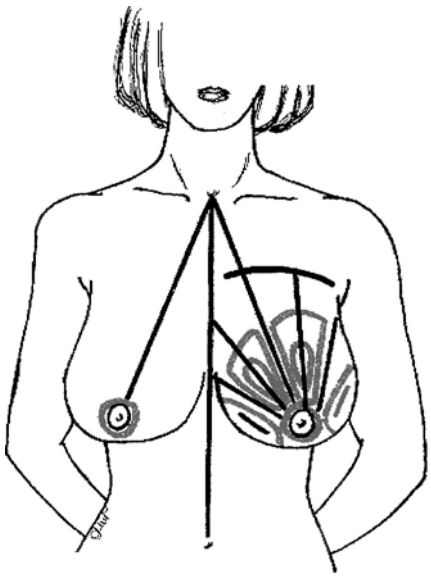

Fig. 40.5. During preoperative planning, a 5-cm-diameter circle is made around the areola to indicate the area that will not be operated on. *Straight lines* indicate lines of subcutaneous skin stimulation. The *rounded lines* indicate areas of thicker breast tissue

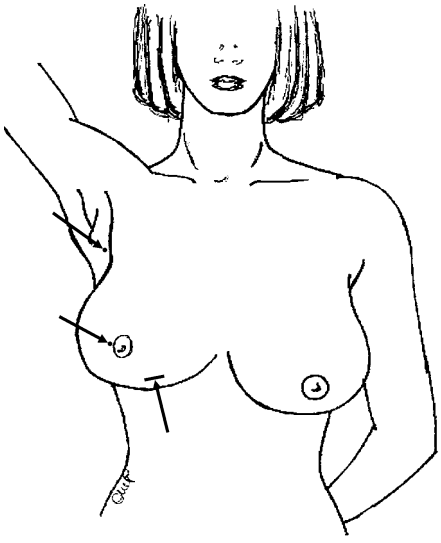

Fig. 40.4. The *incision lines* are shown at the axilla, the submammary fold, and the periareolar area

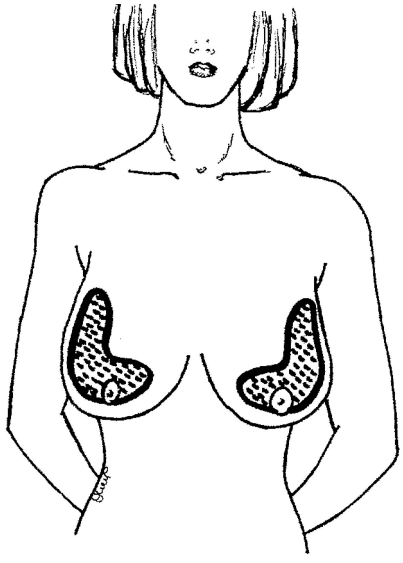

Fig. 40.6. Distribution of glandular tissue in the breast cone

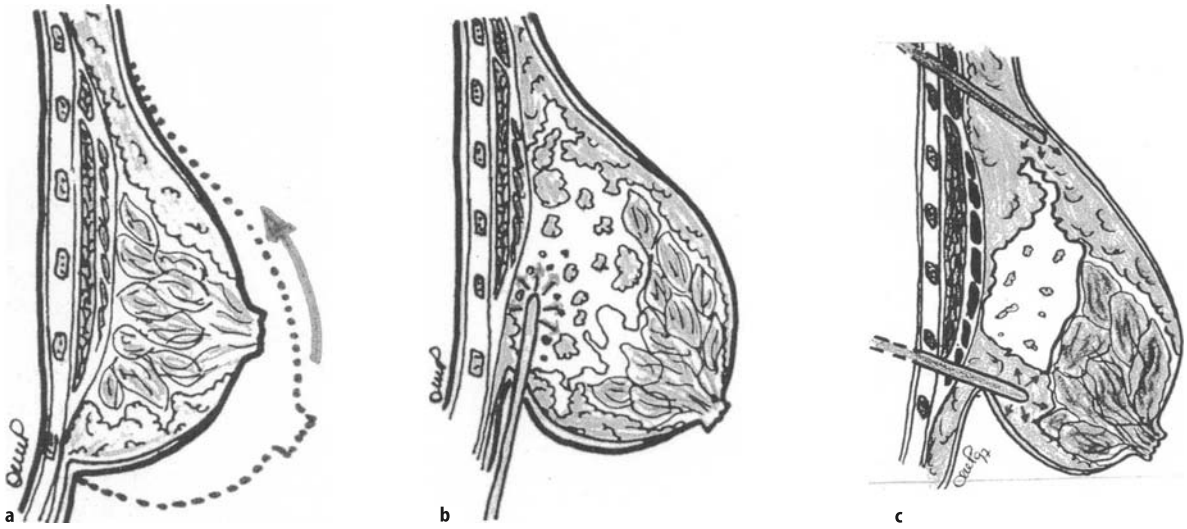

Fig. 40.7. a When the lower pole is thinned, the cone naturally rotates upward. **b** The titanium probe is used to emulsify fat at the lower breast pole. **c** When used to emulsify the subdermal layer of fat close to the skin, the probe stimulates skin retraction

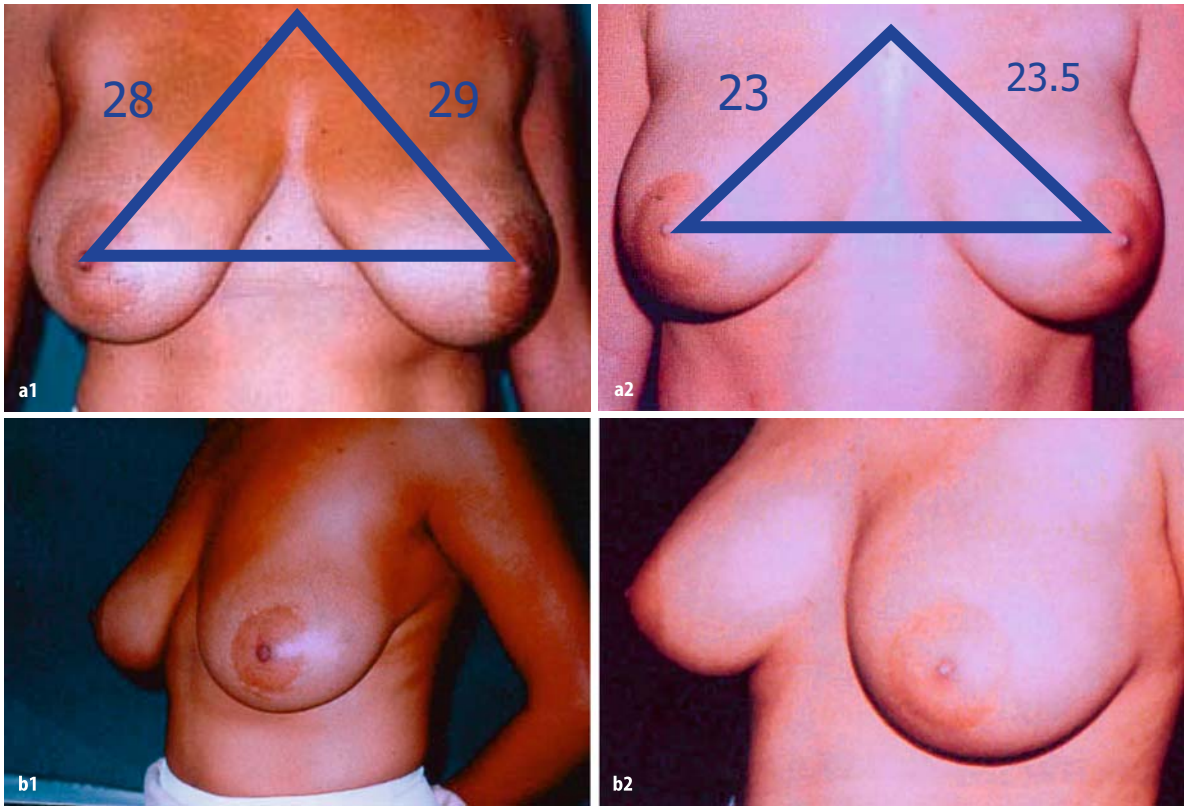

Fig. 40.8. a A 32-year-old patient with moderate breast hypertrophy and third-degree ptosis. **a1** Preoperative frontal view. **a2** Six-month postoperative frontal view: 700 ml was aspirated from each breast, and the nipple-areola complex was elevated 5 cm on the right side and 4.5 cm on the left side. **b** Same patient as before: **b1** preoperative oblique view; **b2** 6-month postoperative oblique view

breast lift to a maximum of 1,200 ml from each breast for large breasts.

Postoperative mammograms are obtained at 1 year and 3 years after the operation. Evaluation of the clinical and radiological results is supervised by a senologist. Particular care is given to the evaluation of breast calcifications and to the long-term evolution of postoperative fibrosis [13].

The duration of the procedure and the amount of energy required to liquefy the excess fat may vary depending on the characteristics of the tissue encountered, the volume of the planned reduction, and the type of breast tissue. Purely fatty breast tissue is easier to treat than mixed glandular tissue, in which fat cells are smaller, stronger, and more dense. Treatment of the target tissues starts with 10 – 15 min of ultrasound energy in fat tissue, which usually produces between 250 and 300 ml of emulsion. The surgical planes, with good criss-cross tunneling and adequate undermining, are routinely followed, as planned in the preoperative drawings. Then the deeper planes are reached, and more time is needed in thicker areas. The infiltration of the tumescent solution in the breast area precedes the application of ultrasound; between 500 and 1,000 ml of solution is needed to obtain good tumescence of the region (Fig. 40.7, center and right).

If the procedure is performed while the patient is under general anesthesia, the typical Klein formulation can be changed slightly. The amount of lidocaine can be reduced to 200 mg in 1 l of solution for postoperative analgesia, or the anesthetic can be completely eliminated if the anesthesiologist prefers standard analgesics in the postoperative period.

Suction drainage is routinely used in the breast for at least 24 – 48 h. Elastic compression support (Topifoam; Inamed, Santa Barbara, CA) is applied for 7 – 10 days, and a brassiere completes the dressing. The dressing helps support the breast and the skin redraping in the immediate postoperative period.

Results are visible immediately after the operation. The skin envelope redrapes nicely and contours the new breast shape and mound. The skin appears soft and pliable; the treated breast tissue also is soft. The elevation of the nipple-areola complex, as a result of the skin contraction and the rotation of the breast mound, is immediately visible. The greatest amount of postoperative elevation of the nipple-areola complex was up to 5 cm (Figs. 40.8, 40.9).

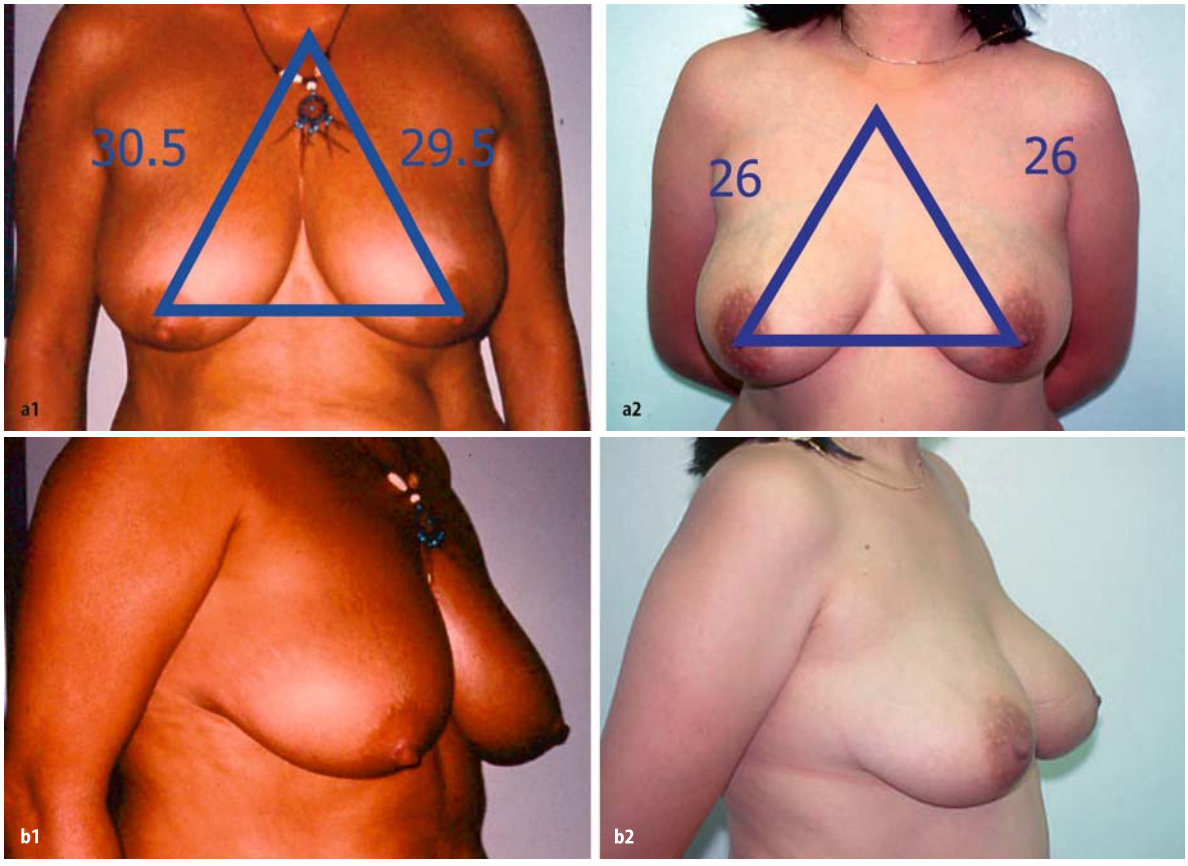

Fig. 40.9. a A 43-year-old patient with severe breast hypertrophy and fourth-degree ptosis: **a1** preoperative frontal view; **a2** 6-month postoperative frontal view; 900 ml was aspirated from each breast, and the nipple-areola complex was elevated 4.5 cm on the right side and 3.5 cm on the left side. **b** Same patient as before: **b1** preoperative oblique view; **b2** 6-month postoperative oblique view

40.4 Discussion

The ideal candidates for a breast reduction with ultrasound-assisted lipoplasty are patients with juvenile breast and patients with fatty or fibro-fatty breast with good skin tone and elasticity.

Preoperative evaluation of the patient is mandatory, including a mammographic study, a breast clinical history, and an evaluation of breast ptosis and the consistency of the breast parenchyma.

Breast reduction with ultrasound-assisted lipoplasty consists of progressive emulsification through the use of a solid titanium probe cannula, which transmits ultrasonic energy to target the fatty component of the breast tissue. Skin incisions are minimal and limited to a 1.5-cm incision at the inframammary fold and another at the axilla.

The modified tumescent solution is used to distend the breast area and induce severe vasoconstriction due to the use of adrenaline. Tumescent infiltration also allows the transmission of ultrasound energy to emulsify the fat cells. Normally, 20 – 30 min of ultrasound application, while preserving the central cone of the breast, including the nipple-areola complex, is enough to reduce the breast brassiere volume by two sizes. Ten minutes of ultrasound can produce 300/500 ml of pure fat emulsification, depending on the probe used.

Along with ultrasound-assisted lipoplasty to the fat layers, starting from the deeper layers and progressing to the more superficial ones, it is advisable to stimulate the superficial layers of the subcutaneous tissue of the upper and lower quadrants using a different angle pattern, as in a standard liposuction. This superficial stimulation with low-frequency ultrasound energy helps enhance the retraction of the breast skin and helps redrape the breast skin to the newly shaped and reduced mammary cone. The fibrosis that follows the dermic insult caused by the passage of the ultrasound probe is probably responsible for the great skin retraction that normally follows and contributes to correct breast ptosis. Up to 5 cm of nipple elevation is possible, if there is great volume reduction along with good stimulation of the subcutaneous layer of the entire area.

A large series of patients with mild to severe hypertrophy and ptosis have been treated in the last 7 years.

In the patients treated, no evidence of calcifications [16] caused by the surgical procedure was found at the 7-year follow-up. Essentially, increased fibrosis of the breast tissue was noticed in postoperative mammograms and is believed to be responsible for the new consistency, texture, and tone of the breasts and, according to the clinical results, the lift of the breast.

Ultrasonic energy can be used safely to emulsify fatty breast tissue and to reduce the total volume of hypertrophic breasts in selected patients [17, 18]. The ideal candidate is the juvenile breast, which normally results in fatty parenchyma, or the breast with postmenopausal involution parenchyma, both of which have good skin tone and elasticity. Ultrasound energy applied to fatty tissue has already been shown to be a selective technique [19]. The energy generated by the ultrasound device, and converted through a piezoelectric crystal transmitter, is administered through a solid titanium probe at different frequencies, depending on the thickness of the targeted tissue.

Fat is easily liquefied when a water-based solution is added to increase the fragility of the cell's adiposity. During the operation, along with general anesthesia or intravenous sedation, we use a wetting solution that is a variation of the well-known Klein tumescent solution.

The solution is composed of 1,000 ml of Ringer lactate and 1 ml (or one ampule) of pure adrenaline. No bicarbonate or lidocaine is used when breast reduction with ultrasound-assisted lipoplasty is performed with the patient under general anesthesia or intravenous sedation. If the operation is performed with the patient under local anesthesia, the modified Klein solution is prepared (1,000 ml of Ringer lactate, 0.75 – 1 g of lidocaine, and 1 ml of pure adrenaline) [20, 21].

Ultrasound-assisted lipoplasty in breast surgery is a relatively young chapter of this new technology. Zocchi [2 – 7] and Goes [1] pioneered the use of the ultrasound probe to dissolve and emulsify the fatty component of breast tissue. However, in the past, liposuction was first used by several authors as an adjunctive procedure in breast reduction. Since publication of the work of Illouz [22], Pitman and Teimourian [23], and Lejour [24, 25], many authors have suggested that liposuction could have a significant role in breast contouring. Later, other authors, such as Toledo and Matsudo [26] and Grazer [27], reported the aspiration of breast fat to reduce volume. Becker [20] and Courtiss [21] reported a few cases in which breast volume reduction was accomplished using a sharp cannula to suction glandular as well as fatty tissue. Most authors have concluded that it is advisable to suction only fat from the breast and to use blunt, not sharp, cannulas, which do not penetrate the parenchyma.

Initially, breast liposuction was used as a temporary measure in juvenile, fatty, hypertrophic breasts, until breast growth was complete and a more definitive operative procedure could be performed. More frequently, liposuction was performed to complete a standard open surgery breast reduction by defatting the axillary aspect of the breast in fatty patients. The selectivity of ultrasound-assisted lipoplasty was shown by Fischer et al. [19] and by Palmieri [28] in their studies. In addition, Scheflan and Tazi [29] introduced endoscopic evaluation of ultrasonically assisted liposculpturing.

Using an auxiliary endoscopic system and camera, they performed ultrasound-assisted lipoplasty using

criss-crossed tunnels and recorded the technique on videotape. An adjacent area was treated with standard liposuction. They compared the lipoplasty technique with standard liposuction, endoscopically assisted and monitored. Their results were as follows:

1. Standard liposuction appears to be a more aggressive technique, with mechanical destruction of the subcutaneous tissue, including the vessels, nerves, and supporting structures, despite the use of 2-mm-wide to 3-mm-wide blunt cannulas.
2. Ultrasound liposculpturing is a gentler, selective method that is aggressive only in the fatty compartments of the body; it spares the vessels, nerves, and elastic supporting fibers.

Alterations in the tissue as a result of ultrasound-assisted lipoplasty consist of a thickened dermal undersurface, markedly thickened vertical collagenous fibers, intact lymphatic vessels, and intact blood vessels. Scheflan and Tazi [29] hypothesized that the horizontal and vertical thickening and the shortening of the collagen in the dermis and ligamentous fibers are responsible for the remarkable skin tightening which follows subcutaneous stimulation with the ultrasound probe. The closer to the skin and the more complete the removal of fat from the intermediate subdermal space, the greater the skin-tightening effect. This skin-tightening effect is of great value in breast surgery, where volume reduction has to be accomplished by skin redraping and recontouring of the breast shape.

40.5 Complications

Skin necrosis can occur using an incorrect approach to the technique, mostly trying to debulk the lateral and medial breast flaps by using ultrasound.

Fat necrosis with secondary tissue induration is a typical sequela of ultrasound surgery; when it is localized in small areas, it can be treated with massage or with corticosteroid local infiltration to soften the area. Loss of sensation is generally limited to the first 3 weeks after the operation; early recovery of sensation is explained by the fact that the central cone of the breast, which is mainly composed of pure parenchyma, is not touched during the operation. Skin sensation is recovered in a few weeks time.

Hematoma is another potential complication in the area of the infiltration, due to improper use of the infiltration needle (sharp needles instead of blunt needles). Hematoma has to be evacuated by the surgeon immediately after the operation.

Mastitis, an inflammatory response in the breast parenchyma as a result of the operation, can also be a complication. The authors prefer to operate on patients only during their nonmenstrual periods; only a minor inflammation response has been noted. When encountered, it is treated immediately with oral anti-inflammatory drugs and wide-spectrum antibiotics on a 3-day cycle; the inflammation subsides rapidly.

Seroma formation is a potential complication of every breast surgery and ultrasound-assisted lipoplasty technique. Regular application of suction drainage and breast compression for several days with a brassiere and foam pads have dramatically reduced this complication to nearly none.

40.6 Conclusions

Ultrasound-assisted lipoplasty for reduction of fatty breasts and fixation has been revealed to be a safe and good technique, when applied in selected patients and performed by a surgeon with expertise in ultrasound-assisted body contouring. Long-term mammographic studies have shown no alterations to the morphology of the breast parenchyma. The typical outcome is more dense breast tissue.

The selectivity of ultrasound, which emulsifies just the fat component of the breast parenchyma, makes it a technique of caution, as it spares the glandular tissue, the vascular network of the gland, breast sensation, and the potential for breast feeding. Breast-feeding and sensitivity tests have been reported in patients who have had the operation, and no alteration has been found at 4-year follow-up [30].

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41 Vertical Mastopexy

R. Graf, D. Pace, R. Rippel, R.C. Damasio, L.R. Araujo, L.G. Neto, T. Al-Yafi, T. Biggs

41.1 Introduction

The goals of modern surgery of the breast are improved shape, symmetry, good function and sensibility and minimal visible scarring. Over 22 years of surgical practice reduction mammaplasties were initially performed with the inverted "T" technique [1, 2]; however, it was realized that, besides the long scar, the breast ended up with no projection or shape. After this period, authors started to perform oblique or "L" incisions [3–9], which eliminated the medial branch of the scar, quite often the one with the worst aesthetic quality.

Many authors [10–19] made efforts to reduce scar length by utilizing only a vertical scar that extended as far as the inframammary crease with the disadvantage of skin redundancy at the level of this crease. Periareolar incision techniques [20–22] allow resection of the skin excess; however, they do not provide a good breast shape, with moderate areolar projection, unless a mesh is fixed over the breast tissue [21, 22].

Recently, working with the philosophy of the periareolar technique associated with the vertical scar technique, it has been possible to reduce scar length, thus avoiding its elongation across the inframammary crease by compensating skin excess around the areola.

It was observed that in every single technique performed, the breast shape after descent resulted in loss of upper pole fullness. Some authors [23–25] used the inferior portion of breast tissue to fill in the upper pole or the areola to achieve a better breast shape. In addition to scar evolution, since 1994 we have been performing the chest wall based flap, which is kept under a sling of major pectoralis muscle to allow long-term maintenance of upper pole volume [7–9].

In order to obtain a better long-term outcome, it is mandatory to redefine breast shape with internal tissue, not with skin sutures, therefore avoiding exaggerated scar tension. It was demonstrated that performing the chest wall based flap under a sling of major pectoralis muscle permits maintenance of this redefinition together with liposuction to the lateral breast area to better define the lateral fold.

The concern with scar length provided the development of new techniques for breast surgery. Lassus [10, 11, 29] used the vertical technique for the first time and Lejour [12–16] described the vertical scar technique widely used among plastic surgeons. The authors observed that breast descent and loss of upper pole fullness was too common with this technique. Therefore, Ribeiro's technique was then utilized [23], which is an inferior pedicle flap, modified by Daniel [24], who associated a bipedicled flap of major pectoralis muscle to keep Ribeiro's flap in a higher position.

Since 1994, these associated flaps have been performed in an inverted "T" technique, oblique or "L" scar and recently in vertical scar mammaplasties. The approach was switched from inferior pedicle flaps to flaps based only on the thoracic wall vasculature, completely detached from the surrounding structures, keeping the overlying dermis to give better support and shape to flap fixation to the muscle sling.

The association of vertical mammaplasty with chest wall based flap and bipedicled major pectoralis flap has been performed in recent cases due to the aesthetically improved results that last in a long-term follow-up. The upper pole of the breast remains with a good volume and the vertical scar is placed above or at the level of the new inframammary crease with a minimal breast descent.

This technique is indicated in patients who need only a mastopexy, when there is no breast tissue in excess to be removed, or for breast reductions where the resection of excessive breast tissue is done from the columns or basis of the breast, after the thoracic wall flap is fixed. With this technique we realized that we remove less breast tissue compared with the other tech-

niques without the use of the thoracic flap. The average of breast tissue resected was 250 g, much less than when we used other techniques without the thoracic flap. In large hypertrophies or severe ptosis, the "D" point should be marked higher to the "M" point, by up to 4 cm. This maneuver is done to leave skin and subcutaneous tissue of the lower breast pole as part of the thoracic wall, with a higher new inframammary crease, decreasing skin compensation in the vertical scar.

The redundant skin in the vertical branch observed during surgery can be compensated with a subcuticular suture that shortens this scar. During the first 2 months of the postoperative period there is flattening of the skin with no need to remove skin horizontally in the inferior portion of this scar, as suggested by Marchac [26]. A round block suture is done around the areola with the purpose of reducing even more the length of vertical scar by compensating skin excess around the areola. We have now changed the suture in order to improve the final result of the areola scar, which gives better results in spreading the areola evenly. Taking larger bites in the skin at the outer skin circle relative to the areola compensates for the difference in the sizes of the two circles.

The goals of a vertical scar technique associated with chest wall based flap and bipedicled major pectoralis muscle flap are:

- Breast upper pole fullness with the patient in a supine position and maintenance of breast position in the standing position
- Minimal breast descent providing a better aesthetic outcome in the long-term follow-up
- Vertical scar that does not cross the new inframammary crease
- No flattening of the central position of the breast [nipple-areola complex (NAC) area] as such with the periareolar approach

41.2 Operative Approach

41.2.1 Markings

The same skin markings can be used to perform either breast reduction or mastopexy, with the only difference being during surgery where tissue removal is done when indicated. A line from the sternal notch to the xiphoid process is drawn (midline). The meridian line is drawn from the midclavicle to the NAC, crossing the inframammary crease ("M" point), which is 12 cm or more from the midline. From the midline, the "A" point is at 20 cm from the clavicle or 22 cm from the sternal notch. With a horizontal pinching maneuver, the breast is moved medially and laterally and two points ("B" and "C") are marked, using the vertical line inferior to the areola as a reference, which demonstrates the skin in excess. Using these three points as a reference, a curved line is drawn around the areola in an oval shape, similar to the periareolar technique. The medial portion of this line is, on average, 9 cm from the midline, and the lateral portion is, on average, 12 cm from the anterior axillary line. Point "D" is marked, 2–4 cm above point "M." Points "BD" and "CD" are joined together in a curved line of approximately 5–7 cm (Figs. 41.1, 41.2).

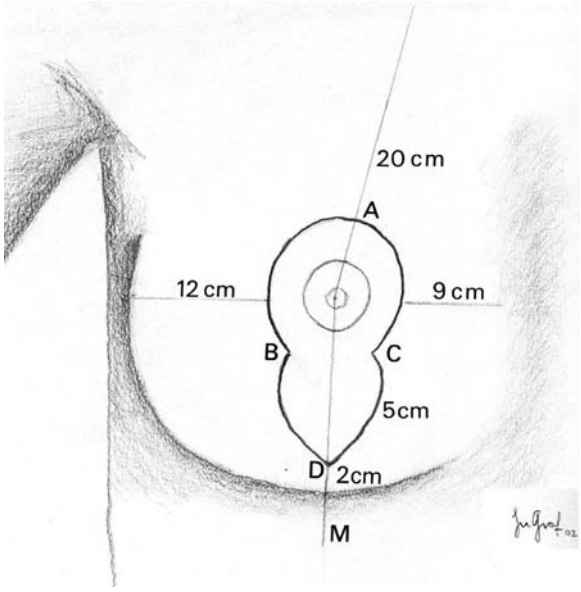

Fig. 41.1. Basic markings of vertical technique. *A* point 20 cm from the clavicle; *B* and *C* pinching maneuver points; *D* point 2 cm above the inframammary crease

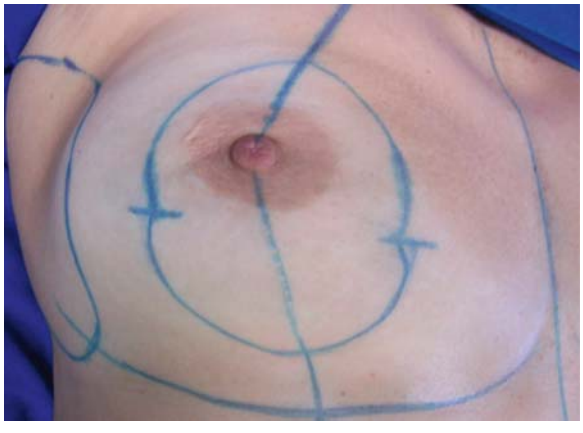

Fig. 41.2. Skin demarcation before surgery

41.3 Technique

Surgery begins with deepithelialization of the area previously described. Dermis is incised along the marked lines, up to 1.5–2 cm superior to points "B" and "C," sparing the upper portion of the areola, which is the pedicle for the NAC (Fig. 41.3).

Dermis is also incised horizontally 1 cm inferior to the areola and subcutaneous tissue is incised perpendicular to the plane of the thoracic wall, reaching the pectoral fascia at the level of the 4th intercostal space. The incision is then made obliquely in the upper portion of the flap, leaving enough tissue breast on either side (breast pillars) (Fig. 41.4). Breast tissue is undermined to the level of the second intercostal space, at the level of the pectoralis major fascia. The lower portion of the flap is dissected carefully down to the original inframammary crease, widening its base until the chest wall flap is formed, which will be based on the arteries of the 4th and 5th intercostal spaces, with approximately the following dimensions, 6–8 cm of width and 4 cm of thickness (Fig. 41.5). A 2-cm-wide bipedicled flap of major pectoralis muscle is dissected just superior to the base of the chest wall flap, using only 50 % of the muscle thickness, wide enough to accommodate the chest wall based flap with no compression at all (Figs. 41.6, 41.7). The usual width of the muscle sling is 8–10 cm. After the flap is passed under the muscle sling (Fig. 41.8), the donor area of the muscle is sutured with two separated

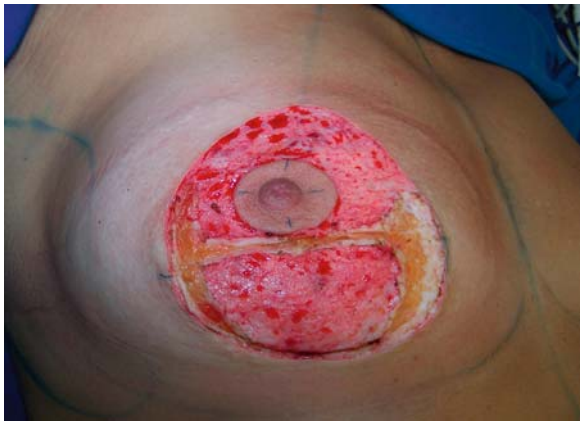

Fig. 41.3. Deepithelization and dermis incision following demarcation, up to 2 cm above points *B* and *C*

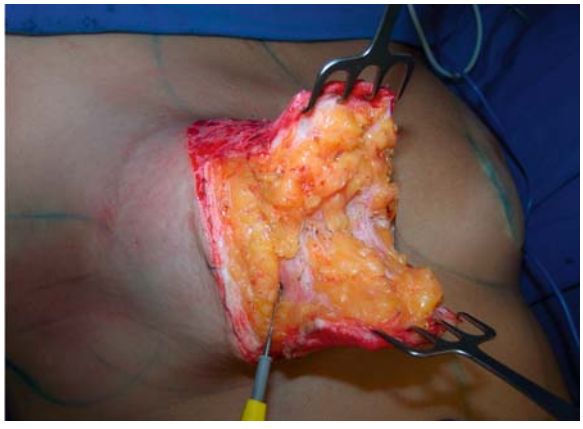

Fig. 41.4. Undermining of chest wall based flap, lateral view

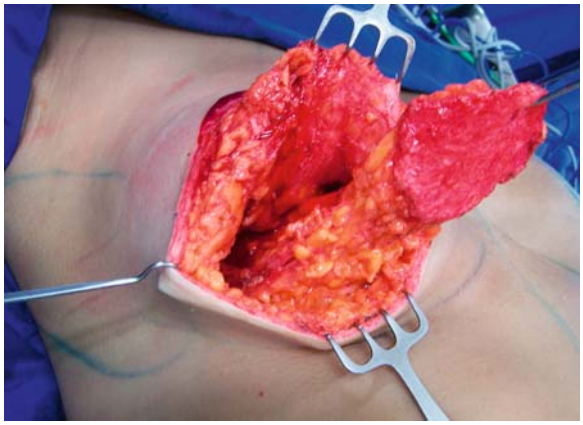

Fig. 41.5. View of chest wall based flap

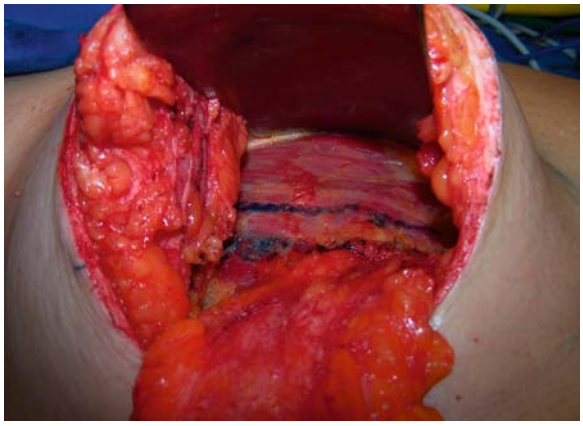

Fig. 41.6. Bipedicled muscular flap

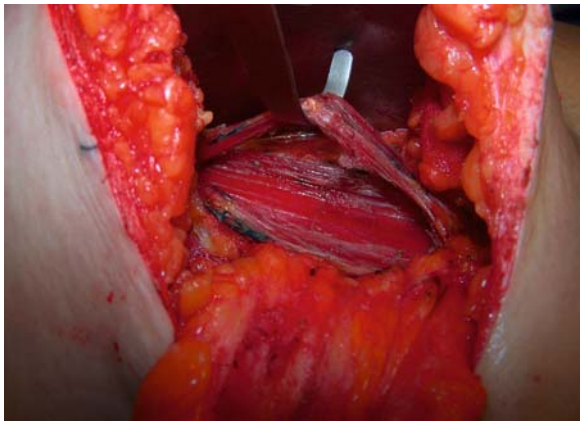

Fig. 41.7. Muscular flap elevated

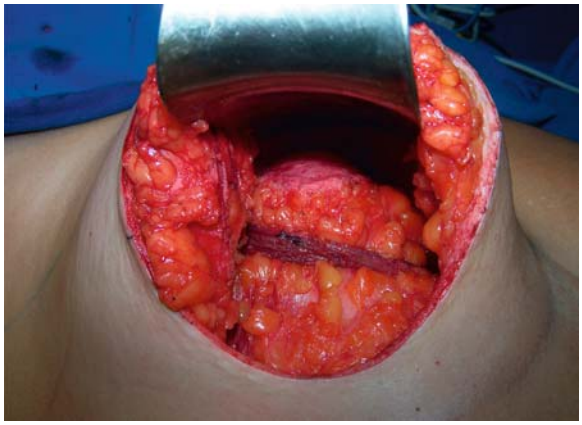

Fig. 41.8. Passage of chest wall based flap under the bipedicle muscular flap

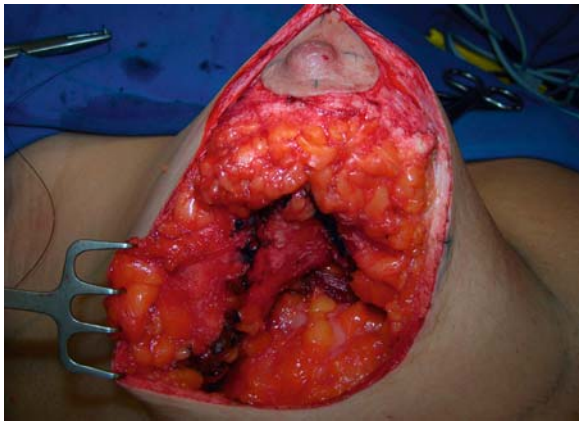

Fig. 41.9. Demarcation of glandular resection

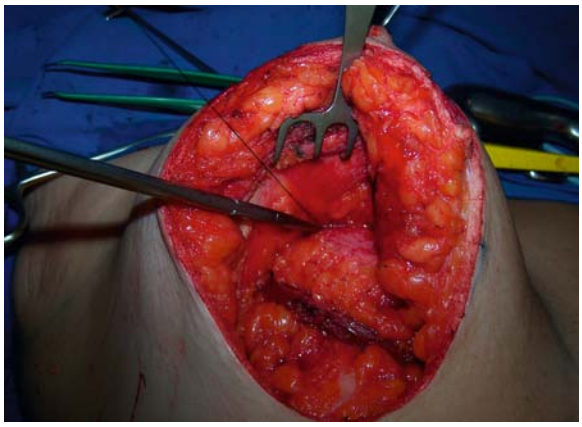

Fig. 41.10. Cranial fixation of chest wall based flap under the bipedicle muscular flap

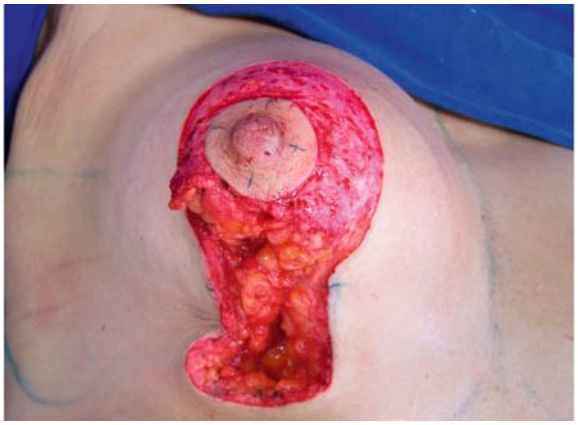

Fig. 41.11. Aspect of the breast after approximation of breast columns

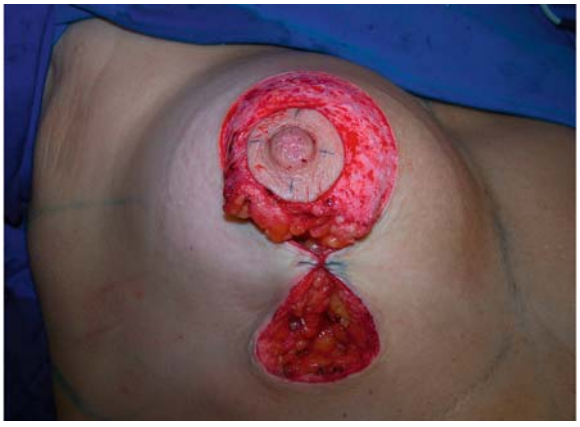

Fig. 41.12. Suture of points *B* and *C* after approximation of breast columns

sutures (2.0 nylon) followed by fixation of the thoracic flap in the thoracic wall with a continuous suture of 2.0 nylon, beginning laterally, reaching the 2nd intercostal space and finishing medially. The size of this flap is similar to a 100 – 200 g implant, so it gives volume to the upper pole of the breast. At this stage, breast tissue is excised as needed as a wedge from the lateral area and also from the superior flap of the breast to achieve the desired breast size and shape (Fig. 41.9). It is important to avoid any resection from the medial column to avoid flattening of the medial breast. The upper breast glandular tissue is sutured to the muscle plane at the 2nd intercostal space, bringing together the medial and lateral pillars to improve breast shape (Fig. 41.10). The medial and lateral pillars are sutured in an inferior to superior fashion using 2.0 nylon sutures (Fig. 41.11). Deep dermis is sutured placing together points "B" and "C" as the first suture and then the skin is sutured (Fig. 41.12). Point "D" is fixated to the deep plane so that the vertical suture is kept at the same level as the new inframammary crease. A subcuticular suture with 4.0 Monocryl is made in the vertical scar to shorten it (Fig. 41.13).

A round block suture is made in the areola to compensate the skin resected around. Another option would be suturing the outer deep dermis skin flap circle to the areola deep tissue, which is our preferred method (Figs. 41.14 – 41.17). No suction drainage is used.

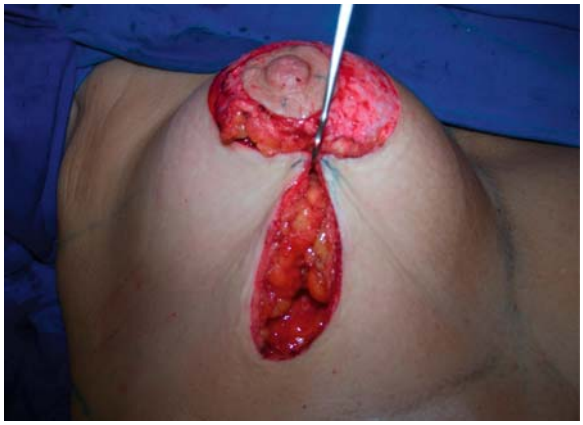

Fig. 41.13. Aspect of vertical incision after approximation suture of points *B* and *C*

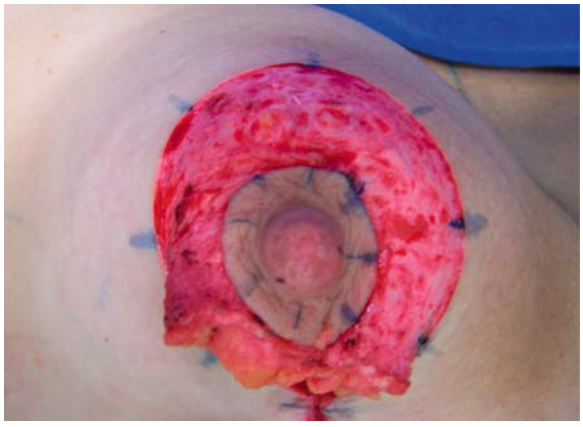

Fig. 41.14. Schematic view of areolar suture

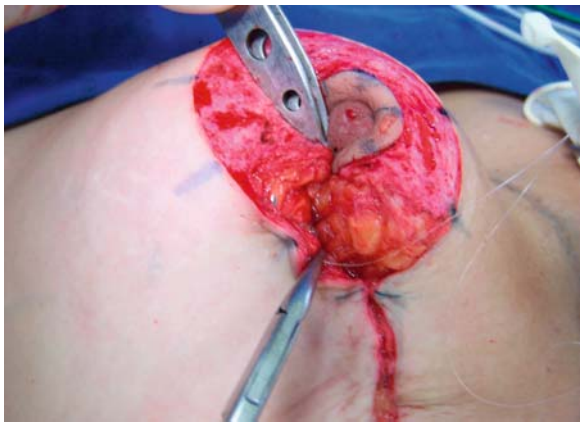

Fig. 41.15. Suture of the nipple areolar complex and dermis

41.4 Postoperative Care

It is recommended to use a bra for 1 – 2 months. Lymphatic drainage for the breast and arms is applied from the 3rd day through the 4th week postoperatively.

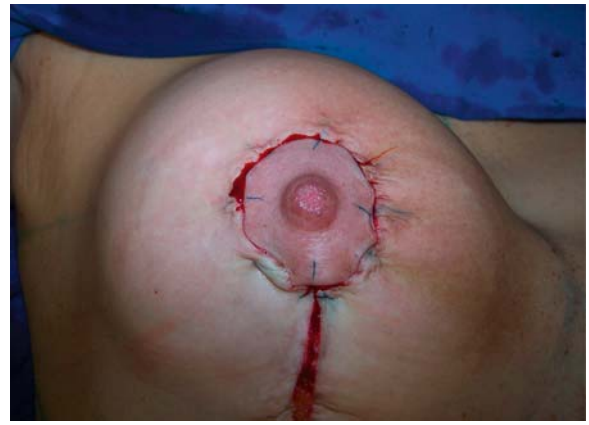

Fig. 41.16. Aspect of the areola after dermal suture

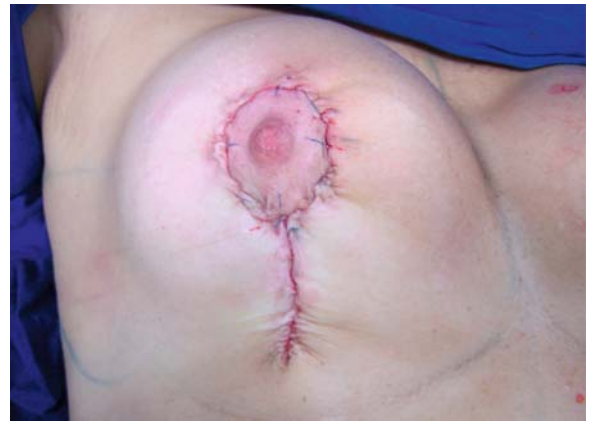

Fig. 41.17. Final skin closure with shortening of vertical incision and round block suture around the areola

41.5 Complications

The most common complication related to the thoracic wall flap is fat necrosis in the distal portion of this flap, which can be dealt with by surgical revision to remove this tissue. Seroma or hematoma is avoided with careful hemostasis during the surgery. Other complications seen in the literature are wound healing problems that can be reduced by not undermining the skin, puckered nipples and the need to revise the inferior pole of the vertical incision, which may have a tendency to form a dog-ear [16, 29 – 36].

41.6 Results

The vertical technique can be performed in patients with several degrees of breast hypertrophy and ptosis, but the best results have been achieved in those patients with mild and moderate breast ptosis, as with any other

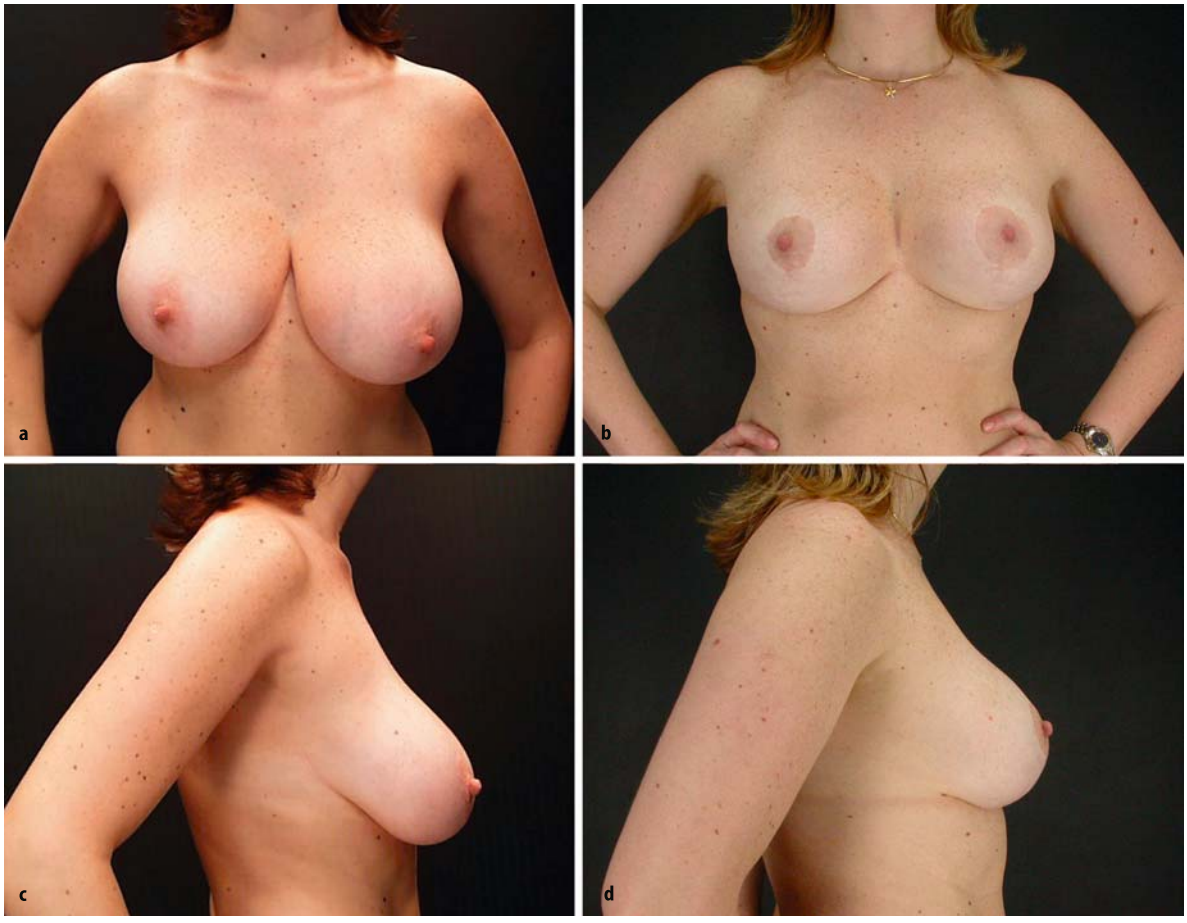

Fig. 41.18. Pre- and 3 years postoperative photos of a 28-year-old patient with breast asymmetry

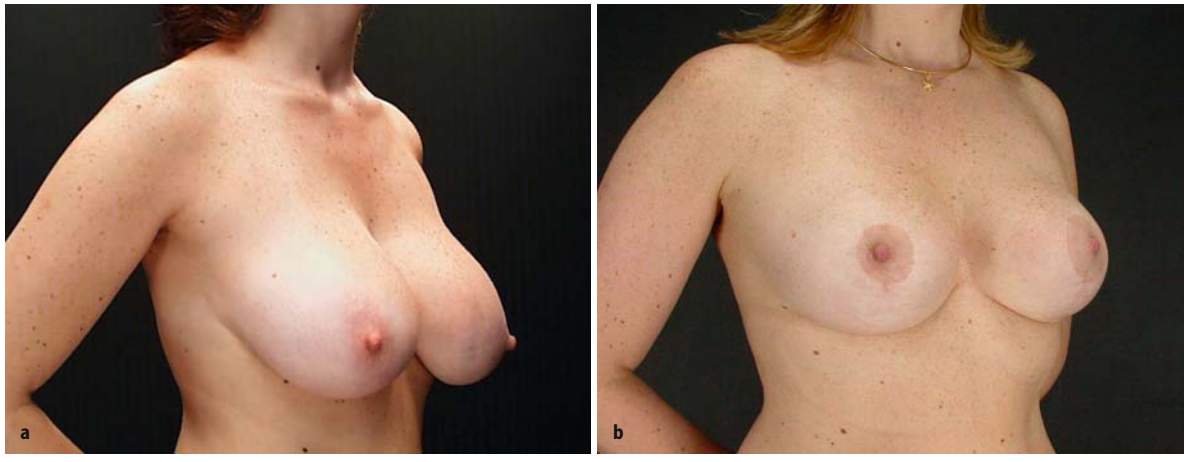

Fig. 41.19. Same patient as in Fig. 41.18, oblique view

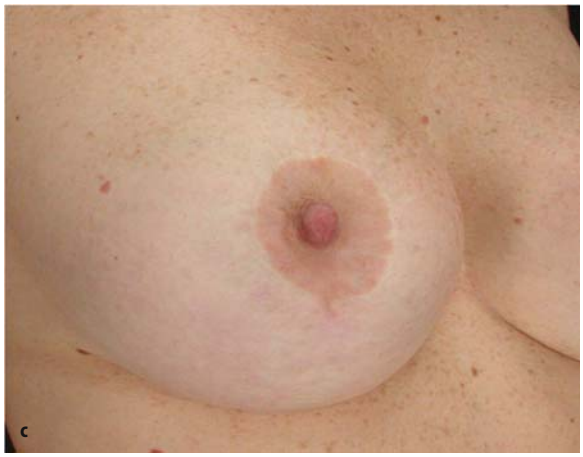

Fig. 41.19. (*Cont.*)

technique. Good results can also be accomplished in large hypertrophies, especially in patients with good skin quality. In the case of severe breast ptosis, point "D" must be marked at a greater distance to the "M" point, up to 4 cm, leaving skin and subcutaneous tissue of the lower pole of the breast as part of the chest wall, therefore elevating the inframammary crease and also decreasing skin compensation of the vertical scar.

Throughout the first 2 months of the postoperative period, it was noticed that there is a settlement of the vertical scar, with no need for scar revision in the form of horizontal resection of skin excess in the lower limit of the scar. In only one case did the skin excess not subside and a surgical revision was performed after 6 months, resulting in a short horizontal scar.

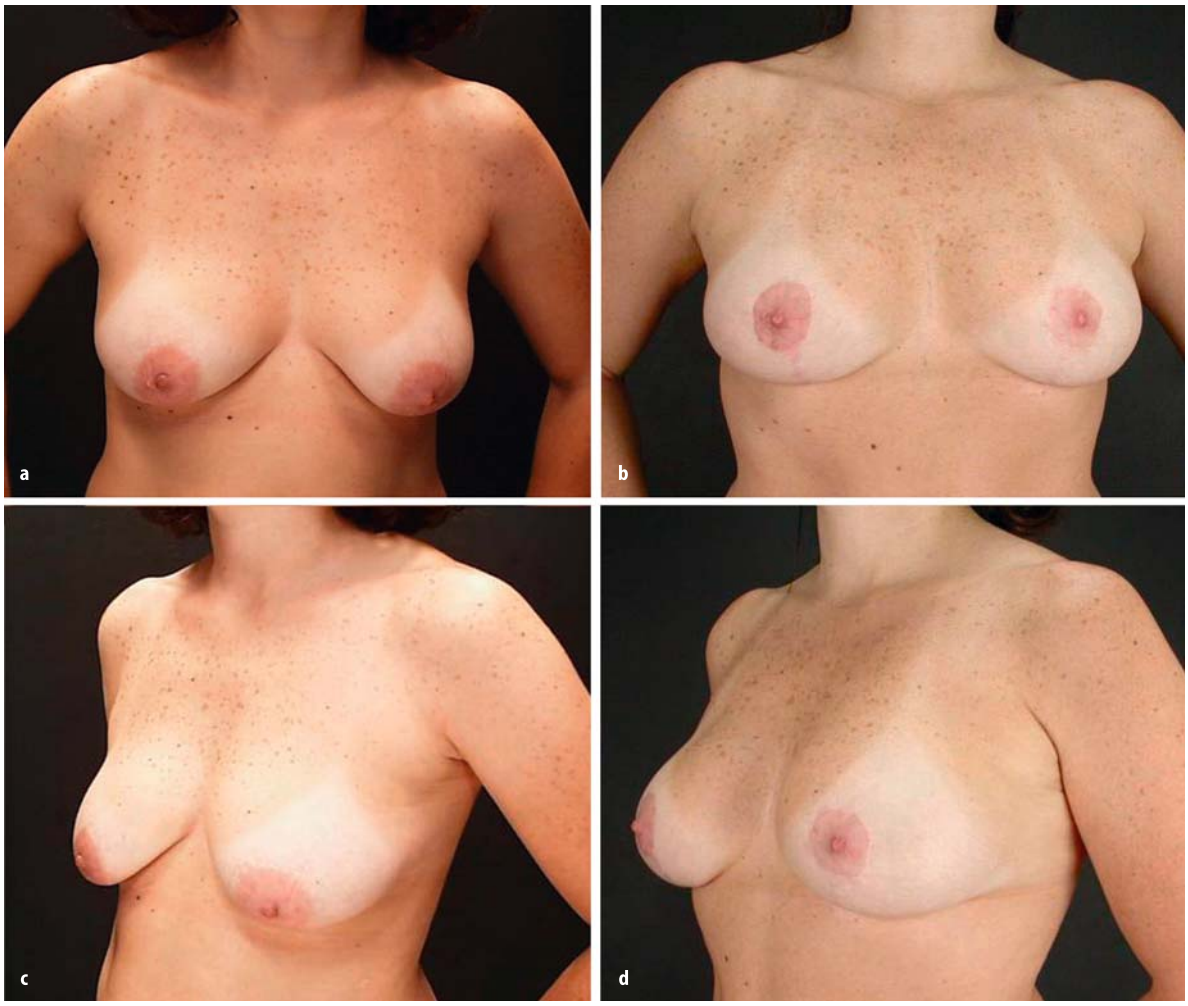

Fig. 41.20. Pre- and 3 years postoperative photos of a 38-year-old patient after vertical mastopexy

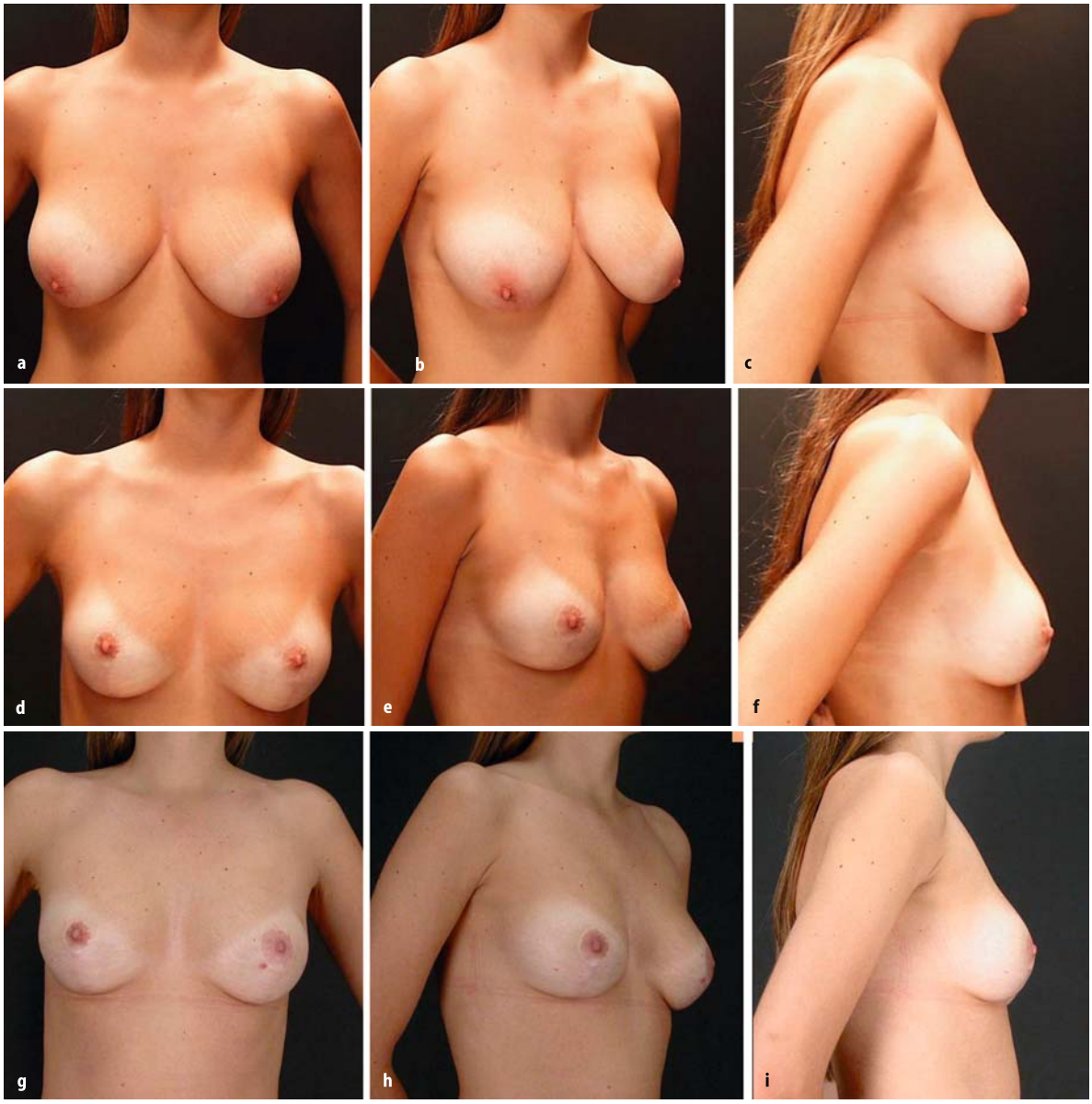

Fig. 41.21. Preoperative (*top*), 3 years postoperative (*middle*) and 4 years postoperative (*bottom*) photos of a 22-year-old patient

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Internal Pedicle Shaping to Improve Aesthetic Results in Reduction Mammaplasty

42

Y.S. Chun, D.H. Lalonde, J.W. May, Jr.

The contents of this chapter have already appeared in *Plastic and Reconstructive Surgery* vol 119, pp 1183–1189, Lippincott Williams and Wilkins 2007. Reproduced by permission.

42.1 Introduction

Reduction mammaplasty has been performed utilizing various techniques to achieve reduction in breast volume and to enhance aesthetic shape. The conventional inverted T-scar method is the most widely used technique in breast reduction given its predictability and versatility [1]. Nonetheless, newer surgical techniques have been developed in order to optimize outcome while minimizing associated complications. Pedicle types include inferior, central, superior, lateral, and bipedicle, all of which maintain the blood supply and innervation to the nipple-areola complex [2–6]. Cosmetically acceptable placement of scars, although debated, has also been emphasized through additional technical modifications including short scar periareolar inferior pedicle reduction mammaplasty (SPAIR), vertical mammaplasty without inframammary scar, or no vertical scar breast reduction [7–10].

A common problem resulting from inferior pedicle reduction mammaplasty is amorphous breast shape and inadequate breast projection. After resection of the medial, central, and lateral breast using the traditional inferior pedicle technique, the pedicle tends to be loose and mobile, lacking any significant form or shape. With this technique, the breast shape depends solely on the skin envelope which may not provide adequate projection. Any shape achieved is dependent in part on tension created by the apposition of the lateral flaps. Mathes, Nahai, and Hester reported a technique of folding the inferior dermal breast flap and suturing it to the chest wall in order to increase projection and avoid the flat breast appearance [11]. Lalonde also described the use of breast-shaping sutures to improve breast shape and projection in his "no vertical scar breast reduction" [8].

We describe our technique of utilizing internal absorbable sutures in inferior pedicle reduction mammaplasty to contour the pedicle for enhanced breast projection and shape. In addition, it decreases closure tension of the lateral flaps as breast shape is in part created by shaping the central pedicle.

42.2 Surgical Technique

The patient is marked preoperatively in standing position. The breast meridian through the nipple, the inframammary fold, and the position of the nipple following reduction is marked. The standard Wise pattern is marked around the new nipple position. The inferior pedicle is deepithelialized, and the breast tissue is excised medially, laterally, and superiorly. After developing the inferior pedicle, which usually measures 8 cm in width at the chest wall base, internal absorbable sutures are utilized to position and shape the pedicle. Using 3–0 Monocryl sutures, the medial and lateral dermal edges of the pedicle are secured to the pectoralis fascia near the inframammary fold, allowing the pedicle to fold on itself and be secured to the chest wall (Fig. 42.1a, b). In most cases, the pedicle dermal folding is shifted medially to add medial fullness to the reduced breast. This dermis to dermis contact produces a secure adhesion which in the long run may decrease bottoming out. The inferior pedicle is further shaped by placing a 3-0 Monocryl suture in a loose running fashion to tubularize the parenchyma in an anterior-posterior orientation, enhancing projection. The pedicle

stands up on its own much like a shaped breast implant (Fig. 42.1c). It is critical that the breast-shaping sutures be tied with loose loops to avoid any necrosis or injury to nerves, blood vessels, fat, and breast parenchyma by constriction. Careful attention is made to avoid devascularization of the nipple-areola complex. The skin envelope is then draped over the shaped central breast mound requiring much less flap suture line tension than is traditionally seen in standard reduction mammoplasty (Fig. 42.1d). Figure 42.2 illustrates a diagrammatic representation of the internal pedicle shaping process. Symmetry is ensured by evaluating the breast shape in upright position. Figure 42.3 demonstrates the significant difference in projection attained through the internal pedicle shaping compared to the non-shaped inferior pedicle. Tension-free closure of the ver-

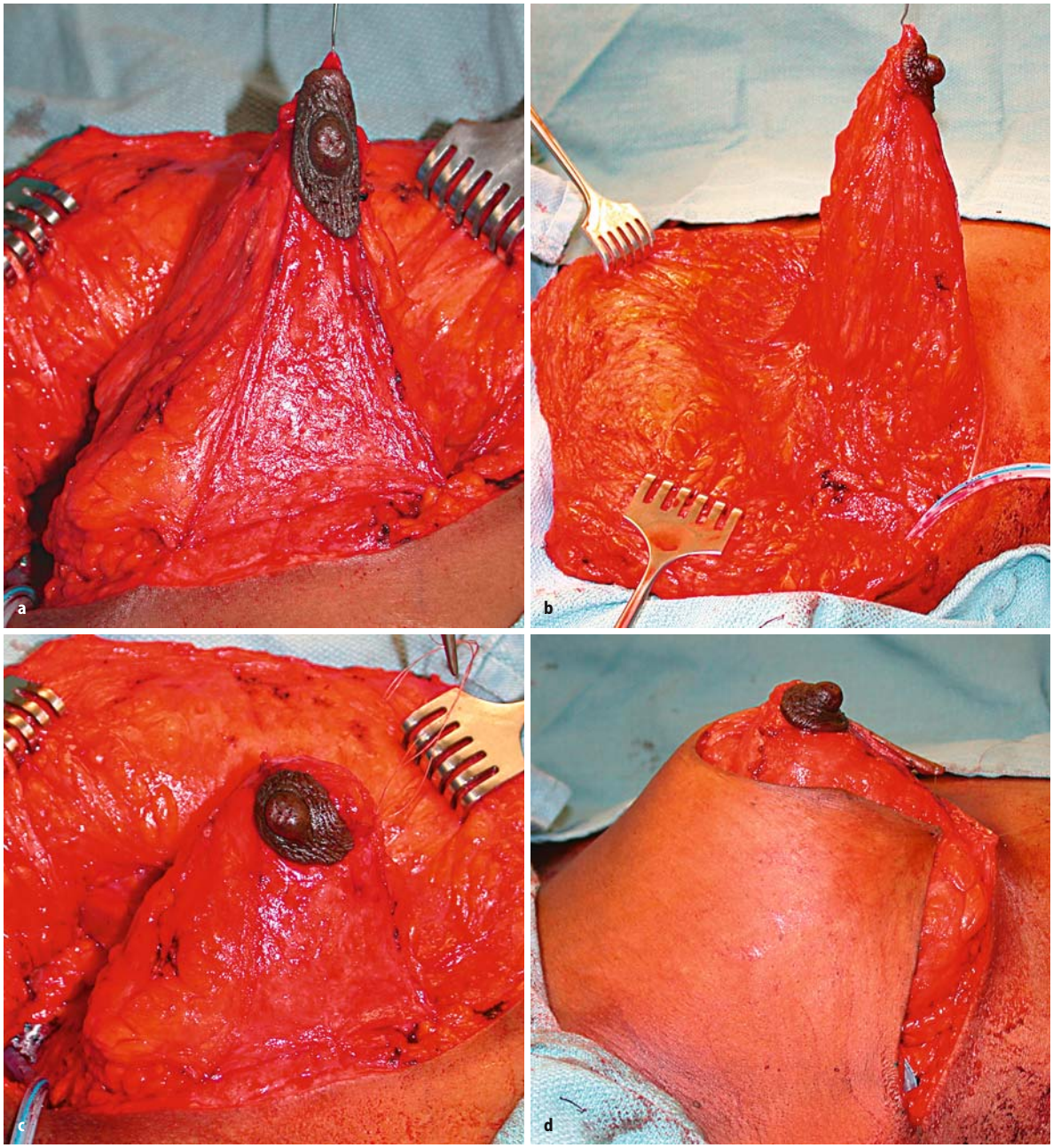

Fig. 42.1a–d. Shaping of the breast during inferior pedicle reduction mammaplasty using internal pedicle-shaping sutures. **a** Inferior pedicle is developed with an 8 cm base width. **b** Medial and lateral dermal edges are tacked onto the pectoralis fascia and the folded pedicle can be shifted medially to provide medial fullness. **c** Shaped inferior pedicle after placement of the loose running suture. **d** Skin envelope drapes over the shaped pedicle with minimal tension

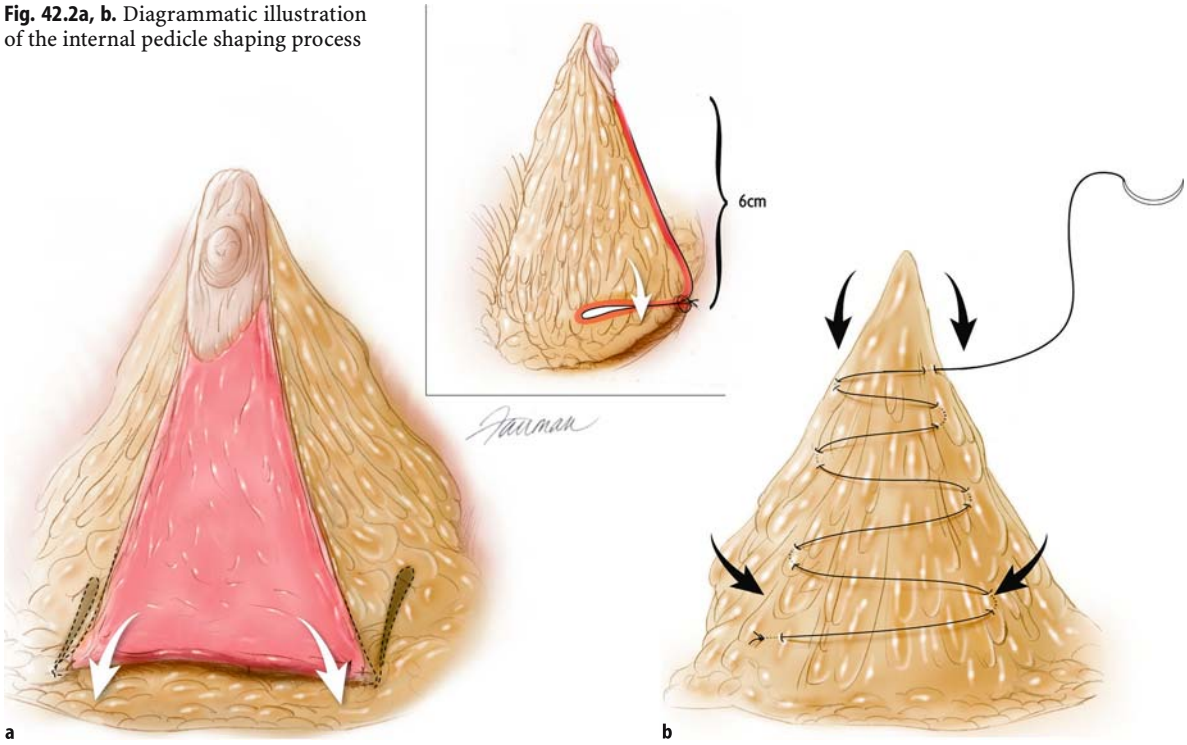

Fig. 42.2a, b. Diagrammatic illustration of the internal pedicle shaping process

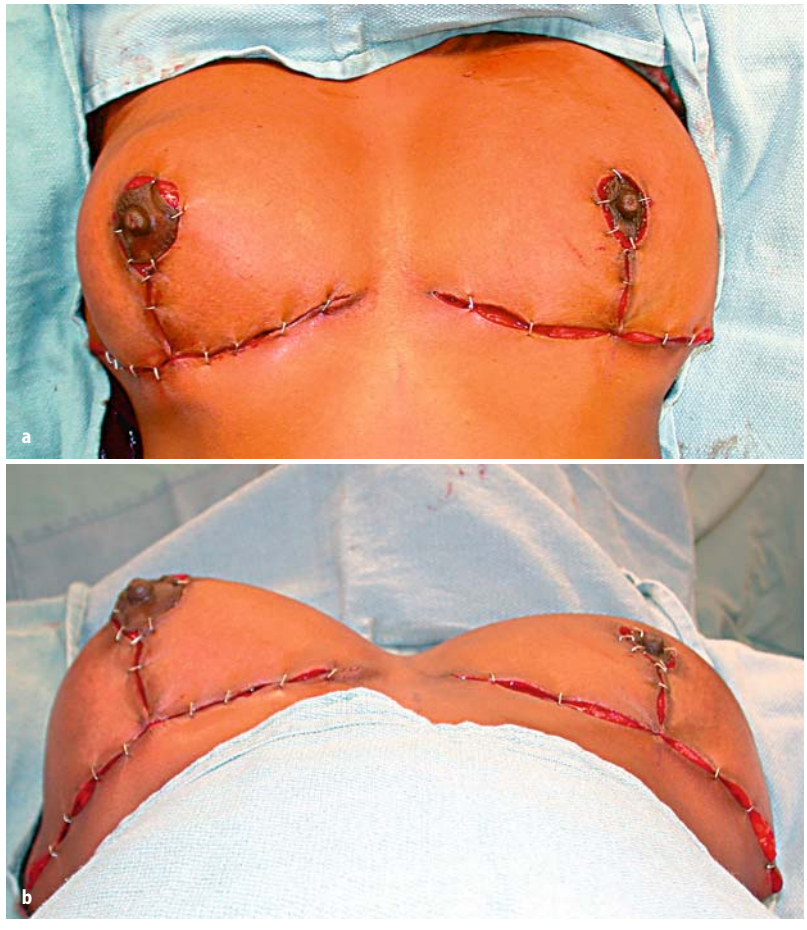

Fig. 42.3. a Comparison between shaped (*right*) and non-shaped (*left*) inferior pedicle after a preliminary closure. AP view. **b** Inferior view shows a significant difference in projection attained through internal pedicle shaping compared to the non-shaped inferior pedicle

tical and inframammary fold incisions is achieved with 3-0 Monocryl sutures. The periareolar closure is performed with 4-0 Monocryl suture in a running fashion. A number 19 Blake drain is placed in each side through the axilla. All incisions are dressed with Steristrips, and a compression dressing is applied. Drains are usually removed on postoperative day 1.

42.3 Illustrative Cases

42.3.1 Case 1 (Fig. 42.4)

An 18-year-old healthy female with macromastia underwent bilateral reduction mammaplasty using the Wise pattern inferior pedicle technique. A quantity of 743 g was removed from the right breast, and 611 g was removed from the left breast. Drains were removed on postoperative day 1, and the patient was discharged in stable condition. Her postoperative course was unremarkable.

42.3.2 Case 2 (Fig. 42.5)

A 50-year-old female with history of macromastia and bilateral axillary lipodystrophy underwent bilateral reduction mammaplasty using the Wise pattern inferior pedicle technique and bilateral axillary liposuction. A quantity of 330 g was removed from the right breast, and 385 g was removed from the left breast. Approximately 50–70 g of additional tissue was removed from the bilateral axilla by suction lipectomy. Her postoperative course was unremarkable. Drains were removed, and the patient was discharged on postoperative day 1.

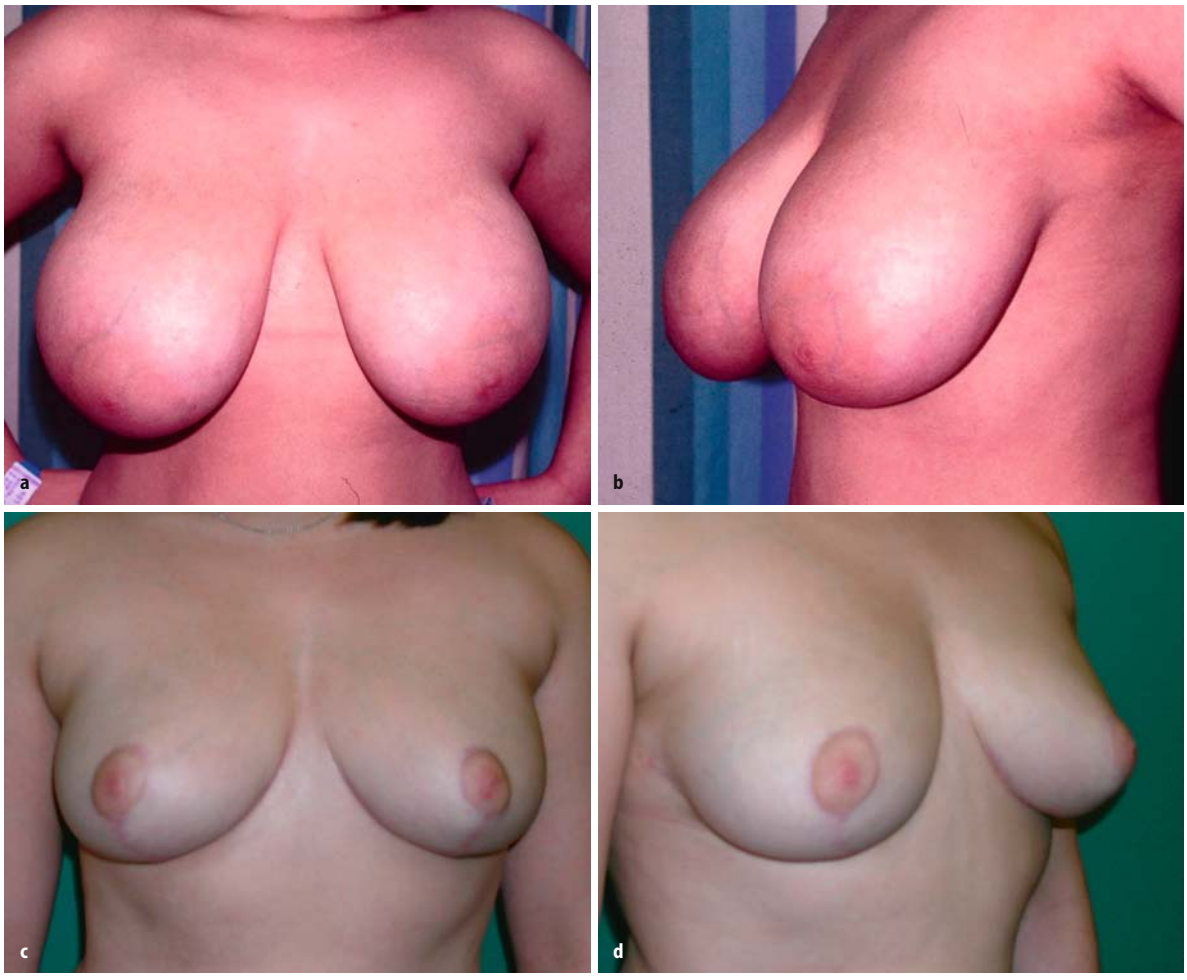

Fig. 42.4. a Preoperative photograph of Case 1, AP view. **b** Oblique lateral view of the same patient. **c** Postoperative photograph, AP view. **d** Postoperative photograph, oblique lateral view

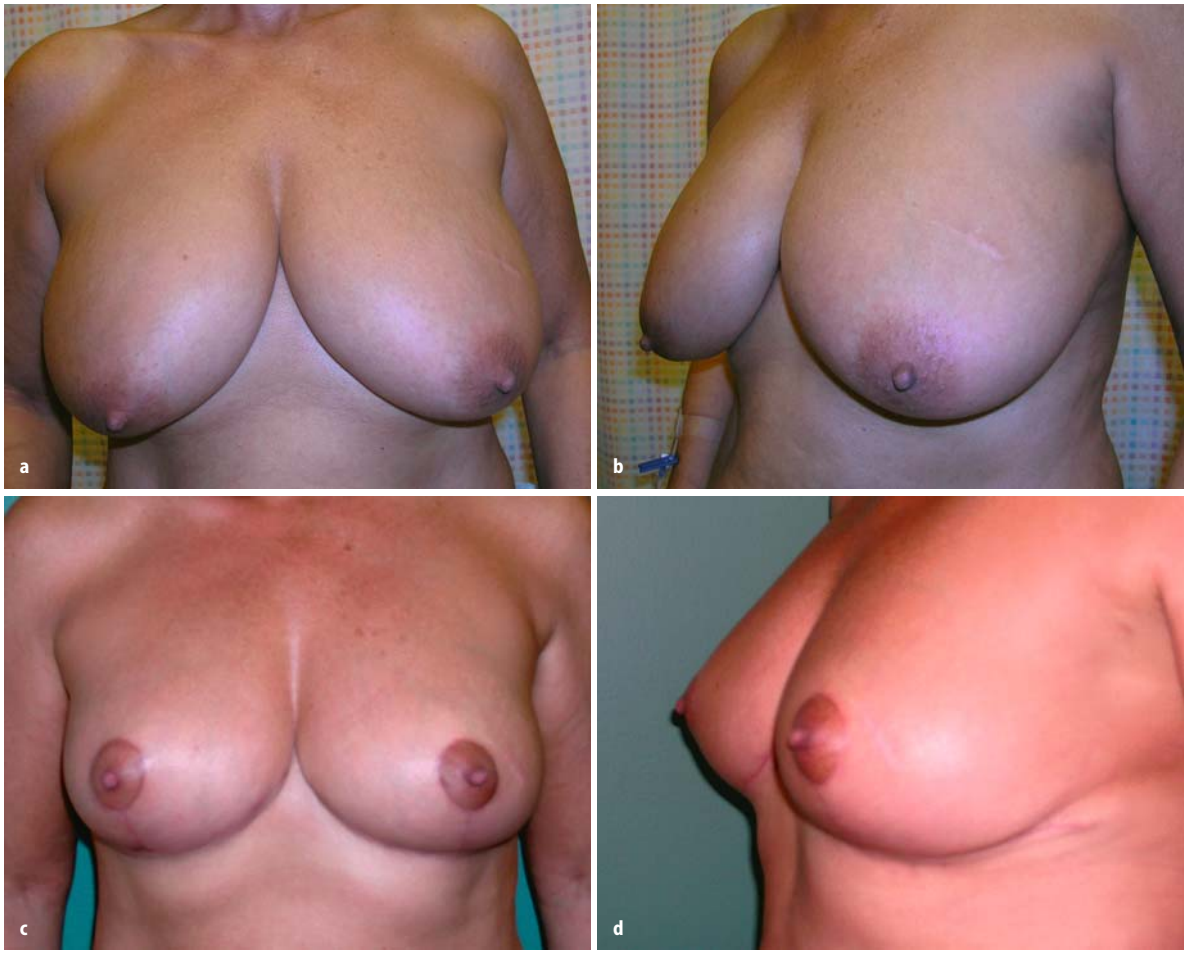

Fig. 42.5. a Preoperative photograph of Case 2, AP view. **b** Oblique lateral view of the same patient. **c** Postoperative photograph, AP view. **d** Postoperative photograph, oblique lateral view

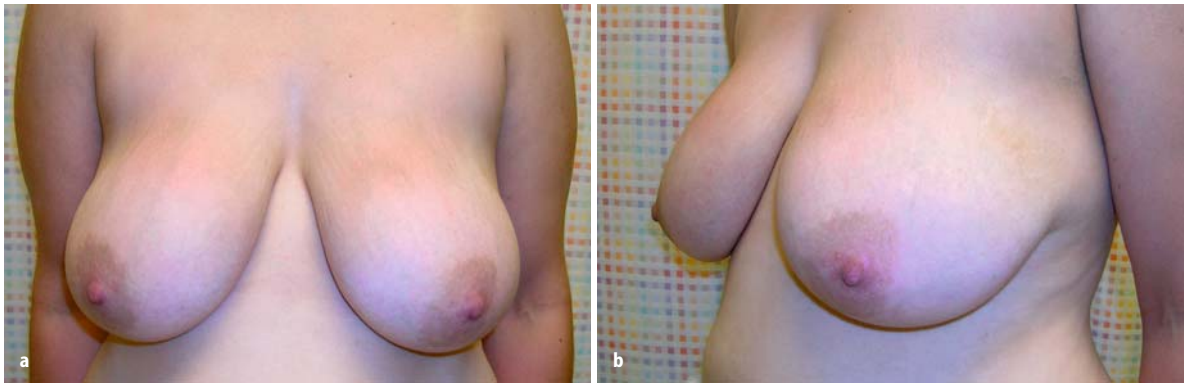

Fig. 42.6. a Preoperative photograph of Case 3, AP view. **b** Oblique lateral view of the same patient

42.3.3 Case 3 (Fig. 42.6)

A 27-year-old healthy female with cosmetic ptosis, macromastia, and bilateral axillary lipodystrophy underwent bilateral cosmetic uplift with minimal reduction mammaplasty using the Wise pattern inferior pedicle technique. A quantity of 180 g was removed from each breast and bilateral axillary liposuction was performed. Drains were removed, and the patient was discharged on postoperative day 1. She had no postoperative complications.

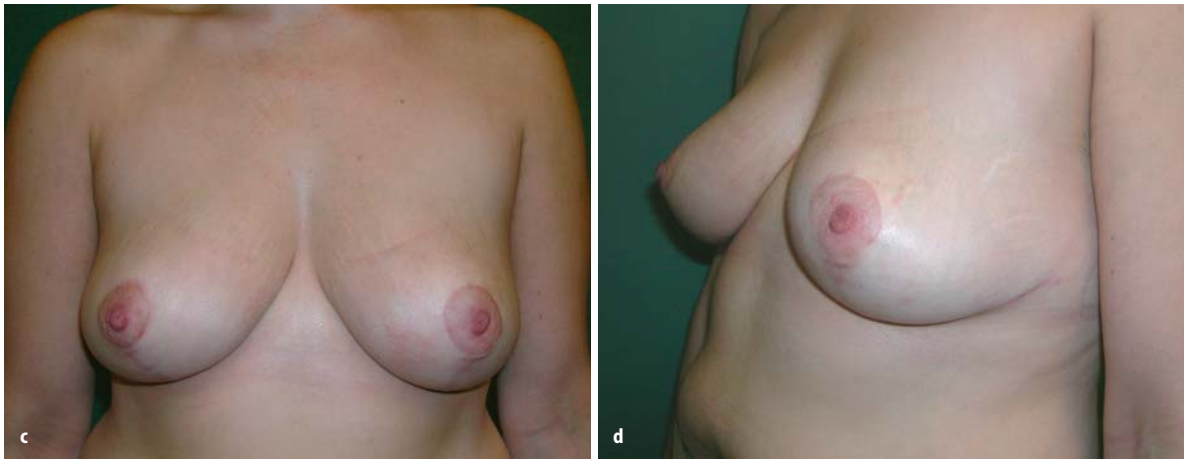

Fig. 42.6. (*Cont.*) **c** Postoperative photograph, AP view. **d** Postoperative photograph, oblique lateral view

42.4 Discussion

Breast contour following reduction mammaplasty is affected by multiple factors including the volume and shape of the retained breast tissue and the skin envelope. After the breast tissue resection is completed, the remaining inferior dermal breast pedicle tends to be mobile and poorly defined in shape, especially when it consists of mostly loose fatty tissue and minimal breast glandular tissue. The pedicle simply lies beneath the skin flap closure and may even migrate laterally within the empty pocket [8]. The simple modification of the inferior pedicle reduction mammaplasty technique by shaping the pedicle can enhance breast projection and contour.

The internal breast-shaping sutures are utilized to position the inferior pedicle, which forms the central breast mound of the reduced breast, onto the chest wall medially and laterally. By the time the absorbable sutures have dissolved, the lateral skin pocket has scarred to the chest wall, and the pedicle has scarred to its desired medial position. An additional loose running suture placed along the superior aspect of the pedicle tubularizes the poorly defined shape into an enhanced projection as this suture is run perpendicularly from the pectoralis fascia upward toward the nipple areola complex. Vascularity and sensation of the pedicle and the nipple-areola complex is maintained by avoiding tight suture loops. The final insetting of the nipple-areola complex also provides additional stabilization to the pedicle. The senior authors have performed over 450 reduction mammaplasty cases with pedicle shaping in the past 7 years with no incidence of infection or significant fat necrosis.

The concept of pedicle-shaping sutures follows the concept of modern facial rejuvenation procedures. In the beginning, facial procedures relied on simply pulling the skin to shape the face. Later, internal suturing of the SMAS, malar fat pad, and platysma have improved facial shaping before skin closure. Breast-shaping sutures (pillar sutures) have been shown to improve projection in the vertical reduction techniques popularized by Lassus and Hall-Findlay [12]. The same pedicle or breast-shaping suture concept can be applied to the inferior pedicle reduction technique just as effectively. This technique of parenchymal shaping can improve the quality of breast shape, just as internal suturing has improved the quality of facial rejuvenation.

Although the internal breast-shaping suturing technique is utilized to modify the conventional Wise pattern reduction mammaplasty in this chapter, applicability can be extended to other pedicle techniques such as the no vertical scar breast reduction. On the other hand, this technique may not be advisable when performing contralateral breast reduction for symmetry during breast reconstruction cases with flaps since most reconstructed breasts with autologous flaps, such as TRAM (transverse rectus abdominis myocutaneous) flaps, tend to be wide-based and lack projection. Augmenting projection on the contralateral side during breast reconstruction may not achieve desired symmetry.

Reus and Mathes showed that their suturing technique of the inferior pedicle to the chest wall still does not prevent long-term inferior migration of breast parenchyma [13]. Similarly, the long-term benefits of pedicle-shaping remain uncertain, and evaluation of long-term results with controls will need to be performed to determine the effects of time and gravity on reduction mammaplasty using internal breast-shaping sutures. Nonetheless, one can be hopeful that the internal scar cocoon which forms between the coned pedicle and surrounding breast flaps will help maintain relatively long-term shape as compared to using skin-only shaping techniques.

42.5 Conclusions

A simple modification of the inferior pedicle reduction mammaplasty by utilizing internal breast-shaping sutures provides several advantages: (1) enhancement of projection is achieved by shaping and positioning the pedicle in an ideal position, (2) shaping of the reduced breast relies less on the skin brassiere, (3) tension on the skin envelope closure from weight of the breast mound can be minimized which should help in the quality of scar postoperatively.

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43 The Crossed Dermal Flaps Technique in Breast Reduction

R. de la Plaza, L. de la Cruz

The authors would like to thank Springer Science + Business Media for consenting to the reproduction of part of the text, illustrations of the technique and some of the photographs of the clinical cases from our article published in *Aesthetic Plastic Surgery* 28:383–392, 2004.

43.1 Introduction

More than a hundred techniques and variations for breast reduction have been published. In the majority, the differences are principally concerned with the method of transpositioning the nipple areola complex (NAC) and the pattern of skin resection.

Skin resection inevitably causes scar sequelae, and this has given rise to a long-running debate over long scar techniques and short scar techniques. There would be no debate if only the extent of the scar was evaluated, as ideally the shorter the better. However, this limitation of scar extension requires other elements to be evaluated in the results. On the other hand, there are a great variety of clinical cases in which we must consider not only volume but also the degree of ptosis, quality of the skin, age, lifestyle, patient's complexion, type of mammary parenchyma and, most importantly, the patient's wishes.

We present the technique which we usually perform in selected cases of mammary reduction. This technique was designed by the first author. We also present the results obtained in 195 patients from June 1986 to June 2006. In 37 % of cases, apart from hypertrophy, we observed marked asymmetry.

The quantity of resected tissues varied between 345 and 4,400 g with an average of 1,099 g in both breasts.

The age of the patients varied between 14 and 69 years, with an average of 36 years.

Most of the operations were performed with the patient under general anaesthesia with controlled hypotension.

The postoperative controls were after 1 month, 6 months, 1 year, 2 years and occasionally longer. The technique used is based on a Wise type skin marking, glandular resection in the lower and lateral poles and the transpositioning of the nipple-areola complex (NAC) with a superior-medial dermoglandular pedicle. The novelty of this technique consists of the use of two horizontal, crossed dermal flaps which have proved to be highly efficient in the prevention of two of the most frequent undesired effects in breast reduction: dehiscence with later bad scar at the level of the junction of the vertical and horizontal suture lines, and displacement of the lower pole after a period, which involves the NAC and the horizontal scar moving upwards and the lengthening of the submammary fold-NAC distances.

We also verify the excellent vascularisation of the superior-medial pedicled dermoglandular flap with only three partial losses of areola, which healed by secondary intention, with no aesthetic repercussions. This flap is very little used at present in spite of the important advantages it possesses during the operation and in the late postoperative period.

The debate over long scar techniques and short scar techniques has intensified in the last 10 years since the diffusion of Claude Lassus's vertical scar technique, performed by him since 1966 [14]. Lejour has been a great defender and instigator of this vertical technique with added liposuction [15–17]. As we said above, the debate would not exist if only the length of the scars was evaluated, because ideally the shorter the better; if this were so, the techniques with periareolar scars exclusively of the Benelli type would be those of choice [1]. However, the poor results offered by the latter in shape and quality of the scar in the long term restrict their indications. On the other hand, there is a great variety of clinical cases in which we must consider the conditions

for the choice of one or another technique, as mentioned above.

In 1978 the senior author of this chapter established the general principles on which he considers reduction and remodelling techniques should be based. These objectives and principles, which have been broadcast since then in communications and participations in round tables at numerous symposia and congresses, constitute the foundation of the dermal crossed flaps technique which we present.

43.1.1 Fundamental Principles

- To avoid tension in glandular and cutaneous sutures which could give rise to ischemia and poor quality scars.
- Suspension of the glandular and adipose tissues with short pedicles or their transposition to the upper pole and fixing to the fascia pectoralis, in order to avoid the said tissues acting as expanders of the skin due to the effects of gravity and the posterior deformity of the breast with relapse of ptosis, as normally occurs in the techniques based on the inferior pedicle, described principally by Courtiss [4] and Georgiade [8] in the late 1970s. Careful selection of the ideal technique is necessary for each case.
- Maximum respect as far as possible of the function of the mammary gland and prevention of artifacts which can interfere with future mammary diagnostics.

43.2 Description of the Technique

Most interventions were performed with the patient under general anaesthesia and controlled hypotension with median arterial blood pressure of 60 mm Hg until after shaping the nipple-areola flap, when arterial pressure was gradually raised.

In our experience, hypotension above 80 mm Hg systolic pressure is not effective, bleeding being very similar to that occurring when pressure is slightly or very much higher. For this we used halothane and trimethaphan up to 1990 – 1991 and halogenated anaesthetic gases, remifentanil, beta blockers, and sodium nitroprussiate since then. We are now using urolapril more frequently as a hypotensive agent. This is a new drug, easier and safer to use than the previous ones, as its effects are easily reversible in cases of sudden drops in blood pressure.

With the patient in an orthostatic position, we mark the ideal position for the nipple, which should be level with a mid humeral line and the anterior projection of the submammary fold, and a line from the union of the internal third with the external two-thirds of the clavicle to the nipple. This point can be modified according to the characteristics of each case. In voluminous breasts, the mark should be moved towards the medial line, avoiding in this way excessively divergent breasts. In very heavy breasts it is useful to evaluate the height of the nipple in order that the caudal traction of the skin does not result in an excessively high position of the same. The remainder of the marking is performed in theatre with the patient semi-seated, anaesthetised, and a sterile surgical field, taking as a reference point the marks already made for the nipple preoperatively. The horizontal incision line is marked 1½–2 cm above the submammary fold and it ascends gradually towards the lateral pole of the breast. We then delimit two rectangular areas under each cutaneous vertex, which will correspond to the union of the vertical suture line with the horizontal line, and which correspond to the future dermal flaps 5 cm long by 1½ cm wide (Figs. 43.1a, 43.2a). We deepithelialise the area using the Wise pattern, this being limited at the lower margin of both future flaps (Figs. 43.1b, 43.2b).

The dermal flaps are then elevated, eliminating all the subcutaneous fat, and resection in one piece of the excess skin, adipose and glandular tissues of the lower pole, with a wedge-shaped prolongation towards the centre of the breast (Fig. 43.1c). We then tailor a pedicled superomedial dermoglandular flap for the transposition of the NAC. The flap is thicker towards its base,

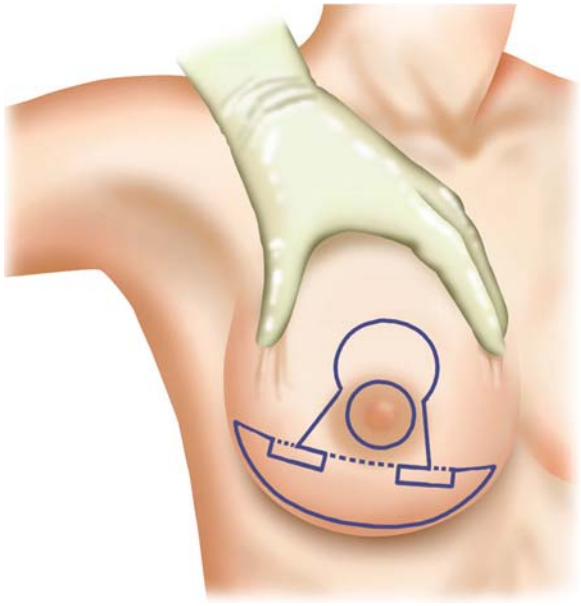


Fig. 43.1. a Preoperative marking of the skin. Observe that the incision is above the submammary fold.

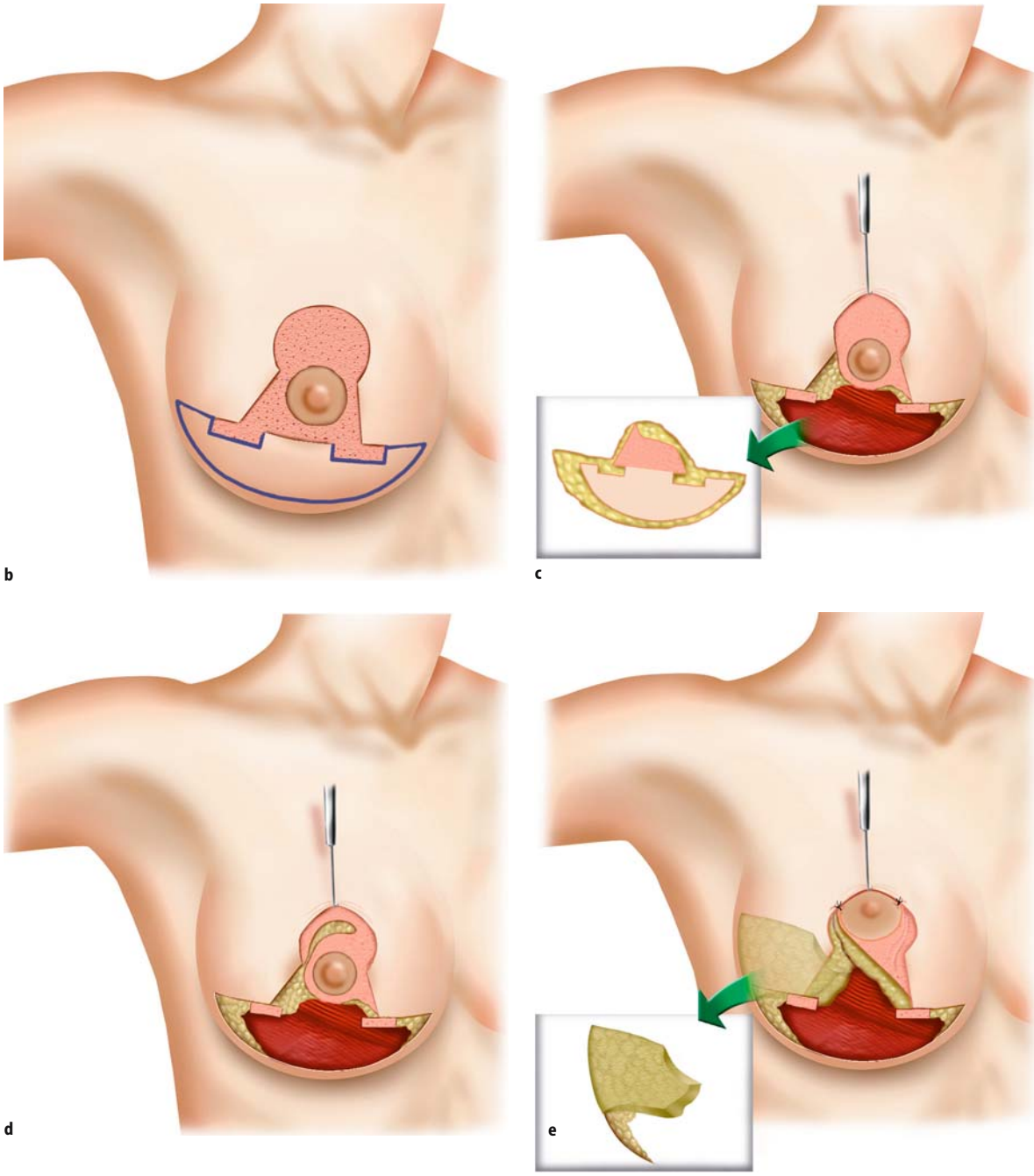
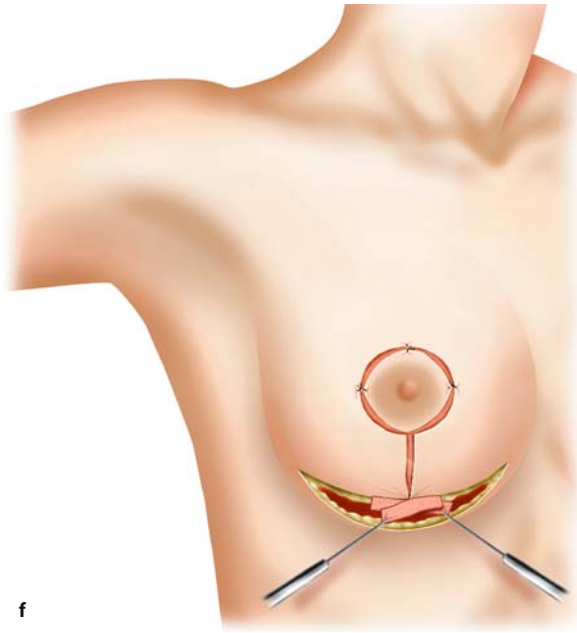


Fig. 43.1. b Shows the deepithelialised area, including the two small dermal flaps. **c** Resected piece, which includes excess skin, adipose and glandular tissues of the inferior pole with a wedge-shaped prolongation towards the centre of the breast. **d** Tailoring of the superomedial pedicled dermoglandular flap for transposition of the NAC. **e** Transposition of the dermoglandular flap. In cases which require greater reduction, this may be performed at the expense of the base of the lateral glandular flap

▷

Fig. 43.2. a Intraoperative view. Preoperative marking of the skin. Cutaneous incision in *blue* and the area of the future dermal flaps in *red*. **b** Intraoperative view showing the deepithelialised area, including the two small dermal flaps. **c** Intraoperative view of the superomedial dermoglandular flap and the dermal flaps. **d** Intraoperative view. Crossing the dermal flaps to avoid tension at the medial line



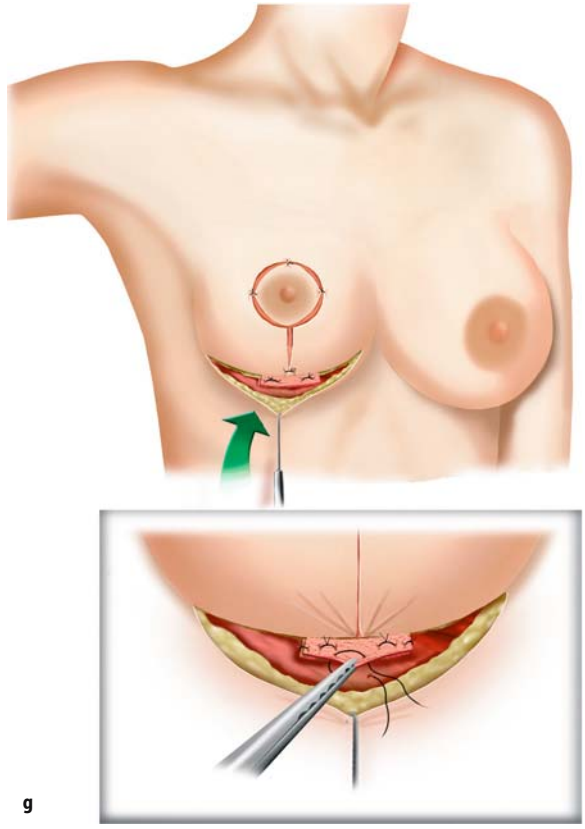


Fig. 43.1. f Crossing of the dermal flaps, taking the lateral tension at the medial line. **g** Suture of the dermal flaps with monofilament glycomer 631 (Biosyn, USSC) horizontal U stitches. The magnified view shows the fixing of the flaps to the musculoaponeurotic wall with non-absorbable 2-0 sutures

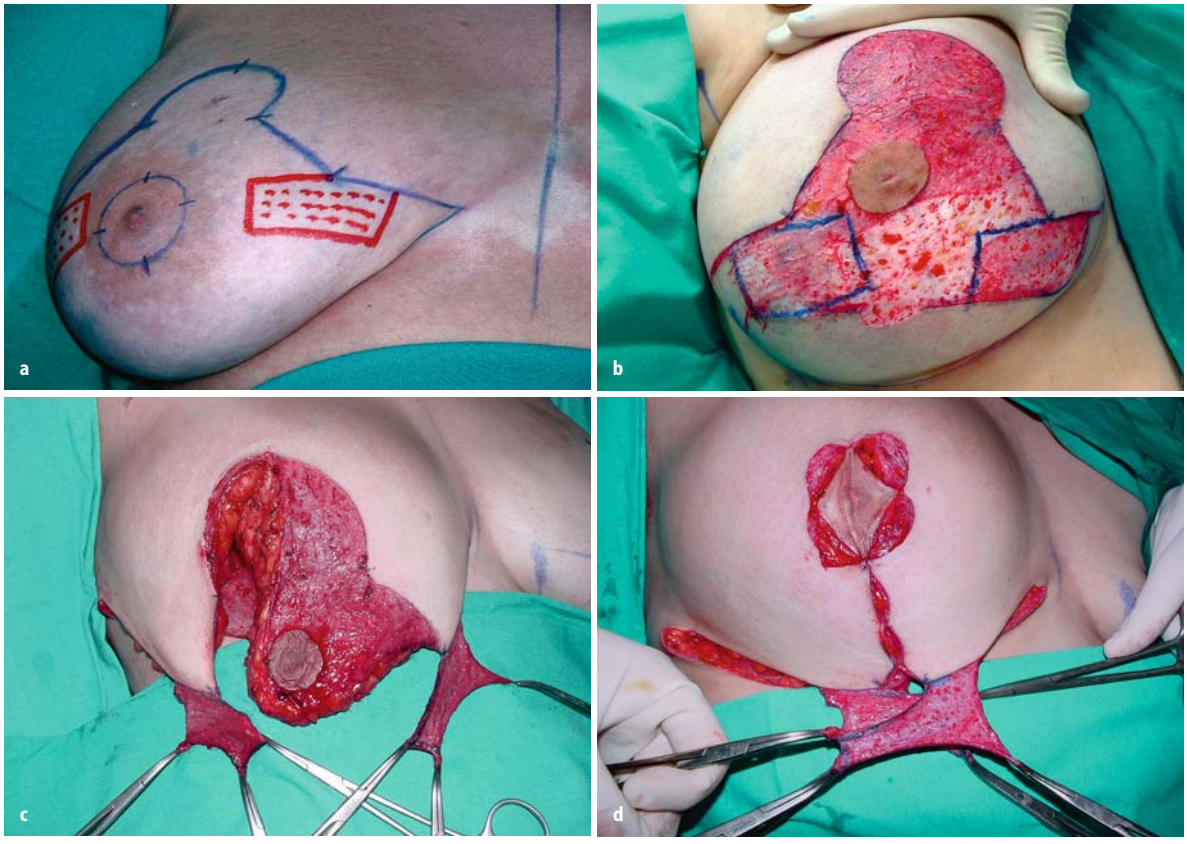


Fig. 43.2 (Legend see p. 352)

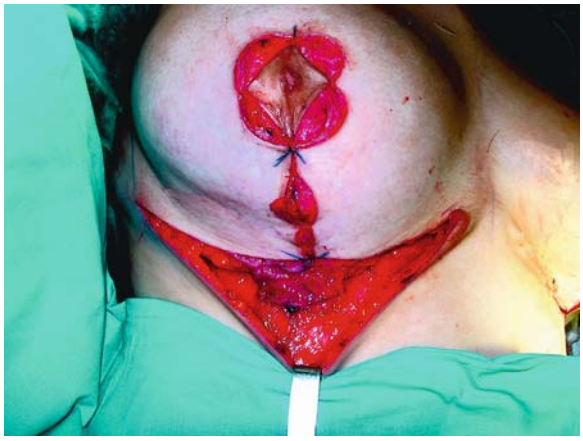


Fig. 43.2. e Intraoperative view. Suture of the dermal flaps to the musculoaponeurotic wall to achieve firmness and stability of the breast

assuring good vascularisation as well as sufficient tissues in the superior mammary pole as has been described in different works by Finger [6], Hauben [10], and Orlando [20] (Figs. 43.1d, 43.2c). The transposition of the superomedial dermoglandular flap is not difficult. In those cases where the morphology of the flap or especially rigid parenchyma make the transposition more difficult, a back-cut or small resection in the superolateral area of the pedicle is performed. It is important that the NAC be rotated easily without tension, and it is desirable to use absorbable sutures in the glandular tissues to fix it to the superior pole of the breast. Conification of the breast is done by suture of the two pillars with 3.0 absorbable polyglycolic acid suture (Dexon Sherwood Medical, St. Louis, MO) until the desired projection is obtained.

In cases where we need greater reduction and remodelling after the breast is assembled, this can be obtained at the expense of a resection of the base of the lateral glandular flap, the volume of which is usually greater in cases of severe hypertrophy (Fig. 43.1e). The base of this pillar can also be sutured to the aponeurotic muscular wall in order to better stabilise it in its most elevated and medial position.

Once the areola is fixed in its new position at the four cardinal points, we proceed to cross the dermal flaps, positioning the medial over the lateral, until both cutaneous angles cross slightly (Figs. 43.1f, 43.2d). Once this superposition is obtained, the two flaps are fixed with Crile forceps and joined with several 4-0 absorbable polyglycolic acid transfixive U stitches. In this way the cutaneous edges of the angles and the vertical lines meet without tension, as all the tension rests on the dermal flaps below the angles (Figs. 43.1g, 43.2e).

The centre of the dermal flaps is fixed to the musculoaponeurotic wall with a 2-0 coated, braided polyester suture (Ti-Cron, Sherwood Medical, St. Louis, MO). The choice of the point where we fix both horizontally and vertically is fundamental to obtaining correct positioning of the breast and the submammary fold. Horizontally this is usually 1½ cm lower than the original submammary fold. Suture of the inferior edge of the crossed dermal flaps to the musculoaponeurotic wall is performed with continuous 2-0 absorbable suture which fixes definitively the position of the dermal flaps and therefore the breast (Figs. 43.1g, 43.2e). It is advisable to defat the central portion of the inferior edge of the horizontal suture so that there is no bulge when this is superimposed on the dermal flaps. For the last 2 years, trying to obtain a shorter horizontal scar, in voluminous breasts we limited the lateral extension of the incision, resecting the excess adipose tissue on a plane very close to the dermis, in this way allowing better remodelling at the expense of cutaneous retraction. We use liposuction as an aid; we do not trust those reduction techniques which are based exclusively on classical liposuction as has been described by Matarasso [19], or ultrasonic liposuction as has been recommended in the works of Zocchi [23] and Price [21]. We even believe that this last type of liposuction can give rise to long-term changes in the glandular tissues which, as yet, have not been sufficiently studied. Until 1999 we used 4-0 and 5-0 absorbable polyglycolic acid sutures in the dermal and subcutaneous planes, and polyamide 6 monofilament suture (Ethilon, Johnson & Johnson Intl., Saint-Stevens, Woluwe, Belgium) intradermically, taking out the vertical and areolar stitches at 5 days, and the horizontal stitches at 15 days. Since that year we changed to 4-0 and 5-0 monofilament glycomer 631 (Biosyn, USSC, Ville St. Laurent, Quebec, Canada), and have observed excellent tolerance and ease of use, both for the surgeon and the patient, as no stitches need removing.

Routinely we use Redon type drainage, brought through the skin behind the anterior pillar of the axilla and moderate compressive dressing with adhesive elastic bandage.

Drainage is removed after 12 – 24 h and the patient is discharged.

After 72 h, the dressing is removed and a normal bra is used, the majority of patients resuming their normal social and working activities.

We recommend the use of hypoallergenic tape (Micropore, 3 M Health Care, St. Paul, MN) over the suture lines for 3 weeks.

43.3 Results

Only two patients presented cutaneous epidermolysis without dehiscence at the level of the union of the vertical and horizontal sutures, with later spontaneous healing, without interfering with the aesthetic result.

Three cases showed partial and superficial necrosis of one of the areolae, healing during the following 3 weeks without secondary surgery.

Three patients developed hematomas, which were drained in the dressing room with no complications. One case presented evident thickening of the scar. No infections were observed.

Seventeen patients required excision of small folds at the medial and/or lateral extreme of the horizontal scar. In one case the cutaneous opening was extended to observe the state of the dermal flaps, and it was seen that at 8 months they were united to the thoracic wall like a ligament. Two patients required remodelling with liposuction of one of the extremes of the scar.

The maintenance of the shape and position of the breasts has been evaluated as very satisfactory during the periodical controls of the patients (Figs. 43.3 – 43.6). During the control after 2 or more years, no upward tilting of the breast was observed, nor significant elongation of the distance submammary fold – areola, which is so typical in this type of technique when fixing of dermal flaps to the thoracic wall is not performed. Also, the horizontal scar remained stable at the level of the submammary fold.

No local or general complications were observed after controlled hypotension, neither operative nor postoperative. In our experience, the principal advantages observed were a diminution of blood loss and a dryer surgical field. The latter facilitates the surgical procedure and reduces the length of the intervention. No patient needed transfusion, which we consider of particular importance given the complications which can arise from this at the present time. This logically results in a more rapid recuperation, allowing the patient to resume her normal activities.

43.4 Discussion

A frequent problem in breast reduction is bottoming-out of the breast after some months or a year. This hap-

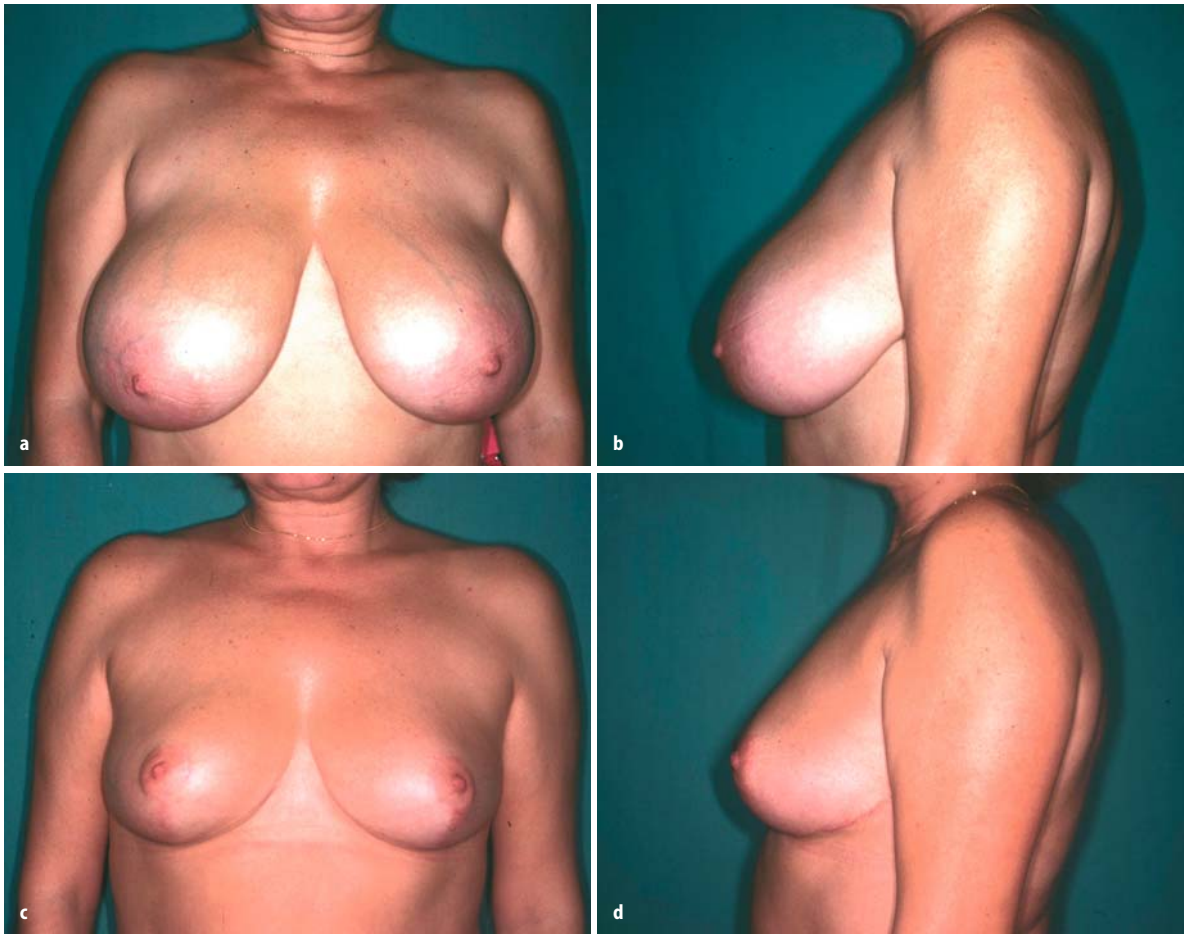


Fig. 43.3. Case 1. Forty-one-year-old patient with severe bilateral hypertrophy and ptosis. A total of 1,472 g was resected. **a, b** Preoperative views. **c, d** Postoperative views after 1 year

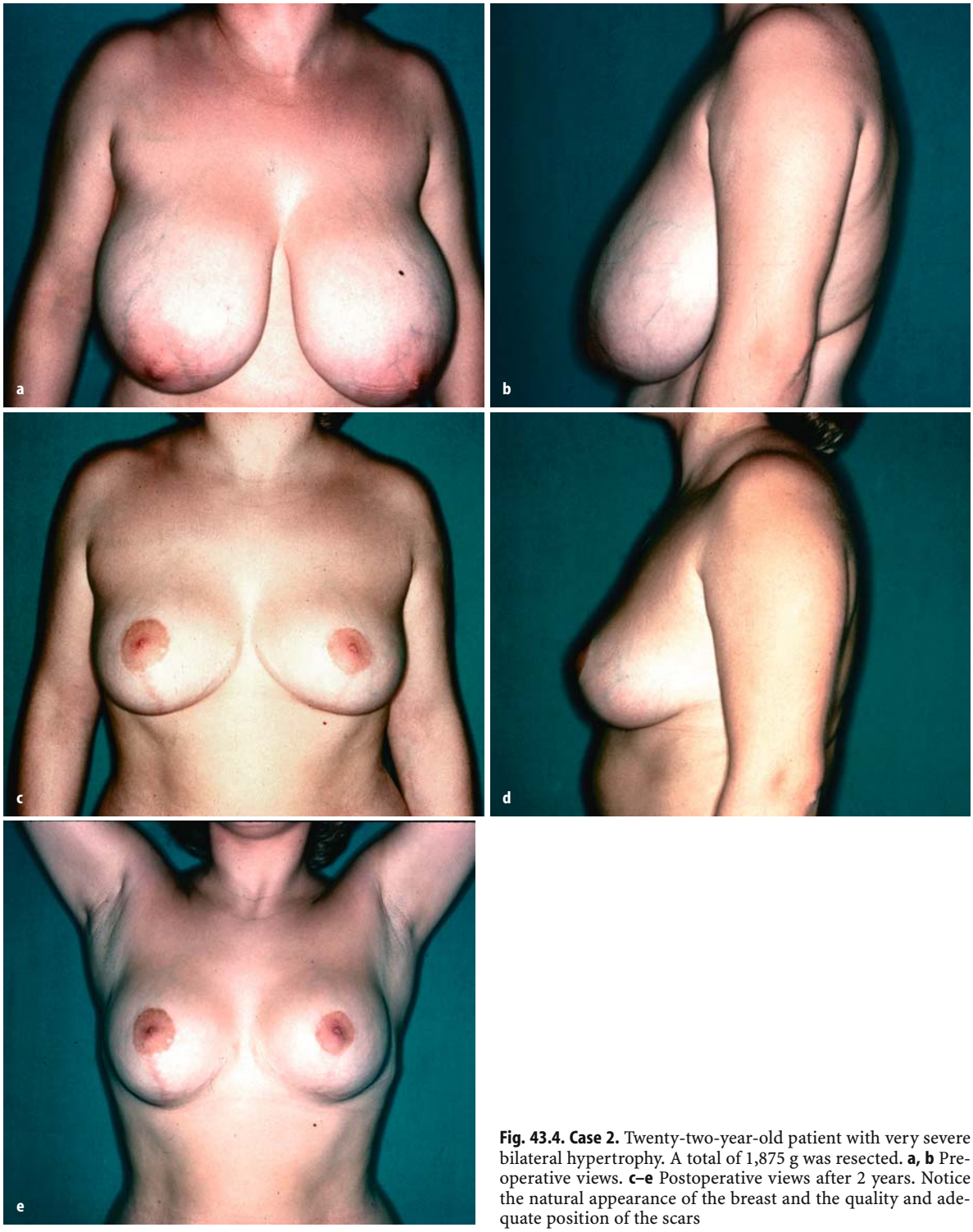


Fig. 43.4. Case 2. Twenty-two-year-old patient with very severe bilateral hypertrophy. A total of 1,875 g was resected. **a, b** Preoperative views. **c–e** Postoperative views after 2 years. Notice the natural appearance of the breast and the quality and adequate position of the scars

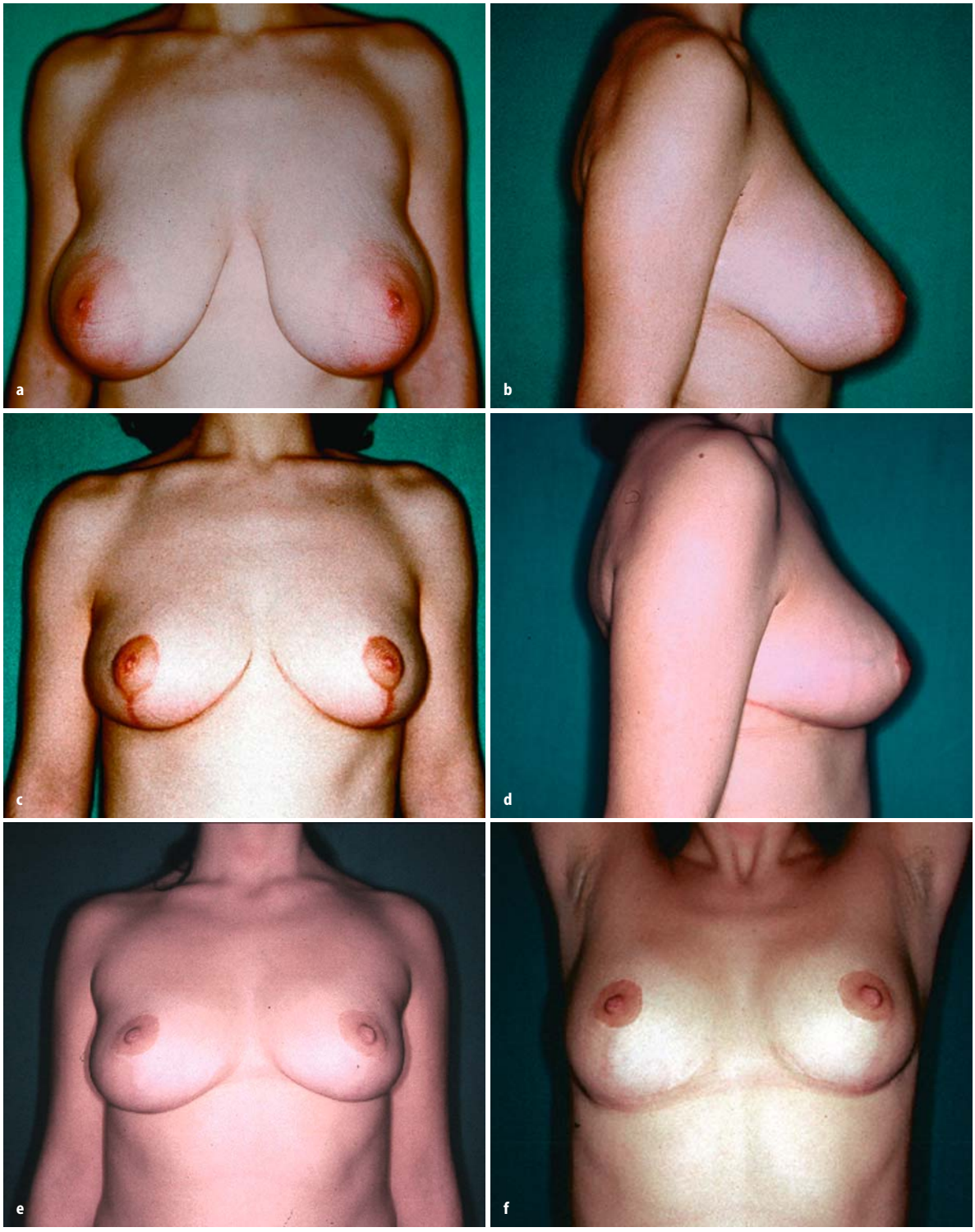


Fig. 43.5. Case 3. Twenty-three-year-old patient with moderate bilateral hypertrophy and severe ptosis. A total of 915 g was resected. **a, b** Preoperative views. **c, d** Postoperative views at 1 year. **e, f** Postoperative views at 9 years. Observe the reasonable condition of the breast and scars, despite her having had two full-term pregnancies during this period

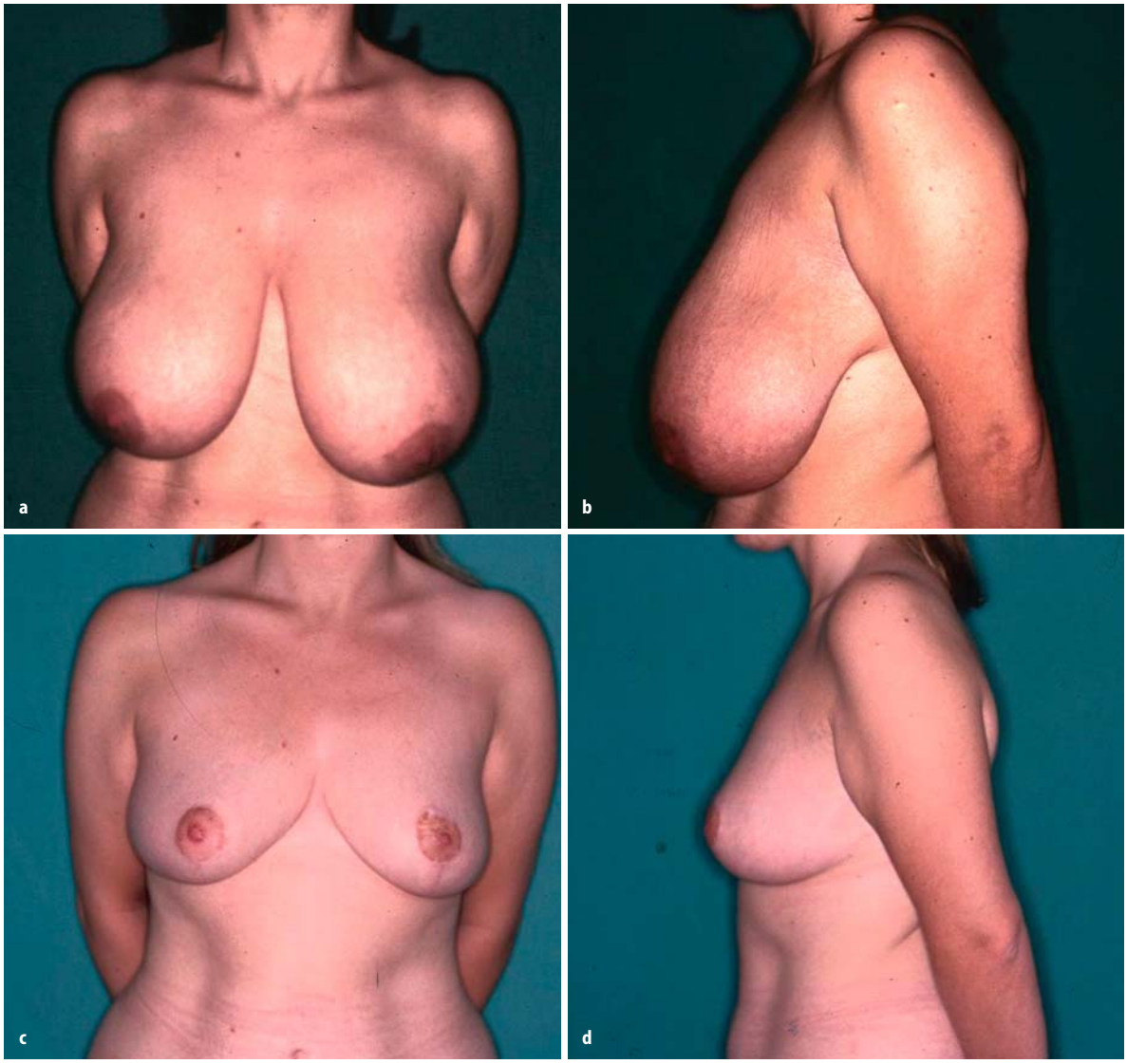


Fig. 43.6. Case 4. Twenty-one-year-old patient with severe bilateral hypertrophy and ptosis with asymmetry. A total of 1,660 g was resected. **a, b** Preoperative views. **c, d** Postoperative views after 1 year. This case reaches a ceiling for pediculated transplanting of the nipple areola complex (NAC), particularly on the left side. This is one patient who suffered a slight epidermolysis of the left areola but who did not require secondary treatment

pens especially with the inferior pedicle techniques described by Courtiss and Georgiade in the late 1970s. The causes of this are usually the use of techniques which base the suspension of the tissues fundamentally on the cutaneous covering, and therefore the glandular tissues weigh on the skin of the inferior pole, which distends and increases the distance between the areola and the submammary fold, lessening the volume of the upper pole, which has the effect of making the areola and the nipple look upwards. In short, the effects of gravity on the tissues act as an expander, which not only distends the skin but also widens the scars. For this reason we have chosen and redesigned a technique in which, as the tissues of the lower pole have been eliminated, the mammary tissues sustain themselves fundamentally thanks to the short-pedicled tissues of the upper pole and the fixing of the lateral and medial pillars to the aponeurotic muscular wall with non-absorbable stitches after dermoglandular resection. After the glandular and adipose excision, the problem we face in the remodelling of the breast is adapting the cutaneous layer in its caudal part. The distance between the areola and the submammary fold, originally already excessive, is increased by the cephalic transposition of the NAC. In the vertical technique, the convex line of the contour of the lower pole is transformed into two concave lines after the excision. Obviously, the suture in the medial line of these two concave lines will greatly re-

duce the skin in a transverse sense and, on converting to a straight line, will also diminish the vertical length, thanks to cutaneous elasticity and retraction. However, this vertical reduction is not always sufficient, dog-ears often being the result on both sides of the scar and excessive length of the scar itself. The solution to this problem is the excision of the dog-ears, converting the vertical scar into a small inverted T, or waiting a few months until the skin retracts, which does not always occur, in which case secondary excision of the excess skin would be necessary. This delay of several months until the reduction of the folds or the second intervention creates an uncertainty in the patient which can often be overwhelming, both for the patient and the medical team. In the last few years, techniques have been designed to improve these aspects, such as those described by Chen [3] and Hall-Findley [13], although both admit that the learning curve for these techniques is longer than for those based on the Wise pattern. In any case, the distance of the NAC from the submammary fold is usually longer than is desirable.

It is well known that techniques with inverted T scars allow a satisfactory cutaneous reduction, both in the transversal and in the vertical sense, naturally at the expense of the transversal scar and possible risks of cutaneous necrosis in the angles of the flaps. However, with the technique we present, the possibilities of necrosis are practically nil, as the tension in the cutaneous suture has been eliminated. This tension increases during the immediate postoperative period due to oedema. On the other hand, with the elimination of tension, both in the vertical and the transversal suture lines, the scars are usually of excellent quality. Fixing the crossed flaps to the musculoaponeurotic wall allows adequate and symmetrical positioning of the breast, and at the same time maintains the position of the submammary fold and prevents sagging of the breast with the unsightly result of deformity of the lower pole, widening of the scars and upward migration of the NAC. We should remember that poor quality scars and the loss of projection of the breast are considered the greatest disadvantages when using inverted T techniques as described by Hidalgo [11, 12] and Davis [5]. In fact, the degree of patient satisfaction after a mammoplasty is directly related to her subjective perception of the scar quality. In an unsatisfied patient, in the majority of cases you will find an aesthetically unacceptable scar as described by Brülman [2] and Makki [18]. We should remember that in the USA mammary reduction is the primary cause of lawsuits, principally due to poor quality and position of scars. **The trajectory of the transverse incision line 1.5 – 2 cm above the submammary fold and the resection of fat below the said line, as well as fat and glandular excision in the lateral pole, allow not only better remodelling of the contour, but also an important shortening of the transversal scar, which is incorporated within the submammary fold.** When there is notable adiposity in the lateral region of the breast (anterior axilla line up to the posterior axilla line) we perform common liposuction with satisfactory results as the skin has excellent retraction.

In our opinion, L, comma, J, and similar techniques are excellent for moderate hypertrophy or narrow based breasts and/or good quality skin which allows retraction. We have been using the reduction in comma for more than 20 years with excellent results in cases like these. The breast reduction techniques which use inverted T shaped incisions are attractive for the surgeon as they are predictable and versatile, with practically no limit in the tissues to be resected nor a reduction in correct remodelling, apart from allowing adequate control of the quantity of tissues to be resected and the process of transoperative remodelling [11, 12].

The use of a dermoglandular flap with superointernal pedicle gives excellent vascularisation to the NAC, propitiates the recuperation of sensitivity of the skin and NAC within 3 – 6 months after surgery, with no significant difference to that found with inferior pedicle techniques as described by Hamdi [9]. It also allows easy transposition, even in those cases of very little ptosis or moderate reduction, and gives great security in those other cases of marked ptosis and even gigantomastia. We should not forget that forced transpositioning of the NAC could lead to ischaemia and secondary deformity of the shape of the areola; this type of flap also gives excellent projection of the nipple.

In our experience, the best indications of the crossed dermal flaps technique are in breasts with moderate hypertrophy and an ample implantation base, moderate hypertrophy with ptosis and poor quality skin and large hypertrophies, including some cases of gigantomastia. In the cases with a large degree of ptosis, we complement the technique with an inferior pedicled dermoglandular flap, of the Ribeiro type, fixing the crossed dermal flaps to the musculoaponeurotic wall through an incision in the base of the pedicle. In other cases, we completely section the pedicle, leaving the vascularisation of the flap at the expense of the perforators. This flap will help to fill up the upper pole of the breast and to increase projection.

43.5 Conclusions

Breast reduction is an intervention which in general gives a high degree of satisfaction, both to the patient and to the medical team. In a survey carried out among the members of the ASAPS and published by Rohrich [22], following a scale from 1 “unsatisfactory” to 5 “very satisfactory”, the degree of surgeon’s satisfaction was 4, both for vertical incision techniques and for

Wise pattern techniques. Patient satisfaction was 5 for Wise pattern techniques and 4 for vertical incision techniques. Another conclusion was that the vertical incision statistically has more complications than the inverted T incision. It is interesting to note the difference in techniques performed in different countries and the reasons are apparently multiple (legal, racial, customs, education at different schools). Whilst in the USA 75% of surgeons habitually use the Wise pattern, in Germany 66% of surgeons choose vertical incision techniques as studied by the Eisenmann-Klein team [7].

Given the results obtained in the short and long term, we believe that this technique has proved to be safe and applicable to an extensive variety of cases. It is easy to execute and to teach, and therefore those who are beginning to use inverted T techniques such as that described, can, from the beginning, diminish the incidence of short and long term complications such as we mentioned before: (1) dehiscence with later bad scar at the level of the convergence of the flaps; (2) bottoming out of the inferior pole, with the horizontal scar displaced upwards and an increase in the distance between the submammary fold and the NAC, and with uniformly good and long-lasting results.

We conclude also that the use of controlled hypotension is of great help in breast reduction, as in our practice it has not implied added risks and has given the previously mentioned advantages. We also insist that in no cases is blood transfusion required, which is very important if we take into account present-day risks inherent in transfusions.

The improvement in breast reduction techniques with minimal scars supposes a lesser use of the inverted T technique in our patients. However, we believe that there are clear indications, when the volume to be resected and the search for optimum long-term results suggest the use of an inverted T technique.

The average volume resected was 1,099 g, which fully justifies the use of this technique as a preferred procedure and evidently supposes an advantage as we only had one case of thickening of the scar among 195 patients operated on.

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Sagittal Reduction Mammaplasty

44

J.G. Poëll

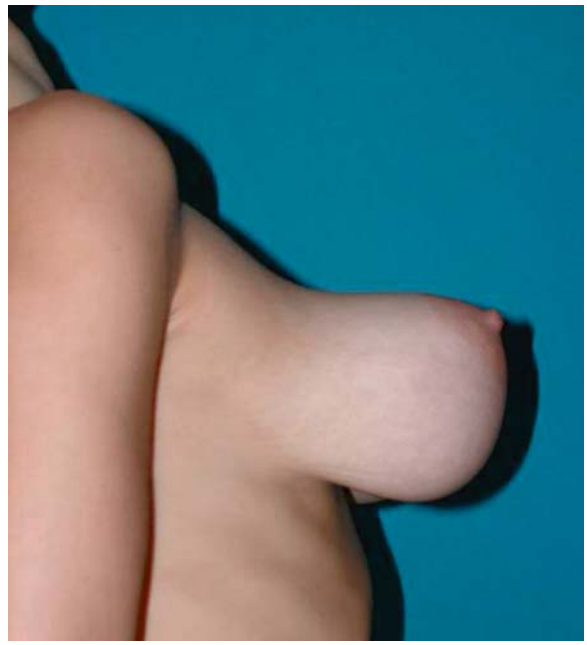

Fig. 44.1. A hanging breast turned 90° to show that the reduction is sagittal and not vertical with regard to both the skin and the gland

The patients seeking our help for breast reduction are often young and probably planning to have children later on in their lives. It is therefore most important to offer them a method that not only leaves few scars but also as much physiology as possible. They need to be able to breast feed and have a normal sensibility. The sagittal reduction the way I perform it fulfils these expectations. You can form a pleasant breast with few scars and preserve sensibility and lactation. Scars can always be lengthened but never shortened. So do them as short as possible from the beginning. The method can be used for all patients from mastopexies to big reductions.

44.1 History

Although the short scar mammary reduction was described in 1925 by Dartigues [1], it was forgotten for a long time and only brought back to use by Claude Lassus in 1970 [2], by Madeleine Lejour in 1993 [3] and certainly also by others unknown to me. After having made reductions with the method of McKissock, Peixoto and Machac, I started with the method of Madeleine Lejour 15 years ago and have used and modified it since step by step over the years. The reduction is not actually a vertical but a sagittal one as both the skin and the glandular resection are sagittal (Fig. 44.1).

44.2 The Patient

The patients seeking our help can be of any age between 13 and 75 years. The troubles that she mentions first are mostly neck and shoulder pain. But when you start asking, the problems are multiple. The breast is the primary focus of a woman's feminine identification. All plastic surgeons are well aware of the disagreeable social re-

actions experienced by large breasted women. The most obvious are often not so subtle comments by friends and people in the street. There is the embarrassment of undressing in front of other girls, which is an impediment to them to joining in with team sports. Large-breasted women come to resent their breasts and dissociate from them. Some even start hating them. Interpersonal contact with the other sex is often unimaginable.

Most of us, plastic surgeons and patients alike, cannot fully comprehend the profound psychological process which we deal with when we alter this so important part of a women's body. But postoperatively breast reduction patients are often the happiest we ever see.

44.3 Anatomical Givens

My method is based on the one of Madeleine Lejour and I have been using it for 15 years, and for 13 years in all cases.

As we are doing harm to the body with every operation our main goal should be: **primum nil nocere**.

We should leave a breast with as few scars and as much physiology as possible.

The method is based on anatomical considerations and logical steps that lead to logical problems during the operation. There is a solution for each one of them.

44.3.1 Perfusion

As we sometimes transpose the nipple-areolar complex (NAC) over a long distance, perfusion can become a problem. I therefore choose a cranial pedicle to be on the safe side. The main perfusion comes from cranially and medially, from anterior perforators of the internal thoracic artery through the second, third and fourth intercostal spaces (Fig. 44.2). A principal vessel passes through the second or third space and divides into two branches with the superior branch supplying the upper inner quadrant and the other branch passing to the areolar area. An equally significant contribution comes from branches of the lateral thoracic artery or the superficial thoracic artery directly from the axillary artery. These enter the breast in the upper outer quadrant and run superficially within the gland giving branches to the skin. There is also an additional contribution from the cutaneous branches of the thoraco-acromial artery. If we preserve these arteries we are most likely not to have any perfusion problems.

With this method we can choose a cranial pedicle as wide as necessary (Fig. 44.3). With the cranial pedicle the NAC can be considered a cranially based axial pattern island flap, with a base rarely narrower than the length of the pedicle. Thus the cranial transposition of the NAC is not a problem as far as the perfusion is concerned.

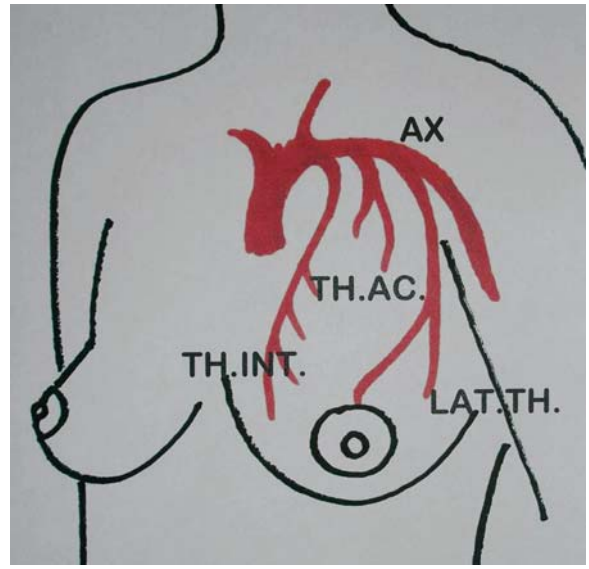

Fig. 44.2. The blood supply from the thoracica interna, thoracica lateralis and acromioclavicular arteries

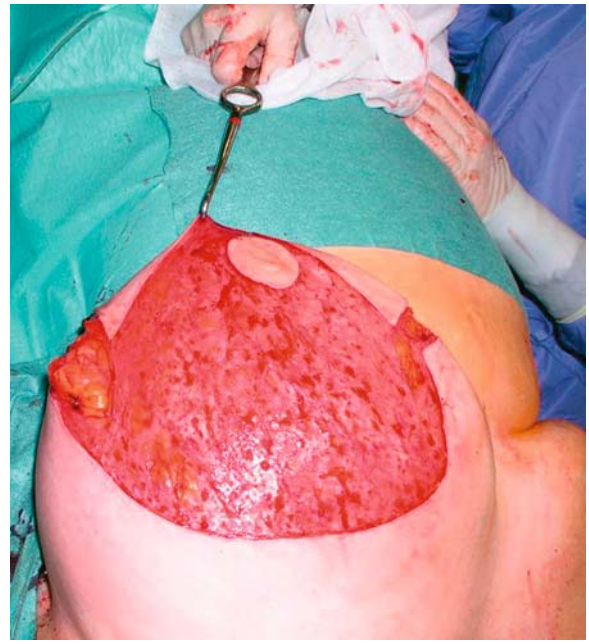

Fig. 44.3. Wide pedicle with large reduction

44.3.2 Sensibility

The nerve supply is mainly from the medial and lateral cutaneous branches of the second, third and mainly the fourth intercostal nerves. They run primarily superficially and can be saved by preserving the superficial

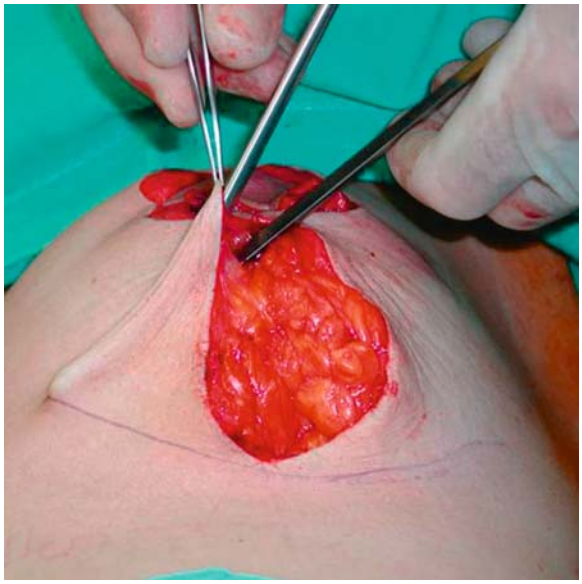

Fig. 44.4. Mobilization of the caudal quarter of the breast. The rest is attached to the skin

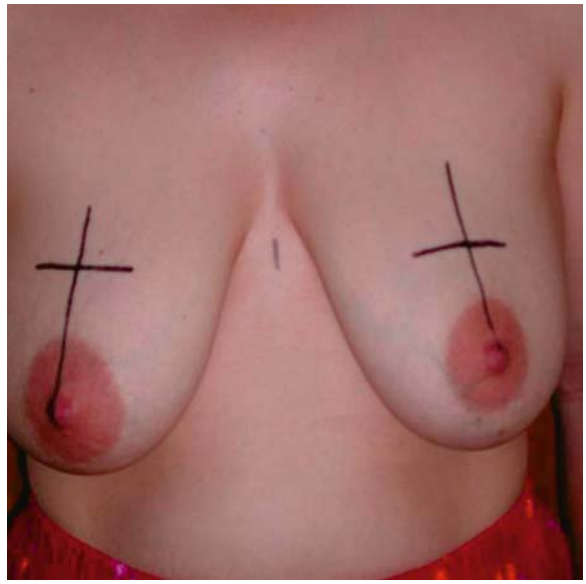

Fig. 44.5. Preoperative marking in a standing position

part of the breast that lies close to the skin. The breast is derived from the ectoderm and I therefore try to preserve as much attachment to the skin as possible. The skin is only mobilized in the caudal quarter of the breast (Fig. 44.4), where a mobilization is necessary to fold the longitudinal scar and keep it as short as possible.

44.4 The Method

44.4.1 Design

Preoperatively only the new position of the nipple is marked in a standing position at the projection of the submammary fold (Fig. 44.5). The distance to the jugulum and to the xiphoid is controlled by measurement to achieve as much symmetry as possible. The new position is central on the breast no matter where the areola is positioned preoperatively. The central axis of the breast is determined by continuing the contour of the neckline. The rest of the design is then made intraoperatively in a supine position in beetle fashion by moving the breast cranially-medially and then cranially-laterally and marking longitudinal lines in these positions. The round upper cut completes the design to a beetle pattern and rarely exceeds 15 cm in width. It is important to resect the skin almost down to the submammary fold, because the whole breast has too much skin after the reduction or even before in the case of ptosis (Fig. 44.6). Depending on the tension of this movement the breast will be more or less firm. The tension is dependent on the quality of the skin. Too much tension will produce a widening of the scar or around the areola to a flattening of the nipple. The areola has a diameter of 36 – 50 mm, depending on the size of the resultant breast.

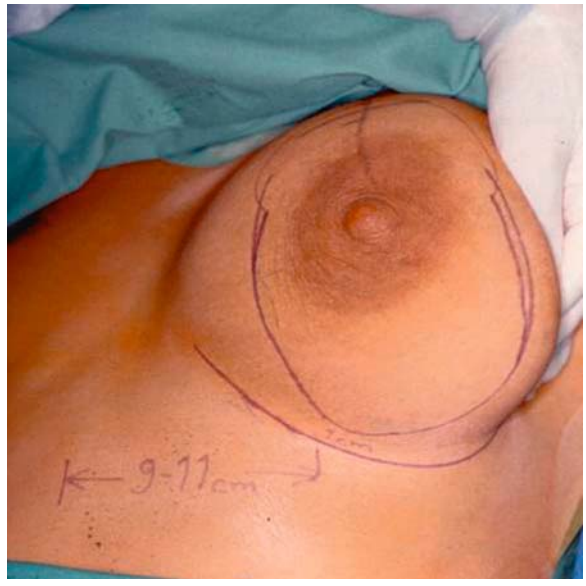

Fig. 44.6. Marking of the skin resection in a supine position, almost down to the submammary fold

44.4.2 Deepidermization

At the beginning of the operation I inject 50 ml saline with 10 ml bupivacaine 0.5 % and 1/2 mg adrenaline into each breast. This prevents major intraoperative

bleeding, thus avoiding blood transfusions and diminishing the postoperative pain in the first hours.

Strangulation of the breast helps for deepidermization. The upper pedicle is deepidermized until about 1 cm below the areola and especially also the border of the whole longitudinal skin incision is deepidermized about 1 cm wide on the whole length (Fig. 44.7). This strip is then utilized to suspend this scar and in this way shortens it dramatically.

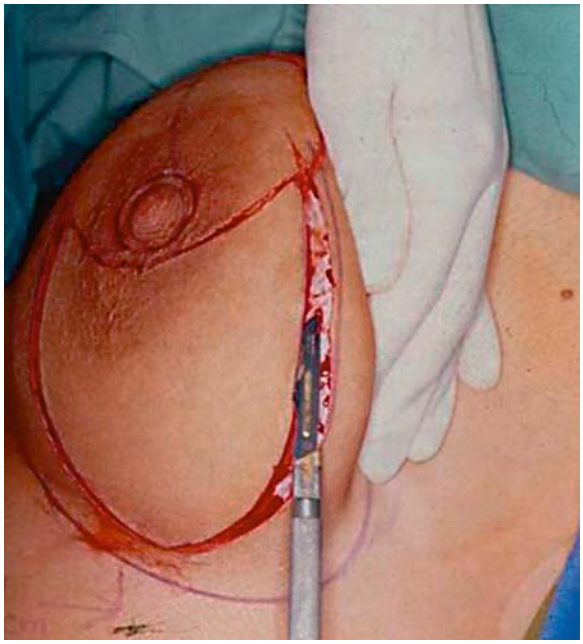

Fig. 44.7. Deepidermization of the longitudinal wound about 1 cm, to suspend the skin on and shorten the longitudinal scar

44.4.3 Liposuction

Liposuction is only used in a few cases where we need to thin out the cranial pedicle to make it more malleable or where we want to remove fat pads on the upper part of the pectoralis muscle or laterally towards the axilla. Liposuction is rarely suitable as a sole procedure to reduce the volume of the breast. Only in old patients could it be of help but always together with a skin reduction. Young patients have a firm breast with a lot of connective and glandular tissue that is not suitable for liposuction.

44.4.4 Reduction

We reduce the breast mainly centrally and in addition also a caudal segment to be able to bring the caudal pillars together to narrow the base of the breast and to produce projection. The caudal part of the breast is reduced rigorously (Fig. 44.8) before the fascia scarpa is reaffixed to the pectoralis fascia at the lowest point of the longitudinal incision to avoid a sliding down of this part. The breast is then reaffixed to the submammary fold (Fig. 44.9). The breast tissue is left in contact with the skin to preserve the nerves and ensure the blood supply and to avoid irregularities at the borders of the breast. The amount of breast tissue left under the skin determines the size of the resultant breast. Only the caudal quarter is mobilized subcutaneously. Here the mobilization is necessary to be able to plicate the skin in the vertical wound to keep this as short as possible (Figs. 44.4, 44.10).

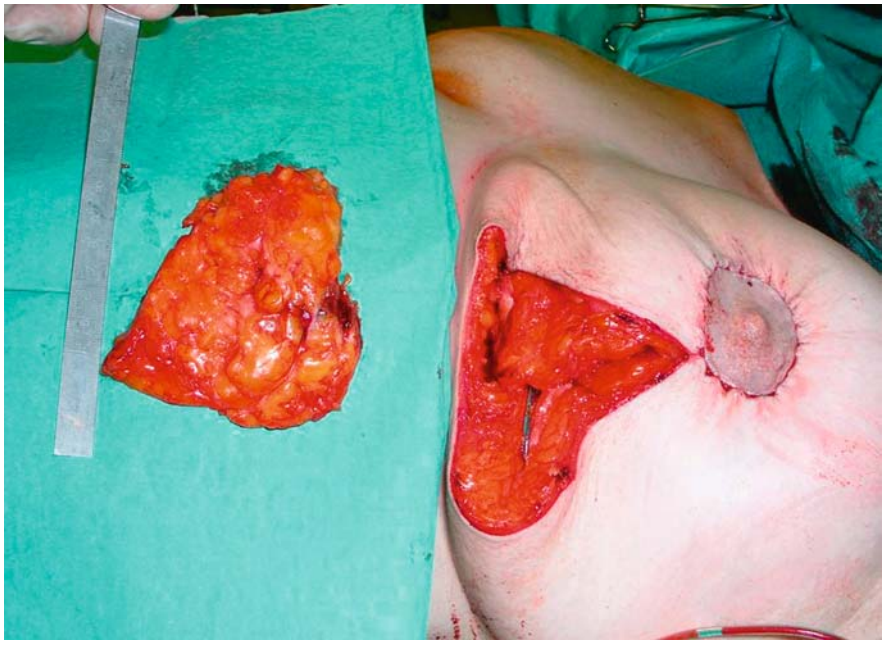

Fig. 44.8. Rigorous caudal resection of breast tissue to prevent too long a caudal part of the breast

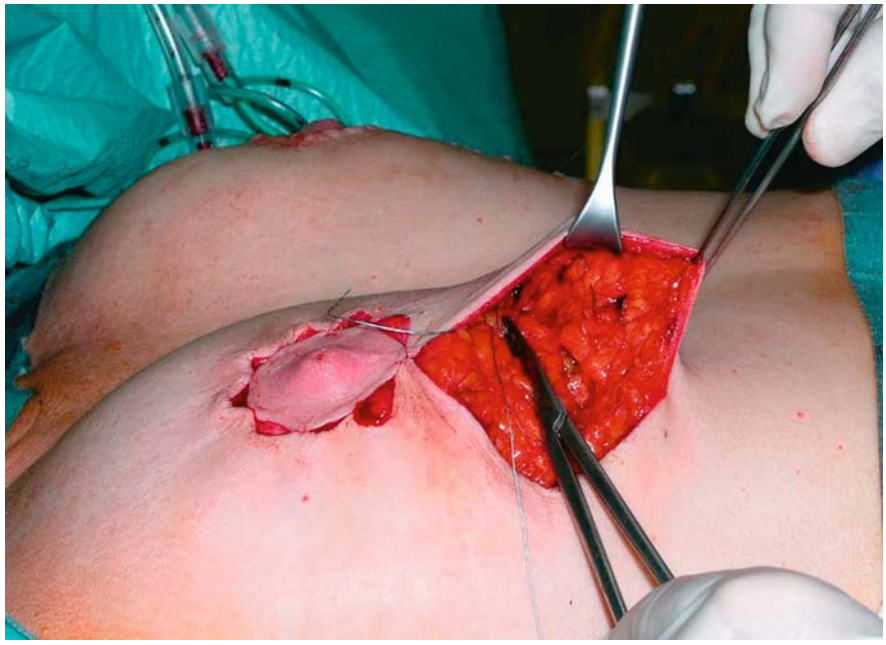

Fig. 44.9. Fixation of the breast to the submammary fold

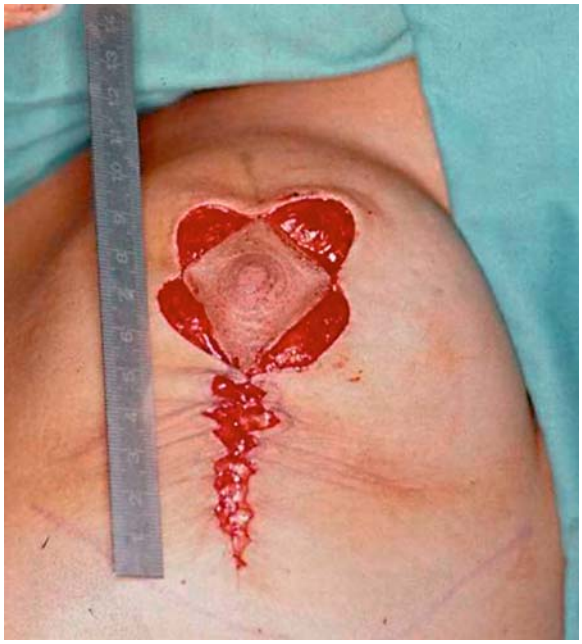

Fig. 44.10. Suspension sutures of the skin on the deepidermized strip of the longitudinal incision

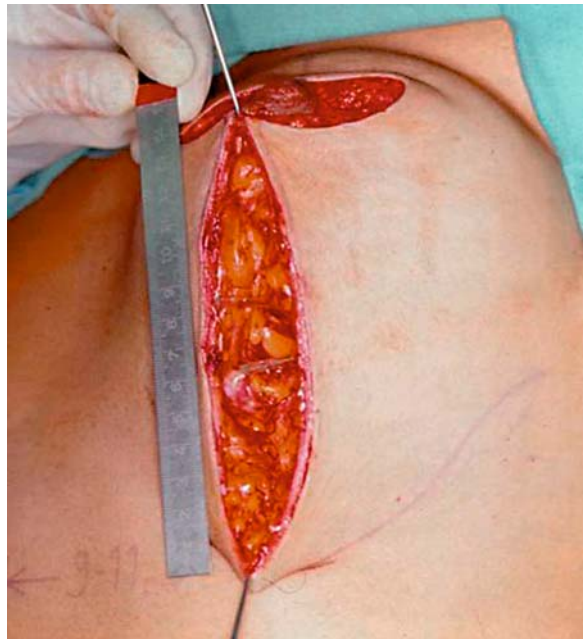

Fig. 44.11. Before the suspension the longitudinal wound is much too long to fit into the breast

44.4.5 Skin Sutures and Suspension

The periareolar sutures are in multiple layers. This allows us to remove the superficial one on the second or third postoperative day thus avoiding visible stitches. The aim of this suture is to flatten the folds that are produced by the purse-string character of the wound after application of the deep sutures. A real purse-string suture as proposed by Benelli is not used.

The longitudial wound is first suspended with single stitches, thereby folding the skin like a curtain. This allows us to shorten the scar from sometimes 15 or more centimetres to 6 or 7 cm (Figs. 44.10, 44.11). With a running intradermal suture the folds are distributed and lowered (Fig. 44.12).

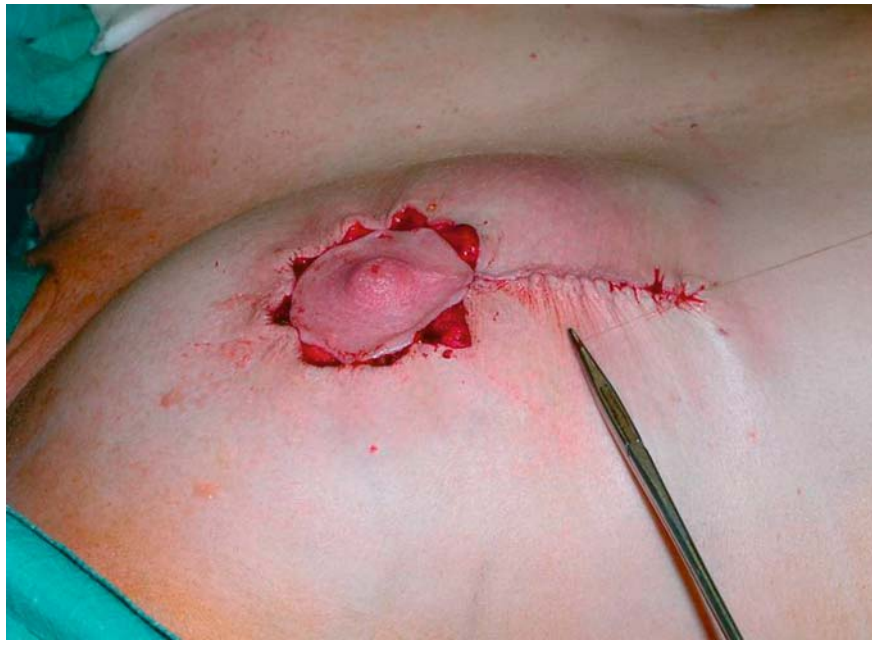

Fig. 44.12. After the folding suspension sutures a running suture with 4-0 Maxon is used to flatten down the folds

44.4.6 Positioning

The breast has two fix points which are the NAC and the submammary fold. This is where it belongs, so I determine the new position of the NAC as the projection of the submammary fold in a standing position and reaffix the breast to the submammary fold during the intervention.

44.4.7 Outcome

The outcome is dependent on the skin quality and on the filler, the breast tissue, and how it is distributed. The non-elastic old skin will never leave a result as good as one with a young elastic skin. The breast tissue is kept mostly in the upper part of the breast thus leaving a breast with a typical fullness here at the end of the operation (Fig. 44.13). This overcorrection will leave a

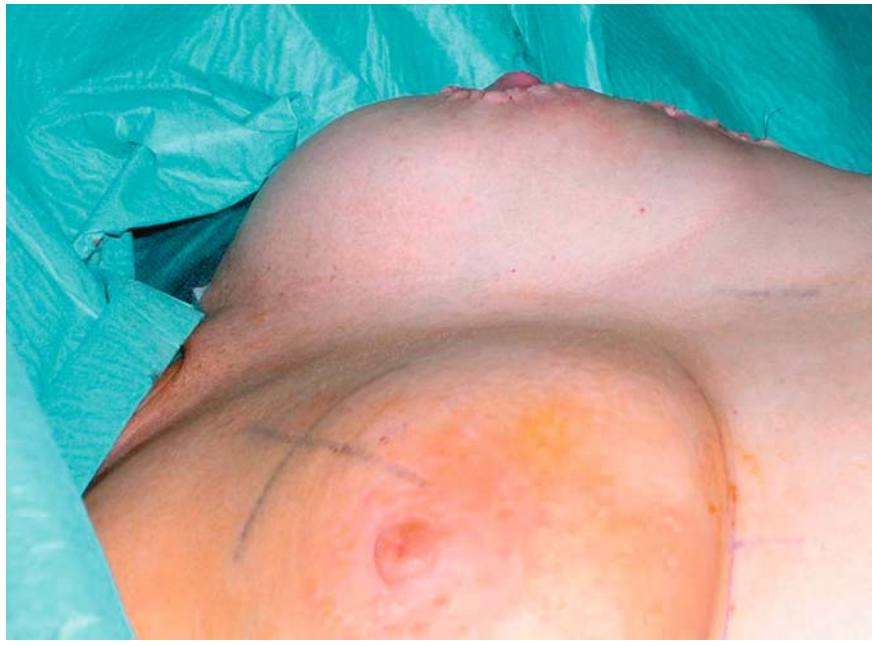

Fig. 44.13. Typical form at the end of the operation with too much volume cranially and a flat caudal part of the breast

normal looking breast within 2–3 months postoperatively. This upper fullness remains quite constant with time and will never droop out in the lower part of the breast. Thus we do not need caudally or otherwise based and often badly perfused flaps. It is preferable to leave the tissue where we want to have it rather than bringing it in from other parts of the breast. By bringing the caudal pillars together we produce projection, narrow the base of the breast and reduce dead space in the central part of the breast where tissue has been removed. Every breast, operated on or not, shows a hollowing beneath the NAC (Fig. 44.14). To bring in more fullness here I perform an everting suture behind this complex (Figs. 44.15, 44.16).

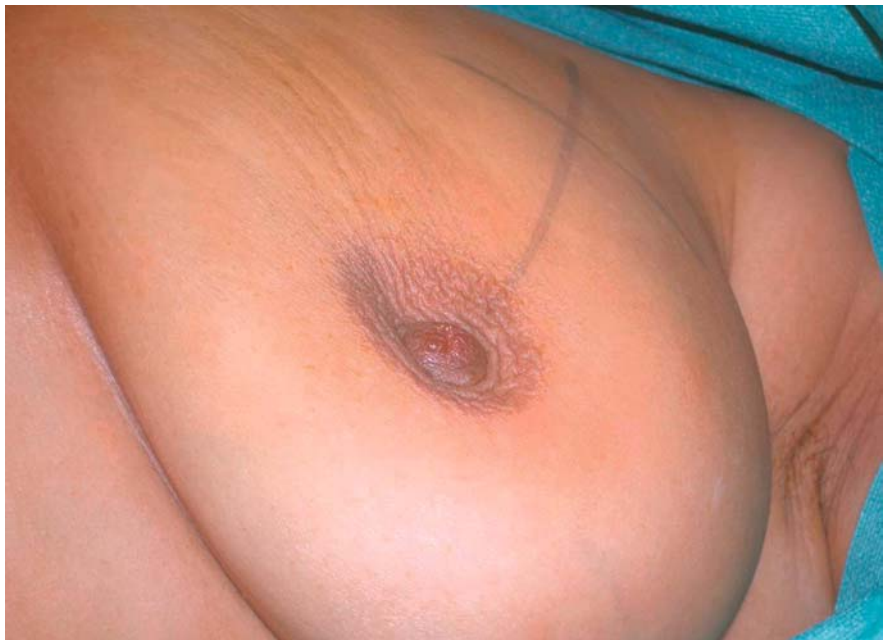

Fig. 44.14. In all breasts the NAC is sunken in preoperatively

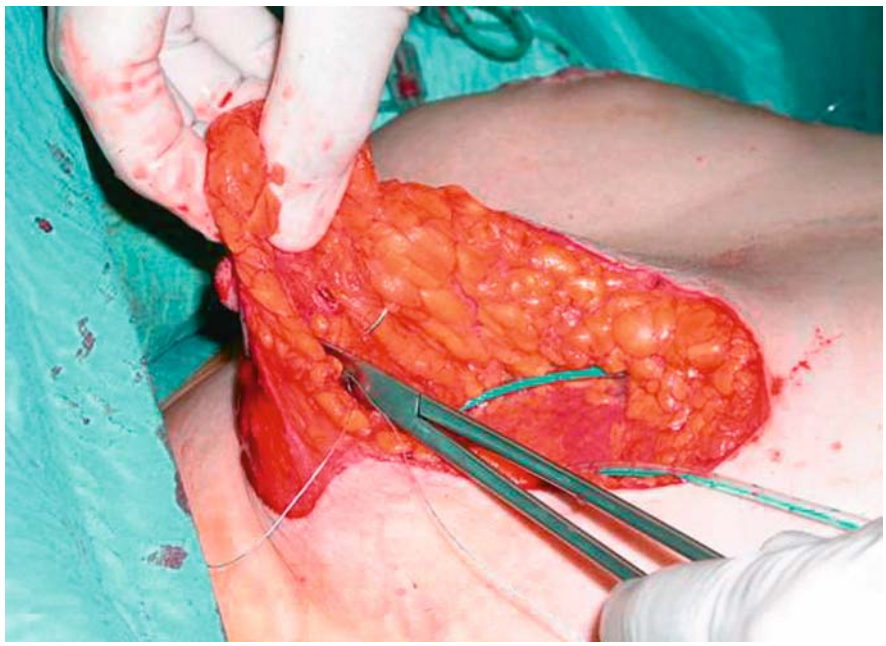

Fig. 44.15. Eversion of the NAC to avoid leaving a sunken in appearance

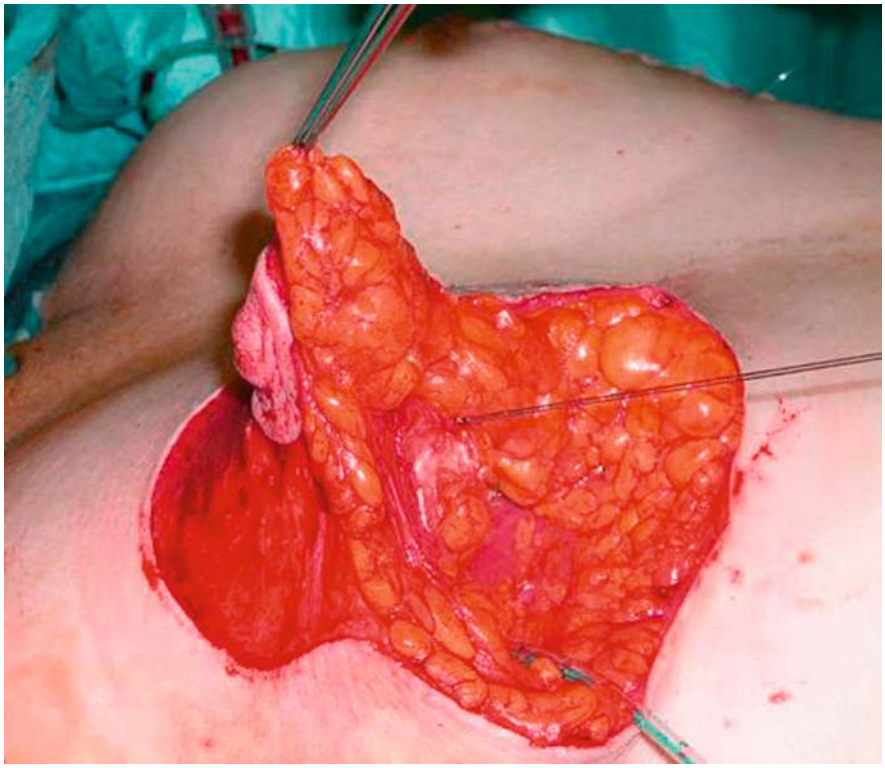

Fig. 44.16. Everted NAC to fill up the central part of the breast and make it more prominent

44.5 Problems and Solutions

The often heard reasons for poor outcomes with any short scar technique are always the same:

- A sagging out of the lower part of the breast
- A too long breast caudally
- A scar that passes the submammary fold
- A dog-ear at the end of the vertical scar

44.5.1 Sagging Out

This problem is much more often seen in the inverted T technique where the breast slides down in a pseudoptosis and leaves the horizontal scar within the breast way higher than the submammary fold (Fig. 44.17). With my technique this problem is extremely rare, because I leave as much tissue as possible in the upper half of the breast within the folded cranial pedicle and the lower part of the breast is shortened and reaffixed to the submammary fold.

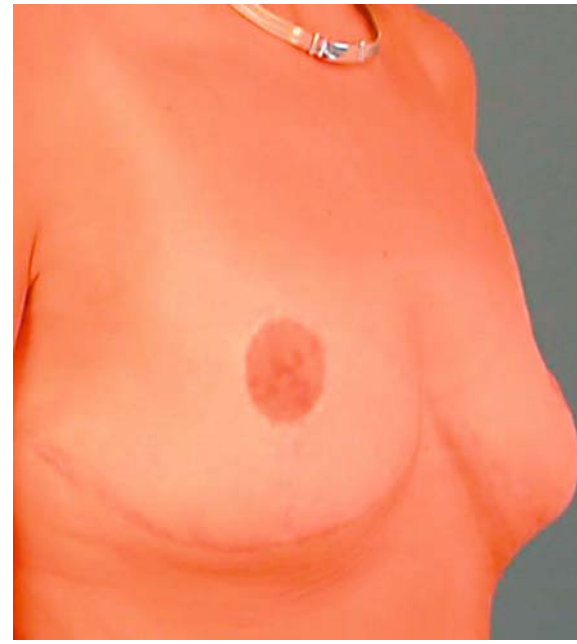

Fig. 44.17. Inverted T scar slid up on the breast after often seen pseudoptosis

44.5.2 Too Long Caudal Part of the Breast

This can be avoided by rigorous caudal resection of the breast tissue. We only leave as much breast tissue between the NAC and the submammary fold as we want. This is an average of about 7 cm. By affixing the breast to its former position its base remains at the submammary fold.

44.5.3 Too Long Scar

To avoid the longitudinal scar becoming too long it is important to suspend it. I fold it like a curtain especially in the cranial half by suspending the deepidermized skin on the borders of the longitudinal scar on itself (Fig. 44.10). This produces deep folds in the skin that are levelled by the running suture that is put intradermally upon it. I use 4-0 Maxon, a suture that resolves within 4 – 6 months.

44.5.4 Caudal Dog-Ear

A dog-ear is produced when we leave too much skin in the caudal part of the breast or the lower part of the scar slides down on the thorax (Fig. 44.18). It is therefore mandatory to resect skin almost down to the submammary fold. There is always a surplus of skin in the hypertrophic or ptotic breast down to the submammary fold.

To be sure that the skin does not slide down on the thoracic wall, we fix the fascia scarpa at this point towards the pectoral fascia (Fig. 44.19).

44.5.5 Unnatural Look

In the first days or weeks the breast might look a little overprojected in the upper part but this will resolve within the short term (Fig. 44.20).

The wrinkles around the areola and in the longitudinal scar will take some months until they disappear, depending on the elasticity of the skin. To reduce this period the patient is asked to massage the scars with digital pressure, thus moving the skin against the underlying structures.

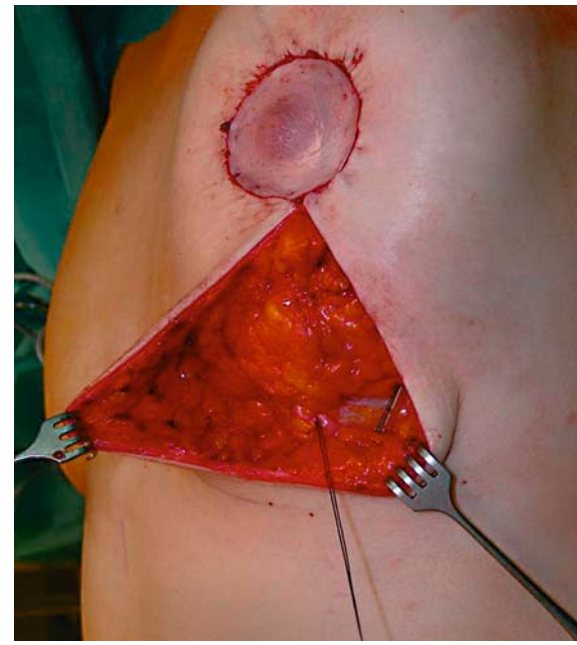

Fig. 44.19. Fixation of the fascia scarpa at the end of the longitudinal scar

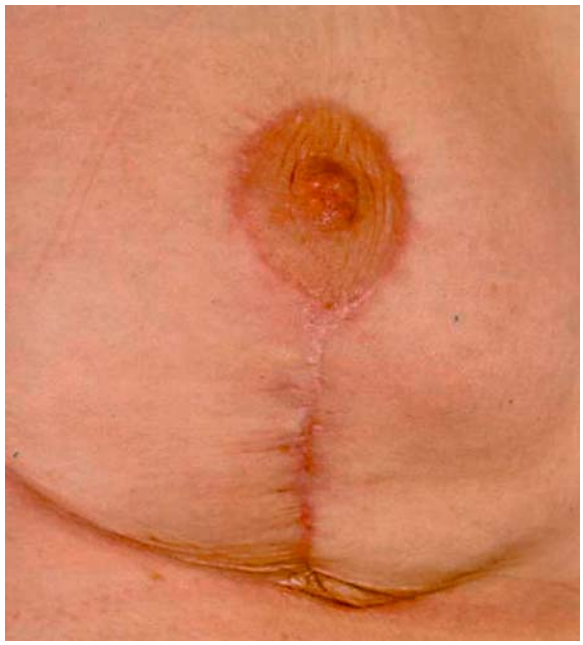

Fig. 44.18. Dog-ear at the lowest point of the longitudinal scar

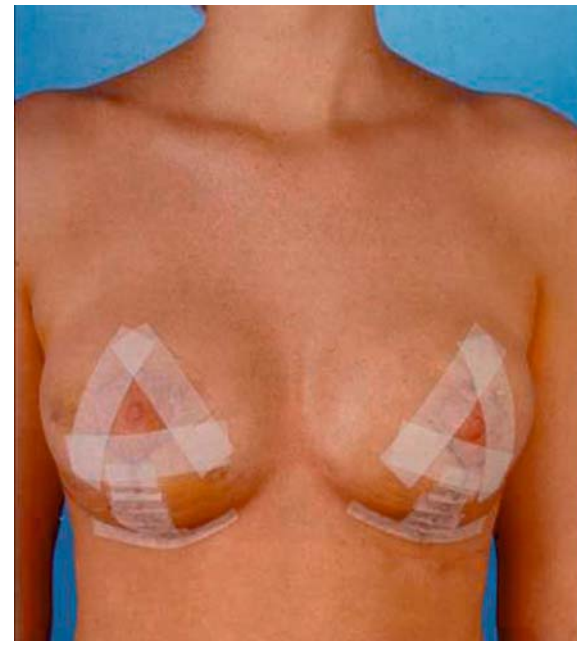

Fig. 44.20. An already normal looking breast after 3 weeks

Fig. 44.21. Natural appearance at the end of the healing period

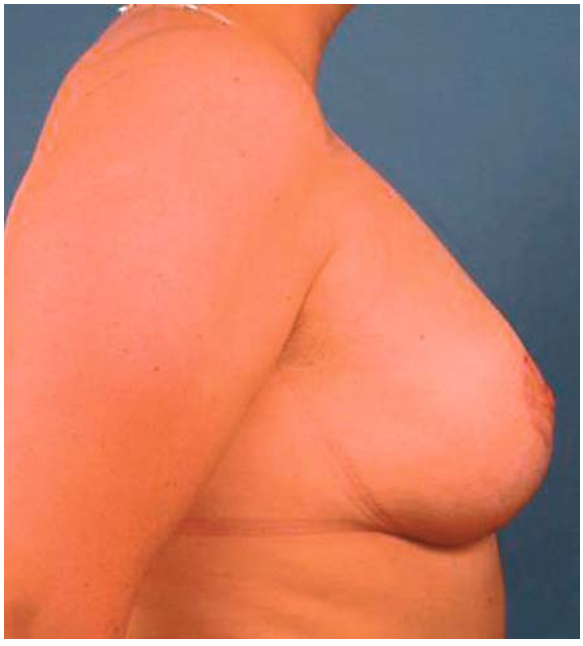

Fig. 44.22. Pleasing fullness in the upper part of the breast which is constant due to plication of the cranial pedicle here

44.6 Conclusions

A breast reduction is never an easy operation. One problem will always be the symmetry no matter what method we choose. With my method I try to leave as few scars as possible on a breast with as much physiology as possible. Scars can always be lengthened but never shortened. This method can be used for all cases from gigantomastia to mastopexies. The cranial pedicle is safe and becomes wider the bigger the resection is. Smaller necroses of the border of the areola are very rare and necroses of the nipple have never been seen.

The learning curve, being longer than in other methods, can be shortened dramatically with a good teacher. The appearance of the breast is very natural with a pleasing cranial fullness (Figs. 44.21, 44.22).

Many happy patients attest to the advantages of this method, which avoids long horizontal scars under the breast, often sliding into it when a pseudoptosis occurs. Sometimes this scar reaches from presternally to way back in the axilla. Mainly in these two zones the tendency for hypertrophic scars to form is very high. These parts of the scars will always be visible in a décolleté or a bikini. The inverted T technique with long horizontal scars should therefore be avoided whenever possible.

It is not only important what you take away but also what you leave. Therefore leave as few scars as possible and do as little harm as necessary. Primum nihil nocere.

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One-Stage Periareolar Breast Augmentation and Mastopexy for Tuberous Breasts and Mild to Moderate Hypoplastic and Ptotic Breasts

45

R.A. Moscona, L. Fodor

One of the most controversial topics in aesthetic breast surgery is the approach to a tuberous or to a mild to moderate hypoplastic and ptotic breast. In these situations, augmentation alone does not solve the problem and even the use of a bigger implant to elevate the nipple as much as possible results in more breast ptosis in the long term. These patients benefit from a mastopexy procedure. It is tempting for patients and also for surgeons to have these procedures performed together. However, this is a contentious decision to make.

Searching for a minimal scar technique led to the development of the circumareolar mastopexy technique. The concept started about 30 years ago, through the contributions of Bartels [3] and Rees [14]. A few years later, refinements of the procedure were brought about by Benelli [4], who described the "round block" technique for periareolar mammoplasty. Since then several techniques based on this concept have evolved. We present our technique and experience with one-stage periareolar breast augmentation and mastopexy.

45.1 Indications

Patient selection is very important because the one stage periareolar mastopexy-augmentation is not ideal for all patients. Tissue quality, degree of ptosis and patient expectations are the most important factors in deciding the technique to be used. The main indications for our approach are:

- Tuberous breasts
- Minimal/moderate ptosis (less than 4 cm nipple elevation)
- Associated wide areola

45.2 Technique

Preoperative markings are made with the patient standing up. Any sign of breast asymmetry is taken into account. The new nipple-areola location is designed by finding the projection of the inframammary line. The amount of skin that needs to be deepithelized is designed as a round-oval shape (Fig. 45.1a, b). The new areola size is designed using a cookie cutter of 38 mm diameter. The skin to be removed and the implant pocket is infiltrated with a local anesthetic solution containing: 40 ml lidocaine 2%, 20 ml Marcaine 0.5%, 1 mg adrenaline and 100 ml normal saline (Fig. 45.1c). The implant location is decided after a pinch test in the upper part of the breast. When the thickness in this area is less than 2 cm, the implant is placed under the muscle. After deepithelizing the skin, a hemicircular infra-areolar incision is made and the breast tissue is transected perpendicular to the muscle (Fig. 45.1d). For submuscular implant placement, a dual plane technique is used. For tuberous breasts, the constricting bands are released and transected through the same approach.

We always use a high profile round silicone gel implant (MHP, CUI, Inamed Aesthetics) or style 410 MX/FX anatomical (McGhan, Inamed Aesthetics). The size is decided according to preoperative measurements and patient approval. After implant placement, the breast tissue is sutured in two layers using a 3/0 Vicryl stitch. The skin wounds are temporarily closed with staplers and the patient is placed in a sitting position (90°). At this stage, a decision to perform any changes to obtain symmetry is made. In order to reduce tension to the areola, the skin defect is closed in a pursestring manner using a straight needle 2/0 nylon stitch. The straight needle has the advantage that a 2–3 cm bite can be achieved, thus avoiding large periareolar skin puckers. With the pursestring suture (Fig. 45.1e, f), the circle is tightened to the new areola size (38 mm). The superficial skin layer is closed with a 4/0 resorbable monofilament stitch. Steristrips are placed on top of the skin to reduce the puckering produced during surgery and left in place for a period of 2 weeks. We recommend wearing a brassiere for 2 weeks.

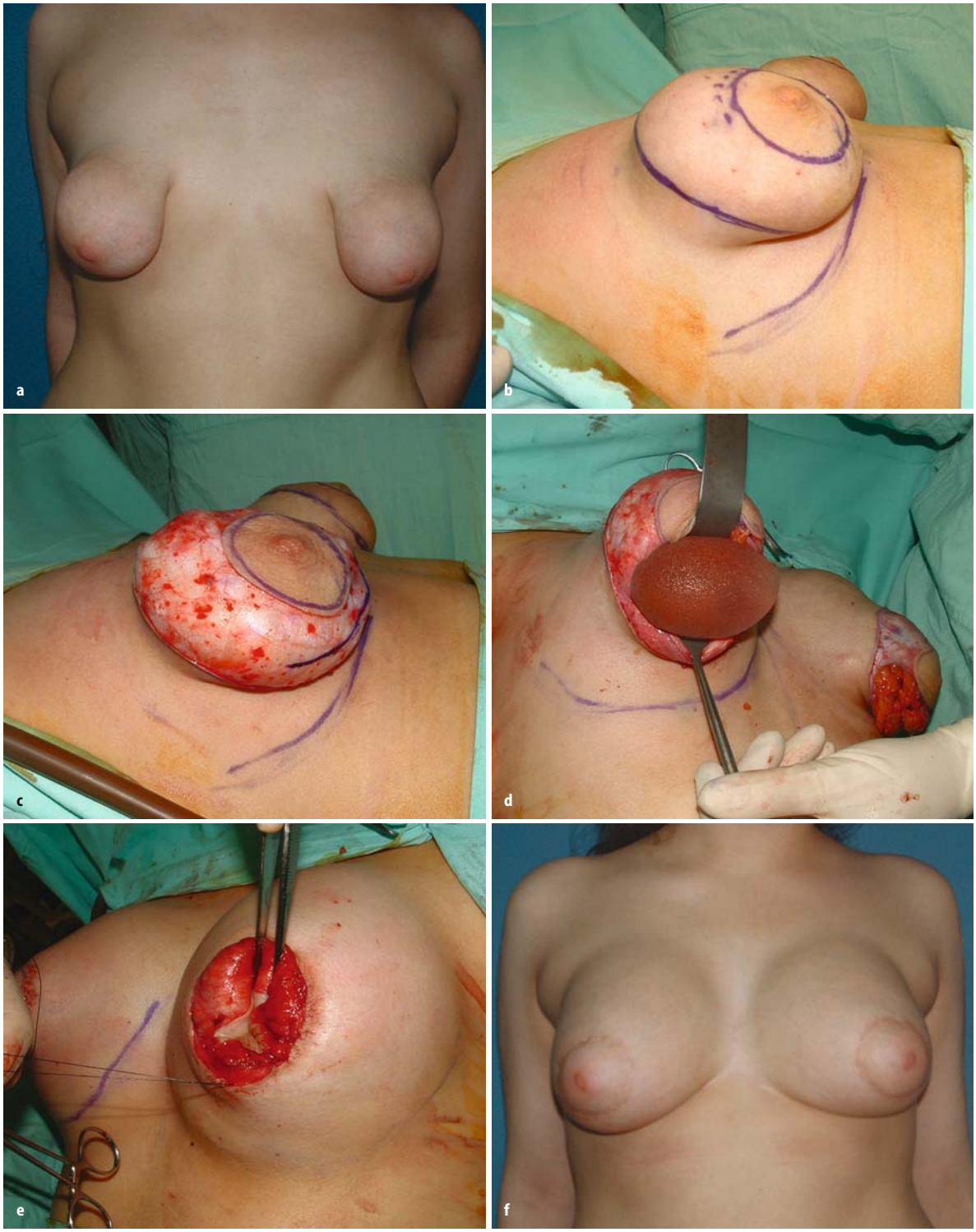


Fig. 45.1. a Preoperative views of a 17-year-old girl with tuberous breasts. **b** Amount of skin that needs to be removed is marked. **c** Marked area is deepithelized. **d** High profile silicone implant is inserted. **e** Pursestring is performed using 2/0 nylon. **f** Postoperative views 18 months after surgery

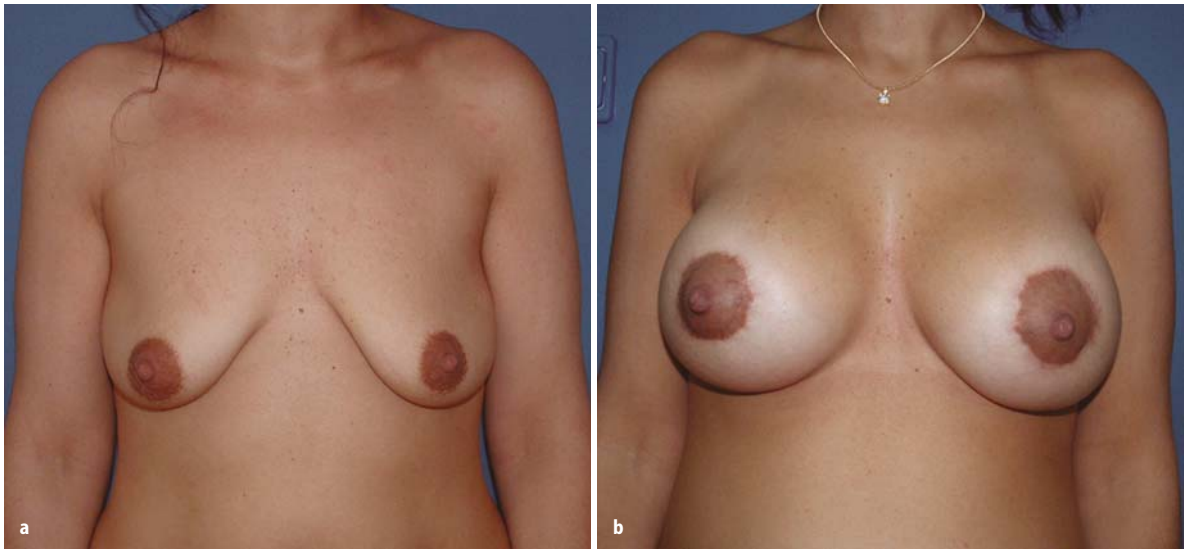
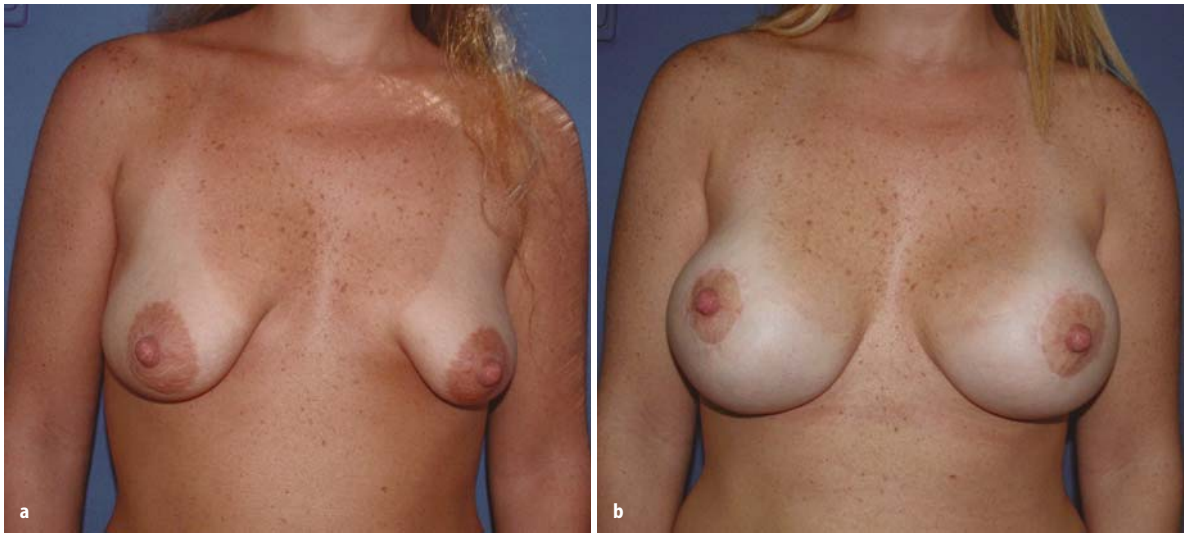


Fig. 45.2. a Hypoplastic breasts with moderate ptosis. **b** Fourteen months after surgery – the patient is happy with the result



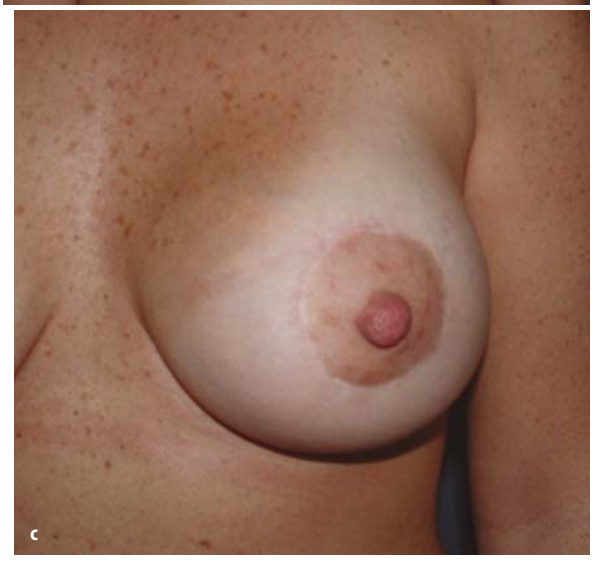


Fig. 45.3. a Preoperative views of a 28-year-old woman with hypoplastic asymmetric breasts. **b** Postoperative views 18 months after periareolar augmentation-mastopexy. **c** Eighteen months after surgery; areola close up

45.3 Results

We have been applying this technique for the past 5 years. Most patients have had a satisfactory result (Figs. 45.2, 45.3). In all cases the periareolar puckering effect produced immediately after surgery disappeared. The complications encountered were: wide areola in three patients (Fig. 45.4), hypertrophic scars in one patient, and capsular contracture Baker grade III in one patient. Ptosis recurrence was present in two patients. A vertical scar mastopexy was performed on them in order to enhance the projection and improve the ptosis.

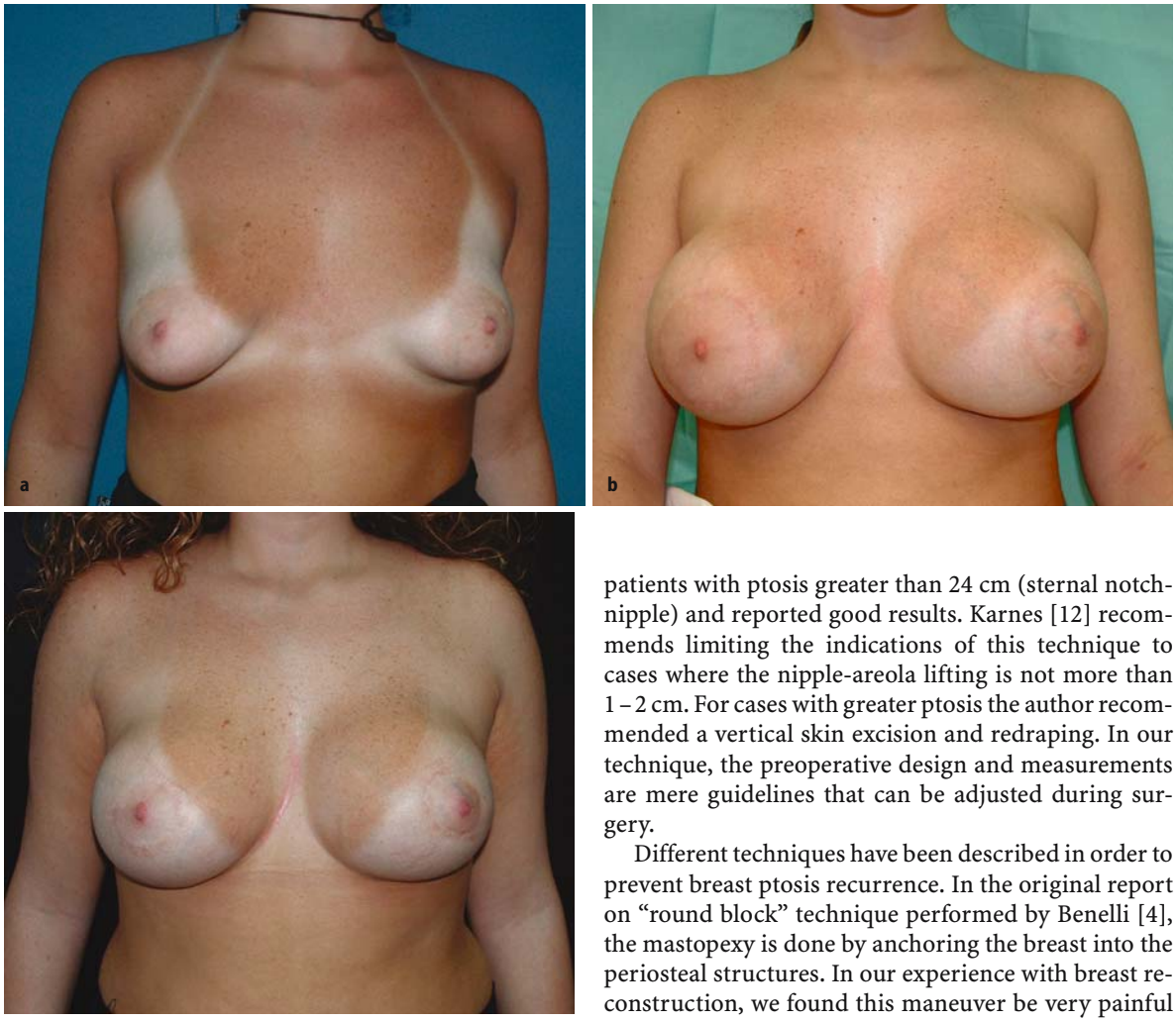


Fig. 45.4. a Twenty-two-year-old woman before procedure. **b** Postoperative view 10 months after surgery; wide areola. **c** Postoperative view 1 year after bilateral areolar reduction – a new pursestring suture was used

45.4 Discussion

The desire of patients to have a nice elevated breast with the least visible scars led to the development of the circumareolar augmentation-mastopexy technique. Several methods have been elaborated over time regarding this technique. The ideal patient for this type of procedure has a wide areola [4], tuberous breasts [4, 18] and minimal ptosis [18]. These were also our initial guidelines for selecting patients.

In his initial report, Bartels [3] designed the new nipple height mainly based on the surgeon's artistic sense rather than on a precise mathematical model. As he noted in his study, this operation has a tendency to stretch and flatten the areola. Elliott [8] performed the circumareolar mastopexy with augmentation even for patients with ptosis greater than 24 cm (sternal notch-nipple) and reported good results. Karnes [12] recommends limiting the indications of this technique to cases where the nipple-areola lifting is not more than 1 – 2 cm. For cases with greater ptosis the author recommended a vertical skin excision and redraping. In our technique, the preoperative design and measurements are mere guidelines that can be adjusted during surgery.

Different techniques have been described in order to prevent breast ptosis recurrence. In the original report on "round block" technique performed by Benelli [4], the mastopexy is done by anchoring the breast into the periosteal structures. In our experience with breast reconstruction, we found this maneuver be very painful for the patients. A double-skin technique with application of polyglactin 910 or mixed mesh was reported by Goes [15]; this seems to be the largest series in the literature on periareolar mammoplasty. He reported clear aesthetic improvement, and it was interesting to learn that he did not have to do any reinterventions for areolar problems in 254 patients. Ceydeli [5] preferred to plicate the breast parenchyma in the superior half of the breast to correct the superior pole hollow.

In earlier reports [9, 10], no areola tension release technique was used. Reducing tension to the areola during the closure phase represents an important step for a good outcome. Stretch-anchoring sutures are placed by Atiyeh [1] in the dermis, inward to the redundant deepithelized areola. He uses a nonresorbable subdermal round block suture. In Karnes' technique [12], the areola diameter is reduced to 45 mm. The high pressure from inside the breast causes the areola to enlarge. This is why we use a pursestring nonresorbable suture and an areola design of 38 mm diameter. A pursestring suture using a nonresorbable material has true value in reducing the areolar tension and has been

applied by many authors performing this technique [5, 6, 8, 12, 15]. We believe that a straight needle helps in performing the technique faster with fewer skin puckers.

The immediate postoperative flattened appearance of the breast improves over a few months [7]. In order to make this event less visible we always use high profile round or anatomical implants. Submuscular implant placement is preferred by some authors [5, 6, 8, 17]. We decide the implant position according to the amount of soft tissue envelope in the upper part of the breast. However, a submammary placement can offer a better projection. We never use drains in our patients although some authors [8] do.

Performing augmentation and mastopexy together might increase the risk of complications, such as infection, implant exposure, loss of nipple sensation, nipple malposition and implant malposition [16]. The revision rate after circumareolar dermoglandular plications can be up to 50 % as reported by Hinderer [11]. Unacceptable areolar spreading was mentioned by Gruber [10] when augmentation-mammoplasty was performed together. Although scar widening was present in almost half of Puckett's patients [13], it did not pose an aesthetic disadvantage, and none of his patients complained about this. Evaluating 34 patients with mastopexy augmentation (74 % using the periareolar approach), Spear [20] reported a complication rate of 8.8 %. According to his report, there are a number of variables that influence outcome, including areola size, scars, implant malposition, recurrent ptosis and capsular contracture. This is why an aesthetically pleasing result to the surgeon may not be pleasing to the patient. In a different study, the same author [19] found that the most common indications for revision were implant related, among them capsular contracture (11/20 patients) and implant malposition. Ninety percent of the revisions included repeat mastopexy. The literature results and technique characteristics for periareolar augmentation-mastopexy are shown in Table 45.1.

Table 45.1. Literature results after one-stage periareolar augmentation-mastopexy

Author/year	No pts.	Follow-up	Results	Complications (pts.)	Technique characteristics
Karnes [12] 2000	N/A	N/A	Universal patient satisfaction	Capsular contracture Scarring	Pursestring nylon 2-0
Goes [15] 1996	254	7 yrs	Aesthetic improvement in pts. with polyglactin 910	Loss of areola sensitivity (10) Hematoma (2) Seroma (3)	Pursestring 2-0 Mersilene Double skin mammoplasty with mesh support
Elliott [8] 2002	N/A	N/A	High satisfaction	Infection (1) Suture broke (1) Capsular contracture (11 %)	Pursestring (nonresorbable) Submuscular implant placement
Ceydeli [5] 2004	35	2 yrs	High satisfaction	Subcutaneous hematoma (1) Seroma (1)	Pursestring 3/0 Mersilene Submuscular implant "Tear-drop" technique
Spear [17] 1990	21	3 – 36 mos	Good scars Areola maintained diameter	Diminished sensation (2) Superficial wounds (5) Periareolar revision (4)	No pursestring Submuscular implant
De La Fuente [6] 1992	9	14 – 22 mos	Satisfactory results	Tendency of areola to enlarge in pts. with very elastic skin	Pursestring Submuscular placement
Erol [9] 1980	6	6 – 36 mos	Good	Periareolar wound	Only mastopexy No pursestring
Gruber [10] 1980	13	9 mos – 3.5 yrs	Satisfactory	Areola spreading Hypertrophic scarring (7) Ptosis recurrence (2)	"Donut" mastopexy ± augmentation
Hinderer [11] 2001	175	N/A	Good results	Hematomas (3) Wound dehiscence (1) Secondary revision (0 %)	Pursestring Retromammary mastopexy
Pucket [13] 1985	26	6 mos – 4 yrs	Satisfactory and lasting	Aesthetic failure (1) Scar widening (12) Oval areola deformity (5)	Crescent design Continuous monofilament nylon suture
Spear [20] 2004	34	Average 2 yrs	Satisfied pts. Average 3.1 on scale 1 – 4	8.8 %	74 % periareolar 26 % vertical limb
Baran [2] 2001	2	1 yr	Good results	–	Pursestring

N/A not available

45.5 Conclusions

In our experience, one-stage periareolar augmentation-mastopexy is a safe procedure if patient selection is done properly. Inappropriate candidates for this procedure are:

- Patients who want very high breasts
- Those who want very projective breasts
- Those with poor skin quality
- Breast ptosis greater than 3 – 4 cm
- High expectations

We strongly encourage the use of silicone gel high profile implants (round or anatomical) for this technique. However, some patients were not satisfied with their breast appearance with this technique.

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Mastopexy / Augmentation

46

L. Franklyn Elliott, P.E. Bergey

46.1

Mastopexy either with or without augmentation provides the type of challenge in aesthetic breast surgery that can be altogether frightening to the new trainee and even give pause to the experienced practitioner. In general, the breast is changing in multiple dimensions and the patient's expectations are high. Frequently, any asymmetries, however minor, are persistently noted by the patient postoperatively as the patient often dwells upon her newly discovered shape.

Despite these challenges, advances have been made in mastopexy, with or without augmentation, over the past decade, generally resulting in a more predictable result for both the patient and the doctor. However, it has been said that mastopexy accounts for the highest number of malpractice suits in the field of plastic surgery of the breast. Therefore, despite improvements in technique and results, plastic surgeons, in general, remain somewhat cautious towards this operation compared to breast reduction, breast reconstruction, or breast augmentation.

During the 1990s it was frequently said – and written – that mastopexy/augmentation should always be performed as a two stage procedure. With current techniques, in our opinion, this two stage approach is generally not necessary. Nonetheless, careful consultation with the patient, meticulous preparation for the operation, and execution reflective of some degree of experience with the procedure are all necessary to achieve the best final result, which is a happy patient.

46.2 The Deformity

In evaluating the patient for mastopexy with or without augmentation, one of the first characteristics to judge is the degree of ptosis. The most basic measure of ptosis is the location of the nipple/areolar complex on the chest wall. A good measure of this location is the distance of the nipple from the sternal notch. The average sternal notch to nipple distance is 21.0 cm, but this can certainly be as short as 18.0 cm in the patient of short stature (5' to 5'2"). Moderate ptosis is 21.0 – 23.0 cm, more severe ptosis is 23.0 – 30.0 cm and severe ptosis is greater than 30.0 cm. Another measure of ptosis is the nipple's relation to the inframammary line. If the nipple is below the inframammary line, generally most patients will significantly benefit from a mastopexy procedure. If the nipple is at or above the inframammary line, generally successful results can be obtained with augmentation mammaplasty alone. It is important to spend some time discussing the patient's ideal postoperative result along with a discussion of the incisions that are necessary to achieve that result. When the surgeon explains that a scar all the way around the areola is required, or around the areola and down vertically to the inframammary fold, the patient may reconsider their ideal postoperative result and accept a breast that is slightly lower on the chest wall but with less scarring on the breast. Pre- and postoperative photographs of previous patients can help this determination. It is interesting to note the degree of postoperative ptosis some patients will tolerate when shown photographs of a typical postoperative result, especially when there are no other scars on the breast other than those for augmentation mammaplasty.

A distinction has frequently been made between mammary and breast ptosis. In mammary ptosis, the gland itself has bottomed out and in breast ptosis, the entire breast has advanced down the chest wall. With current techniques, it does not appear that the difference between these findings significantly affects the postoperative result since breast tissue will be transferred superiorly with whatever technique is performed. On the other hand, if the bottoming out of the

breast is accompanied by a severe lack of tone of all the tissue, this finding has a correlation with postoperative recurrence of the ptosis, either with or without an implant. Thus, the tone of the gland has a good deal to do with the lasting nature of the postoperative result.

Another factor that can significantly affect the longevity of the postoperative result of a mastopexy is the condition of the skin. The chief characteristic of the skin that causes concern is its elasticity. The elasticity is significantly less in patients with stria. The age of the patient does not necessarily dictate skin elasticity, which often has more to do with the number of pregnancies, presence of stria, and rebound phenomenon of the skin itself. The main point of the assessment of these skin characteristics is to be able to inform the patient that conditions are not good for a long lasting result as a result of poor elasticity as opposed to when the skin is more youthful and elastic.

The final assessment of the patient's breast is with regard to size. With current techniques (except in the instance of severe weight loss), it is generally not necessary to add a breast implant to achieve a successful result with mastopexy. Thus the use of an implant generally is limited only to those patients who want to be lifted **and** want to be larger. Some patients are thrown off by this, as they expect to always need augmentation with a breast lift. The patient can certainly preview the resultant size with the placement of implants in the bra. If the patient is wearing a padded bra routinely, this suggests that they want to be larger.

If a patient wants to be larger, the discussion ensues as to how large they would like to be. We generally try to determine if the patient wants to be a B-C cup size, C cup size, or greater than a C-cup size. This type of differentiation usually guides us to the proper implant size. It is very important to reach a final decision with regard to implant size prior to the operation, as preoperative planning depends on this to a certain degree.

46.3 The Operation

46.3.1 Minimal Ptosis: Less than 24.0 cm

While not entirely cast in stone, measurement of sternal notch to nipple distance of less than 24.0 cm can generally be considered minimal breast ptosis. If a mastopexy is decided upon (and not just augmentation alone), the technique used for the breast lift is usually the circumareolar technique, either with or without an implant. With this minimal degree of ptosis, preoperative planning is chiefly focused upon choosing the final position of the nipple. This is usually 21.0 cm from the sternal notch, but can be 20.0 or 19.0 cm in the patient of short stature. It is always wise to make the nipple slightly lower as opposed to slightly higher than the ideal nipple level. It is very difficult to lower a nipple/areolar complex, but quite easy to slightly raise it later if need be. The remaining marking is an ellipse 2.0 cm above the nipple site, continuing around the current nipple/areolar complex (Fig. 46.1). Subcutaneous undermining is then performed up to the pectoralis major muscle from the 10 to the 2 o'clock position and inferiorly down to the pectoralis major at the inframammary line from the 4 to the 7 o'clock position. Inferiorly, this dissection is quite close to the skin in order to encourage skin retraction on the inferior pole in the postoperative period. If an implant is to be used, the breast is dissected off of the pectoralis major muscle for approximately 2.0 – 3.0 cm, exposing the underlying pectoralis major muscle. The pectoralis major muscle can then be entered and the subpectoral plane dissected to the dimensions of the breast. An implant is then inserted and generally the muscle is not closed over the underlying implant.

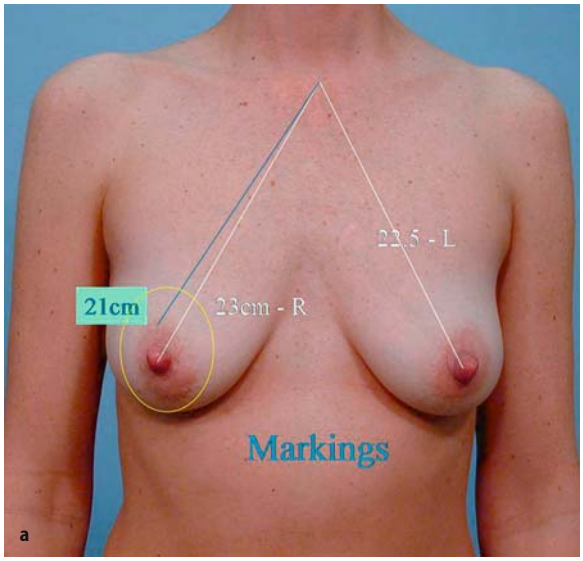


Fig. 46.1. a Preoperative drawings for circumareolar mastopexy-augmentation. *White line* indicates ultimate ideal nipple position. *Yellow line* is proposed incision.

To effect the lift, the breast tissue is first tacked up superiorly in tiers using permanent braided suture. The first tier is from approximately mid-way up the breast tissue to the pectoralis epimysium. A second tier is added, generally from the de-epithelialized dermis superior to the nipple/areolar complex to a position approximately 2.0 – 3.0 cm cephalad to this dermis. These two tiers of suture rotate up the breast tissue to a more cephalad location on the chest wall. Usually three sutures are included in each tier. Inferiorly, the breast tissue is plicated in a transverse direction by displacing the central inferior breast tissue superiorly and plicating the medial and lateral tissue to itself using braided

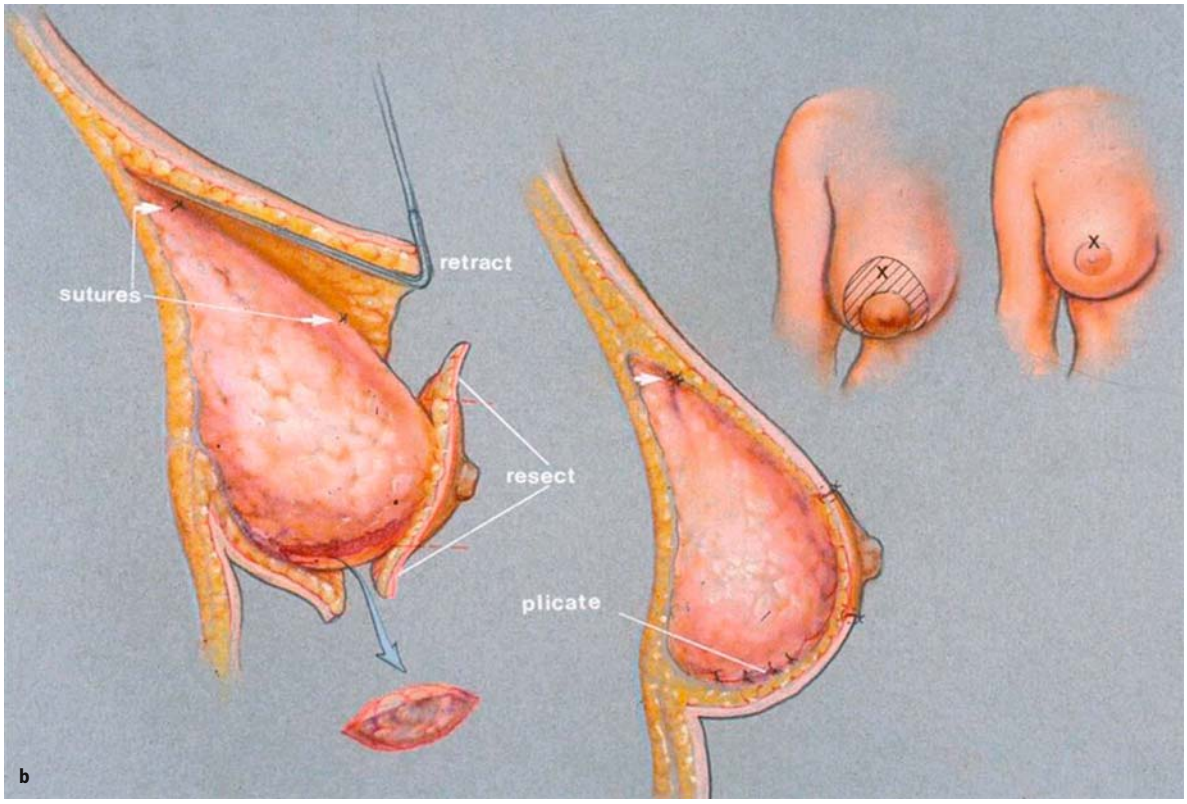


Fig. 46.1. b Operative steps on circumareolar mastopexy. See text for full description of technique

permanent suture. Several sutures are added in order to bolster and support the inferior pole of the breast and give added projection to the breast. A drain is placed inferiorly to prevent fluid accumulation over the underlying muscle and breast implant. The drain also encourages retraction of the skin on the inferior pole, where it is often needed.

The larger ellipse is then closed around a normal nipple/areola size in the subdermal level using a braided permanent suture on a straight needle. The skin is carefully distributed around the circle to prevent gathering. The final skin closure is done in two additional layers. The breast is supported by Medipore tape for 10 days to 2 weeks after the procedure. Once the tape is removed the patient is requested to wear a support bra at all times for an additional 2 weeks.

46.3.2 Moderate to Severe Ptosis: 24.0 – 30.0 cm

Breast ptosis in these patients is more severe and requires a more aggressive operation.

The circumareolar-vertical incision is almost always used for patients with moderate to severe ptosis while the inverted-T incision is rarely used. In essence, this operation moves the excess skin around the nipple/areolar complex down to the inferior pole, where it is removed. Furthermore, more aggressive management of the gland is carried out in order to treat the more severe ptosis.

Preoperative markings, again, begin with the choosing of the site of ultimate nipple position. Once this is chosen, a mosque type circle approximately 2.0 cm above the eventual nipple site, gently curving around on each side, is drawn by hand (Fig. 46.2). Displacing the breast first to the left and then to the right, the medial and lateral incisions are marked. These extend down to approximately 3.0 – 4.0 cm above the inframammary fold and at this point the two lines are joined together. A slightly less vigorous displacement of the breast to the left and right is done when an implant is to be used as opposed to when mastopexy alone is to be performed. However, initially, it is certainly better to leave a little extra skin than to take too much. Thus, markings tend to be slightly conservative in this inferior skin takeout estimate.

Once the incisions are made, the intervening skin is de-epithelialized and incisions are made medially and laterally directly down to the pectoralis major so as to isolate the inferior breast tissue in based superiorly between the medial and lateral incisions. All the breast tissue is dissected down to the inframammary fold so

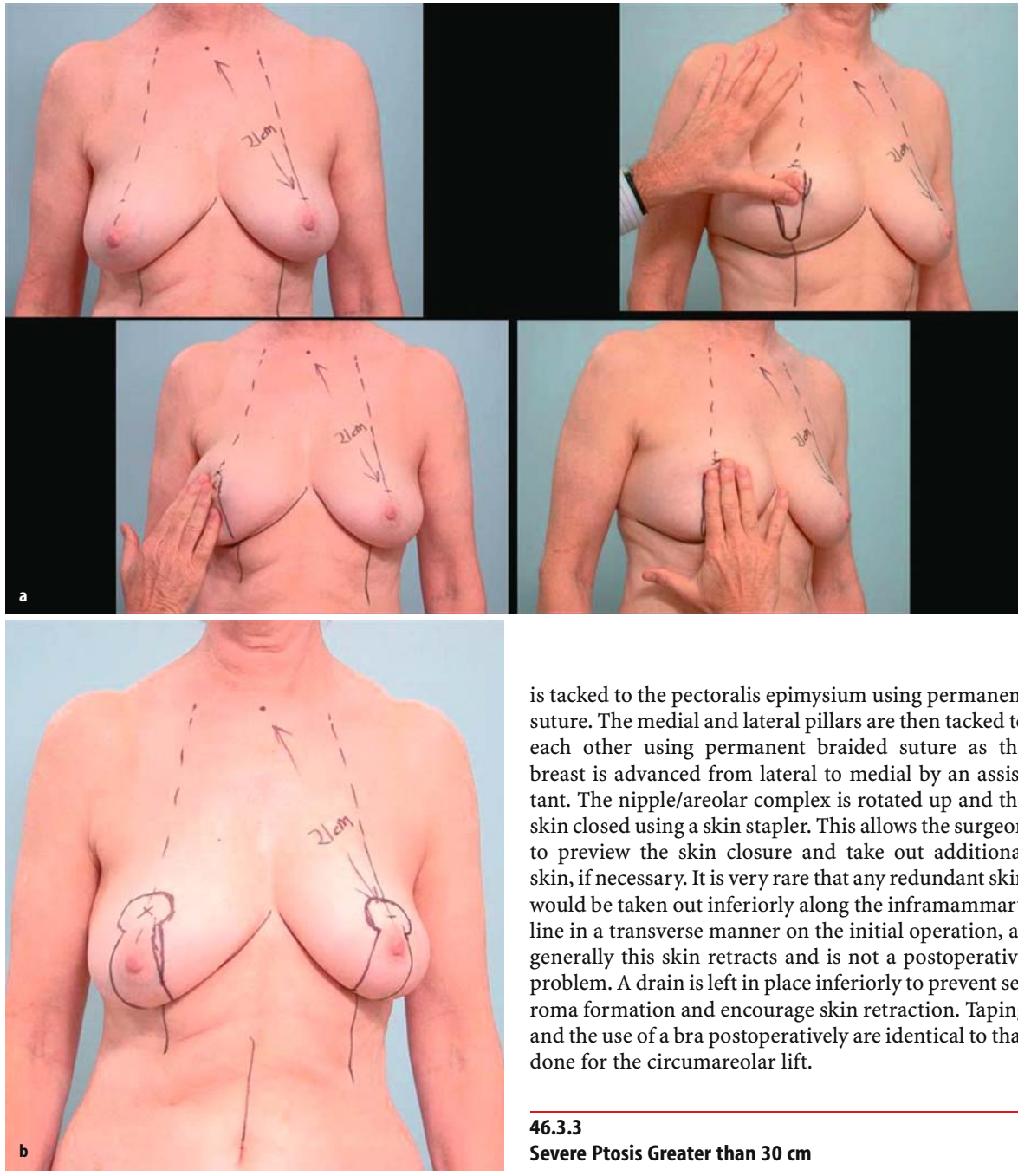


Fig. 46.2. a Preoperative markings for bilateral mastopexy-augmentation. **b** Completed markings

that the fold can be elevated. This tongue of breast tissue is dissected off the pectoralis major muscle, exposing it for insertion of the implant, which is done in identical manner as that described above for the circumareolar technique. A pocket is created superiorly up towards the 12 o'clock position on the breast, creating a space for the inferior tissue to be advanced. This tissue is tacked to the pectoralis epimysium using permanent suture. The medial and lateral pillars are then tacked to each other using permanent braided suture as the breast is advanced from lateral to medial by an assistant. The nipple/areolar complex is rotated up and the skin closed using a skin stapler. This allows the surgeon to preview the skin closure and take out additional skin, if necessary. It is very rare that any redundant skin would be taken out inferiorly along the inframammary line in a transverse manner on the initial operation, as generally this skin retracts and is not a postoperative problem. A drain is left in place inferiorly to prevent seroma formation and encourage skin retraction. Taping and the use of a bra postoperatively are identical to that done for the circumareolar lift.

46.3.3 Severe Ptosis Greater than 30 cm

Severe ptosis usually requires an inverted "T" incision due to the significant excess of skin and the poor tone of that skin (Fig. 46.3). This type of breast is usually found in the massive weight loss patient. In this patient we have found that extensive internal suturing of the breast parenchyma as well as subpectoral implants are both necessary to obtain a satisfactory result. These patients are significantly different from the more aesthetic first two groups, which rarely if ever require an inverted "T" incision.

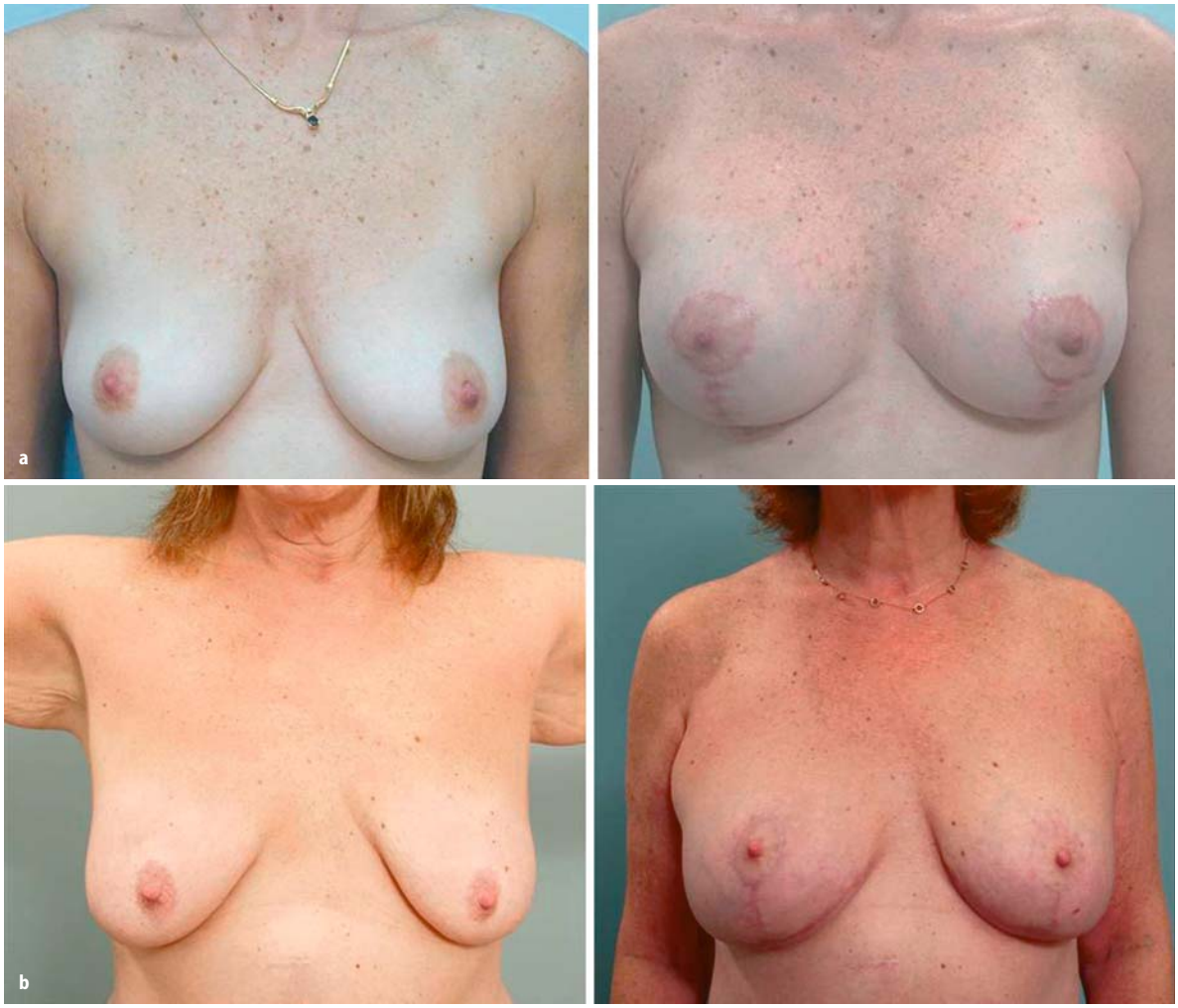


Fig. 46.3. a Massive weight loss patient with bilateral inverted "t" mastopexy-augmentation using bilateral 300-cc smooth saline implants. Frontal view. **b** Left oblique view

46.4 Type of Implant

It is currently possible to use gel implants in the United States when a mastopexy is performed. Therefore, one has the option of using either saline or gel implants. We feel that the gel implant is most appropriately used for the very thin patient. This patient has very little breast tissue and/or very little subcutaneous tissue. When there is a B-cup size or more, there will probably not be a great deal of difference in the postoperative result with the use of the saline or gel implant. Round implants are also preferred because breast shape is being dictated by the gland as opposed to the implant itself. Careful preoperative assessment with regard to size is critical to achieve symmetry postoperatively. Implants of slightly different sizes can be used if necessary to correct any breast size asymmetries.

46.5 Discussion

With experience, it is impressive and even sobering to note that some patients get a better, more long lasting result than other patients even though the same technique is used (Fig. 46.4). This variation seems to relate to the condition and tone of the breast tissue and the overlying skin. These qualities must be diagnosed by the surgeon and discussed carefully with the patient preoperatively so that the patient will have appropriate expectations. Techniques as described above in general should "last" for 5 years or more. It is not appropriate to apply the circumareolar technique to moderate or severe degrees of ptosis. The result will simply not be as successful. On the other hand, if patients are chosen carefully and informed as to their skin and breast tone, appropriate expectations can be imparted. It is always important to caution the patient that a second opera-

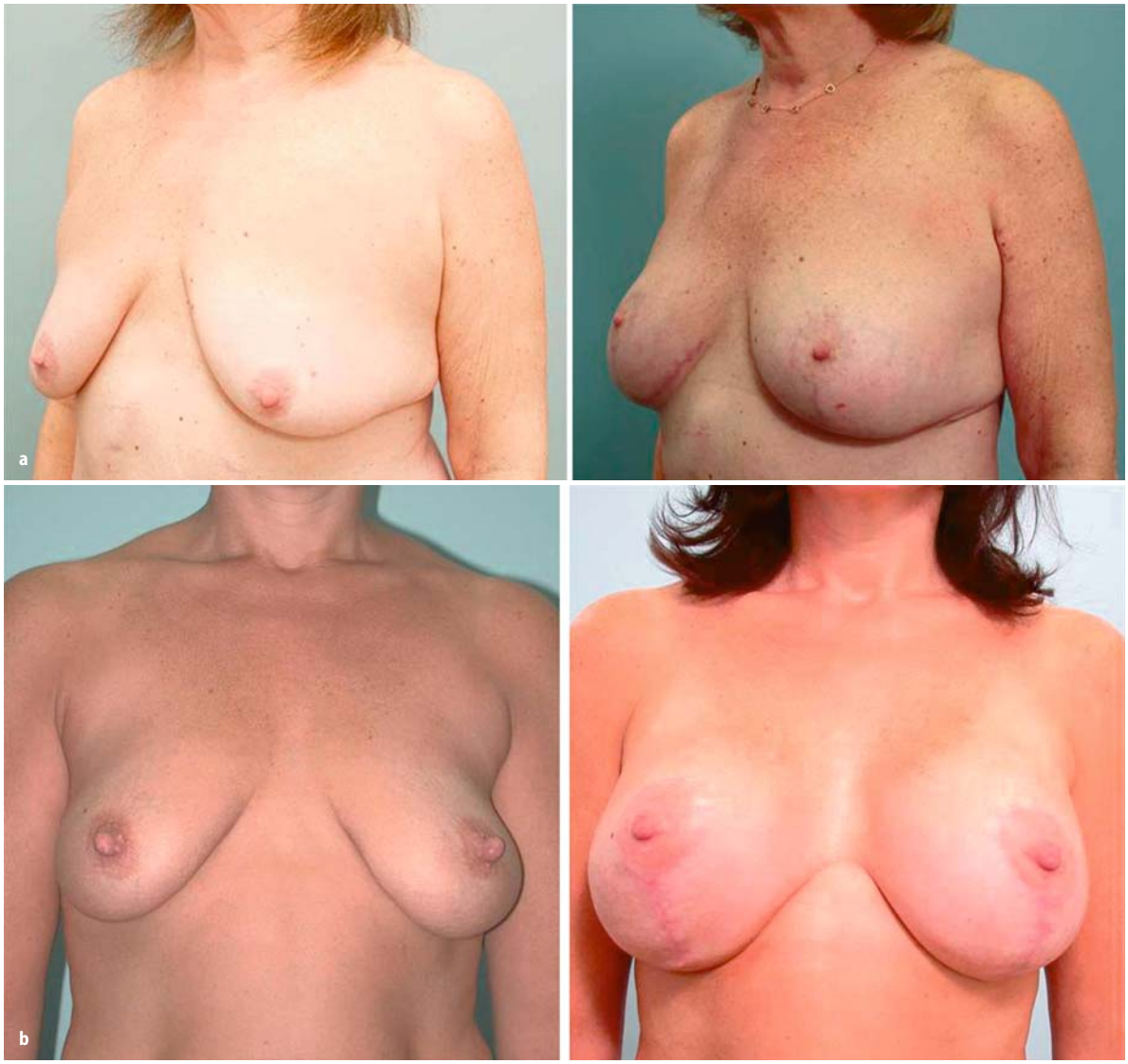


Fig. 46.4. a Good result with vertical augmentation-mastopexy. Excellent control of inferior pole in presence of good skin tone and good glandular tone. **b** Vertical augmentation-mastopexy – average result with some bottoming out associated with poorer glandular tone and satisfactory skin

tion may be needed. In general, this should refer to small adjustments to the circular nature of the areola, possible removal of excess skin at the inframammary line when using the vertical technique, and revision of wrinkling around the areolar with the use of the circumareolar technique. It is also quite possible for implants to not be in exactly the same position after postoperative healing. Slight capsular contracture can elevate one implant and not the other. Seromas, or even small hematomas, can swell the tissues and cause the implant to be displaced upward on one side. These are vagaries that distress the young surgeon and needle the more experienced surgeon, but are part and parcel to this operation wherein implants, capsule, muscle, breast tissue, skin, subcutaneous tissue are all being changed in a three dimensional manner.

Breast shape may be reflective of the type of lift technique performed. The circumareolar lift tends to create a flatter, somewhat wider breast than the vertical lift, which creates a narrower, projecting breast (Fig. 46.5). However, in the case of the circumareolar lift, the use of an implant can ameliorate some of these changes and give a more projecting, less broad result. When a mastopexy is being performed on one breast to match an opposite breast, it is very important to assess the opposite breast shape and size to determine which technique should be used. This is particularly important in the breast reconstruction setting wherein a TRAM (trans-

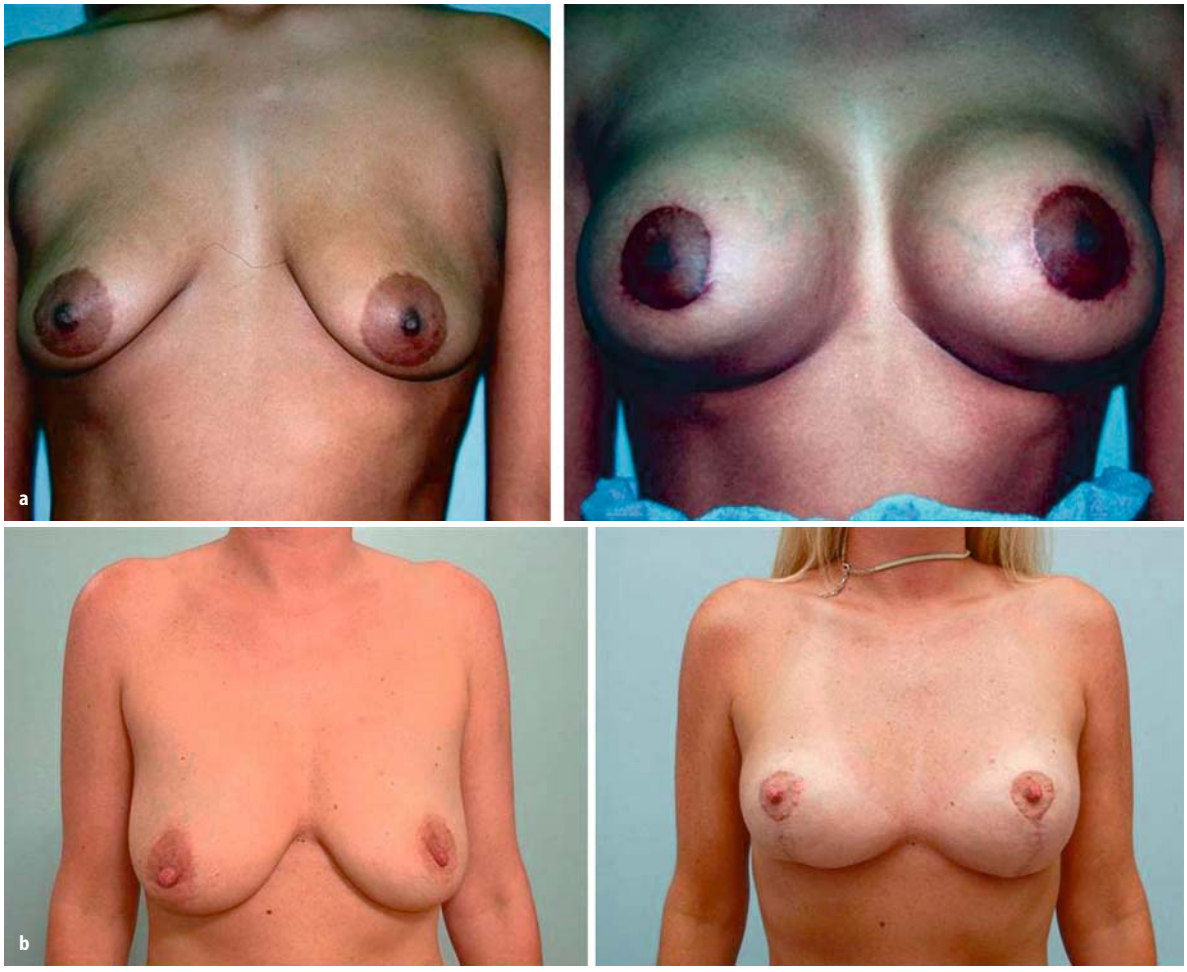


Fig. 46.5. a Note tendency towards flatness of circumareolar technique is somewhat overcome by implant. **b** Bilateral vertical mastopexy-augmentation with 200-cc smooth saline implants. Note narrowing of breast with more natural projection

verse rectus abdominis myocutaneous) flap may have produced a broad, flat breast, while implant reconstruction may have produced a more projecting, narrower breast (Fig. 46.6).

It cannot be overemphasized that the circumareolar technique should not be overused. It is tempting to try to make it "work" in order to save the patient the scarring, when it is truly not indicated. It is better to carefully inform the patient of the power and strength of the vertical lift to insure that they will get a better result.

All of the above comments have to do with the experience of this surgeon with these particular surgical techniques. A multitude of techniques have been suggested by many authors for achieving predictable, long-lasting results for mastopexy. When many techniques exist, probably many are generally successful but none are always successful. It is probably accurate to say that we do not yet have a perfect answer for all patients in a single operation. Nonetheless, results are increasingly predictable due to improved operative techniques and better patient selection. It is important though that younger plastic surgeons continue to have a deep respect for this operation and that all plastic surgeons diligently try to completely and thoroughly inform their patients preoperatively which is, in my opinion, the best prescription for a satisfied patient postoperatively.

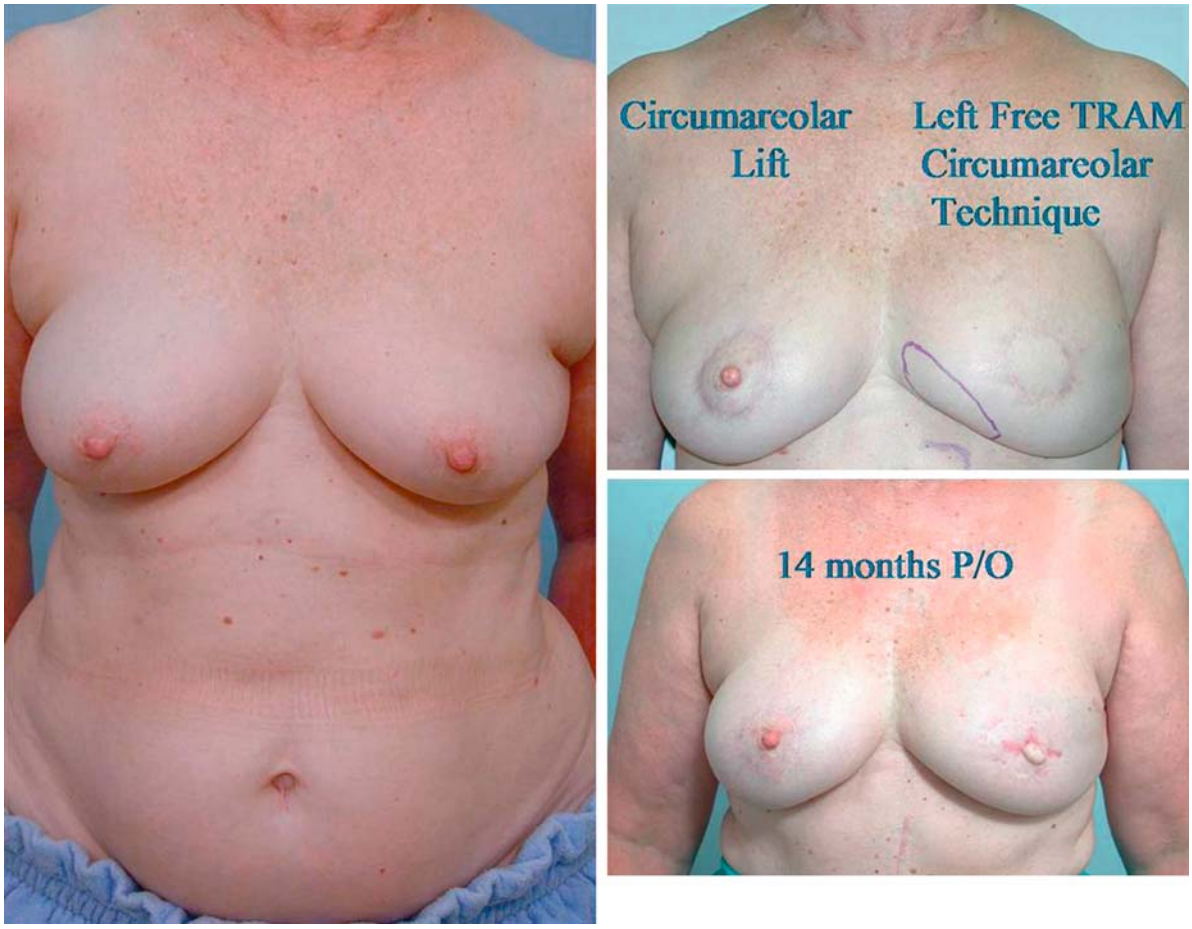


Fig. 46.6. Immediate TRAM reconstruction *on the left* and circumareolar mastopexy *on the right*. Note flatter broader shape of circumareolar mastopexy matches TRAM shape well

Refinements in Breast Augmentation: How to Obtain Aesthetic and Natural Results

47

Manuel García-Velasco

47.1 Introduction

Breast augmentation is a very popular operation in aesthetic surgery, in spite of the ban on silicone gel implants by the FDA; in the USA, the number of patients looking for larger breasts has increased in last decade [1, 3]. The ultimate objective in this procedure is to obtain an aesthetic result and fulfill patients' desires [8]. The ideal breast shape and volume vary considerably in different countries and are influenced by culture and fashion, an important factor being the surgeon's criteria. It is my strong belief that we, as plastic surgeons, should follow universal patterns of beauty. A beautiful breast must look natural and in proportion with the rest of the body; unfortunately a number of patients have erroneous ideas about this and are sometimes fixed with the impression that the bigger the breasts the more attractive they are. Hammond [6, 10] and others agree with the opinion that larger implants will give more complications and less natural results especially in thin patients; therefore, it is very important that the surgeon orients the patient before the procedure. In this chapter I will describe the pitfalls in obtaining an aesthetic and natural augmented breast focusing on the technique and the proper implant selection.

The surgical objective in breast augmentation is to achieve the following aesthetic goals (Fig. 47.1):

- The point of higher projection of the breast should be at the level of the nipple areola complex or slightly below
- Natural cleavage
- Lateral projection no more than 2 cm out from the lateral wall of the thorax
- Upper pole with a descendent projection
- Less visible scar
- An unnoticeable contour of the implant

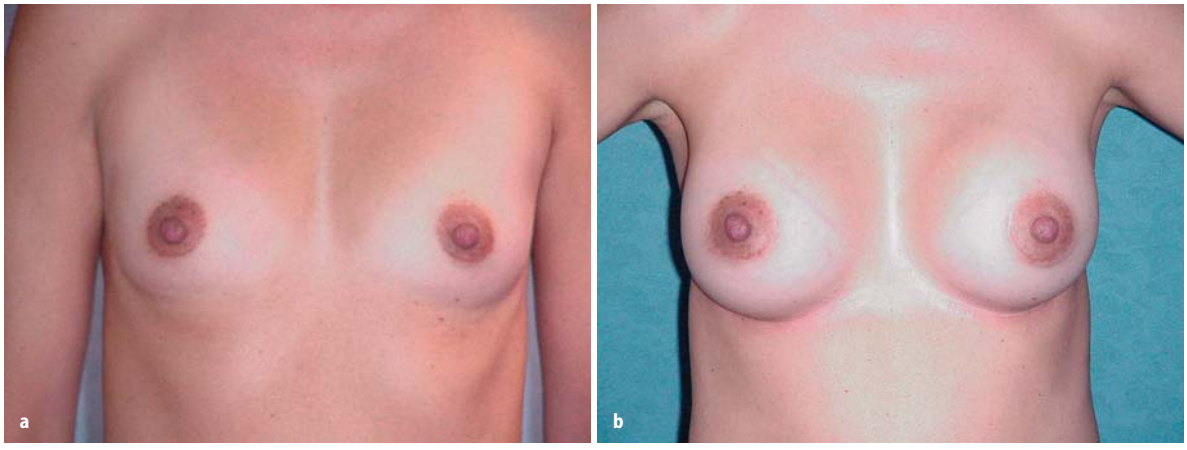


Fig. 47.1. Pre- and postoperative results, 2 years after the operation, 215 cc natural profile textured implant. The inframammary fold was descended. The aesthetic goals described in the text have been achieved. **a, c, e** preop.; **b, d, f** postop.

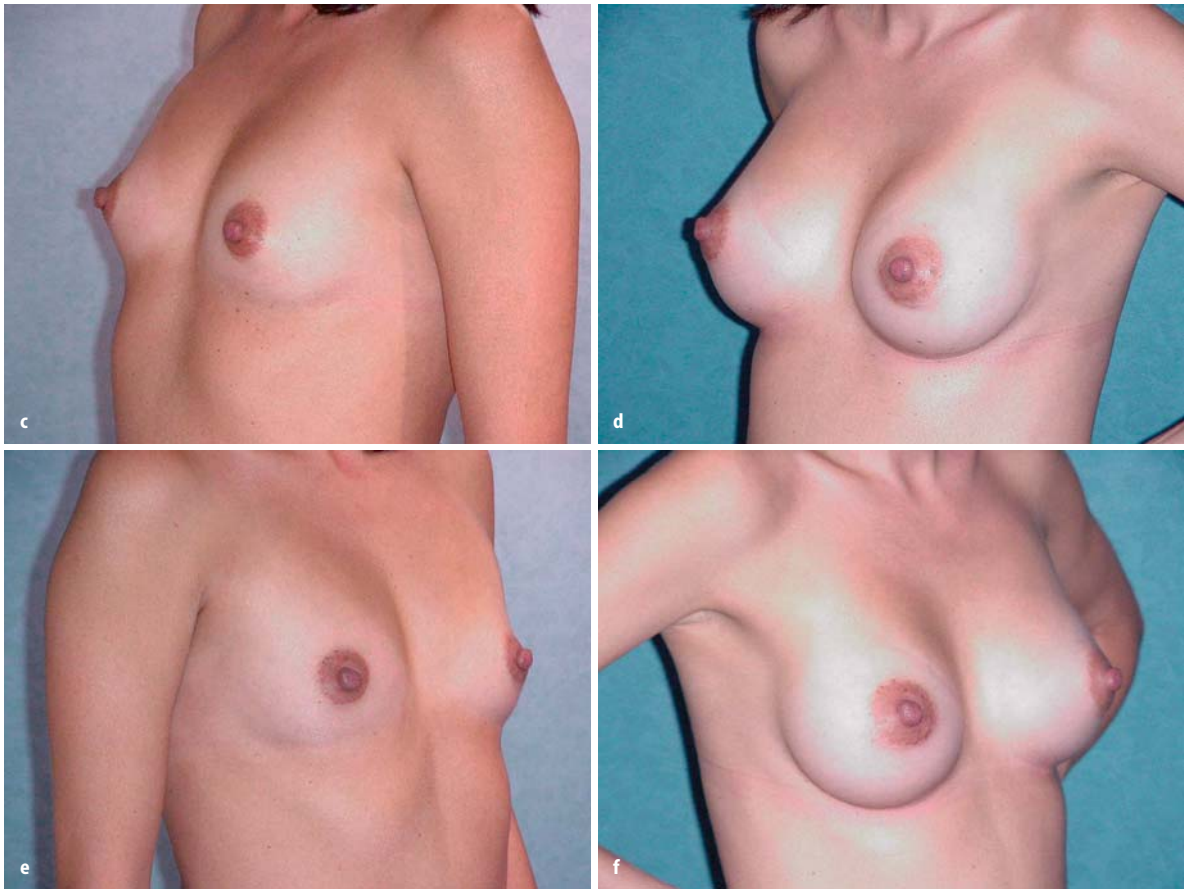


Fig. 47.1. (*Cont.*)

Several authors have described their own thoughts as to how to achieve good results in breast augmentation [10, 12]. Tebbets [15] has published his method with a very complete analysis of the patient, which I found a bit complicated and with the limitation of the use of a single brand of implants. Other articles [2, 10, 12] have focused on the different incisions, plane of location, selection of filler and shell of the implant; up to now there has been no consensus regarding some of these topics. The International Breast Implant Registries will come out with better answers in the near future. For the last 10 years I have followed a personal system based on a complete patient evaluation, proper implant selection and a surgical technique aimed at reducing complications with minimal scars and directed to a satisfactory placement of the implant for each case.

47.2 Personal System for Breast Augmentation

47.2.1 Patient Evaluation

47.2.1.1 Interview

Patients come to our office with the desire of improving their body image by means of enlarging their breasts and of secondarily enhancing their shape. Designed seizers and used implants are tried inside a bra so that the patient may have an idea of how they will look when dressed. Pre and post photographs are shown of cases with similar physical conditions and different sizes of implants. If the patient is found to have no proper idea whatsoever of what she wants and does not like the results that have been shown, she is recommended not to undergo the operation.

47.2.1.2 Physical Examination

The examination is directed toward the following aspects:

- Thorax shape, diameter and its relation to height and pelvis
- Presence of asymmetries
- Breast diameters: vertical, transverse and nipple areola complex
- Breast volume and shape
- Compliance of tissues
- Degree of existing ptosis and skin flaccidity

47.2.2 Implant Selection

There are a vast variety on the market with different volumes and shapes, and surgeons must find the most adequate to fulfill the case requirements. The patient's wishes are very important in the selection, keeping in mind that it should be under aesthetic parameters. Considering that the compliance of the tissue determines the strength given by the implant (Fig. 47.2), I try to keep the total volume (actual mammary volume calculated compared with the seizer or used implants plus the device) within the following boundaries:

Patient's height	155 – 165 cm	165 – 175 cm	175 – 190 cm
Total volume	300 – 400 cc	400 – 500 cc	> 500 cc

Patients with a wider thorax require bigger implants.

For the selection of the implant shape the transverse and vertical diameters of the breast are considered, a round low to moderate profile being selected for volumes less than 220 cc or to correct gross asymmetries. I do not use high profile implants because in my experience they do not give a very natural result and almost always will give a round upper pole. Anatomical contours or the natural profile (Silimed) are chosen for bigger sizes or when the requirement for a proper profile in the upper quadrant is needed. I usually prefer the contour implant with a larger vertical diameter; the projection will vary in each case depending on the transverse diameter of the breast. In my experience I

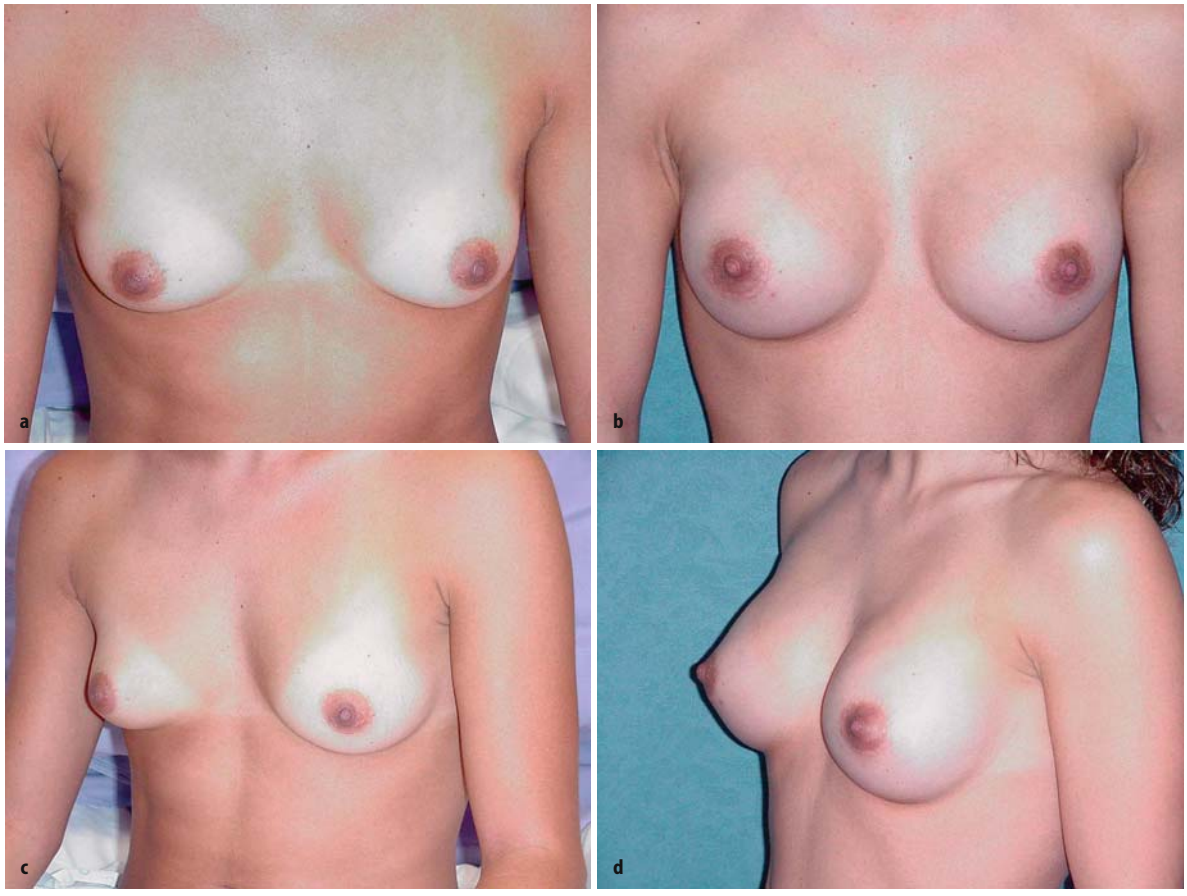


Fig. 47.2. Pre- and postoperative pictures. A 215 natural profile implant was placed in the retropectoral space. The chest circumference was 82 cm and transverse diameter of the breast 10 cm. Tissue compliance did not allow a bigger implant. **a, c** preop.; **b, d** postop.

prefer the textured shell, I have less capsular contracture, and the rippling described with these implants [3] is avoided with the proper plane of location.

Based on this evaluation the surgical technique is planned, the volume and shape of the implant are decided upon, and the seizers and the chosen pair of implants along with one size higher and lower are taken to the operating room.

47.2.3 Surgical Technique

47.2.3.1 Incision

The hemiperiareolar incision is used in 98% of cases with zigzag shape as described by Gryskiewicz [5] or following the irregularities of the areola, the resulting scar being less noticeable (Fig. 47.3). With a diameter of 3 cm, the length of the incision may reach almost 5 cm. In smaller cases, the incision is prolonged on the border and a small crescent moon shaped piece of skin is removed under the areola to increase the perimeter. I never use the axillary approach in order not to disturb the lymphatics of the mammary gland. Okwueze and others [7, 9] have proven that there is no problem regarding loss of sensibility of the nipple areola complex with this incision and I have observed the same in my own cases. The plane is approached through a medial transmammary dissection. Some criticism may be given to this method for the possible impairment of future breast feeding in nulliparous woman [16]. There are not many articles written on this respect and a few are just anecdotal. Contamination is another possible contraindication but no infection has been observed in all cases operated on except for only a slight cellulitis in one case that did not affect the implant. This approach allows the plane to be reached directly from above and the future placement of the inframammary fold is much easier, since the area is not disrupted by the inframammary incision.

47.2.3.2 Plane Selection and Dissection

The selection of the plane location for the implant is based on the amount of breast tissue present, and the flaccidity of the skin. Tebbets has stressed the importance of the quantity of soft tissue present in the upper pole and at the level of the inframammary fold; for me, if there is enough breast parenchyma or fat to hide the contour of the implant, the retromammary plane is selected (Fig. 47.4). I do not go under the fascia in the upper dissection as described by several authors [11, 17] because I think that it is too thin to really accomplish the benefits described, the only advantage being the better preservation of the lymphatics. The undermining is carried out to create a pocket slightly bigger than the implant. It is important to go far enough medially to create a nice cleavage. Care is taken not to overdo it to avoid synmastia, and lateral undermining is done trying to avoid injury to the sensory nerves.

When a retromuscular space is decided upon, the plane is approached directly on the pectoral muscle, dissociating the fibers right on top of the 4th or 5th rib to avoid any lesion to the intercostal muscles. The undermining is done by blunt dissection under the pectoralis major, and its inferior origin is transected using the Colorado needle. This maneuver is under direct vi-

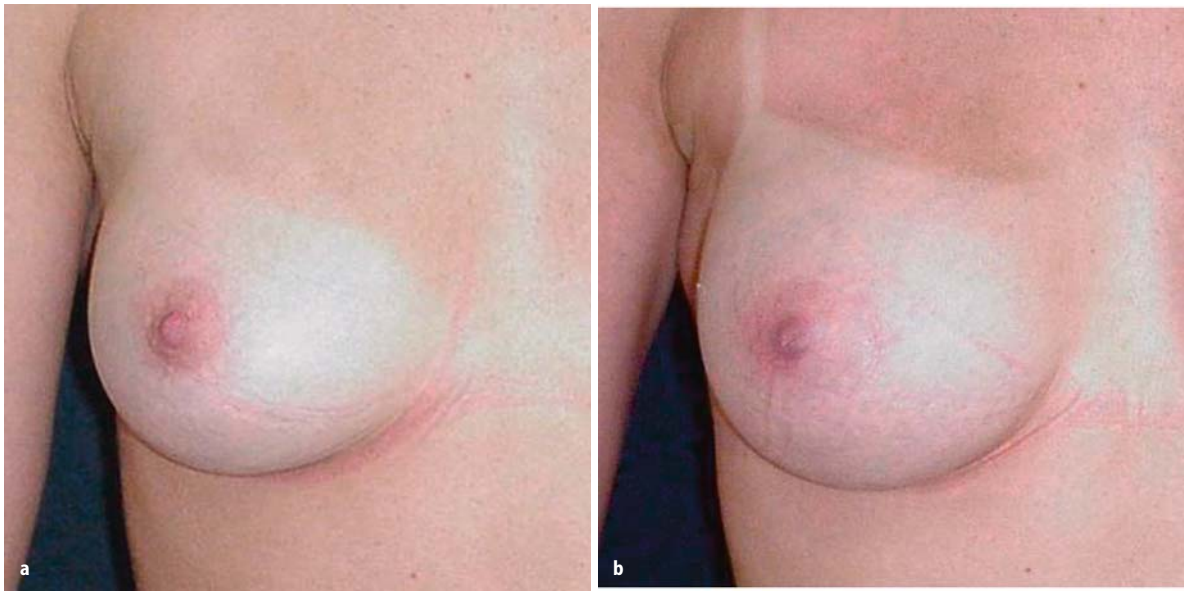


Fig. 47.3. Nine month postoperative result of periareolar incision; the scar is almost unnoticeable. **a** preop.; **b** postop.

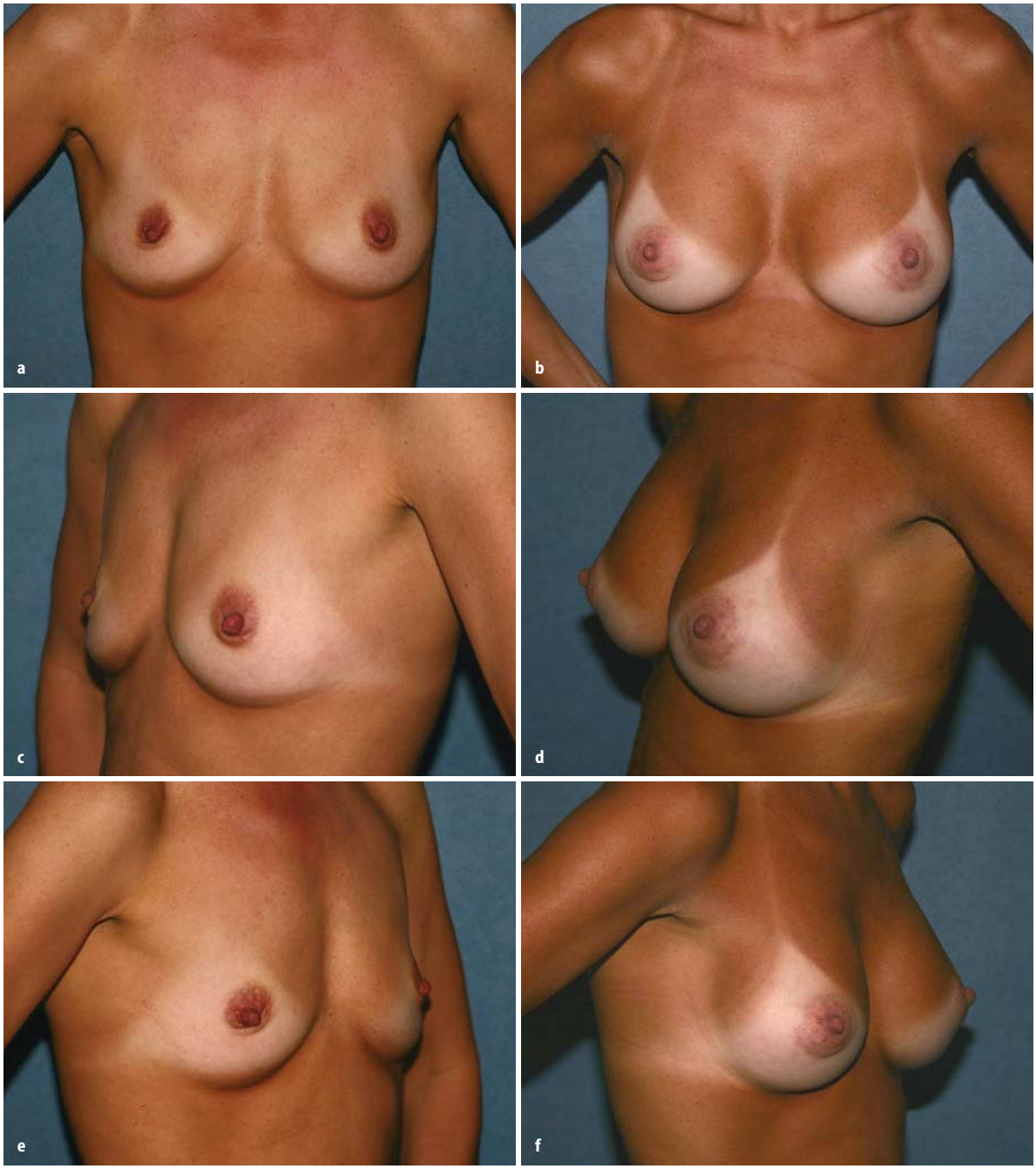


Fig. 47.4. This patient's height was 175 cm, thorax diameter 86 cm. A 310 anatomical shaped implant was employed, and the retromammary plane was decided upon since the patient had enough breast parenchyma to cover the implant. **a, c, e** preop.; **b, d, f** postop.

sion from the muscle opening, and the superficial fascia is transected if the inframammary fold needs to be lowered, which may cause the inferior border of the implant to be felt by the patient, but if this is explained prior to the operation she will not complain about it. The aesthetic advantage is very important since the implant will be properly located in order to position the projection in the right place. The sternum origin is not divided (Fig. 47.5), the fibers being just elevated enough to create the desired cleavage. This technique is similar to the type I dual plane described by Tebbets [13 – 15], but I never separate the parenchyma muscle attachments as in type II and II, since I believe that the muscle will be displaced upwards too much and may create a sling that will push the implant too low. For ptotic and flaccid cases another procedure is carried out that will be de-

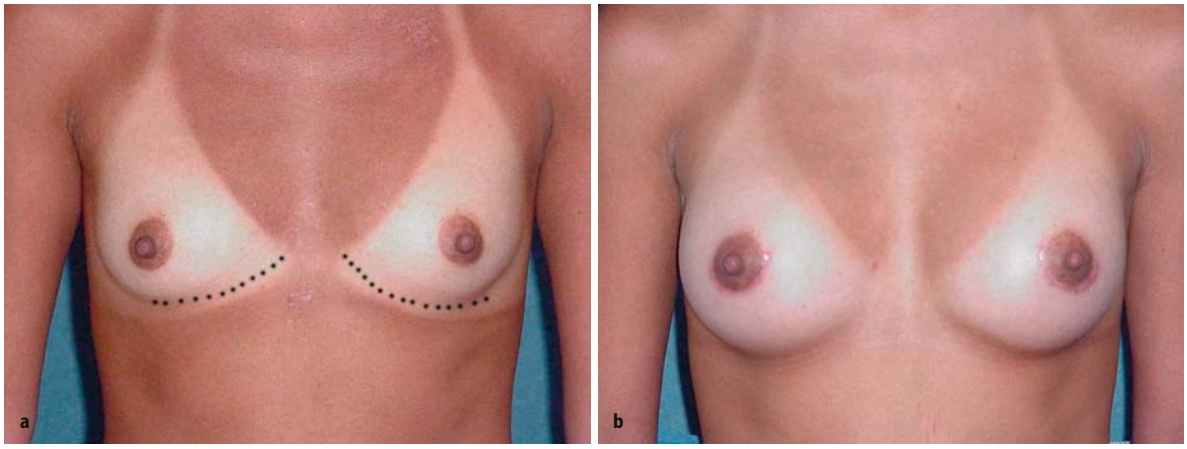


Fig. 47.5. *Dotted area* shows where the pectoral major is sectioned. Postoperative result 1 year after a 225 g anatomical shape implant was used. **a** preop.; **b** postop.

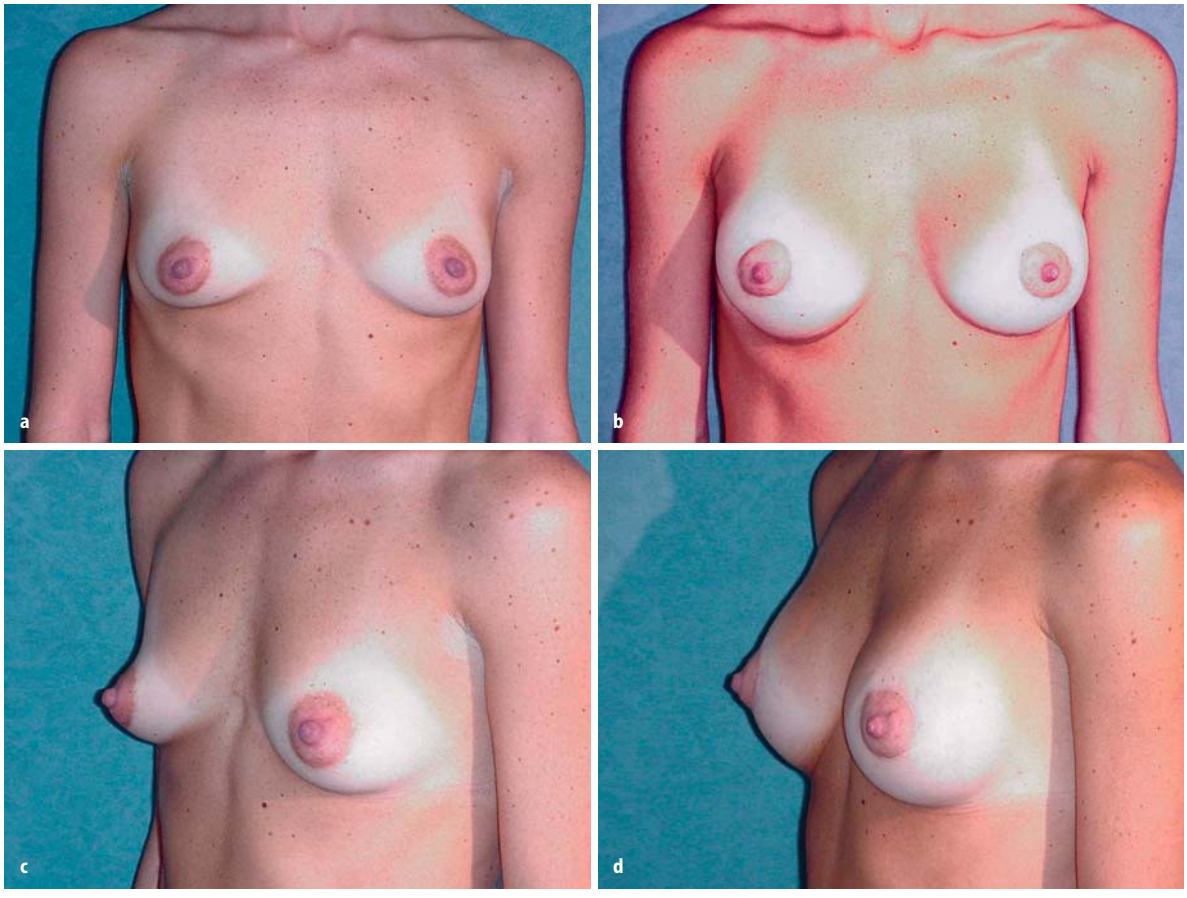
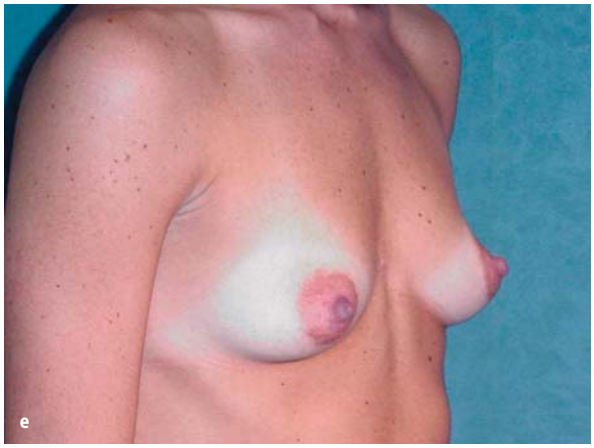


Fig. 47.6. Patient with breast atrophy and skin flaccidity. Periareolar mastopexy was performed and a 210 round moderate profile was placed in the retromammary plane; result after 12 months. **a, c, e** preop.; **b, d, f** postop.

scribed below. Laterally the serratus muscle is not elevated; I find this totally unnecessary. I have not seen any lateral displacement of the implant if the fascia is not sectioned in this portion. At the end of the procedure 5 cc of rovipacaine 7.5% is infiltrated in the muscle to decrease postoperative pain.

In all cases, the implant is irrigated with a solution of cefalothin and a negative suction drain is left for 12–24 h. A surgical bra is indicated for 3 weeks, and an elastic band in the upper pole is used for 2 weeks in retropectoral locations.



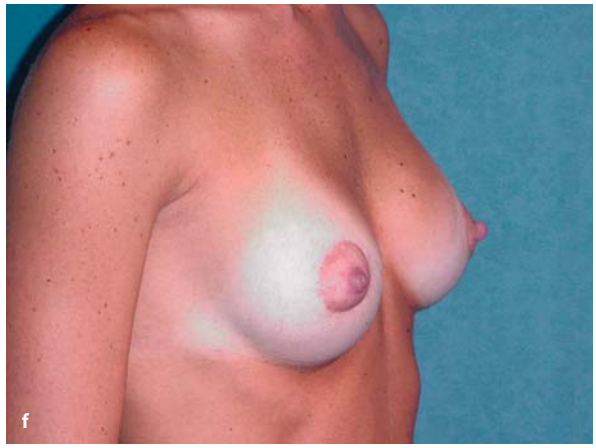


Fig. 47.6. (*Cont.*)

47.2.3.3
Breast Augmentation in a Ptotic Breast

The correction of the breast with ptosis and flaccid skin sometimes becomes a real challenge to achieve optimal results, since most patients with this condition used to have a nice breast shape and volume before the event that made the mammary gland atrophy took place; in most cases, this is pregnancy or weight reduction. If the breast has an adequate volume, I see no reason to use an implant, unless requested by the patient; however, I always explain that the increase in weight of the breast may cause secondary ptosis. If there is parenchyma atrophy, ptosis of the nipple areola complex and the skin is flaccid, I usually perform a skin mastopexy and I use a small implant [4]. The technique may be with a periareolar (Fig. 47.6) or vertical incision, and sometimes with a small transverse correction, depending on the severity of the case.

47.3 Conclusions

Breast augmentation is a surgical procedure that has to accomplish both fulfillment of the patient's desires and achievement of a natural and aesthetic result. Patients need to be carefully selected and oriented, and at the same time a proper evaluation of the case, and choice of the most adequate implant and plane of location are essential to obtain a consistently excellent result.

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Breast Augmentation: Particular Pearls for the Subpectoral Technique

48

A.A. Mottura

48.1 Introduction

The subpectoral approach for breast augmentation is in our speciality a very common surgical technique. I want to describe here some what I call new pearls or not universally known tricks that facilitate the subpectoral technique. These personal concepts are how to program the surgery, how to perform swift and efficient surgery, how to provide some hours postoperative pain relief and what to do in the case of malposition of the implant.

I describe some maneuvers and tactics used in my routine in single augmentation mastoplasty that may or may not be used for asymmetries, tubular breasts, breast ptosis or secondary cases, problems that are beyond the scope of this paper.

48.2 Surgical Technical Aspects

The primary preoperative evaluation is performed at consultation, with the patient standing in front of a big mirror. In this instance, the size of the patient and her thorax, the size of the breast and of the areola are analyzed as well as the position of the submammary fold. Then different implant seizers (used implants) are placed in a special bra and the patient selects the size she likes most. The surgeon suggests the shape of the implant or if they are too small or big and different implants in case of asymmetries.

Minutes before surgery, with the patient standing, I mark the incision lines, the extent of the dissection and the new position of the IMF (inframammary fold) if needed. During surgery, I will use only the implants already selected by the patient (Figs. 48.1, 48.2).

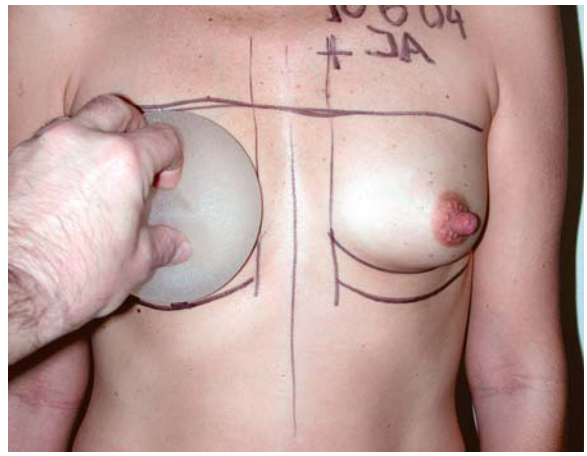


Fig. 48.1. Before surgery, the implant delimits the extension of the dissection

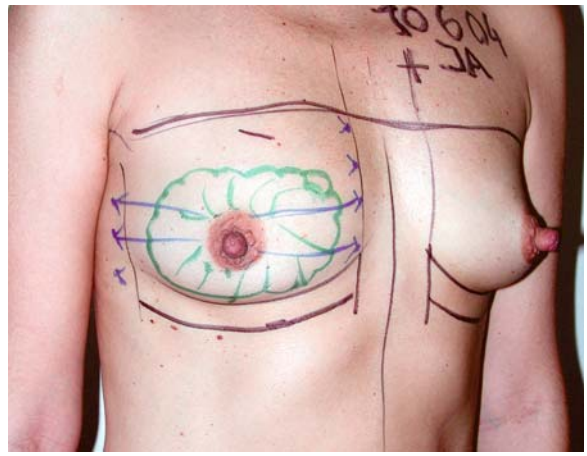


Fig. 48.2. The inframammary fold should be lowered 2 cm. The size of the parenchyma and the cutaneous branches of the intercostal nerves are penciled on the skin

When the patient is asleep under deep sedation, I proceed with the infiltration of local anesthesia already prepared with 25 cc lidocaine 2%, 25 cc bupivacaine 0.5%, 1 cc adrenaline 1:1,000 and 450–550 cc saline solution. The infiltration is performed touching the external aspect of the 6th rib and injecting the anesthesia in an irradiated way in order to facilitate the subpectoral

and serratus anterior dissection. Then the infiltration continues at the medial part of the breast, at the border with the sternum where the cutaneous branch of the intercostal nerves emerge and at the lateral emergence of the lateral cutaneous nerves. While I am infiltrating this last area, at the medial axillary line, I introduce the needle into the inferior border of each rib, blocking the 3rd, 4th, 5th and 6th intercostal nerves, adding extra anesthesia and also producing vasoconstriction at the intercostal arteries and veins. Then if the approach is axillary, the anesthesia is complemented with infiltration under the incision lines, all the area to be dissected and in the path to the subpectoral space. If the technique is periareolar, also under the incision line, I infiltrate the parenchyma and the submammary space. If the technique is submammary, I infiltrate also under the incision line and at the submammary space and at the submuscular plane.

In the axillary approach, the incision is marked in one of the submammary creases. Then 5 cm skin is undermined downwards and with the index finger I try to determine the pectoralis major muscle and to enter through its posterior aspect. In the submammary approach, the incision is made 1 cm above the new submammary fold and in the lateral half of the gland. Then the pectoralis major muscle is divided obliquely lengthways and separating 5 – 7 cm its fibers along their course always touching first and dissecting over the external aspect of a rib, this way avoiding dissection of the intercostal muscle (Figs. 48.3 – 48.5). In the areolar approach, the incision of preference is in the inferior half of the areola, but in the case of a small areola, a round periareolar incision produces a wide tunnel for the dissection and implant introduction. The parenchyma is sectioned and the submammary space is dissected obliquely, making a small space only for the dissection of the pectoralis major muscle, which is carried out in the same way as for the submammary approach.

The submuscular pocket dissections differ according to the approach selected. During an axillary approach, the fingertip dissects the pocket beginning from the superior part where the muscle is separated from the thoracic wall, the index finger releases the insertion of the muscle in its inferior part of the breast, then the finger separates the serratus anterior insertion from the ribs using the fingertip with the nail rasping the external aspect of the ribs making tunnels and then connecting these two to three tunnels. This dissection is continued laterally until the fingertip feels strings emerging perpendicularly from the thoracic wall that are the perforators of the lateral intercostal nerves. Finally I try to disrupt the long muscle fibers that are usually present more medially crossing the IMF. In the dissection of the pocket from the axilla, sometimes the length of my finger is shorter than the extent of the planned pocket and I need to use a dissector as a prolongation of my fingertip. In the areolar approach, I make a 5 cm incision at the fascia, I dissect the trajecto-

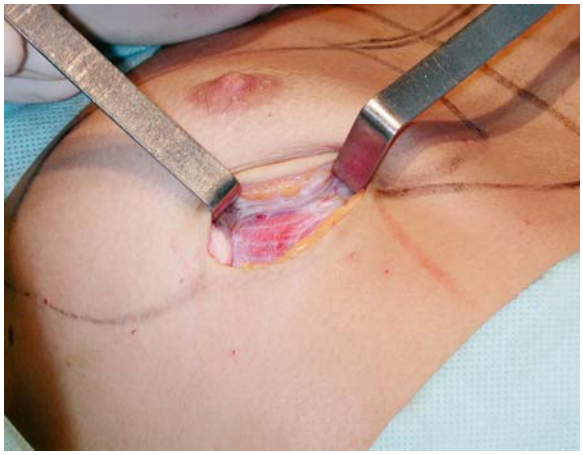


Fig. 48.3. The oblique direction of the pectoralis major muscle fibers, which are going to be divided

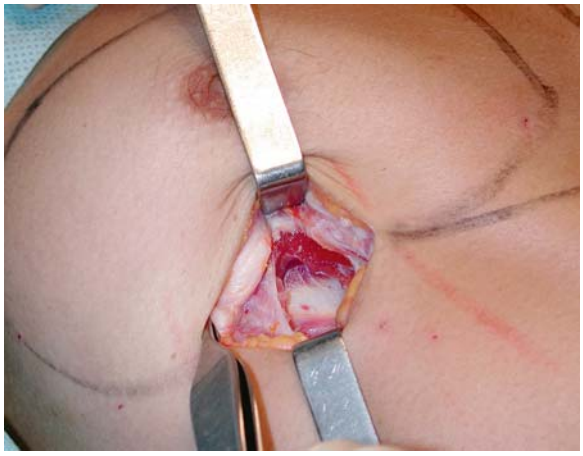


Fig. 48.4. The muscle is separated obliquely along the direction of the fibers

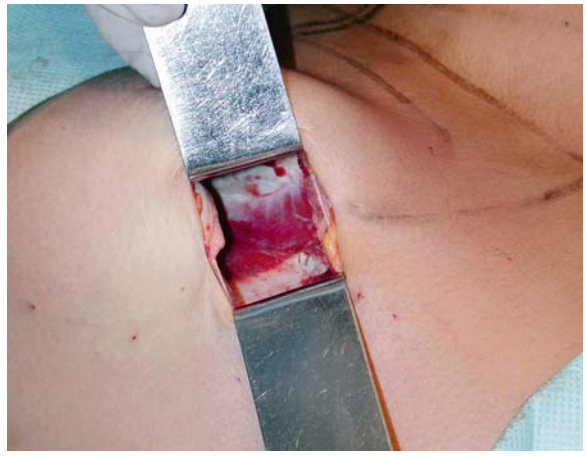


Fig. 48.5. The subpectoral dissection. Note the scarce bleeding during the surgery

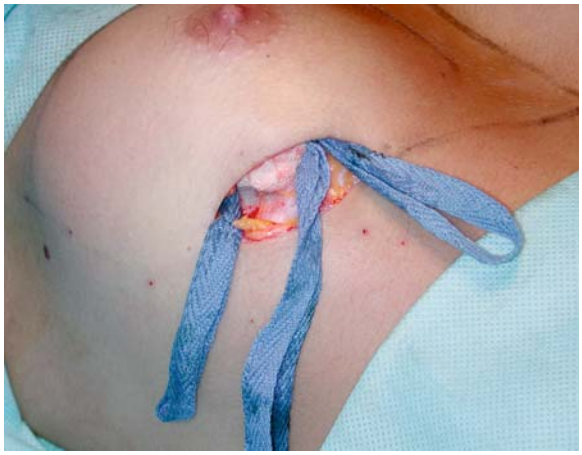


Fig. 48.6. The three compresses are placed in the pocket

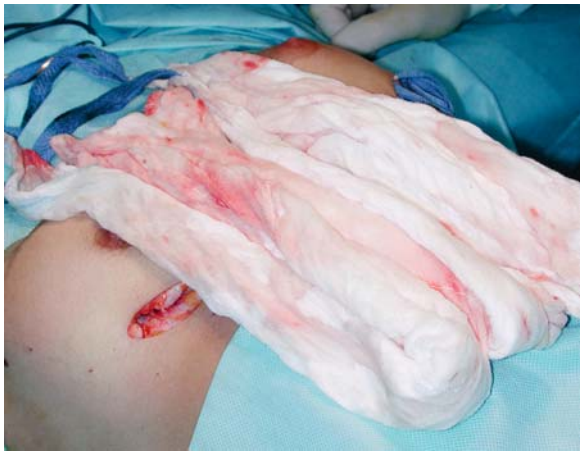


Fig. 48.7. The compresses removed showing no bleeding

ry along the oblique direction of the muscle fibers and with the scissors I separate the muscle fibers above the external surface of a rip. Once I have introduced my index finger I proceed to dissect the pocket in the same way. With the submammary approach I make the same oblique fascia incision and dissection but the inferior fiber detachment of the pectoralis major muscle from this lateral approach is not easy to perform at the inferior IMF area and sometimes I have to take the scissors for assistance. The disruption of the pectoral fibers from the ribs is different in the three approaches because from the axilla, the direction of the index finger is from the superior part of the breast, from the areolar approach it is from the medial part of the breast and from the inframammary approach it is from the inferior and lateral part.

Once the pocket is dissected at one side, I insert three big compresses into the pocket and I move to the other side. Meanwhile I am working on the second breast; the compresses stop the bleeding and distend the cavity. Once I have inserted the three compresses in the second breast I come back to the first and I remove each one of them watching which has a significant blood spot; this way I see where it was bleeding (Figs. 48.6 – 48.10). Very seldom I have to use the coagulator because of the profuse local anesthesia with vasoconstrictors, and after 15 min compression all the vessels are coagulated. Regularly I use two compresses when the implant is small, less than 220 cc and four compresses when the implant is over 360 cc.

Before the introduction of the implants, I wash all the operated surfaces and the cavity with an antibiotic solution, also washing the implants and the gloves.

Then the textured implants are introduced. The implant should reach and fill all the inferior edge of the dissection. When the patient lies in a supine position with the arms separated from the table, the implant should be placed at the inferior half of the breast (Fig. 48.11).

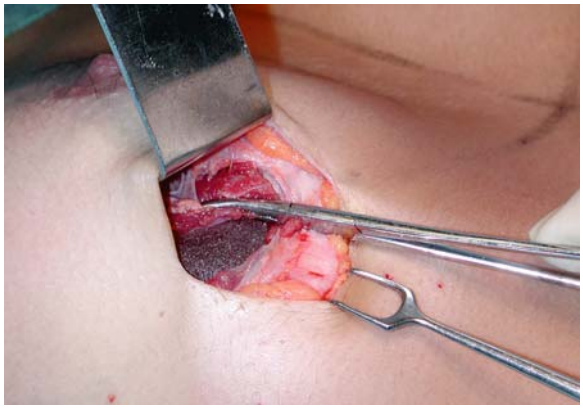


Fig. 48.8. Both muscular edges are sutured above the implant

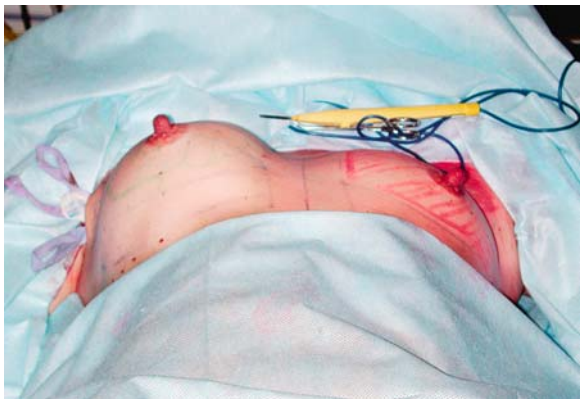


Fig. 48.9. During an axillary approach, the three compresses are placed on the right side

In the areolar or submammary approach, both wedges of the divided muscle are mobilized separating each side from the implant surface with the fingertip to approximate each other for suturing (Fig. 48.8). In my routine, I do not leave any drainage. Once the implant is isolated behind the muscle, the parenchyma or the skin is meticulously sutured.

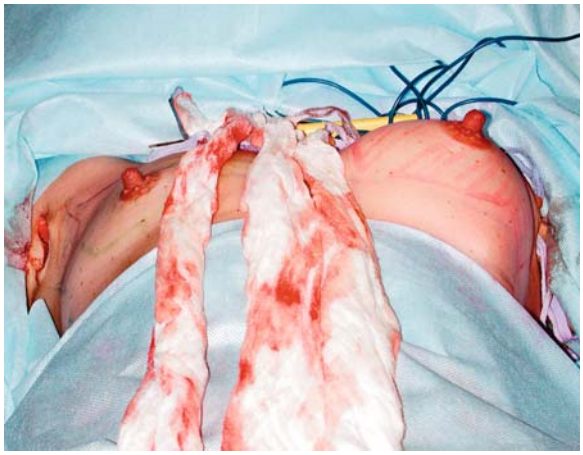


Fig. 48.10. The three compresses on the right side were removed, showing very scarce bleeding, while on the left side the compresses are still inside

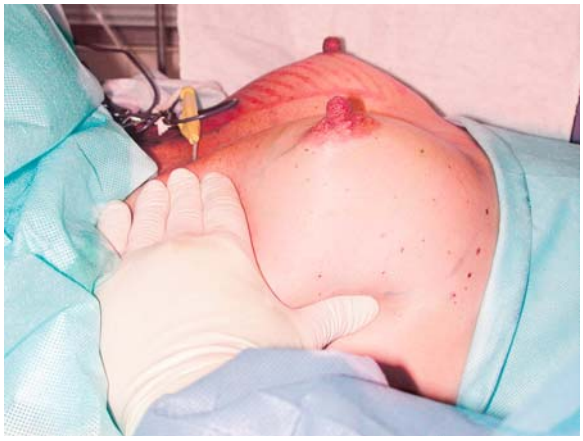


Fig. 48.11. When the patient is lying with the arms separated, the implant should be placed in the central part of the gland and in the lower pole

48.3 Results

I am reporting on my experience of more than 700 submuscular implants. Only as an exception do I use the subglandular approach. In my routine I use the axillary approach approximately 50% of the time, the areolar techniques 30% of the time and the submammary technique 20% of the time.

Wound dehiscence and rippling are complications that I no longer have after placing all the implants in the submuscular pocket.

Since I do not disrupt the lateral and medial sensitive branches of the intercostal nerves, sensitivity of the areola is not altered in the axillary and submammary procedures but some months of hypoesthesia can be observed after the areola approach.

Infection of the implants after preoperative antibiotic and washing the operative field and pocket have not been found in the last 15 years. With the cohesive gel implants, capsular Baker II and III contractures are observed in less than 2% of cases. No Baker IV contractures were observed in the last 15 years.

If after surgery any kind of malposition of the implant is observed, it is resolved immediately. No migration of the implant was observed over time, in my opinion because the textured surface sticks to the thoracic wall and to the pectoral muscle.

48.4 Discussion

The selection of the implant is done before surgery and according to the patient's wishes, avoiding claims or regrets about the size of the implant that are sometimes pointed out to the surgeon. Once the patient has fixed in her mind that the size selected is what she wants, after surgery this will never be an issue again. Then the patient's selection of the size of the implant is her responsibility. When it is done by the surgeon, it is the surgeon's responsibility. I never change the implant during surgery, because I suppose that if I studied the case enough before surgery and I concluded that the implants were the appropriate size and shape, the anatomy and the plan cannot be different when the patient is lying or sitting during surgery. Full attention should be given when the surgery is being planned. In the selection of the implant, the size of the thoracic wall and the size of the implant should be analyzed. The implant should be placed without interrupting the medial and lateral cutaneous perforators of the intercostal nerves. Therefore big thoraxes permit big implants, but in small thoraxes big implants cannot be introduced without the possibility of interruption of these sensitive nerves and patients should be aware of that. In case she insists on having big implants, a subglandular approach should be considered.

Deep sedation should continue during the duration of the surgery and the patient is required not to move during surgery. I do not use general anesthesia because gases are vasodilators and mechanical breathing usually alters the venous pressure, increasing bleeding. With this kind of anesthesia, nausea and vomiting, the side effects of general anesthesia are minimized.

The aim of the profuse local anesthesia is to blockade the sensory nerves, to facilitate the dissection and to decrease dramatically the bleeding, as a consequence of a vasoconstriction that lasts 4–6 h after surgery [7–12]. After this time, all the vessels are coagulated and postoperative analgesia lasts for some hours. The injection of the first breast takes 5 min and then the second breast is also infiltrated. The surgery begins at the first one (when 5 min has elapsed), and after having dissected the pocket and left the compresses in place, I

begin surgery on the second breast. Between the infiltration and the surgery there is always an elapse of some minutes, the time needed for vasoconstriction and for a correct nerve sensitivity blockade. For effective local anesthesia, between 250 and 300 cc anesthetic solution per breast is needed. During surgery, coagulation is barely used, around 2 – 5 times for each breast.

The incisions are made at the top of the armpit, at the inferior part of the areola border or at the lateral half of the future submammary crease, between 6 and 7.30 o'clock. This way the scar is not visible from a frontal view, even when the patient raises her arms. The lateral incision, between 7.30 and 9 o'clock, was proposed by Cachay Velazquez [2] with the same purpose but I find it too lateral.

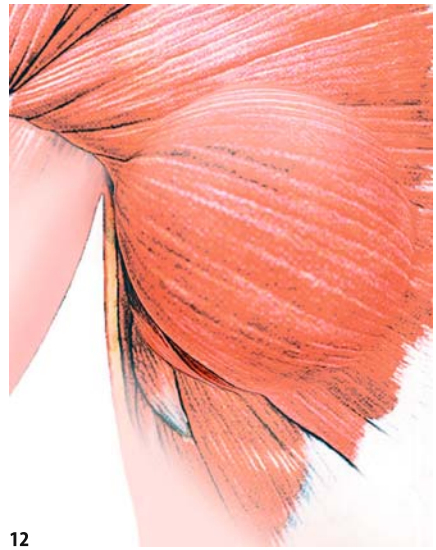
Despite the incision, the pectoralis major and serratus anterior muscles cover the external surface of the implant, this way avoiding the extrusion of the implant, as was described by Trolius [14]. Extremely careful attention has to be paid not to exceed the dissection of the marked IMF. This is one of the most important parts of the surgery. As I learnt this technique before the endoscopy era, as did other surgeons [6], I do not find I can obtain better results or that endoscopy can facilitate the surgery, as was reported by Graft [5].

Total muscle coverage was reported by Dempsey and Latham [4] (Fig. 48.12). Then Biggs [1] suggested releasing the inferior and medial origin of the pectoralis major muscle, so that the contraction of the muscle would not force the implant superiorly (Fig. 48.13). Tebbets [13] popularized the dual plane, not dividing the sternum origin of the pectoralis major muscle but without covering the lateral aspect of the implant with the serratus anterior muscle (Fig. 48.14). In my routine, the medial insertion of the pectoralis major muscle at the sternum is not disrupted but the inferior submammary border of the pocket is the only part where the implant remains not covered by the muscle (Fig. 48.15). I stress the importance of not having any muscular fibers at this inferior area, so that the motion of the muscle contracts the muscle above the implant without moving or displacing it (Fig. 48.16). The extent of the submuscular pocket is something that should be considered according to the size of the thoracic wall and the size of the implant. For example: a large implant will have problems fitting into a small thorax, without disrupting the lateral and medial branches of the intercostal nerves. In general the dissection should extend beyond the diameter of the implant because its volume needs more room than its diameter. But I usually do not dissect superiorly the 3rd intercostal spaces, avoiding in this way the superior displacement of the implant.

The three compresses are placed vertically, one in the medial aspect of the pocket, the second in the lateral part of the pocket and the third in the middle. After the introduction of the first one, I compress and accommodate it with my index finger and then I do the same with the second to make room for the third that is placed in the middle. This way, the extent of the dissection of the pocket can be also watched from outside.

The size of the implant and its relationship with the thoracic wall size should also be considered when a nice projection of the breast is desired. With a small thorax and a big implant, the muscle is going to be in a high degree of tension, limiting its anterior projection. The high textured surface [3] of the implant is fixed to the muscle and to the thoracic wall and this way, both the weight of the implant and the gravity that facilitate its ptosis are avoided. Most of the implants used are round in shape, seldom are low profile ones used and very seldom the anatomically shaped implants are used.

Capsule contracture has a much lower incidence



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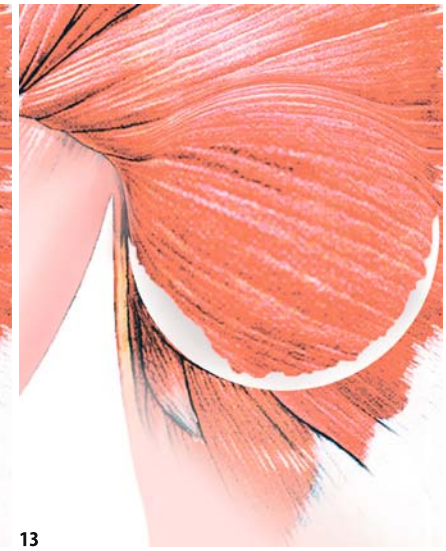

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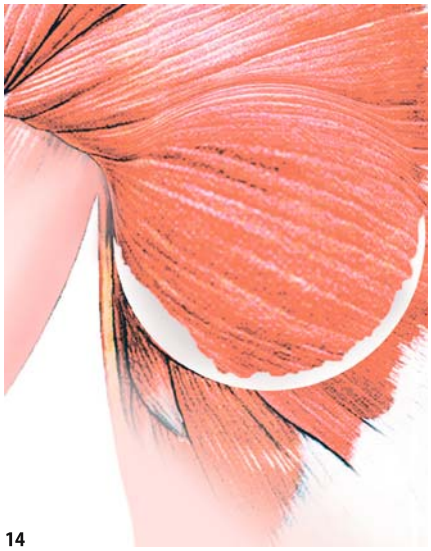
Fig. 48.12. The implant totally covered by the muscles

Fig. 48.13. As Biggs stated, the pectoralis major muscle is divided medially and at the submammary fold while the lateral part of the implant is not covered by the serratus anterior muscle



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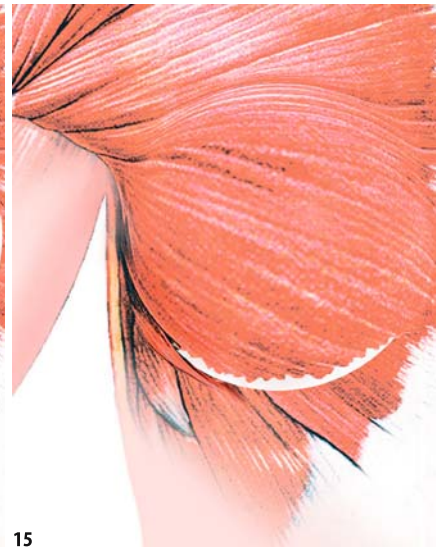

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Fig. 48.14. According to Tebbets, the pectoralis major muscle is not divided at the medial sternum side, only at the submammary fold area, and is not covered by the serratus anterior muscle

Fig. 48.15. I only divide the pectoralis major muscle at the submammary fold and the implant remains almost totally covered by the muscles

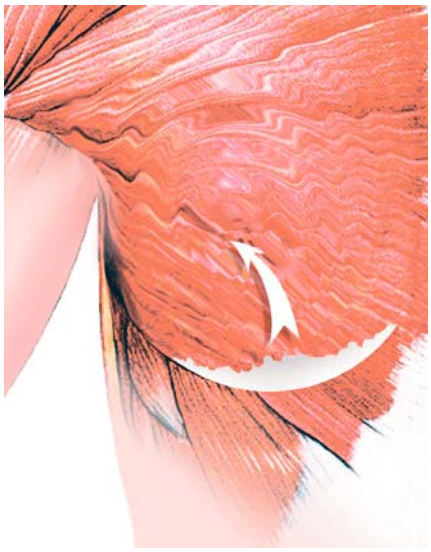

Fig. 48.16. During motion, the contraction of the pectoralis major muscle does not displace the implant

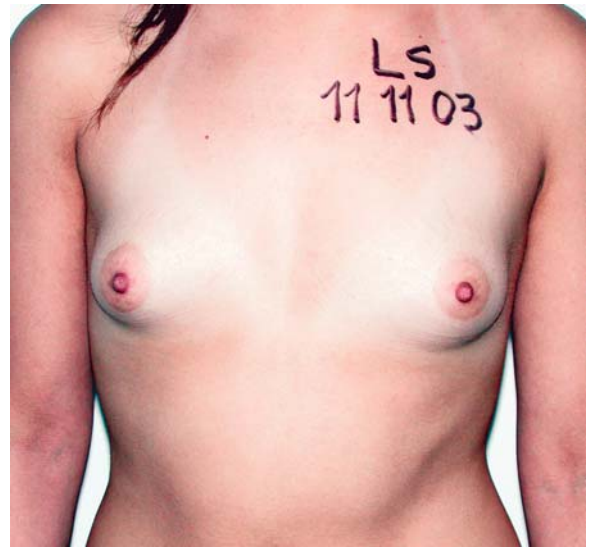

Fig. 48.17. Preoperative view

since we are using the new cohesive breast implants. In the last 3 years our incidence of this problem has been less than 2%. The low rate can be explained because cohesive gel is not able to bleed and because the envelope of the new implants is thicker than previous ones. The lower rate of infections could be another factor in this low incidence.

For 15 years I have washed out the wound and the cavity and rinsed the implant and my gloves with cephalosporin antibiotic solution before touching it. This way I only have two postoperative subcutaneous infections to report. In case the implant is introduced upside down I pour in more antibiotic solution since in an aqueous medium it is much easier to rotate the implant.

Drains are not used routinely. I only have to report one case of a unilateral hematoma at the axilla that was drained in the office.

If in the first postoperative days I observe that the implant has been positioned superiorly, I try to reposition it with manual maneuvers and if that fails, I take the patient to the operating room and open the wound preferably before the 10th postoperative day, enlarging the submammary fold if needed, without removing the implant. In this period, the wounds and the dissected areas can be reopened easily. Before beginning the reoperation, I infiltrate the wounds and the surrounding areas of the implant and the intercostal nerves with local anesthesia, so as to have reduced bleeding and also for postoperative pain relief. If the position of the implant is a little low, good results can be obtained with a special brassiere, as recommended by Trolius [14] (Figs. 48.17 – 48.26).

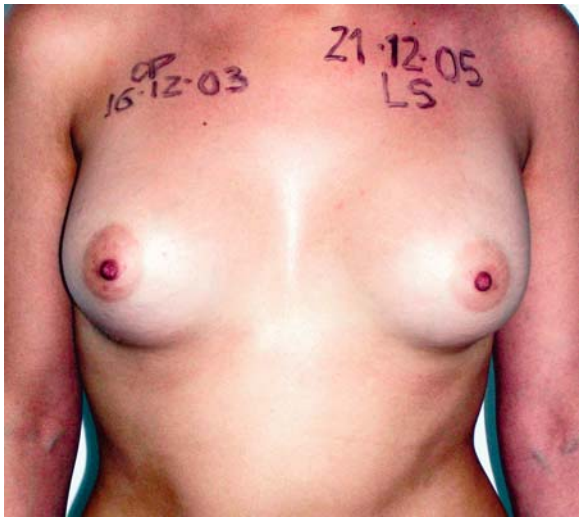

Fig. 48.18. Two years postoperatively

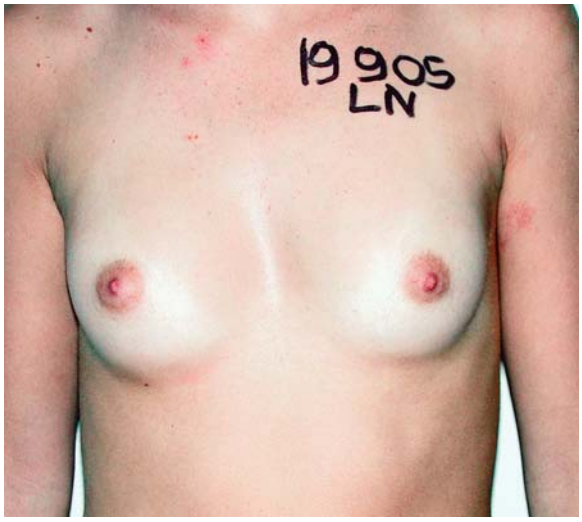

Fig. 48.20. Preoperative view

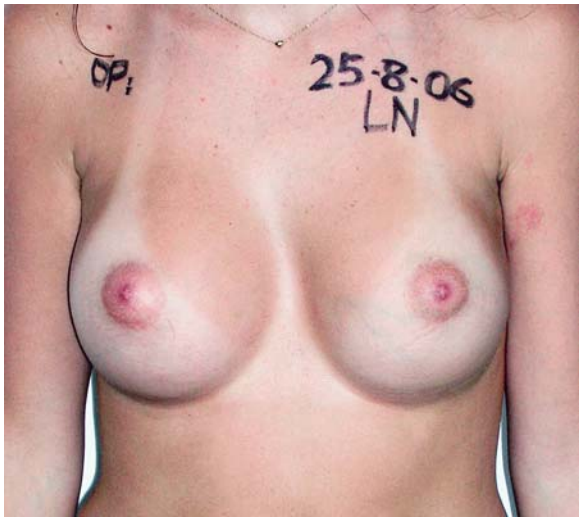

Fig. 48.22. Eleven months postoperatively

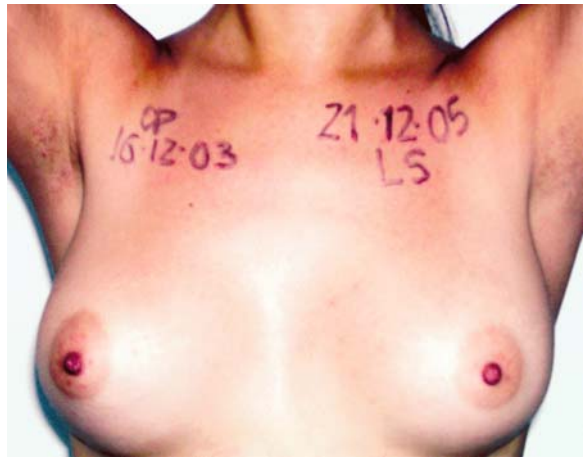

Fig. 48.19. The axillary scars are inconspicuous

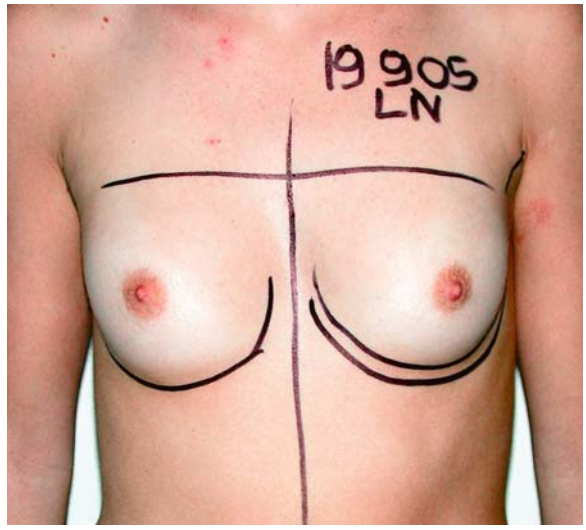

Fig. 48.21. On the left side, the inframammary fold should be lowered

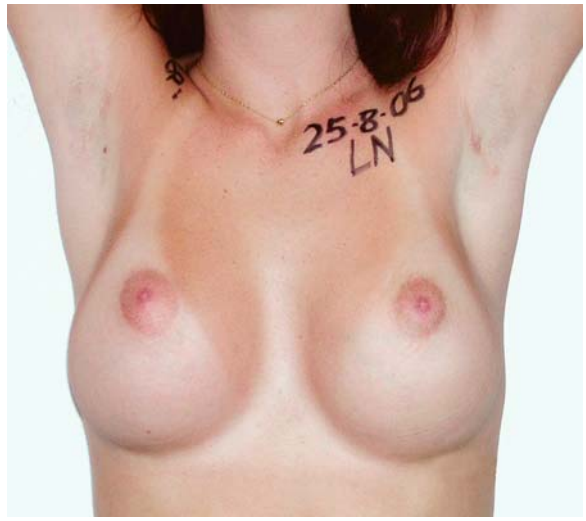

Fig. 48.23. The scars placed horizontally on the top of the armpit are inconspicuous

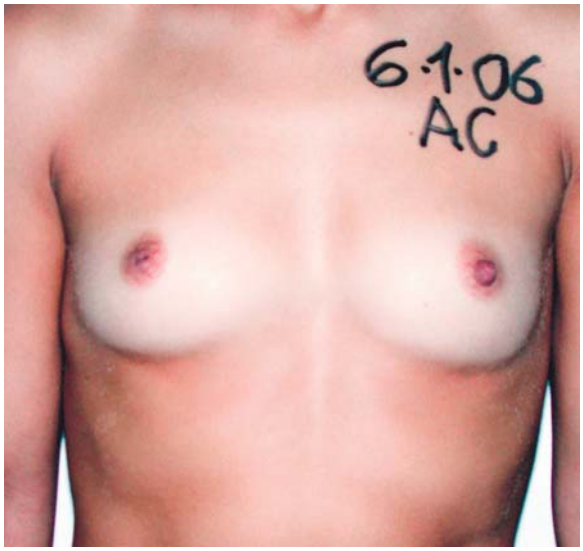

Fig. 48.24. Preoperative view

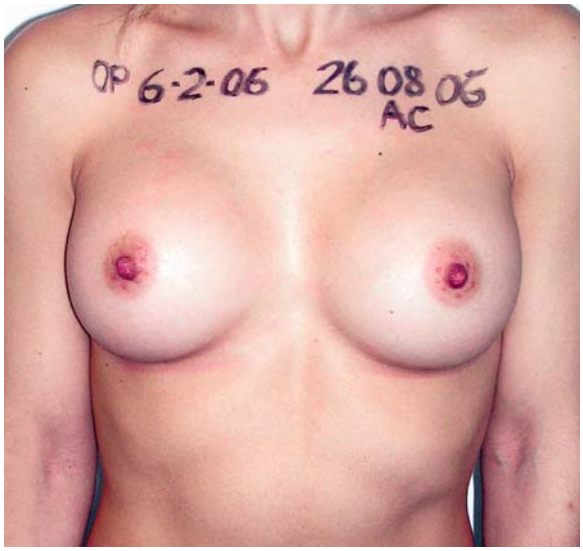

Fig. 48.25. Six months after surgery

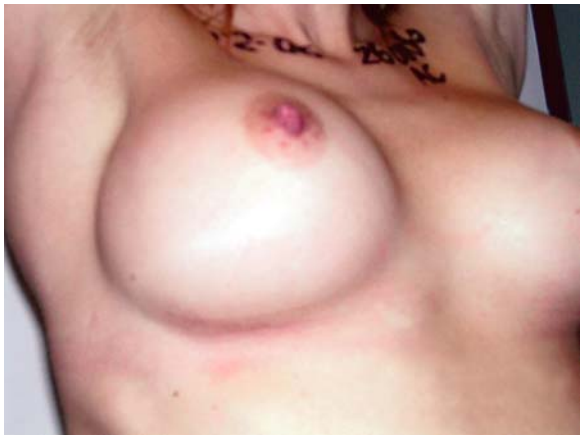

Fig. 48.26. The inframammary scar between 6 and 7.30 o'clock is hardly visible

48.5 Conclusions

Some new ideas that I see as being of help to the surgeon in performing an easier and faster augmentation mastoplasty are: no seizers during surgery, profuse local anesthesia providing anesthesia, vasoconstriction, facilitating the dissection and giving some hours of postoperative analgesia. Digital submuscular dissection of the pectoralis major and serratus anterior muscles cover the implant almost totally, thus avoiding extrusions and rippling. Using high textured implants helps the adherence of the implant to the surrounding tissues. Leaving two to four compresses for 10 – 15 min helps vasoconstriction and distends the pocket. In case of malposition of the implant, it has to be repositioned within the first 10 days.

This way I can perform a breast augmentation in an easy and swift way, using the submuscular approach, and leaving the implant with almost total muscle coverage.

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Transaxillary Subfascial Breast Augmentation: Optimizing Outcomes

49

R. Gemperli, A. Mendonça Munhoz

49.1 Introduction

Regardless of progress in surgical procedures and breast implant technology, augmentation mammaplasty remains a technique in development. The decision as to the plane of placement and which type of implant to use is an exercise in balancing a number of objective and subjective factors. Aesthetic expectations, patient's physical individuality, surgeon's experience, lifestyle factors and implant – soft tissue relations, all influence the decision process, surgical planning and outcome [5, 12, 13]. To date, there is no consensus concerning the best procedure. The main advantages of the technique should include safety, reproducibility and acceptable complication rates. Probably, these goals are not achievable by any single procedure and each technique has advantages and limitations.

Subfascial placement of breast implants has been mentioned as an alternative that has some of the advantages of both the subglandular and submuscular techniques while minimizing the disadvantages of each [3, 4, 10, 11]. Despite the debate regarding the concept of the suboptimal soft tissue coverage provided by the subfascial technique and the limitation of the pectoralis fascia thickness [15], some clinical series have demonstrated a satisfactory outcome in selected patients [3, 4, 11].

Recently, the transaxillary approach seems to have gained new status with the advent of endoscopic techniques [4, 10 13, 14]. Essentially, the majority of the series have employed the submuscular plane and the endoscopic assistance which provides precise hemostasis and release of soft-tissue attachments [5, 12 – 14]. As a consequence of the advances in techniques, the subfascial plane has been associated with the axillary approach. Introduced by Graf et al. [4], the subfascial transaxillary technique is particularly attractive for selected patients and includes some benefits due to placement of the incision in the axilla, thus avoiding visible signs of surgery on the breast mound [4, 10, 11]. Additionally, the pectoralis muscle fascia is a well-defined structure in the upper thorax and is useful in minimizing the appearance of the edges of the implant [3, 4, 10, 11].

49.2 Patient Selection and Surgical Planning

The technique is best indicated in patients with small volume breasts without ptosis. In patients who do not want the presence of breast scars or have a poorly defined inframammary fold, the technique is particularly advantageous. With the patient sitting, skin markings are planned: the inframammary sulcus, the limits of the pocket, the anterior axillary line, and the new inframammary fold. It is important to lower the inframammary fold and for small implants the new fold is located 0.5 – 1 cm below, and for large implants, 3 cm may be required. The incision is marked and the deepest natural fold is chosen. It is imperative to keep the incision in the limits of the axilla, never crossing outside the lateral edge of the pectoralis major muscle.

49.3 Surgical Technique

The procedure is performed with the patient under intravenous sedation in combination with local anesthetics (0.25% lidocaine/epinephrine 1/100,000). Both breasts are symmetrically infiltrated with a total volume of 200 cc. The infiltration is performed in the planned dissection plane using a long needle (the boundaries of the pocket, the axillary incision, the region between the current and the new inframammary

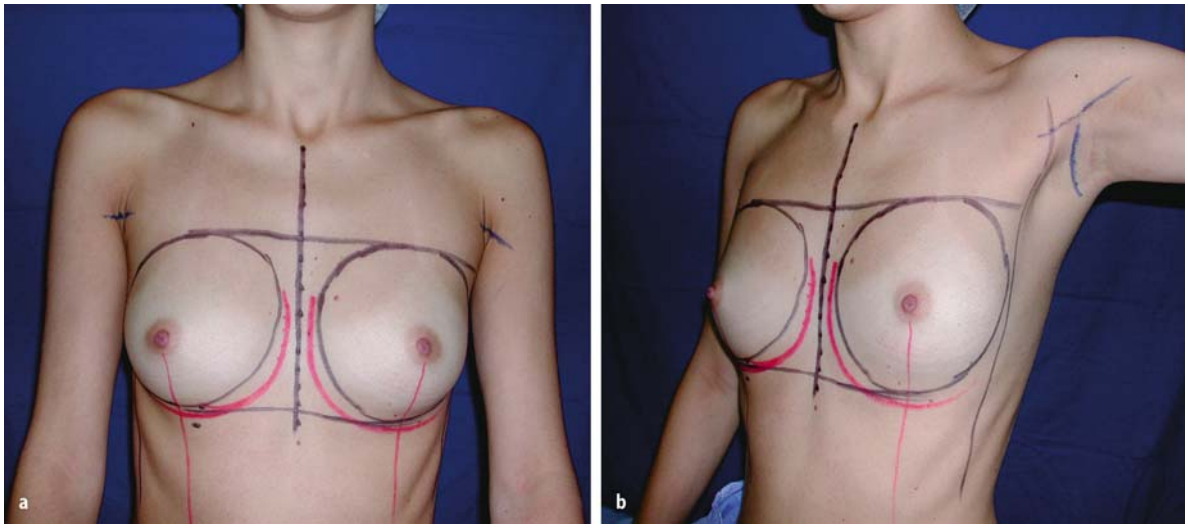

Fig. 49.1a, b. Skin markings are designed: the current inframammary sulcus, the anterior axillary line, the limits of the pocket and axillary dissection and the future inframammary fold. The new inframammary fold was located 1 cm above the original fold (**a**). It is important to maintain the incision in the limits of the axilla, and usually the deepest natural fold is chosen (**b**)

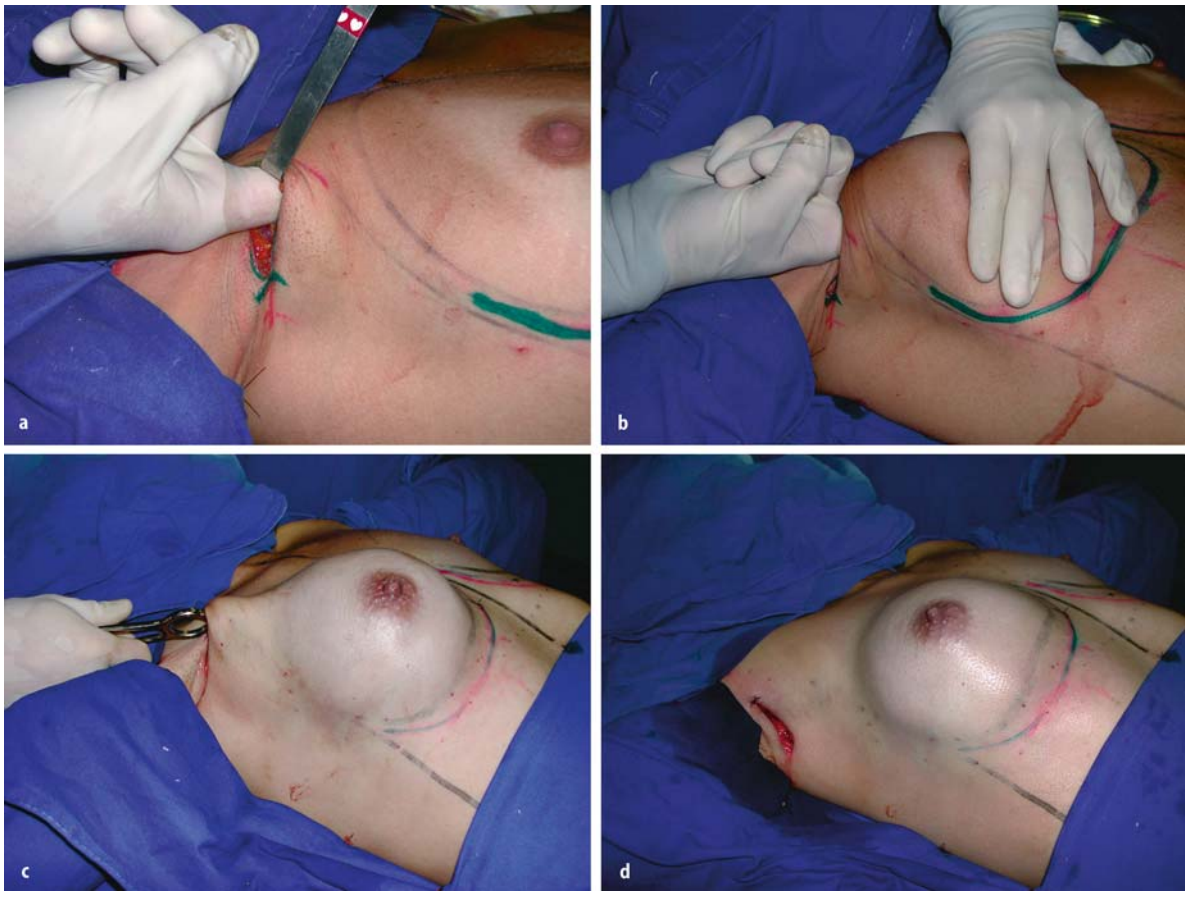

Fig. 49.2a–d. The axillary incision is performed and subfascial blunt dissection is done with the finger and with gently sweeping maneuvers the fascia is separated from the muscle as far as the finger can reach (**a, b**). When the distalmost margin is reached, the breast dissector is introduced and is used to complete the dissection (**c**). The silicone gel implants are placed in the subfascial location and the patient is positioned upright to assess implant position and breast shape (**d**)

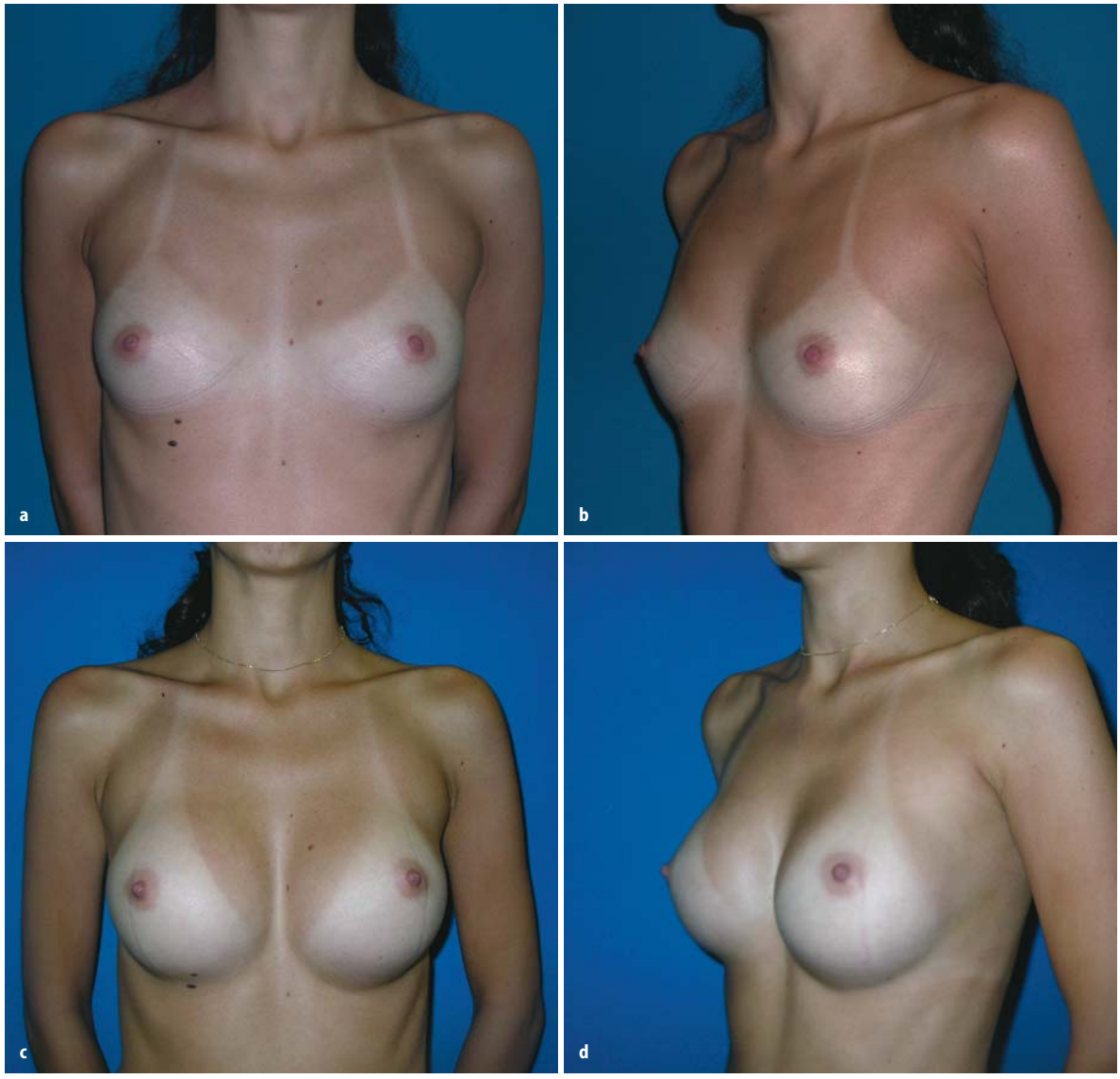

Fig. 49.3a–d. Preoperative frontal and left oblique view of a 25-year-old patient with hypoplastic breasts (**a, b**). Two years postoperative appearance with a very good outcome. A bilateral 220-cc McGhan 120 style was used (**c, d**)

fold). An incision is made in the axillary fold and the superficial fascia of the pectoralis muscle is opened. Subfascial blunt dissection is performed with the finger and with gently sweeping maneuvers the fascia is separated from the muscle as far as the finger can reach. When the most distal margin is reached, the breast dissector is introduced and is used to complete the dissection. The breast is lifted away from the chest, consequently elevating the gland and muscular fascia, facilitating the passage between them and the breast dissector. The boundaries of the pocket and the new inframammary fold can be checked with the dissector, and enlarged by stretching if necessary. In order to avoid injury to the lateral cutaneous nerves and the lymphatic channels, the lateral aspect of the pocket dissection is minimized. The silicone gel implants are placed in the subfascial location and the patient is positioned upright to assess implant position and breast shape. Layered wound closure is done using non-absorbable in the pectoralis fascia, subcutaneous and subdermal planes; and absorbable subcuticular running sutures.

49.4 Postoperative Period

The procedure is performed on an outpatient basis. At the end of the surgery, an elastic band is used over the

superior breast poles and maintained for 4 weeks with the aim of avoiding superior displacement of the implants. All patients received intravenous antibiotics and oral antibiotics were continued for 48 h. The adhesive straps are removed on day 5 and the patients are advised to wear a normal bra associated with the elastic band across the upper breast pole. Patients are instructed to avoid lifting for 6 weeks.

49.5 Technical Aspects and Optimizing Outcomes

Most complications occur in the initial postoperative period and are directly related to the axillary incision [10]. The majority are minor, predictable and do not impair the final result. Axillary subcutaneous banding is occasionally observed and some authors believe that this may be attributed to inflammation of the cutaneous nerves or sclerosed lymphatic channels [1, 7, 10]. It is important to inform the patients previously and they are instructed to perform a local massage after the first postoperative week [10].

Another aspect is related to intercostobrachial nerve damage and lymphatic system preservation. Previous clinical series noted an incidence of sensory loss in 1 – 24 % of the patients; however the true incidence of intercostobrachial injury is not defined [2, 10]. Similarly as proposed by Tebbetts [14], it is important to not dissect near the nerve and to preserve the axillary fat. The subcutaneous tissue should be undermined parallel to the skin and superficially to the axillary fat to avoid nerve injury [10].

Concerning the lymphatic channels, it is important to perform a minimal undermining in the lateral aspect of the breast to avoid interruption between the breast tissue and the axilla. Currently, analysis of axillary lymph nodes provides crucial information for adjuvant therapies in breast cancer, and sentinel lymph node biopsy has been proposed as an alternative in selected cases [6]. One might surmise that a previous dissection in the axilla could interrupt the normal lymphatic system and jeopardize the oncological treatment [8 – 10]. Our previous observation has demonstrated that the lymphatic channels can be preserved and that sentinel lymph node mapping is feasible with this technique [8, 9]. However, additional studies with larger clinical series are necessary to analyze the accuracy of the procedure in patients with a previous transaxillary approach [9].

Finally, postoperative care is crucial for the aesthetic outcome and to avoid implant displacement. Thus, an elastic band should be used over the superior breast poles and maintained for 4 weeks with the rationale of preventing upward migration of the implants and ensuring that the lowered inframammary crease remains at the desired height. As the breast edema subsides, the band tension requires some adjustment, and the patient should be seen at appropriate intervals to supervise band tension [10].

49.6 Conclusions

Transaxillary subfascial augmentation mammaplasty is an advanced technique in aesthetic breast surgery. In selected patients the procedure ultimately unites the advantages of the submuscular technique but eliminates the disadvantages of postoperative discomfort and disturbing muscle movement of the breast. The thickness of the fascia increases from the inferior part to the upper third of the pectoralis muscle. In this last region, the fascia can present a good coverage of the implant and the edge is neither visible nor palpable. The incision location presents positive aspects. It is less visible than the inframammary/periareolar scars and in patients with a poorly defined inframammary fold, it can be valuable. Transaxillary subfascial breast augmentation can play a useful role for breast augmentation. The success of the technique depends on patient selection, an adequate technique and careful postoperative management [10].

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50 Subfascial Breast Augmentation

R. Graf, D.T. Pace, R.C. Damasio, R. Rippel, L.R. Araujo, L.G. Neto, T. Al-Yafi

50.1 Introduction

Breast augmentation has been a very common procedure in plastic surgery in the last few decades with multiple options for incision location, implant design and-pocket plane. Implant position or pocket plane in breast augmentation has been the subject of some controversy because an implant can be positioned in a subglandular, retropectoral or subfascial plane (Fig. 50.1). For an optimal result, the implant must have adequate soft tissue cover; otherwise it can be palpable or visible. The position of an implant in a retroglandular space has significant disadvantages if the soft tissue cover is inadequate. In addition to implant palpability and visibility, incidences of fibrous capsular contracture, rippling and nipple sensation alteration and numbness are higher [14]. In order to obtain correction of the problems encountered in the retroglandular placement, the utilization of the retropectoral space has become commonplace. The disadvantages of subpectoral placement include a more invasive procedure, increased postoperative discomfort and visible flattening or distortion of the breast when the pectoral muscle is contracted [14]. If the muscle is released inadequately medially, the implant may ride too high or if the muscle is released excessively the implant may be displaced inferiorly and laterally [2, 9, 11, 12].

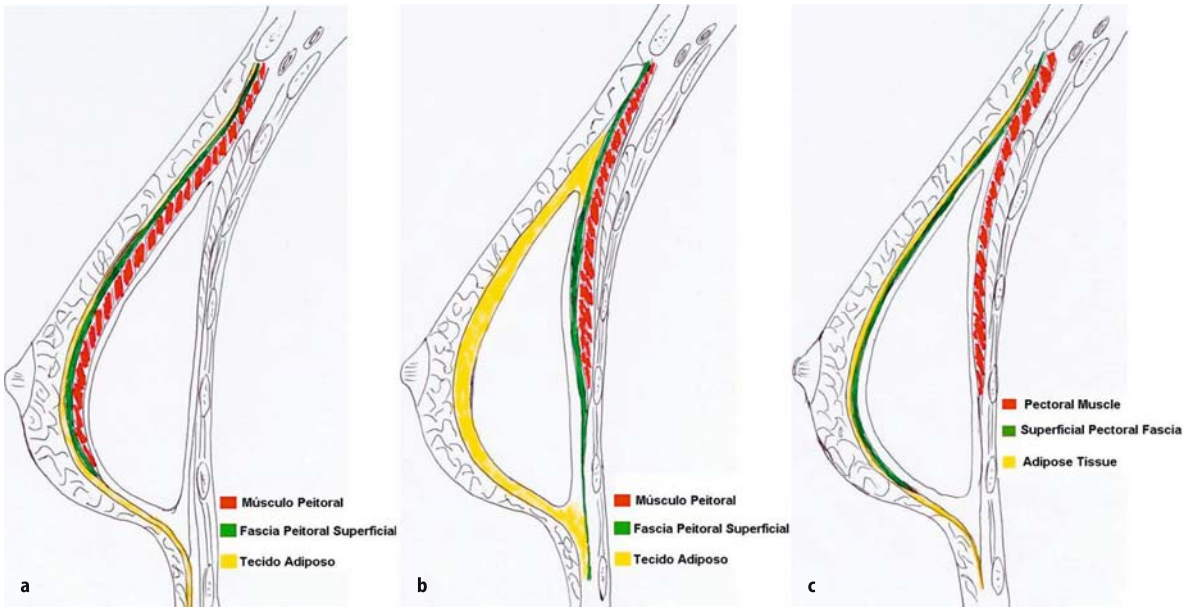

Fig. 50.1. Illustration of the anatomical plane of dissection: *left* submuscular; *middle* subglandular; *right* subfascial

A reasonable solution to the problem of acquiring adequate soft tissue coverage without distortion of the implant through muscle contracture has been the use of the subfascial plane [1, 7, 8, 15]. As the pectoralis muscle fascia is a well defined structure and very consistent in the upper thorax, it can be used to minimize the appearance of the edges of the implant on the skin, making them less noticeable. The integrity of the muscle is preserved and the implant is totally covered. The fascia supports the implant without requiring additional tissue to give a good aesthetic result. In the subfascial plane, there will be no alteration to the breast shape by muscular contraction, so consequences of displacement due to muscular movement will be avoided.

The preoperative evaluation includes the analysis of breast tissue and thoracic shape, the elasticity of the breast, the presence of ptosis, and the distance between the nipple and the inframammary fold.

Goals of subfascial position are a good shape with a natural result. There is additional soft tissue between the implant and skin, also improving mammary glandular tissue resistance in the upper pole, leading to a less noticeable implant edge.

50.2 Anatomical Considerations

The breast is essentially a skin appendage contained within layers of the superficial fascia. The superficial layer of this fascia is near the dermis and is not distinct from it. The deep layer of the superficial fascia is more distinct and is identifiable on the deep surface of the breast when the breast is elevated in a subglandular augmentation mammaplasty [10]. There is a loose areolar tissue between the deep layer of the superficial fascia and the fascia that covers the pectoralis major [17] and continues to cover the adjacent rectus abdominis, serratus anterior and external oblique muscles (Fig. 50.2). This fascia has its origin on the clavicle and sternum, extending toward the lateral border of the muscle to form the axillary fascia. At the caudal border of the pectoralis muscle, the clavipectoral, pectoral, and serratus anterior fasciae become continuous and form suspensory ligaments that extend to the breast's inframammary fold [17]. The deep fascia covering the lower aspect of the pectoralis major muscle is well defined, as is the fascia of the serratus anterior muscle. This deep fascia is continuous with the fascia of the external oblique and rectus abdominis muscles. The upper portions of the external oblique and rectus abdominis muscles and their overlying fasciae are deep to the lower portion of the breast. The digitations (spreading) of origin of the external oblique muscle are associated with the lateral inferior fibers of the pectoralis major muscle and laterally with the serratus anterior muscular digitations (spreading). We have observed that the pectoralis major fascia tends to be thin and more fragile over the lower two-thirds of the muscle.

50.3 Operative Approach

The approaches can be axillary, inframammary or periareolar, depending on the patient's wishes, anatomy or history of pregnancy. The axillary approach is ideal for patients presenting with mammary hypoplasia and breast skin flaccidity without ptosis. This approach has the advantage of leaving no scars on the breast. The inframammary approach provides easy access and permits the use of large implants. These two options leave intact breast parenchyma. In patients with slight ptosis or with downward displacement of the nipple areola

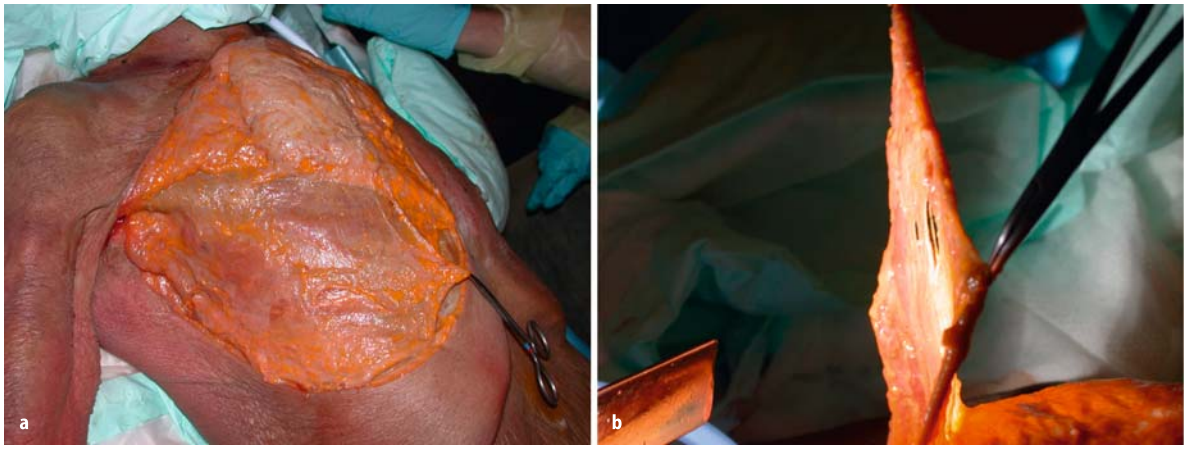

Fig. 50.2. Anatomical study of the pectoralis fascia. Note that it continues with the serratus and rectus abdominalis fascia

complex, a circumareolar incision is utilized and excess periareolar skin is excised as described by Benelli and Goes [3, 7].

50.3.1 Markings

Preoperative marking is performed with the patient standing up. The design of the pocket for the implant is marked. The inframammary crease is marked, and a new inframammary crease is also marked, parallel to this one, 2 cm below. The anterior axillary line is drawn on the lateral side. A line is drawn 1 or 2 cm from the midsternum line and extended cephalically to the level of the second intercostal space.

50.4 Technique

Epidural block associated with sedation is the preferred option for anesthesia, where the arms are abducted 90° and the dorsum is slightly elevated. The incision lines are infiltrated with epinephrine, 1:300,000, using an average of 20 cc on each side.

50.4.1 Axillary Approach

The axillary incisions are placed in a natural crease, or "S" shape, approximately 4 cm in length, but never crossing beyond the lateral edge of the pectoralis muscle. Careful dissection exposes the lateral border of the pectoralis muscle where the fascia is incised and the plane between the pectoralis muscle and its fascia is undermined by blunt dissection, and then by endoscopy retractor or direct view, the subfascial pocket is created. The thickness of the fascia increases from approximately 0.1 mm in the inferior part to approximately 0.5 mm in the upper third of the pectoralis muscle, with good coverage of the implant [14]. In the cephalic portion, the fascia is more defined and resistant. Its inferior portion is thinner and more friable. This undermining should be done very carefully to avoid fascia injury and if there is doubt about the plane, some muscle fibers may be lifted with the fascia. The limits for blunt dissection are the third intercostal space superiorly, 1.5 cm from the midline medially, 7 cm below the areola to the original inframammary fold or 1.5 cm below it inferiorly if the original distance is less than 5 cm, and the anterior axillary line laterally. The distance between the implants should be approximately 2–3 cm and the distance between the areola's medial border and the midsternal line should be about 9–10 cm (Fig. 50.3). Once dissection is completed, a meticulous evaluation for bleeding is carried out, and the implant is inserted into the pocket. Breast sizers may be used.

50.4.2 Inframammary Approach

A 4-cm incision is made in the proposed inframammary crease, lateral to the medial breast line, and the skin and subcutaneous tissue are incised. When the thin fascia is visualized at the areolar's level, it is incised and the subfascial pocket is undermined superior and inferiorly as described above. The inframammary approach offers advantages of providing easy access, no disruption of the breast parenchyma and the possibility of using any size of implant (Fig. 50.4).

50.4.3 Periareolar Approach

The periareolar approach to augmentation mammaplasty was first described in 1970. Once the periareolar

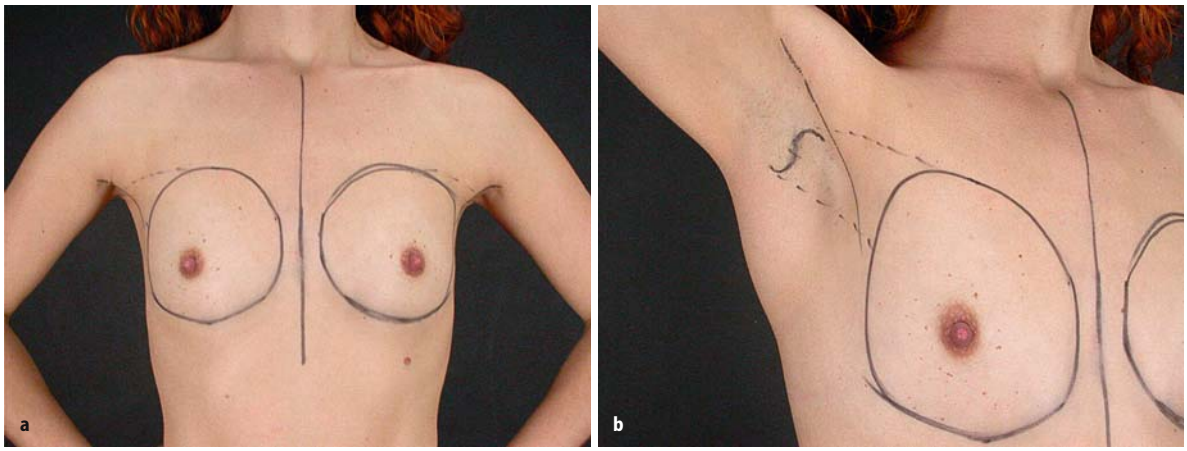

Fig. 50.3. Axillary breast augmentation markings: **a** the pocket to be undermined; **b** the S-shaped incision in the axilla

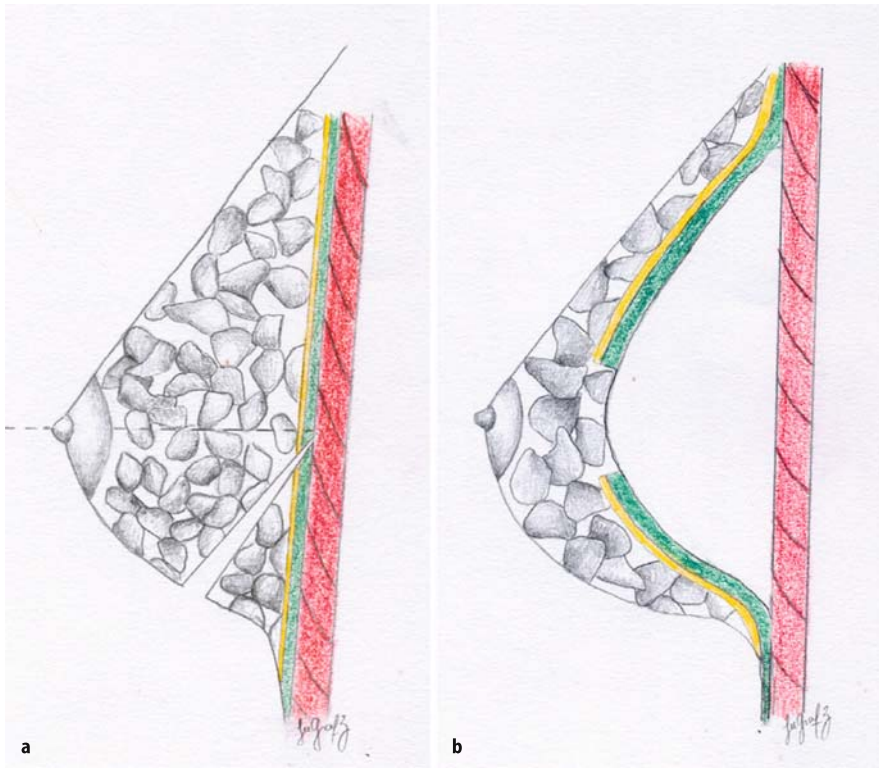

Fig. 50.4. The inframammary approach going direct to the fascia and opening it at the level of the areola. *Right* the implant in the subfascial plane

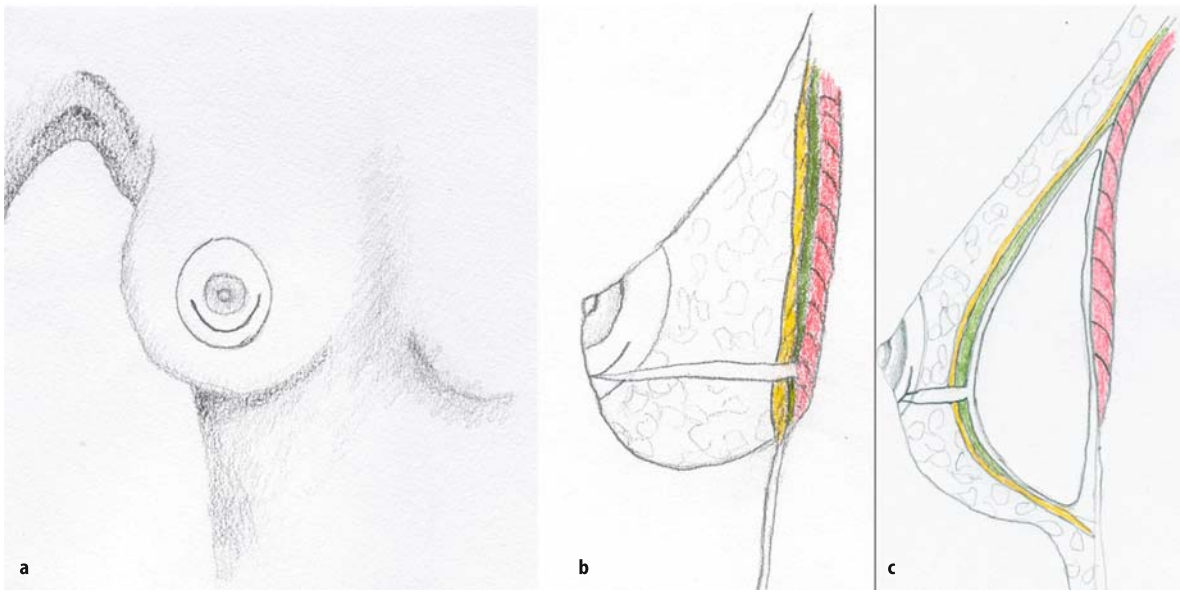

Fig. 50.5. The periareolar approach going direct to the fascia and opening it. The implant is in the subfascial plane

incision is made, the gland is divided perpendicularly to the thorax, until it reaches the fascia. At this point subfascial dissection is carried superiorly and inferiorly, making the same pocket as described above (Figs. 50.5, 50.6). The periareolar augmentation gives the option of a central point of access for the creation of an implant pocket, which allows easy and accurate dissection in all directions [15].

Meticulous hemostasis is routinely maintained. Suction drains are not used routinely.

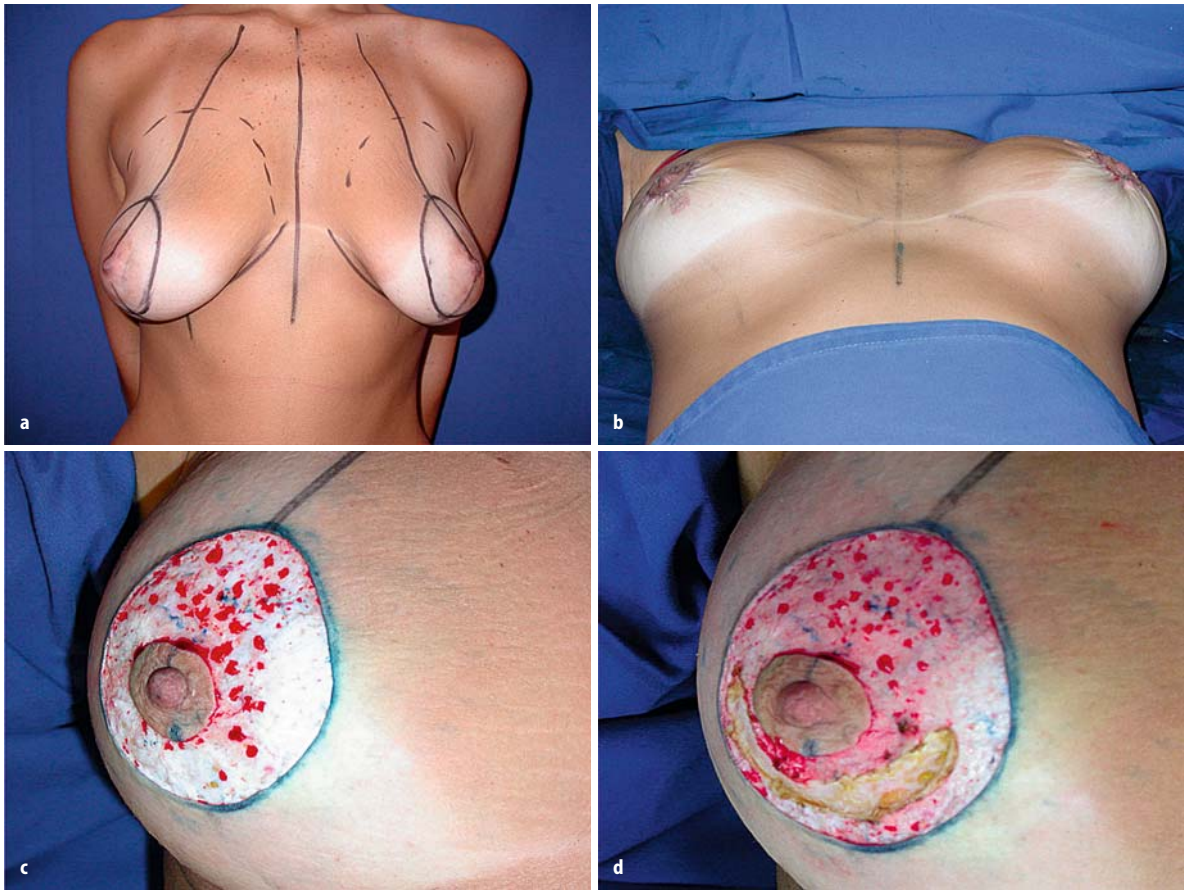

Fig. 50.6. Periareolar approach: skin markings to remove the skin excess in a patient with mild ptosis (**a**), skin deepithelialization and inferior incision (**c, d**) and immediately postoperatively (**b**)

50.5 Postoperative Care

It is recommended to use a bra and if the approach is an axillary incision an elastic band is used on the upper pole of the breast for 1 or 2 weeks to help maintain the implant at the correct position. Regular movements of the arms are allowed after that.

50.6 Complications

Malposition of the implant is one of the complications of breast augmentation. Low displacement of the implant can be encountered in the postoperative period in patients with skin laxity prior to surgery. Superior displacement of the implant can be encountered if the surgery is performed through an axillary incision. Other complications have been minor (2.2 % Baker II contracture, 1.2 % hematoma, 1.0 % brachial hypesthesia, 1.0 % asymmetry, seroma 0.4 %, axillary fibrous banding 0.8 %, and infection 0.4 %). As described by Stoff-Khalili and colleagues comparing the results of subglandular, subpectoral and subfascial augmentation, the total rate of complications was significantly diminished in the latter group [4, 5, 6, 13, 14].

Some complications can be avoided using technical maneuvers including careful hemostasis. Using gauze in the pocket is not advised because the possibility of foreign body (gauze tread) might cause reaction. If needed, a suction tube might be used.

Using the no touch technique for handling the implant also minimizes complications. In addition, the patient is advised to minimize the use of her arms for 1 week. We did not find an increased rate of capsular contracture with the subfascial technique relative to the submuscular technique. No patients undergoing the subfascial implant procedure developed implant distortion due to pectoralis muscle movement. The implants edges were not noticeable, even in the larger size implants.

50.7 Results

Utilizing the subfascial technique resulted in a more natural look for the breasts with good soft tissue coverage of the implants and no possibility of implant distortion during pectoralis major muscle contraction. It also showed a similar complication rate to those of other techniques (Figs. 50.7 – 50.9).

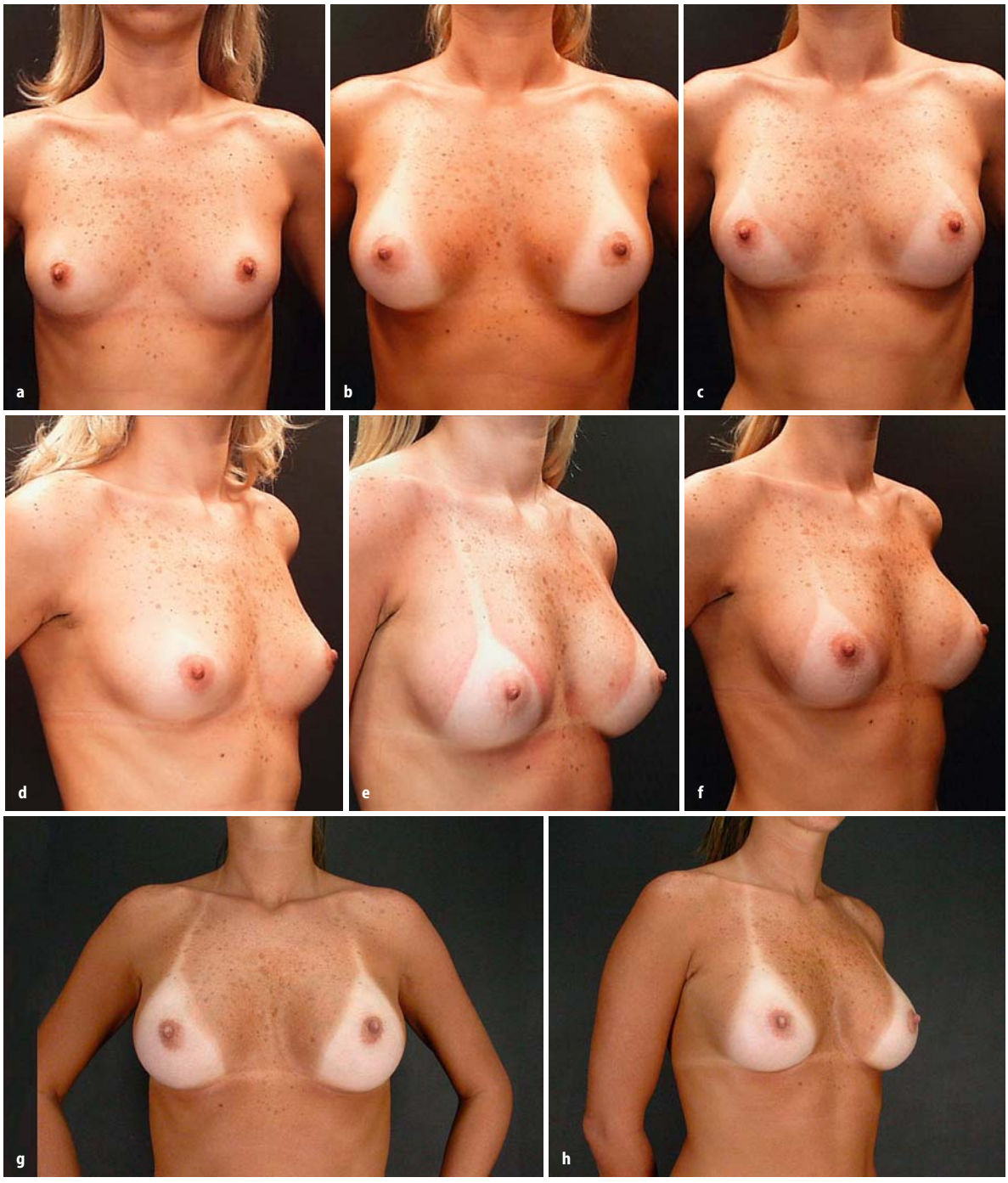

Fig. 50.7. Transaxillary subfascial technique in a 25-year-old patient, front and oblique views, cohesive gel, anatomical, moderate profile, 235 ml, pre-, 6 months, 2 years (**a – f**) and 5 years postoperatively (**g, h**)

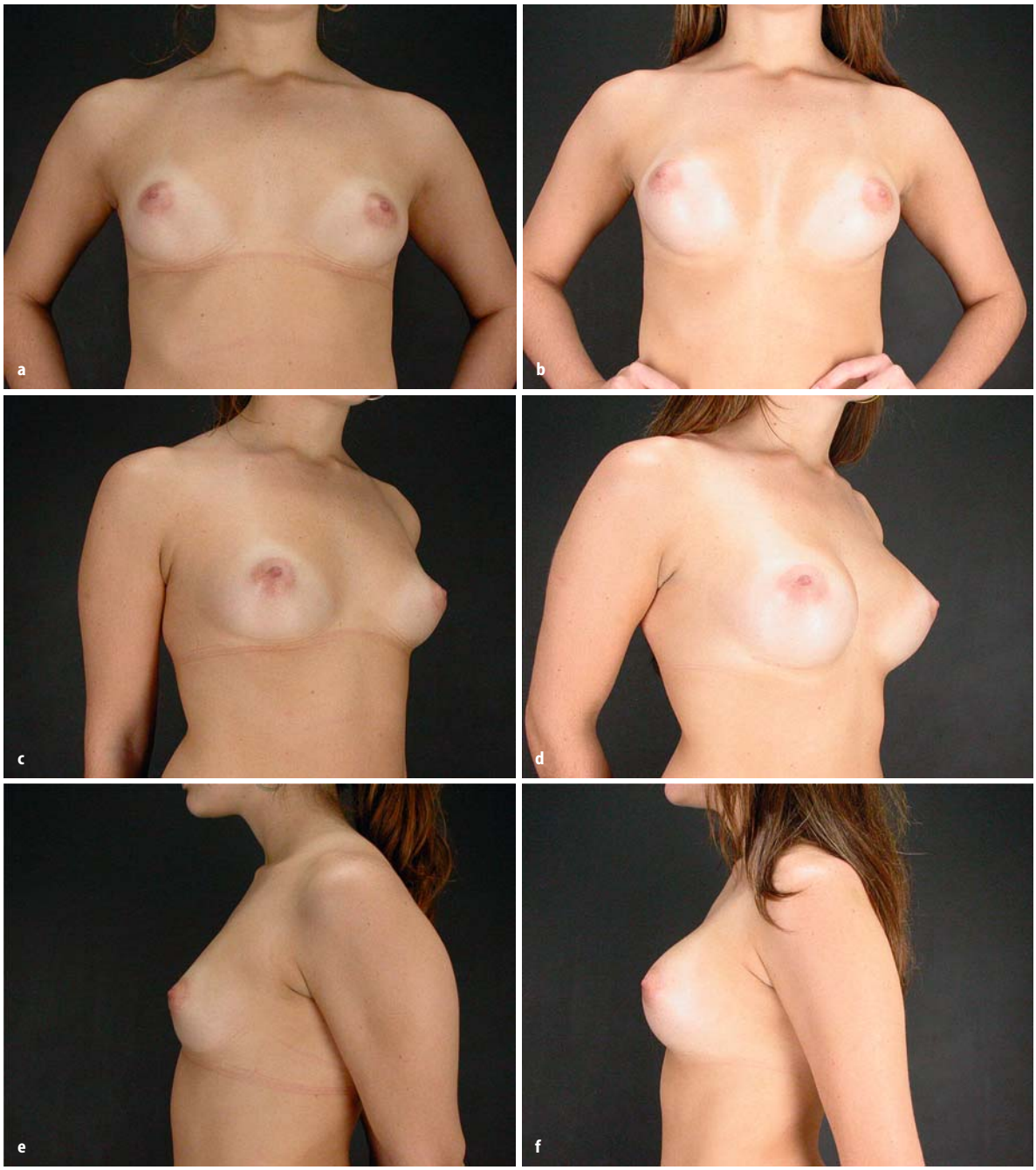

Fig. 50.8. Inframammary subfascial technique in a 19-year-old patient, front, oblique and lateral views, cohesive gel, round, high profile, 220 ml, pre- (**a, c, e**) and 1 year postoperatively (**b, d, f**)

50.8 Discussion

The subfascial placement has become the preferred technique for breast implants in our practice. Because the pectoralis muscle fascia is a well-defined structure and very consistent in the upper thorax, it can be used to minimize the visualization of the edges of the implant, making them less noticeable. Compared with the subpectoral insertion, the subfascial implant gives the breast a nicer contour and a more natural look. Long-term complications of severe capsular contracture, especially after subglandular augmentation mammaplasty, have been successfully reduced.

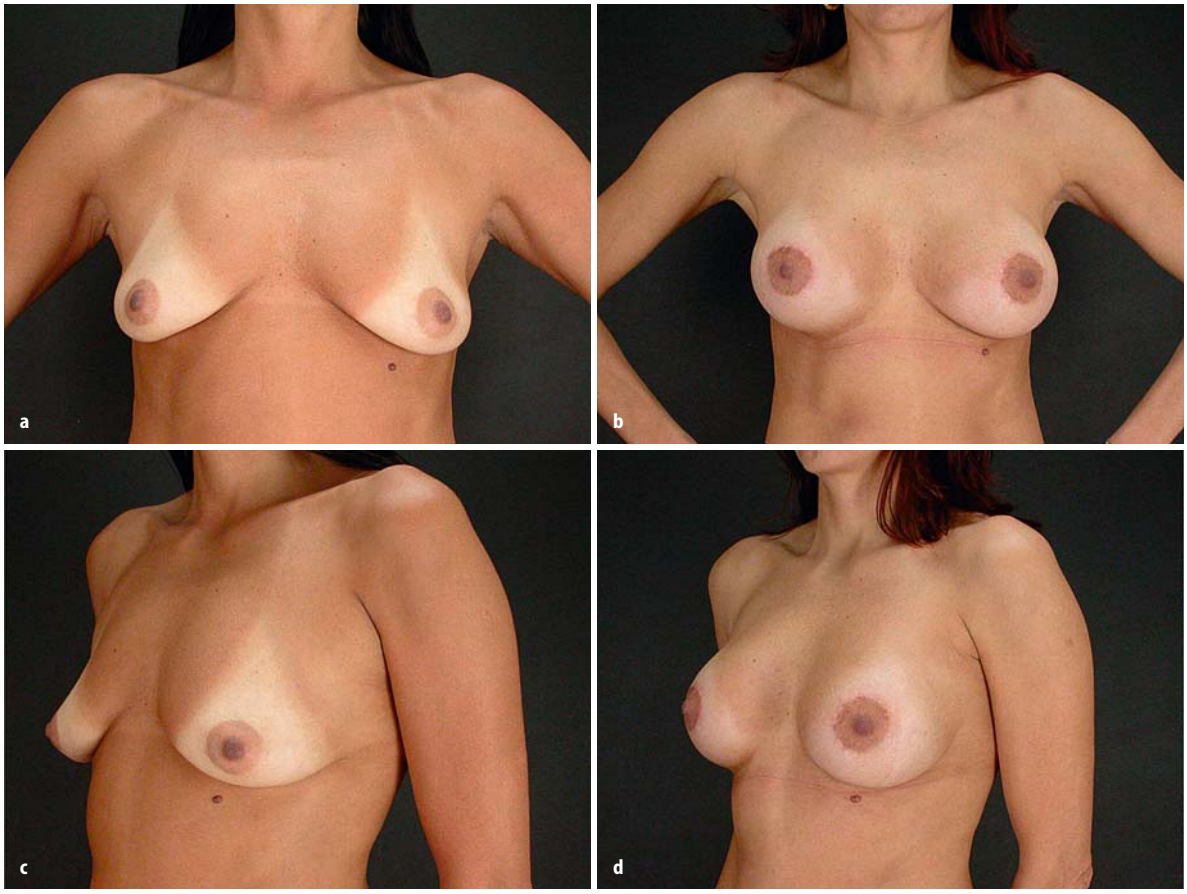

Fig. 50.9. Periareolar subfascial technique in a 46-year-old patient, front and oblique views, cohesive gel, round, high profile, 260 ml, pre- (**a, c**) and 1 year postoperatively (**b, d**)

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51 Cohesive Breast Implants: A Significant Difference?

B. Cunningham

51.1 Three Generations of Gel Implants

It may seem quite surprising to most of the plastic surgeons around the world that the Americans are the last to be able to use silicone gel implants without significant restrictions being placed on them. The FDA Advisory Panel recommended approval of the devices in the spring of 2005, and the Agency issued "Approvable" letters in the summer of the same year to the two domestic manufacturers of the devices. Despite this scientific foundation for these devices, they were not finally approved until November of 2006. The round devices have not been approved, and it is felt that the shaped devices, currently so popular in Europe, will not be evaluated for at least a year after final approval of the round devices.

In his standard setting article of 1997, Dr. W. Peters concisely characterized the three different "generations" of silicone based breast implants [1]. This description has been reaffirmed as the standard citations by others [2–4]. Each generation had specific characteristics that distinguish it as significantly different than the preceding iteration of the devices.

The first generation implants featured thick shells and a firm gel. They were produced until approximately 1979. Second generation devices were significantly different from their predecessors, with thin shells, and a thin less viscous gel inside. The gel was almost liquid in consistency. Loss of shell integrity resulted in the gel freely flowing out of the implant into the surrounding scar capsule, with the shell collapsing into it, producing the characteristic "linguini" sign on MRI [5]. The implants had no effective barrier layer, so the shell wall was permeable to the shorter chain fragments of the gel, and when it diffused through the shell was called gel bleed and was detectable as a film layer on the exterior of the implant.

Surgeons are currently implanting the third generation of breast implants. Generation three implants are characterized by firmer gel and thicker multi-layer shells with a barrier coat, resulting in extremely low gel bleed. These devices represent a dramatic departure from generation two implants. The devices never have an exterior film layer, and the cross linking of the gel is so complete that if the implant is cut in half, none of the gel flows out of it (Fig. 51.1).

To describe this characteristic "stickiness" of the gel in these implants, they are all referred to as "cohesive," meaning the contents hold together and will not disperse when the shell is broken. Despite the increased firmness, generally, these implants do not fracture.

Fig. 51.1. Sample of Mentor smooth round MemoryGel implant cut in half

There were differences from manufacturer to manufacturer regarding when they abandoned generation two and moved to generation three; the current devices have been in use for almost 20 years. There have been no significant design differences in these generation three devices, but there have been improvements and refinements in manufacturing techniques. Many feel that the negligible level of small chain fragments which escape from the devices explains why they do not seem to have high levels of capsular contracture as seen in early generations.

51.2 What Are Cohesive Gel Implants?

The manufacturers have regulated the levels of cohesion among the generation three implants to obtain the desired clinical characteristics and usage of the device, but the basic class characteristics remain the same across the generation. Generally, greater cross-linking of the gel results in a firmer, form stable device. When this is coupled with an asymmetrically shaped shell, unique shapes can be created for different clinical situations.

For each manufacturer, the description of the device varies. Mentor has a scale used internationally to differentiate the different cohesive products. Cohesive 1 refers to the current round gel products being used in the Adjunct and Core Gel studies, currently under review by the FDA. Cohesive 2 is a slightly more firm gel used internationally in round gel implants. Cohesive 3 is the most firm (form-stable) option and it is used in the CPG product. The Mentor CPG device, the Inamed style 410 introduced in 1993, and the less cross linked 410 "Soft Touch," represent the most cross linked end of the generation three spectrum, and are form stable asymmetrical devices. These devices have textured shells to help maintain their rotational stability.

These devices are referred to as "anatomical" gels because of this ability to create and sustain a shape. While the clinical data is still being analyzed, there are both advantages and liabilities with the more firm shape stable gel products: they are more palpable, they require more precise surgical technique when implanting, and run the risk of rotation. Different techniques, such as a longer incision, must be used for their implantation. This evolutionary difference in the anatomical gels may represent a good option for patients with specific needs, such as patients who need the implant to define the breast shape (reconstruction or thin tissue augmentation patients), but for patients with existing breast tissue, a round silicone implant is also a great choice. The surgeon must evaluate the benefits versus the risks of these shaped devices, and make the best choice for the patient

In addition, there appears to be some disadvantage to too much cross linking, as there have been published reports of implanted devices with gel fractures in the most cross linked device, the Inamed 410 [6]. Under extreme localized stress the firmer gels can fail along fracture planes (gel fracture). With gel fracture the shape of the device will become distorted, even to the point that the implanted breast will become misshapen. This type of device failure does not involve a ruptured shell, but a reoperation may be necessary to achieve a properly shaped breast mound.

To illustrate how minor differences in the characteristics of generation three devices can make a significant difference in clinical behavior, it is important to note there are only two substantive differences between Mentor Core and CPG cohesive breast implant devices: (1) the firmness of silicone gel filler and (2) the contour shape. The difference in shape of the devices is derived from the shape of the shell that surrounds the silicone gel filler. This shape is determined by the mandrel upon which the shell is formed during manufacture. The difference in firmness of the gel filler between Core and CPG is the result of a slightly higher crosslink density in the CPG product. This produces a firmer, more shape-retaining gel.

51.3 Technical Differences Among Cohesive Gel Devices

A chemical crosslink is formed when two reactive sites on a crosslinker molecule attach, through chemical reaction, to two separate polymer chains that contain sites that can react with the crosslinking molecule. Thus a link is formed through chemical reactions between the bridging molecule (crosslinker) and two polymer chains. The greater the number of crosslinks (crosslink density) the more firm a gel will become.

The two reactive moieties that combine to form the crosslinks are silicon hydride (SiH) on the shorter crosslink molecules and vinyl groups that are pendant to (attached to) the polymer chains. The silicon hydride groups are internal to the shorter bridging molecules (the crosslinker). The pendant vinyl groups are spaced along the longer polymer chains. The firmness of the silicone gel filler depends directly upon the number of crosslinks between the polymer chains, and, therefore, upon the amount of crosslinker included in the formulation before the reaction between the silicon hydride (crosslinker molecule) and the polymer chains with the vinyl pendant groups. This means simply that, for a given set of polymers in a gel formulation, the *sole* determinant of gel firmness is the amount of crosslinker included in the formulation.

Mentor has demonstrated the fact that crosslink density is the only discernible difference between Core and CPG devices by measuring physical and chemical properties of those devices [7]. The data confirm that the physical properties (ultimate tensile properties, impact resistance, and cyclic fatigue results) of the shells of the two product families are statistically the same. This is as expected since the chemical components and processes for making the shells for the two families are essentially the same.

Since the chemical intermediates and manufacturing processes for producing the shells for the Core (Round) and CPG devices are essentially the same, the chemical character of the two are identical, and homogeneous across the generation three devices. Stated simply, the chemical bonds and the relative numbers of those bonds per unit volume of shell that are formed in the manufacture of the shells are identical for both families of products. The only differences in the shells of the two families are that the CPG devices (1) have a contoured shape and (2) the texturing is slightly more porous (a less rough surface) than the shells of the Core (Round) family.

Similarly, the only differences in the gel filler of the CPG and Core (Round) devices is that the CPG gel formulation contains a slightly higher level of crosslinker relative to the vinyl polymer than does the Core (Round). This means that the kinds of chemical bonds in the gel that are formed in the manufacture of the devices are the same in both product families. There is simply slightly more of the crosslink bonds in the gel filler of the CPG devices.

It is highly likely that Mentor and Inamed are similar in chemical constituents, and this is borne out in the physical data presented in the Core Gel studies in 2005 [8]. The only significant difference is the level of diphenyl compounds incorporated in the Inamed shell elastomer. One can speculate then with a fair degree of certainty that the singular significant difference in the less cohesive to the more cohesive devices in the Inamed product lines is the crosslink density, as is the case with Mentor devices.

It should be noted that any change in the design of an implant will often involve compromises. The increase in firmness of the gel filler in breast implants is no exception. Under extreme localized stress the firmer gels can fail along fracture planes (gel fracture). With gel fracture the shape of the device will become distorted, even to the point that the implanted breast will become misshapen. This type of device failure does not involve a ruptured shell, but a reoperation may be necessary to achieve a properly shaped breast mound. Mentor has experienced very few instances of this type of failure but is continuing to closely monitor returned devices for this type of device complaint.

The issue is not whether cohesive gel implants represent a new generation of devices, they probably do not, but whether the differences in shape and firmness really present a significant advantage to plastic surgeons and their patients. We will be able to answer this question with authority once the preapproval studies are completed and the data reported. More importantly, we will ultimately have data showing how these implant design changes are incorporated, not into the practices of expert researchers, but into the practices of the average plastic surgeon who chooses to use them.

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Liposuction VII

Liposuction in Arm Lymphedema Treatment 52

H. Brorson

52.1 Introduction

Lymphedema is a chronic disease with increased volume giving considerable dysfunction in terms of decreased mobility, heaviness, susceptibility to infections, and psychological and cosmetic problems. This influences activities of daily living and leisure as well as dress. In spite of the development of modern cancer treatment, lymphedema is still an important and to a great extent an underestimated problem.

Cancer treatment often implies removal of lymph glands and radiation therapy. Breast cancer affects more than 6,000 women per year in Sweden, and about a third are affected with lymphedema [1]. Treatment of gynecological tumors (about 2,000 cases per year) leads to leg lymphedema in up to 40 %. Prostate cancer treatment (about 7,000 cases per year) can lead to lymphedema where the incidence varies due to the aggressiveness of the therapy (5 – 66 %). The incidence of lymphedema after treatment of penis cancer (60 cases per year) and inguinal metastases is very high. Other tumors where treatment can lead to lymphedema are, for example, lymphoma, malignant melanoma, head and neck tumors and lung cancer.

In contrast to other types of edema, e.g., cardiac edema, chronic lymphedema has a high content of adipose tissue. Due to the decreased or absent lymph transport there is, in the course of time, an increased formation of adipose tissue, and in later stages also fibrosis.

Soft tissue infection (cellulitis or erysipelas) can worsen the lymphedema and is mostly caused by streptococci.

Lymphedema can be divided into various stages due to the tissue changes [2]. It can also be divided into primary and secondary forms. The later in life a lymphedema appears, the more important it is to exclude other diseases, especially cancer, as a cause of the edema.

Patients with lymphedema represent a large group and must be treated because an untreated edema can give considerable dysfunction. If diagnosed early the suffering of the patients can be prevented and economic resources can be saved.

There is, so far, no cure for lymphedema. The basis for all lymphedema treatment is adequate compression therapy. If conservative therapy fails, liposuction can give complete reduction of the excess limb volume. To maintain this outcome it is an absolute necessity to provide the patient with ample amounts of compression garments. It is important to measure the excess volume, as changes can be a sign of progression of the underlying disease.

The Swedish national guidelines for lymphedema treatment were released in 2003 and can be accessed on the internet at www.lymfödem.nu.

52.2 Pathophysiology

The lymph normally removes the proteins from the interstitium. If the transport is blocked, the proteins remain in the tissues and will osmotically bind lymph fluid. The increased amount of lymph dilates the lymph vessels and gradually the valves become insufficient and the lymph transport is obstructed or ceases [3 – 7].

52.3 Definitions

Edema is defined as a volume increase in a body part and is initially caused by an accumulation of fluid. Edema is a symptom and not a diagnosis. A lymphedema is caused by decreased lymph transport capacity caused by disease, malformation or earlier treatment (e.g., surgery, radiation) and leads to accumulation of lymph in the interstitium with secondary changes in the tissues.

Pitting means that a depression is formed after pressure with the fingertip on edematous tissue, resulting in squeezing lymph into the surroundings (Fig. 52.1a). To standardize the pitting test one presses as hard as possible with the index finger, for 1 min, on the region to be investigated. The amount of depression is estimated in millimeters. Edema dominated by hypertrophied adipose tissue and/or fibrosis shows little or no pitting (Fig. 52.1b). *Stemmer's sign* implies that one with difficulty, or not at all, can pinch the skin at the base of the toes or fingers. This is due to increased fibrosis and is characteristic for lymphedema.

52.4 Lymphedema Leads to Adipose Tissue Accumulation and Fibrosis

This phenomenon can be illustrated by the following example: Breast cancer treatment typically includes excision of regional axillary lymph nodes as staging and often radiotherapy for eradication of regional tumor spread. Both measures interfere with normal lymph drainage from the arm, and subcutaneous arm lymphedema, dominated by fluid, commonly ensues. Pitting is seen after pressure (Fig. 52.1a).

In healthy subjects the rate of blood flow and lymph flow through adipose tissue is inversely related to its growth, and a slow flow rate is considered one condition for lipogenesis and further deposition of fat. This process is enhanced by the transformation of macrophages into adipocytes [8]. This may explain the marked hypertrophy of the adipose tissue seen in patients with chronic lymphedema (Fig. 52.2) [9]. Subsequently subcutaneous lymphedema becomes firm and denser and is dominated by adipose tissue hypertrophy, and pitting is usually less pronounced or sometimes absent (Fig. 52.1b). Probably pinocytosis of white blood cells, in combination with activation of fibrocytes, increases the connective tissue component of the primordial loose subcutaneous fat [10]. Fibrosis can totally dominate the excess volume of the extremity in patients with longstanding lymphedema, especially in the lower extremity.

52.5 Diagnosis

52.5.1 Anamnesis

A careful anamnesis, for example regarding earlier diseases, operations, and irradiation, is important. When, where, and how the edema started, the progression of the edema, which treatments have been tried and the result, are other important questions for a correct diagnosis.

52.5.2 Clinical Examination

Skin changes are investigated: reddening, hyperkeratosis, pigmentations, leakage of lymph, scars, wounds,

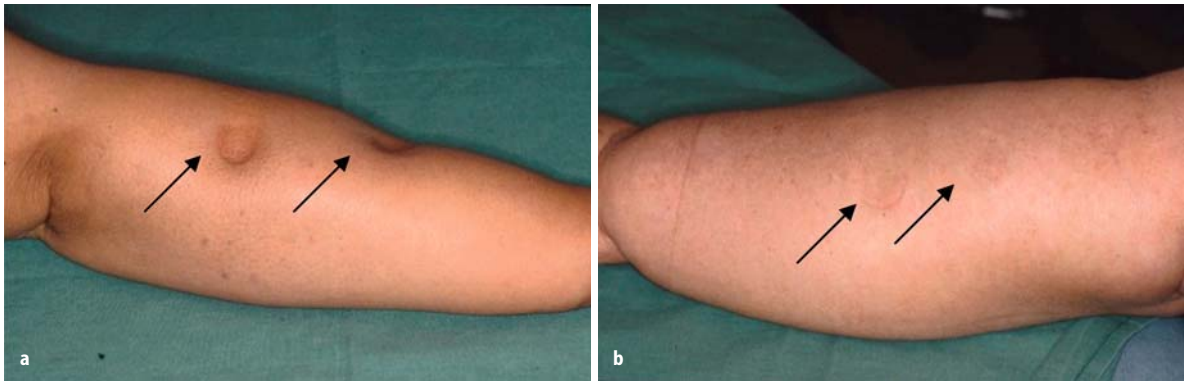


Fig. 52.1. a Marked arm lymphedema after breast cancer treatment with deep pitting of several centimeters (grade I edema). The arm swelling is dominated by fluid, i.e., accumulation of lymph (© Håkan Brorson 2007). **b** Pronounced arm lymphedema after breast cancer treatment (grade II edema). There is no pitting in spite of hard pressure by the index finger for 1 min. A slight reddening is seen at the three spots where pressure has been exerted. The "edema" is completely dominated by adipose tissue. The term "edema" is in this stage improper as the swelling is dominated by hypertrophied adipose tissue and not by lymph. In this stage the aspirate contains no or a minimal amount of lymph (Fig. 52.8) (© Håkan Brorson 2007)

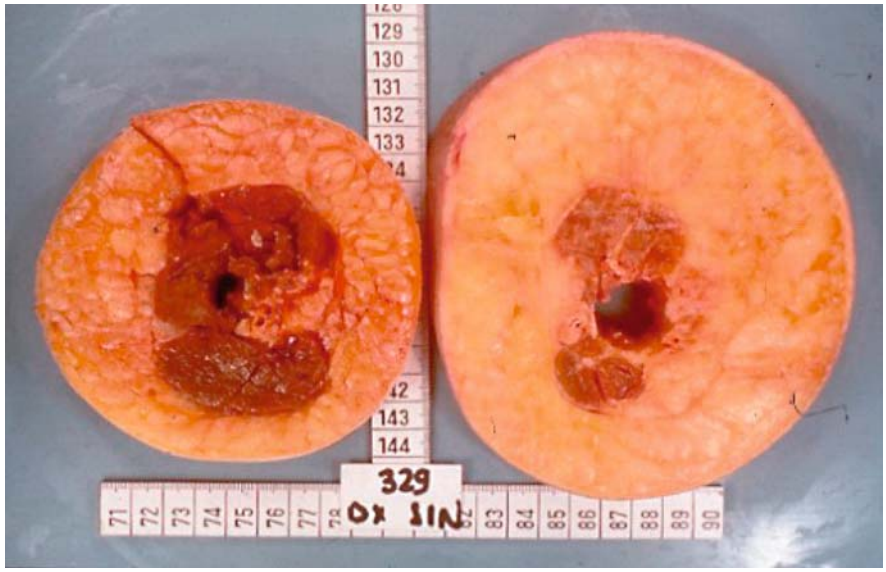


Fig. 52.2. Cross section of upper arms, autopsy samples. The hypertrophied adipose tissue of the lymphedematous left arm is clearly seen (source: C.-H. Håkansson, Department of Oncology, c/o Southern Swedish Regional Tumor Registry, Lund University Hospital, Lund, Sweden) (© Håkan Brorson 2007)

and dermatitis due to irradiation. Palpation of the affected area(s) and all regional nodes should be done. The range of motion in nearby joints is measured, and a note is made of the presence of pitting and Stemmer's sign. The volume of the edema can easily be measured with the water displacement method, the extremity is lowered into water and the displaced volume is a measure of the volume of the extremity. The difference between the lymphedematous and healthy extremity represents the edema volume. The volume can also be calculated with the help of repeated circumferential measurements along the extremity, but this method takes longer and is less accurate. The clinical investigation can in doubtful cases be supplemented with indirect lymphoscintigraphy, CT, or MRI, especially in patients with primary lymphedema.

52.5.3 Other Investigations

Laboratory investigations are not necessary to establish a lymphedema. In doubtful cases, for example when suspecting a malignancy, some blood tests (hemoglobin, EVF, albumin, creatinine, liver tests) can give an indication of a disease in kidneys, liver or gastrointestinal tract with associated protein loss. When suspecting a cardiac insufficiency an X-ray of the heart and lungs is taken. Pen-Doppler (CW-Doppler) can be used to demonstrate reflux in the saphenous and popliteal veins. Color duplex, plethysmography, vein pressure recordings, and phlebography can be used to further delineate the venous system. Direct lymphangiography, where oily contrast medium is injected direct in-

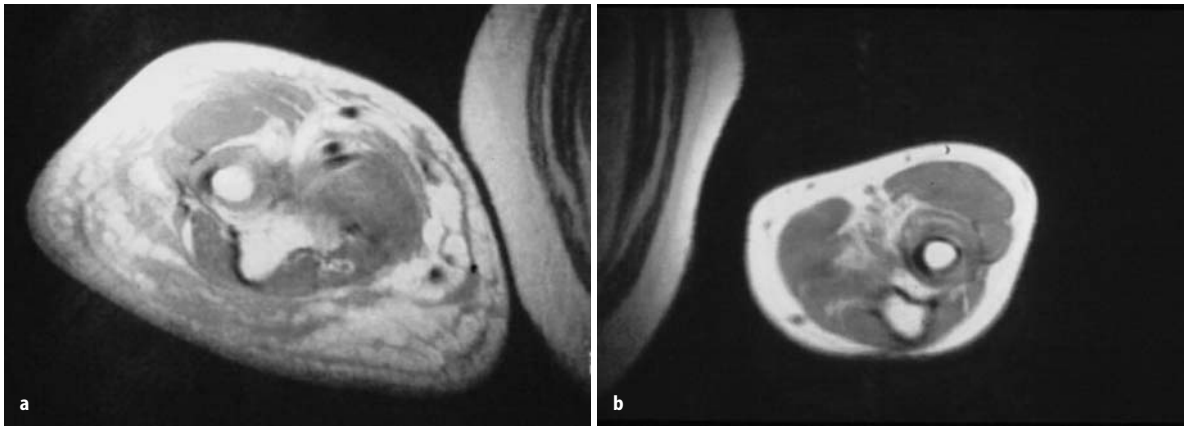


Fig. 52.3. a MRI (elbow region) showing a right-sided, secondary arm lymphedema after breast cancer treatment in the elbow region. Note the honeycomb pattern (© Håkan Brorson 2007). **b** The healthy left side in the same patient for comparison (© Håkan Brorson 2007)

to the lymph vessels, is seldom used as local infection or inflammation with damage to the lymphatics can occur. Also hypersensitive reactions and pulmonary embolism can ensue. Indirect lymphoscintigraphy using intradermal or subdermal injection of ^{99m}Tc-labeled microcolloid has nowadays replaced direct contrast lymphography as the preferred imaging tool for peripheral lymphedema, and is therefore particularly suited for studying patients with lymphedema where microcirculatory dynamics are already suboptimal [11]. CT and MRI can be used when suspecting primary or secondary malignancy in enlarged lymph glands. Differentiation between adipose tissue and water from other soft tissue can also be made. This can be seen as a reticular pattern reminiscent of a honeycomb (honeycomb pattern) (Fig. 52.3). Venous insufficiency can often be differentiated to a lymphedema with MRI.

52.6 Treatment

To date there is no cure for lymphedema in the sense that one can reconstruct the damaged lymph system so that normal function is completely reestablished. Patients must therefore be informed that lymphedema is a chronic disease, but that conservative treatment, where compression with a garment plays an important part, can relieve the symptoms. Sometimes surgery is needed, but even after a successful operation, compression garments must be used.

52.6.1 Surgical Treatment

Despite prophylaxis the lymphedema will often progress slowly but steadily, necessitating a surgical approach. Surgical treatment, when tissue is removed, becomes indicated in patients who fail to respond to conservative treatment because of hypertrophy of the subcutaneous adipose tissue, and later fibrosis [8–10]. The swelling, the "edema," does not show any pitting. The surgical intervention is therefore consequently directed towards the adipose tissue hypertrophy of the swelling, and not towards the fluid component, i.e., the lymph.

Various surgical procedures have therefore been proposed to reduce lymphedema, including interventions to the subcutis and deep fascia [13–19], and skin grafting [20, 21]. None of these methods gave satisfactory or long-lasting results.

The breakthrough in reconstructive microsurgery has stimulated the interest in creating such connections. During recent decades, anastomoses have been established between lymph nodes [22] or lymph collectors [23, 24] and the venous system. Promising results have recently been reported after transplantation of lymph collectors [25, 26], as well as after the creation of various forms of lymphatic venous anastomoses [27, 28].

Even if the microsurgical methods are attractive from a physiological point of view, they do not give consistently satisfactory results. Most of the patients need to wear compression garments after surgery, which indicate that normal lymph transport has not been achieved. Complete reduction cannot be achieved in patients with a chronic lymphedema using microsurgery because the hypertrophied adipose tissue remains unchanged.

52.6.1.1 Liposuction

A surgical approach, with the intention of removing the hypertrophied adipose tissue, seems logical when conservative treatment has not yielded satisfactory edema reduction and the patient has subjective discomfort of a heavy arm. This condition is especially seen in chronic, large arm lymphedemas around 1 l in volume, or when the volume ratio (edematous arm/healthy arm) is 1.3. The edema must not show any, or possibly minimal, pitting on pressure. By removing the excess adipose tissue the risk of developing lymphangiosarcoma will decrease. Preliminary clinical reports, although not impressive, warranted further refinement and evaluation of the procedure [29, 30].

At the Department of Plastic and Reconstructive Surgery, Malmö University Hospital, Malmö, Sweden, the first liposuction of an arm lymphedema was undertaken in 1987, but it was not until 1993 that a more detailed treatment protocol was established and a lymphedema unit with a team was founded. The aim and direction was arm lymphedema after breast cancer treatment, as this is a large and common problem. There is no upper age limit in order to be accepted for surgery, but active tumor disease and ulcerations are contraindications [31].

Surgical Technique

By the use of liposuction the excess hypertrophied adipose tissue is removed under bloodless conditions (Figs. 52.4–52.9). General anesthesia is used in most cases but some patients prefer nerve blockade in the combination of a plexus and scalenus block. Neither local anesthetic nor epinephrine is injected locally; hence the "dry technique" is used.

Through around 15–20, 3-mm-long incisions, the shoulder and arm – and even the hand and proximal phalanges when indicated – are treated (Figs. 52.5, 52.6).

Cannulas are connected to a vacuum pump giving a negative atmospheric pressure of 0.9. The cannulas are

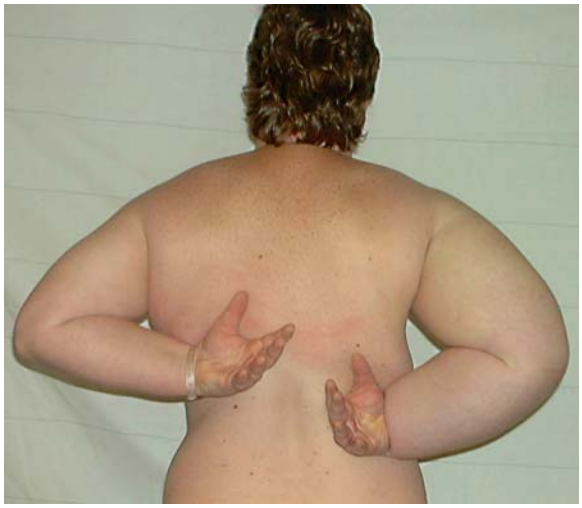


Fig. 52.4. Preoperative picture showing a patient with a large lymphedema (2,865 ml) and decreased mobility of the right arm (© Håkan Brorson 2007)

15 cm long with an outer diameter of 3 and 4 mm and have three openings at the tip. The finer cannula is used mainly for the hand, fingers, and distal part of the forearm, and also when irregularities are remedied. The openings differ from normal liposuction cannulas in that they take up almost half of the circumference in order to facilitate the liposuction, especially in lymphedemas with excess fibrosis (Fig. 52.7).

Liposuction is executed circumferentially, step-by-step from hand to shoulder, and the hypertrophied and edematous fat is removed as completely as possible (Figs. 52.5, 52.6, 52.8).

When the arm distal to the tourniquet has been treated it is compressed by using sterile rolls of bandage to stem bleeding and postoperative edema. The tourniquet is removed and the most proximal part of the upper arm is treated using tumescent technique (Fig. 52.6d). The incisions are left open to drain. A sterilized, standard compression garment is applied (Jobst Elvarex BSN Medical, compression class 2) on the arm.

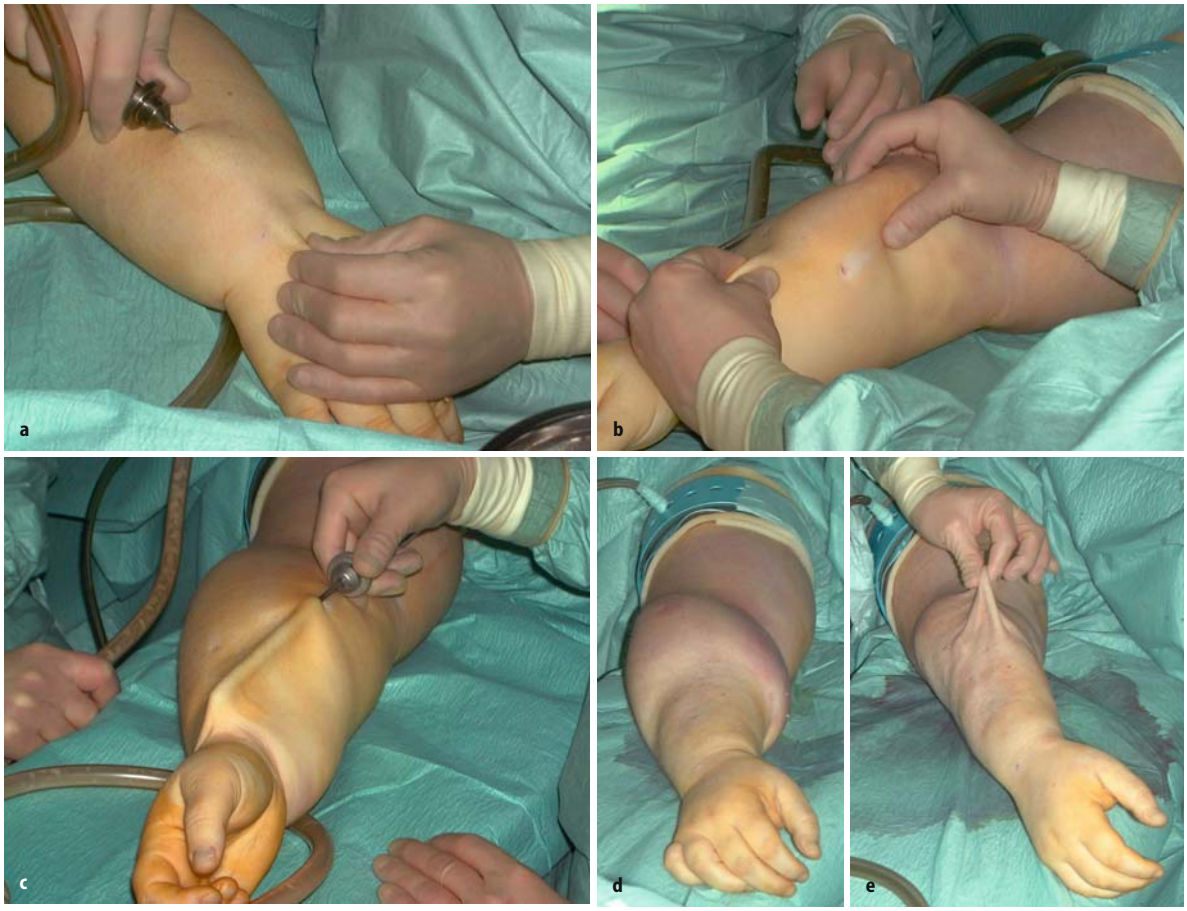


Fig. 52.5. a Liposuction is performed on the distal forearm. As much hypertrophied adipose tissue as possible is removed (© Håkan Brorson 2007). **b** The left hand pinches the treated distal forearm, while the right pinches an untreated area (© Håkan Brorson 2007). **c** The cannula lifts the loose skin of the treated forearm (© Håkan Brorson 2007). **d** The distal half of the forearm has been treated (© Håkan Brorson 2007). **e** Lifting the excess skin after liposuction. The skin contracts within a few days (© Håkan Brorson 2007)

Fig. 52.5. f Treated areas are subsequently compressed firmly to stem bleeding after removal of the tourniquet in order to perform liposuction also of the proximal upper arm. After liposuction a standard compression garment is applied (© Håkan Brorson 2007)

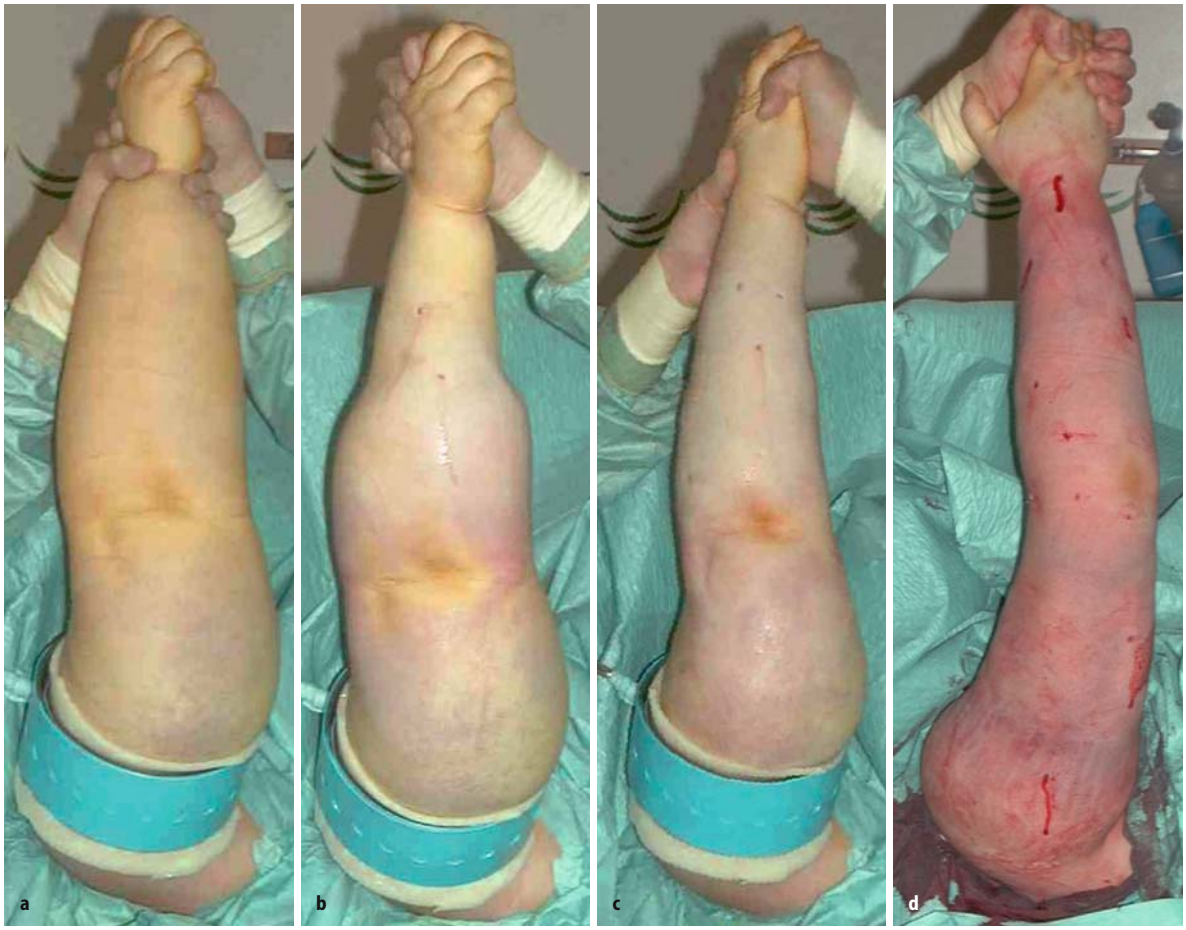


Fig. 52.6. Peroperative pictures from the beginning (**a**), during (**b, c**), and at the end (**d**) of surgery in the patient shown in Figs. 52.4 and 52.9 (© Håkan Brorson 2007)

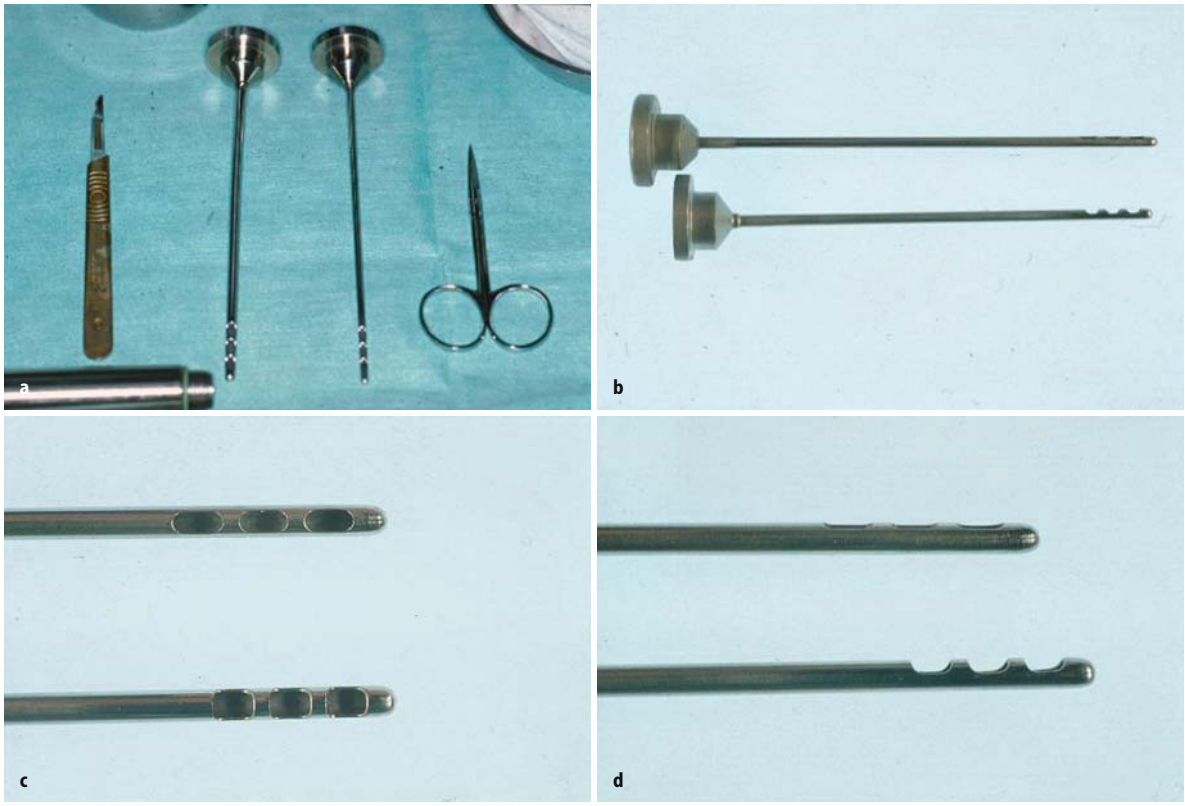


Fig. 52.7. a The liposuction cannulas are 15 cm long and have an outer diameter of 3 and 4 mm (© Håkan Brorson 2007). **b** Standard liposuction cannula (upper cannula) and liposuction cannula for lymphedema (lower cannula) (© Håkan Brorson 2007). **c** In the tip there are three openings (frontal view). Note that the openings of the lower lymphedema cannula take up almost half of the circumference, compared to the upper standard liposuction cannula, in order to make liposuction more efficient; see **d** (side view) (© Håkan Brorson 2007). **d** Side view of the cannulas shown in **c**. The lower cannula is used for lymphedema and the upper one for standard liposuction procedures (© Håkan Brorson 2007)

Fig. 52.8. The aspirate contains 90–100% adipose tissue. This picture shows the aspirate from the lymphedematous arm of the patient shown in Figs. 52.4–52.6, and Fig. 52.9 before removal of the tourniquet. The aspirate sediments into an upper adipose fraction and a lower fluid fraction. The adipose fraction was 90% (© Håkan Brorson 2007)

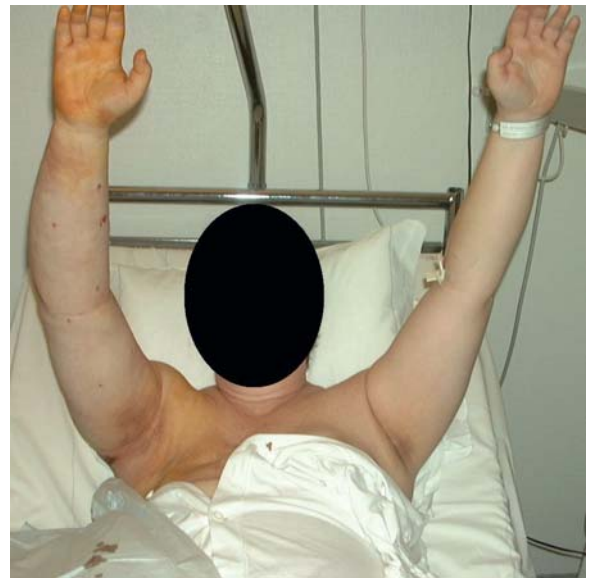


Fig. 52.9. The compression garment is removed 2 days after surgery in order to take measurements for a custom-made compression garment. A significant reduction of the right arm has been achieved as compared to the preoperative condition seen in Fig. 52.4 (© Håkan Brorson 2007)

The size of this garment is measured according to the size of the healthy arm. A sterilized interim glove (No. 111089, Jobskin interim care garment for burn scar management, Smith & Nephew), where the tips of the fingers have been cut to facilitate gripping, is put on the hand.

The following day, a standard gauntlet (=a glove without fingers, but with a thumb) is put over the interim glove after the thumb of the glove has been cut off (Jobst Elvarex BSN medical compression class 2). If the gauntlet is put on right after surgery, it can exert too much pressure on the hand when the patient is still not able to move the fingers after the anesthesia. Operating time is 2 h on average. Isoxazolylpenicillin or cephalosporin is given intravenously for the first 24 h and then in tablet form for 2 weeks.

Postoperative Care

The arm is held raised during the hospital stay, usually for 3–4 days. Two days postoperatively, measurements are taken for a custom-made compression garment, a sleeve and glove, compression clas 2 (Jobst Elvarex BSN medical).

The patient alternates between two standard compression sleeves and gloves the first two postoperative weeks. At the 2-week control the new custom-made compression garment is applied, alternating this with a standard one until the 1-month visit. During the subsequent course, this rigorous compression regime, referred to as controlled compression therapy (CCT), is maintained exactly as described below [12].

Controlled Compression Therapy

The compression therapy is crucial, and its application is therefore thoroughly described and discussed at the first clinical evaluation. If the patient has any doubts about continued CCT, she is not accepted for treatment. After institution of the compression therapy, the custom-made garment (Jobst Elvarex BSN medical, compression class 2, rarely class 3) is taken in at each visit, using a sewing machine, to compensate for reduced elasticity and reduced arm volume. This is most important during the first 3 months when the most notable changes in volume occur. At the 1-month visit another custom-made compression garment is measured for, alternating this with the old one until the 3-month visit. At the 3-month visit, the arm is measured for new custom-made garments. This procedure is repeated at 6 and 12 months. It is important, however, to take in the garment repeatedly to compensate for wear and tear. This requires additional visits in some instances, although the patient can often make herself such adjustments. When the edema volume has decreased as much as possible and a steady state is achieved, new garments can be prescribed, using the latest measurements. In this way, the garments are renewed three or four times during the first year. Two sets of sleeve-and-glove garments are always at the patients' disposal, one being worn while the other is washed. Thus, a garment is worn permanently, and treatment is interrupted only briefly when showering and, possibly, for formal social occasions. The patient is informed about the importance of hygienic measures and skin care.

The life span of two garments worn alternately is usually 4–6 months. After complete reduction has been achieved the patient is seen once a year when new garments are prescribed for the coming year, usually four garments and four gloves (or four gauntlets). In very active patients the six to eight garments a year may be needed.

Arm Volume Measurements

Arm volumes are recorded for each patient using the water displacement technique. The displaced water is weighed on a balance to the nearest 5 g, corresponding to 5 ml. Both arms are always measured at each visit, and the difference in arm volumes is designated as the edema volume [32, 33]. The decrease in the edema volume is calculated in percent; thus:

$$\frac{(EA_{pre} - HA_{pre}) - (EA_{post} - HA_{post})}{EA_{pre} - HA_{pre}} \times 100$$

where

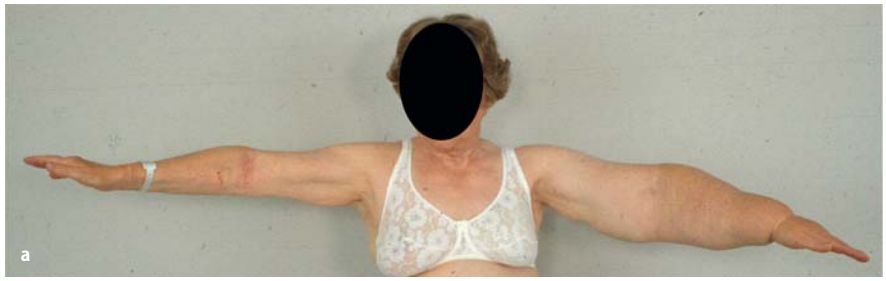
EApre = edematous arm before treatment
HApre = healthy arm before treatment
EApost = edematous arm after treatment
HApost = healthy arm after treatment

Arm volume measurements for calculating the edema volume are measured at each visit.

Results

A prerequisite to maintaining the effect of liposuction is the continuous use of a compression garment (Figs. 52.10, 52.11).

The already decreased lymph transport capacity is not further impaired by liposuction [34]. Liposuction decreases the incidence of erysipelas. The point of bacterial entry may be a minor injury to the edematous skin, and impaired skin blood flow may respond inadequately to counteract impending infection. Reducing the edema volume by liposuction increases skin blood flow, and probably decreases the reservoir of proteinaceous fluid and adipose tissue, which may enhance bacterial overgrowth [35]. Through the combination of liposuction and CCT the lymphedema can be completely removed. Long-term follow-up (7 years) does not show any recurrence of the edema [12, 33, 36, 37].



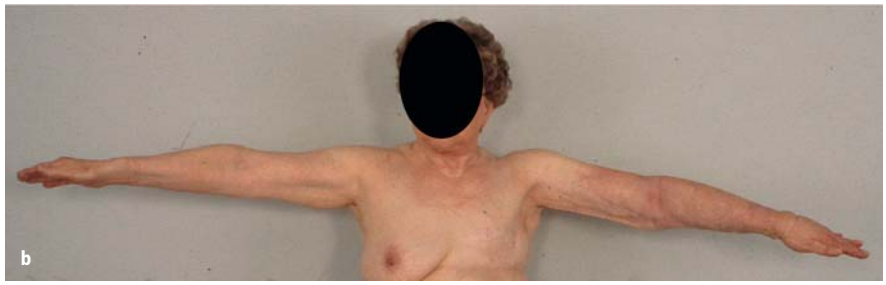
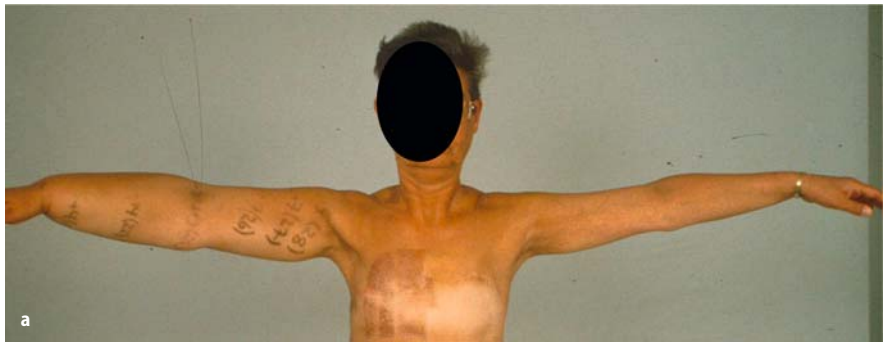


Fig. 52.10. a A 74-year-old-woman with a preoperative edema volume of 3,090 ml in the left arm for 15 years (© Håkan Brorson 2007). **b** Clinical result 1 year after liposuction (© Håkan Brorson 2007)



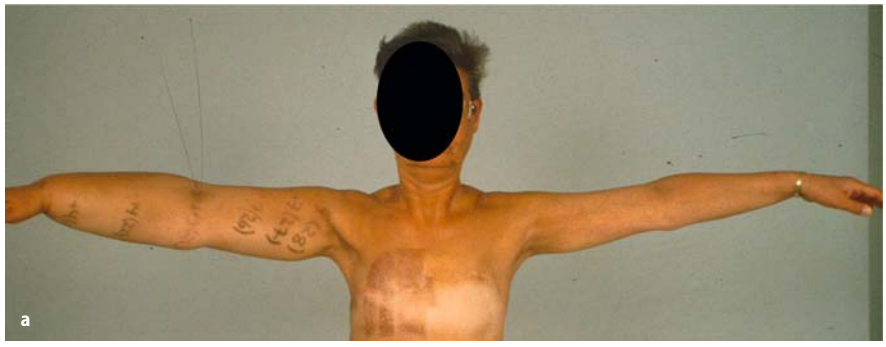


Fig. 52.11. a A 53-year-old woman with a preoperative edema volume of 2,050 ml in the left arm for 8 years (© Håkan Brorson 2007). **b** Clinical result 7 years after liposuction (© Håkan Brorson 2007)

52.7 The Lymphedema Team

To investigate and treat patients with lymphedema, a lymphedema team comprising a plastic surgeon, an occupational therapist, a physiotherapist and a social welfare officer is a must. A 60-min period is reserved for each scheduled visit to the team, when arm volumes are measured, garments are adjusted or renewed, the social circumstances are assessed, and other matters of concern are discussed. The patient is also encouraged to contact the team whenever any unexpected problems arise, so that these can be tackled without delay. In retrospect, a working group such as this one seems to be a prerequisite both for thorough preoperative consideration and informing patients, and for successful maintenance of immediate postoperative improvements. The team also monitors the long-term outcome, and our experiences so far indicate that a visit once a year is necessary to maintain a good functional and cosmetic result in most cases after complete reduction.

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Glandular Shaving: A New Treatment Modality for Axillary Hyperhidrosis

53

H. Menke

53.1 Introduction

Primary hyperhidrosis is excessive uncontrollable hypersecretion of the eccrine sweat glands without any discernible cause. These sweat glands are localized in the deep dermis and the superficial subcutaneous tissue. Although the excessive hypersecretion of the eccrine glands is odourless, there is a multifarious impairment. The more common idiopathic hyperhidrosis has a prevalence of 1%. Secondary hyperhidrosis can be caused by a variety of underlying conditions (Table 53.1). Upper hyperhidrosis affects the armpits in 31% of cases, the axillary region and hand in 37%, and the palms in 20% [3]. There are a variety of treatment options available for patients with hyperhidrosis, including topical treatments, botulinum toxin injection, and surgical therapy (Table 53.2). Although alternative treatments exist, only the surgical therapy is associated with high efficacy rates by reduction of the gland density and characterized by a definite duration of effects.

Table 53.1. Causes of primary and secondary hyperhidrosis. (Modified according to [1])

Primary:
Idiopathic hyperhidrosis
Secondary:
Physiological (emotional condition, physical activity)
Endocrine disorders (hypoglycaemia, hyperthyroidism)
Neurological disorders (syringomyelia, cerebrovascular accident)
Drug association (antidepressants, antiemetics)
Menopause
Malignant disease (Hodgkin's disease, carcinoid syndrome, pheochromocytoma)
Infections
Cardiovascular and respiratory disorders

Table 53.2. Treatment options for hyperhidrosis

Topical medication
Aluminum chloride
Other chemical agents (ethyl alcohol, glutaraldehyde, formaldehyde)
Botulinum toxin
Systemic medication
Anticholinergics
Other systemic treatments
Psychotherapy
Surgical management
Sympathectomy
Thoracic (T1) T2–T9 (endoscopic, cervical, axilla)
Lumbal L2–L4
Excision of axillary tissue
Liposuction
Chemical sympathectomy
CT controlled thoracic sympathicolysis
Iontophoresis

In the following I introduce a new technique for selective sweat gland reduction.

53.2 Operative Procedure

Preoperatively the hyperhidrotic areas can be mapped with an iodine starch test and outlined with a marker. The iodine starch test has been used to map the areas of axillary hypersecretion. The axilla is painted with an iodine tincture, and then dusted with starch powder. As sweating begins, iodine and starch react to produce a dark purple colour in the areas with eccrine glands (Fig. 53.1).

The ambulatory procedure is carried out with the patient under local anaesthesia. The patient is placed in a supine position with the arms abducted approximately 120°. After infiltration of about 40 cc Jet-Klein solution into the axilla, surgical sweat gland removal is performed subcutaneously with a small handshaver (Fa Storz, Tuttlingen, Germany) using the same stab incision. This type of handshaver is routinely used for smoothing of the cartilage in wrist arthroscopy. The one-sided aperture of the instrument contains a fully controllable rotating head with a diameter of 2.5 mm.

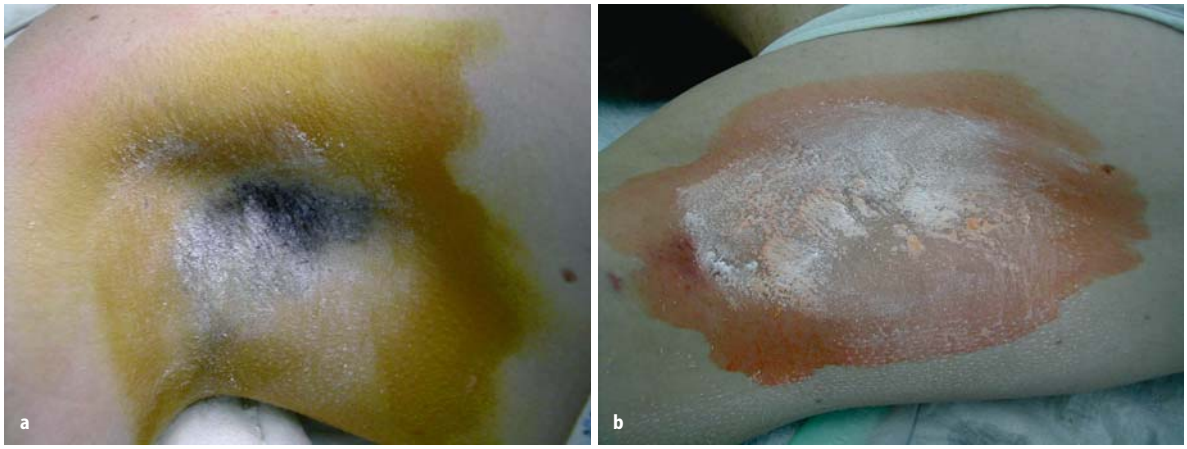

Fig. 53.1. a A starch iodine test is used to outline the sweat glands. Iodine solution and starch interact in the presence of sweat to produce a purple colour in the areas with eccrine glands. **b** Absence of coloration in the treated area

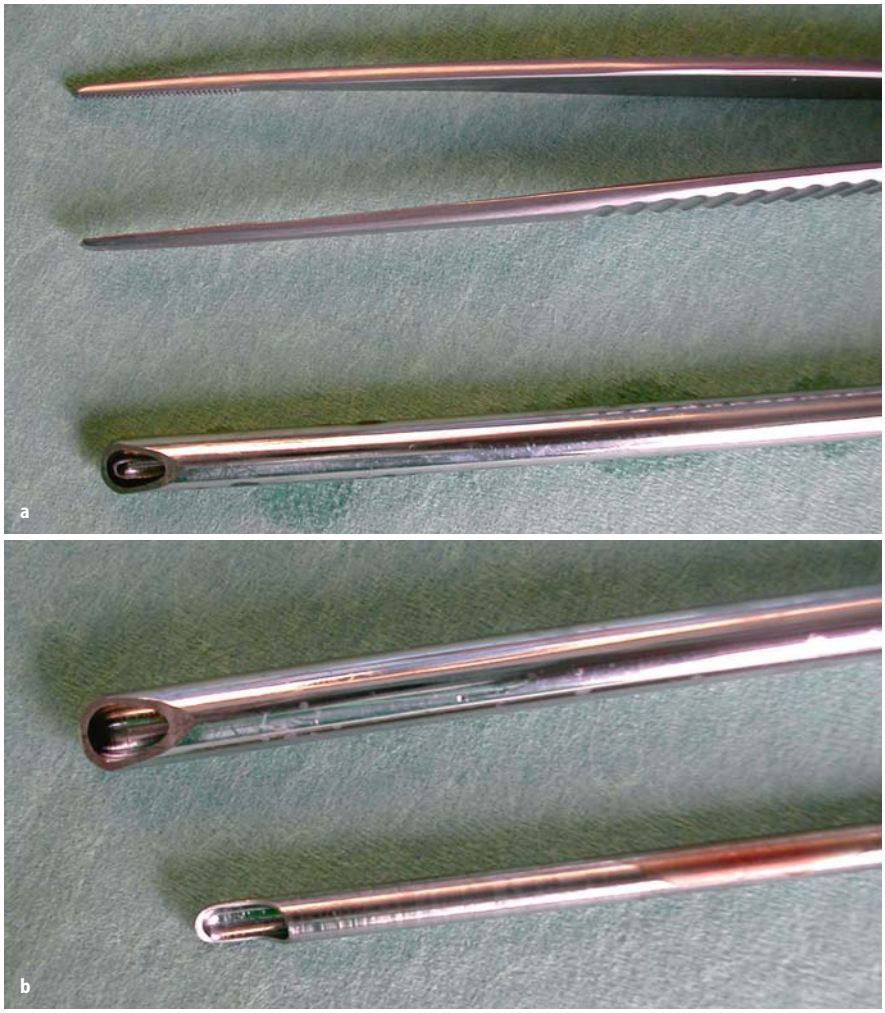

Fig. 53.2. a Head of the hand shaver with an external diameter of about 2.5 mm and the interior rotating cannula. **b** External cover and internal cannula separated

Easily performed hair extraction with forceps shows the evidence of adequate radical gland removal.

All patients achieved very good results in sweat gland reduction without any complications and wound healing problems. Scarification of the axilla was not reported.

53.3 Discussion

A variety of therapies have been introduced for the treatment of primary hyperhidrosis, including conservative and surgical procedures. An effective treatment option is favoured to improve the patient's quality of life, and a permanent reduction of the axillary hypersecretion can be achieved in patients with primary hyperhidrosis. Unfortunately generalized and systemic risks and potential complications are associated with the variety of treatment modalities (Table 53.3).

A more radical excision of glands and subcutaneous tissue with the four-quadrant flap technique was described in the 1960s by Skoog and Thyresson [6]. Alternatively a subcutaneous curettage has been used to attempt axillary adenectomy [7]. A variant method of suction adenectomy using ultrasonic liposuction is thought to minimize the risk of bleeding [5, 8]. The proposal of "glandular shaving" combines the principles of axillary curettage and liposuction. The instrumentation of a hand shaver, which is well known in wrist arthroscopy, allows a controllable and effective treatment. The direction of the half opened head section protects the axillary structures beneath. The excellent efficacy rate results through the permanent removal of the eccrine glands and the denervation [6]. Generally it must be noted that Botox toxin injections have

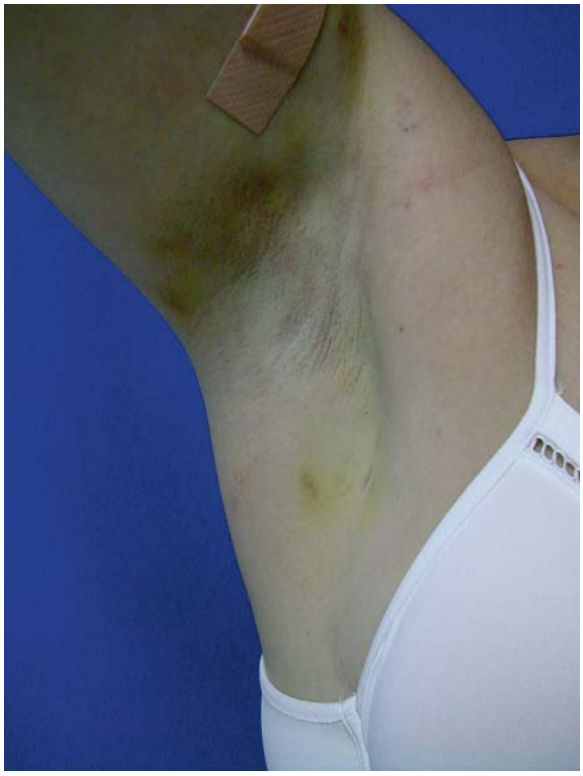

Fig. 53.3. Axilla 3 days after "glandular shaving." In the overview there is a minimal residual haematoma with a successful wound healing

Table 53.3. Possible side effects of different treatment options for hyperhidrosis

Treatment	Side effect/comment	
Topical treatments	Short effect, skin irritation, time-consuming, local contamination	
Systemic medications (anticholinergics)	Dry mouth and oral mucosa, constipation, urinary retention	
Iontophoresis	Repeated therapies (ca. 15), painful sensation, erythema, paraesthesia Contraindications: pregnancy, cardiac pacemaker, orthopaedic implants	Effect duration 2–14 months, treatment option for palmoplantar hyperhidrosis
Botulinus toxin	Effect 3–8 months Hand muscle weakness, antibody production, painful injections	70–80% reduction in axillary sweating, 25–30% in palmar sweating
Local excision	Scarification	
Open surgical	Infection, wound healing problems	
Subcutaneous curettage	Haematoma, seroma	
Axillary liposuction		
Thoracoscopic sympathectomy	Hand and axilla T2–T4	Primarily palmar effect
	Horner's syndrome, pneumothorax, interruption of the thoracic duct, haemothorax, phrenic nerve paresis, deaths	Side effect of sympathectomy, compensatory sweating in the face, trunk and limbs up to 50% Gustatory changes
Lumbal sympathectomy	Sexual dysfunctions (impotence, anorgasmia)	
Chemical sympathectomy	Lumbal L2, L3 plantar Thoracic T2, T3 hand, axilla	Neuralgia, compensation Sweating

only a limited duration of effects for about 4 – 6 months and require repeated injections [2, 4]. The painful injections and the costs of the drug are a limitation to its wider use.

53.4 Conclusions

The "glandular shaving" procedure is a cost effective treatment modality to reduce sweat gland hypersecretion in axillary hyperhidrosis with an excellent efficacy rate. The procedure is well tolerated and can achieve remarkably good patient satisfaction.

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Lipomioplasty with VASER: A New Approach to Body Contouring

54

E. Bolivar de Souza Pinto, R. Federico, S.P. Pessoa de Melo, L. Contin, R. Pessoa Martello de Souza

54.1 Introduction

Since the beginning of the 20th century many surgeons have tried to alter the body contours to fit the concepts of beauty of each period of time. Since its introduction by Illouz, liposuction has become the gold-standard option for body contouring surgery, i.e., the treatment of localized fat deposits. Initially, improvements in standard lipoplasty outcomes were due primarily to advances in the aspiration cannula tip design and reductions in diameter. Other advances in lipoplasty involved the addition of technology and techniques that used energy-based devices, such as external ultrasonic assisted lipoplasty, ultrasonic assisted lipoplasty (UAL), and power assisted lipoplasty (PAL). In this article the author describes a new approach to lipoplasty, combining a new body contouring technology, the VASER, with a new technique where cannulae and probes are only passed in the same direction as the muscular fibers underneath instead of the more traditional cross-tunneling. Excellent results have been achieved and the number of revisions after lipoplasties has been decreased.

54.2 History of Liposuction and Ultrasonic Assisted Lipoplasty

Dujarrier (1920) first attempted to remove subcutaneous fat with a uterine curette, but tragic complications led to the amputation of the patient's leg. No technical innovations were developed until 1970, when Joseph Schrudde took the first of three major steps in the development of modern lipoplasty. Schrudde used a delicate curette to remove fat from the lower leg through a small incision. Then Arpad and Fisher in 1976 developed a fat removing system by means of hollow cannulae equipped with suction (motor-driven suction cannula), but many local complications occurred [3]. They also developed the crisscross tunnel formation technique, consisting of tunneling from multiple incisions, which is still used today, and is believed to avoid irregularities and bring more uniform results. In 1977, Illouz took a third step, introducing the technique known nowadays as "standard lipoplasty." It consisted of the infiltration with a hypotonic saline solution containing hyaluronidase in the subcutaneous tissue and the use of a negative pressure device with high suction power connected to a cannula to remove fat deposits.

In 1982 de Souza Pinto introduced the treatment of the superficial layer of the subcutaneous tissue and included the approach to the dorsum in 1983, procedures which had not been possible until then. The technique was named "superficial liposuction" and was spread worldwide by Gasparotti in 1990. In 1987 Foumier presented the "dry technique," in which no wetting solution was used. Reinforcing Illouz's theory, Klein in 1987 described the tumescent technique, in which high volumes were infiltrated in the subcutaneous fat before aspiration, minimizing the blood loss.

In the late 1980s, Zocchi developed the ultrasonic assisted lipoplasty, which was based on the emission of continuous ultrasound energy to selectively fragment/emulsify fat prior to its aspiration. This technology was first popularized by Scuderi with his experience with the first generation UAL device (SMEI, Casale, Monferrato, Italy), which delivered continuous ultrasound through blunt, solid, thick probes (4–6 mm in diame-

Fig. 54.1. VASER

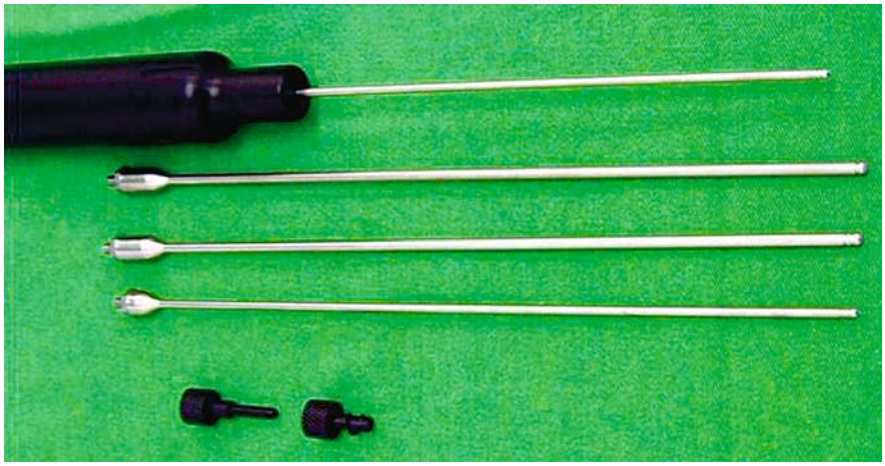

Fig. 54.2. VASER cannulae

ter) to pretreat fat. Second generation machines (Mentor, Lysonix) featured hollow ultrasonic cannulae for simultaneous fat fragmentation and aspiration, but the internal narrow lumen diameter (only 2 mm) did not allow an efficient evacuation of the fragmented tissue. Several complications were noted, especially related to the inadvertent excessive exposure of the treated tissues to ultrasound energy. These complications were mistakenly blamed on the technology itself rather than inappropriate use of the technology. Such a situation stimulated surgeons to define guidelines for the development of a more efficient and safe ultrasound-based lipoplasty technology. The VASER device was developed as an answer to the search for an enhanced ultrasonic device that might overcome the limitations of the first and second-generation UAL machines (Fig. 54.1).

54.3 The VASER Device

VASER is a device used for pre-treating the fat tissue with ultrasonic energy that causes selective fragmentation/emulsification of the fatting component of the tissue matrix. The technology is designed to optimize the micromechanical effect of the ultrasonic vibration and to minimize thermal effects [5]. The VASER system uses small-diameter titanium solid probes (2.9 and 3.7 mm) with grooves near the tip to increase fragmentation efficiency (Fig. 54.2). These grooves redistribute the ultrasonic energy, transferring some of the vibration from the tip to a region just proximal to the tip, consequently increasing the fragmentation efficiency and diffusing the energy so that the intensity of the energy is greatly decreased compared to earlier generation devices. The probe design can result in a nearly 50% reduction of applied power with improved fragmentation capability in the continuous mode and still achieve the desired fragmentation of the fatty tissue. Such a gain in efficiency allowed the development of what is called VASER mode, which works with pulsed ultrasonic energy delivery, reducing the applied power even further, while maintaining efficiency. VASER mode results in a nearly 50% reduction of power with a slight loss of efficiency when compared to continuous mode operation. Thus, it is important to emphasize that simply turning down the power in first- and second-generation equipment will never achieve the desired results because the efficiency of fragmentation falls together with the decreased amplitude [8].

54.4 Morphohistology of the Fat Tissue

The fat tissue is divided into two layers: superficial and deep. The deep layer has the same characteristics all over the body. On the other hand, the disposition and characteristics of the fat cells, the density of the conjunctive septi, and the structure of the collagen within the superficial layer of the subcutaneous tissue are different in each part of the human body, as described by De Souza Pinto. This is the basis for the different skin retraction after liposuction in each part of the body.

54.5 The Lipomioplasty Technique

The technique addresses both the superficial and deep layers of the subcutaneous tissue in the search for skin retraction and harmonious fat removal. It demands a careful surgical sequence to achieve the desired results and so the following steps are considered fundamental:

54.5.1 Marking

The preoperative markings are considered essential for the success of liposuction. They must be done with the patient standing in front of a triple faced mirror, in such a way that the patient may follow the surgeon's movements and markings. It allows the interaction between surgeon and patient, matching their desires and real treatment possibilities.

The markings are done according to the muscle fibers underlying each area (Fig. 54.3). It is especially important to draw with different colors the limits of the muscles and the direction of their fibers so as to define the placement of the skin incisions and guide the movement of the cannulae intraoperatively (Fig. 54.4).

54.5.2 Antisepsis

Antisepsis is done with the patient standing in the operation room. We use an iodopovidone solution and start in the less contaminated areas and then go to the more contaminated ones. The patient is then placed in position and submitted to general anesthesia. We use low flow general anesthesia with Sevoflurane.

54.5.3 Infiltration of Wetting Solutions

Appropriate amounts of wetting solutions should be used with the tumescent technique (approximately 1.5:1 infiltrate/aspirate ratio). It is important to use sufficient wetting solution. In our service a solution containing 0.4 mg/ml of lidocaine and epinephrine (1:500,000 epinephrine/solution ratio) is used. The surgeon must be sure the solution is uniformly and evenly distributed all over the area to be treated. A gentle fullness and firmness is desired (Fig. 54.5). Both the deep and the superficial layers should be infiltrated. The wetting solution should be infiltrated slightly beyond the boundaries of the areas marked for treatment and so should all the potential port locations. Sufficient

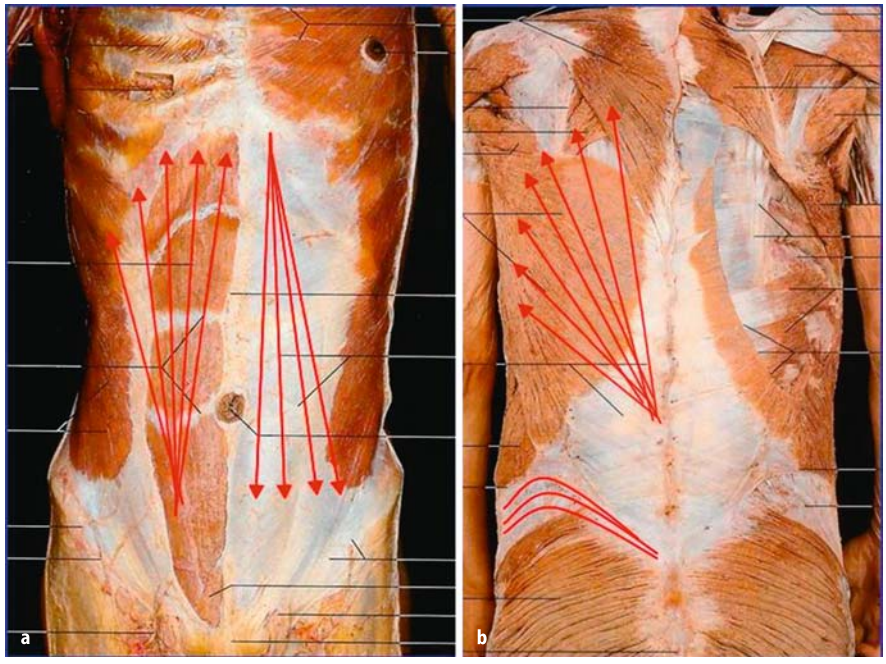

Fig. 54.3. Muscle fiber direction

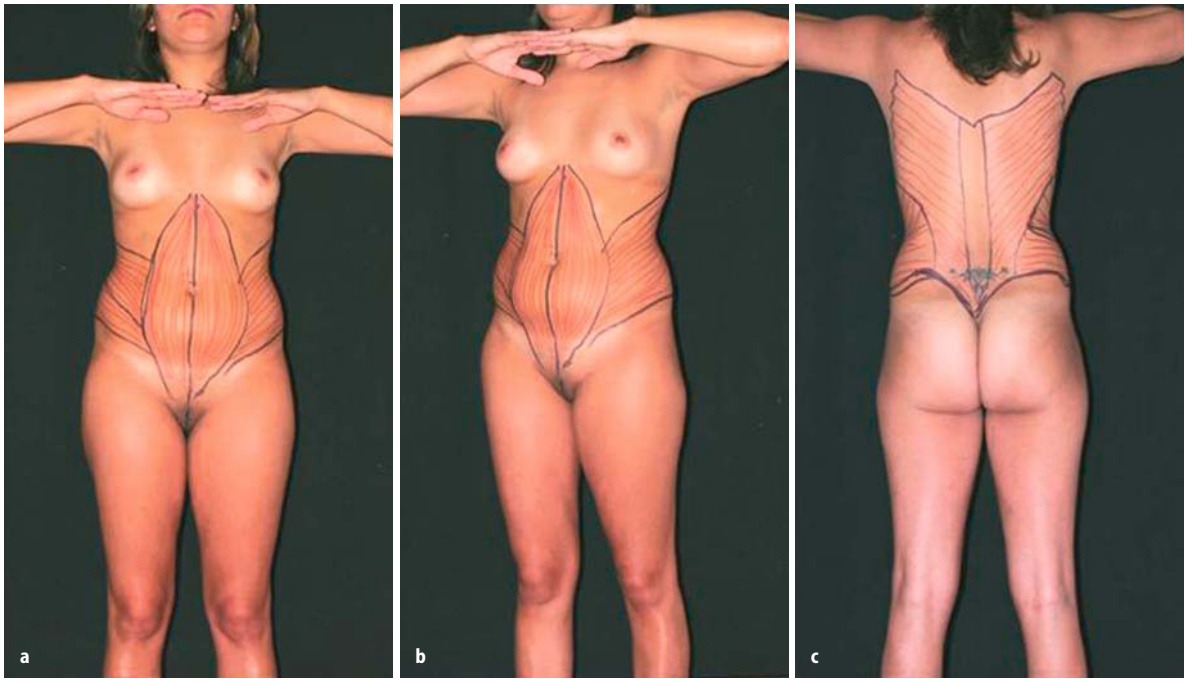

Fig. 54.4. Marking following the muscle fibers

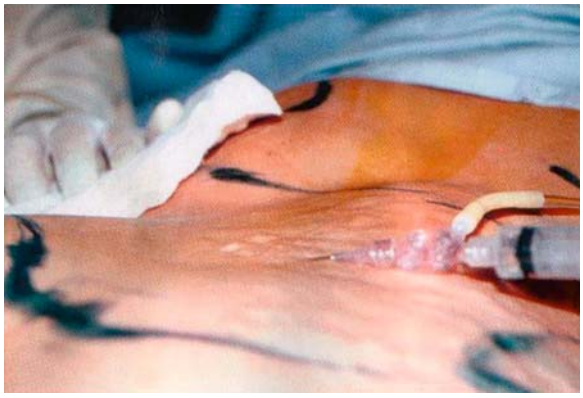

Fig. 54.5. Infiltration final aspect

time must be allowed for the vasoconstrictive effect of the solution to take place before emulsification, usually 10 min minimum. The amount of lidocaine infused should not exceed 35 mg/kg of body weight under the risk of toxicity.

54.5.4 Position of the Patient

It is extremely important to offer comfort and safety to the patient. The patient must be placed in different positions according to the area to be treated, in such a way that the movement of the cannulae may be done safely in the desired direction. The patient may be lying on her back, on her belly, or on her sides.

54.5.5 VASER and Aspiration

Both the superficial and deep layers are treated, but in a different way. The deep layer is approached to diminish local fat deposits and the superficial layer is treated in a careful manner, the skin retraction and refinement being done with the aim of avoiding irregularities. First we use the VASER device to pre-treat fat. Access incisions 3 – 4 mm in length are made in the boundaries of the marked areas and skin protectors are placed. They are specially designed to protect incision edges during the fragmentation phase without extending their length. Such ports must always be used to guarantee the safety of the method. The vibrating probe should not be levered at the skin port as this will cause heating of the port.

Protecting the skin near the skin port is mandatory so as to avoid accidental lesion in the undesirable situation in which the probe comes into contact with exposed skin (Fig. 54.6). Once the probe is introduced through the port, simple axial back-and-forth movements are done in the same direction as the muscle fibers underneath the treated area and without levering to the sides or up and down. The probe should be kept moving and never left in one location. It is to be smoothly moved at a speed that the tissue and the VASER settings will allow without excessive pushing. Punching the dermis from below and end-hits should be avoided.

As for choosing the mode of ultrasonic wave emission, the continuous mode should be used in very fi-

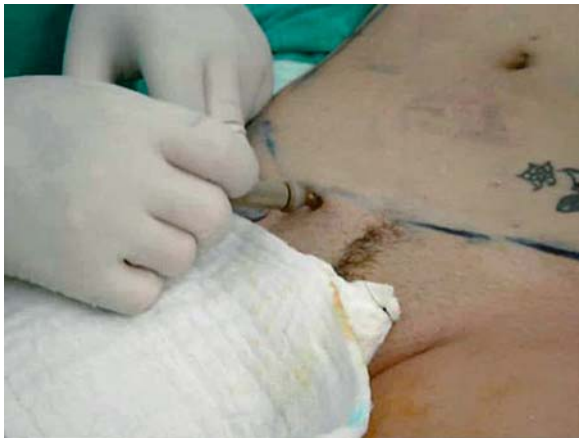

Fig. 54.6. Skin port and wet towel to protect the skin

brous tissues, for faster fragmentation and when tissue emulsification is not readily achieved with the VASER mode. The VASER mode, instead, is better for more delicate work, finer sculpting or softer tissues. The device must be adjusted in such a way that the probe moves smoothly through the tissue. In general, the surgical end-point occurs with loss of resistance of the tissues to the probe.

After emulsification of all the targeted localized fat deposits, aspiration can be carried out by suction assisted lipoplasty or power assisted lipoplasty. Once again, it is important to follow the direction of the muscle fibers of the area. We believe that performing the movements in such a way enhances the body contour, featuring the shape of the muscles with more pleasant and attractive results and fewer irregularities. We have also observed better skin retraction, probably due to stimulation caused by the muscle contraction in the same direction.

54.5.6 Dressing

Incisions are closed with sutures and dressings are placed. Compressive garments are used for at least 30 days. Later care includes lymphatic drainage to resolve remaining nodules and accelerate regression of swelling.

54.6 Results and Clinical Outcomes

When the features of VASER are analyzed and compared to earlier UAL equipment, patient and surgeon satisfaction is good, pain is average for lipoplasty procedures, and bruising and swelling are minimal. In our routine we see a decrease in the number of revisionary lipoplasties compared to traditional methods. We also notice better skin retraction with good results and increased patient satisfaction when using the lipomioplasty technique, specifically better body contouring with more natural and non-stigmatized results (Figs. 54.7 – 54.16).

54.7 Complications

The most recent series show a minimal to zero incidence of complications with the use of VASER while the average incidence of complications with earlier UAL devices is around 5%. The most common complications related to UAL are seromas, prolonged dysesthesias, burns, induration, contour irregularities, hyperpigmentation, cellulitis and prolonged swelling, but all

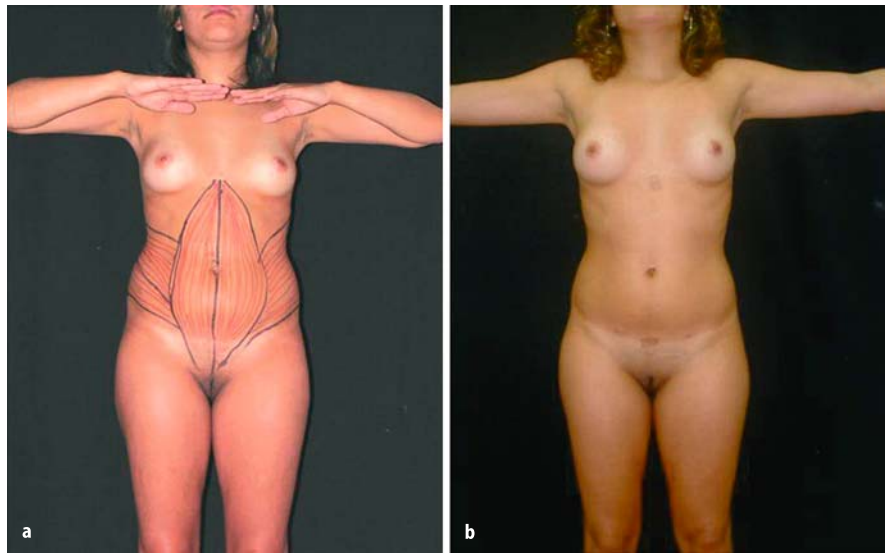

Fig. 54.7. Patient 1: pre- and postoperatively at 6 days

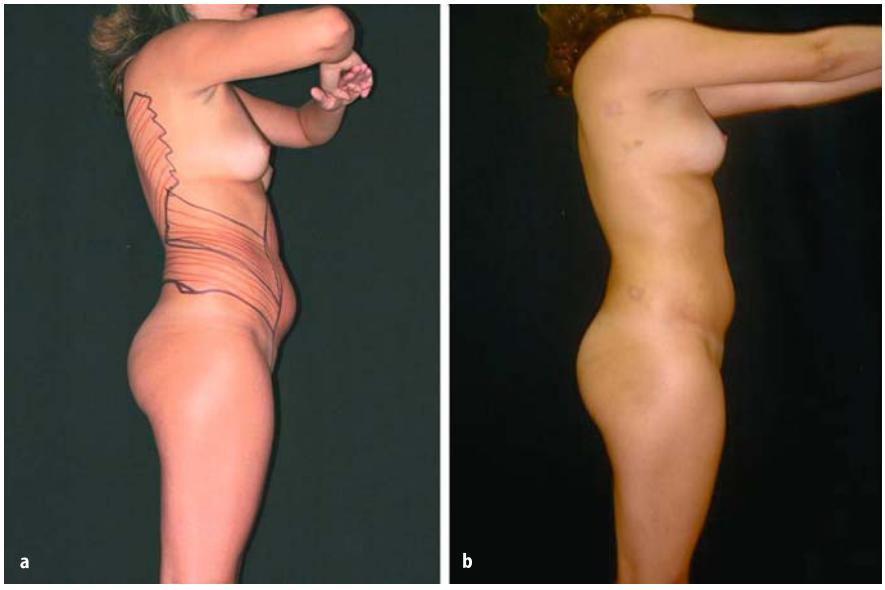

Fig. 54.8. Patient 1: pre- and postoperatively at 6 days

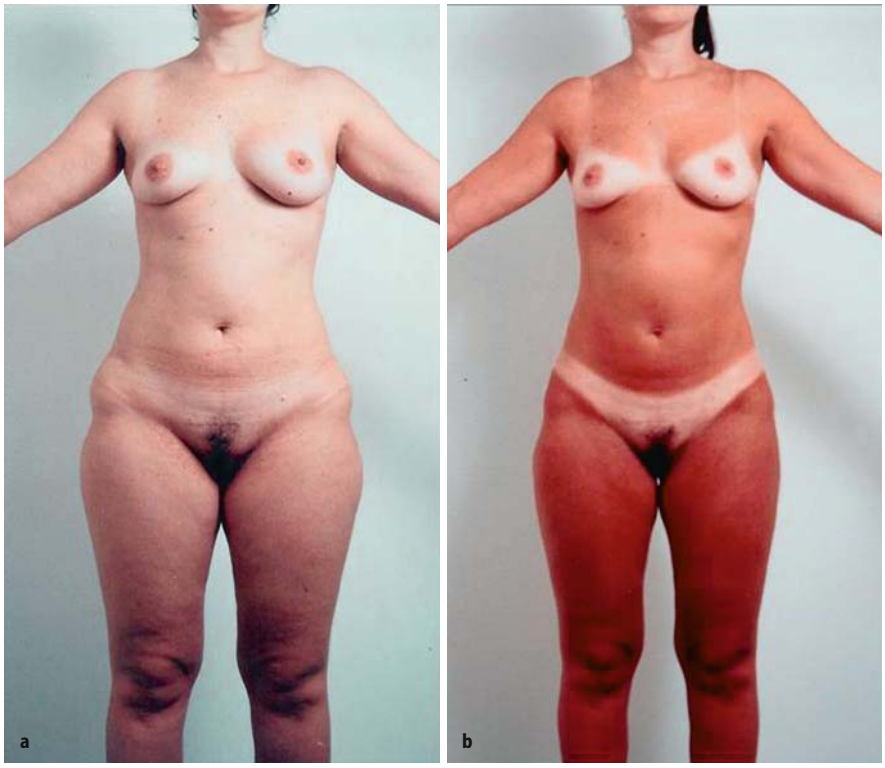

Fig. 54.9. Patient 2: pre- and postoperatively at 90 days

of them have been reported as being related to the use of excess energy or application for too much time. Considering the neural injury, it has been shown that it is actually related to the exposure period, rather than the use of ultrasound energy itself.

The decreased incidence of such complications with the use of VASER can be explained by the reduced energy demanded for emulsification due to the optimization of the applied energy by the grooved probes and the pulsed emission of energy in the VASER mode. Reports in the literature of burns and ischemic injuries related to UAL systems seem to be related to execution problems, such as end-hits and intimate contact with the dermis from below. The application of UAL to the undersurface of the dermis must be avoided. The core body temperature remains stable during the VASER application and the subcutaneous temperature during the time of application of ultrasonic energy remains below

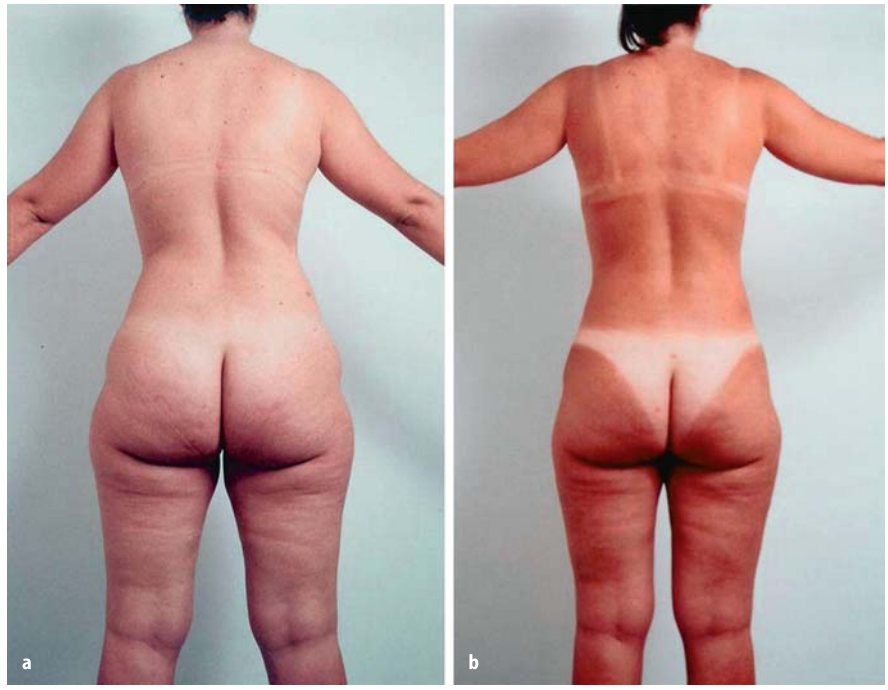

Fig. 54.10. Patient 2: pre- and postoperatively at 90 days

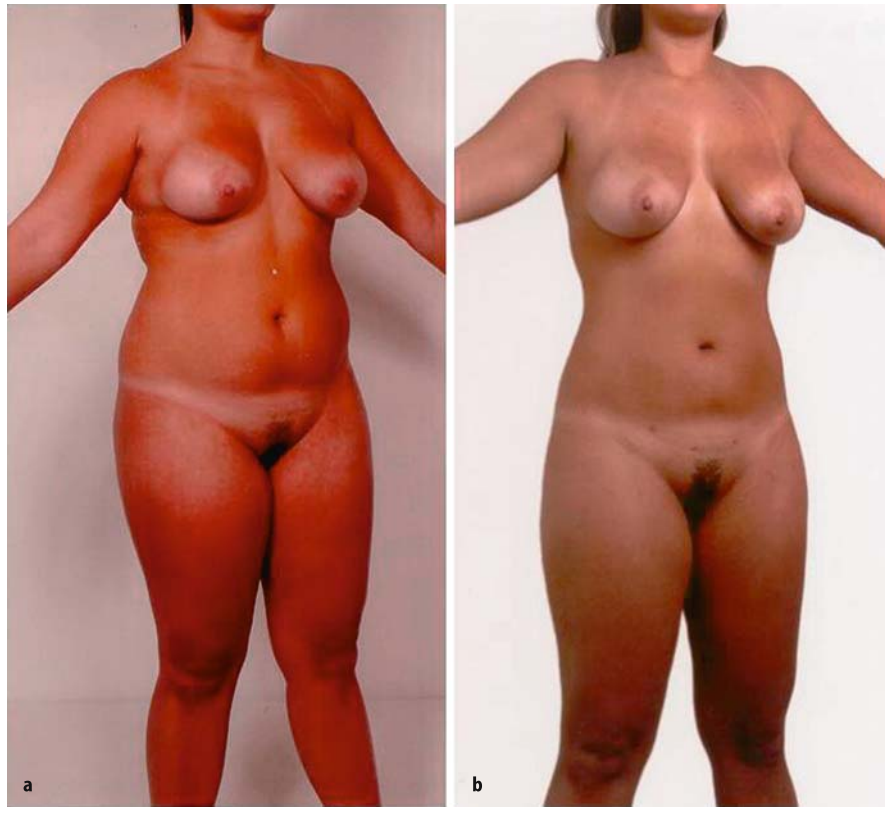

Fig. 54.11. Patient 3: pre- and postoperative at 30 days

the body core temperature at all times thanks to the wetting solution. The incidence of burns is not related to any UAL method itself, but to its mistaken application. It appears that the VASER device in the hands of surgeons who are trained in UAL can produce excellent results with a lower risk of complications than has been reported for earlier UAL equipment.

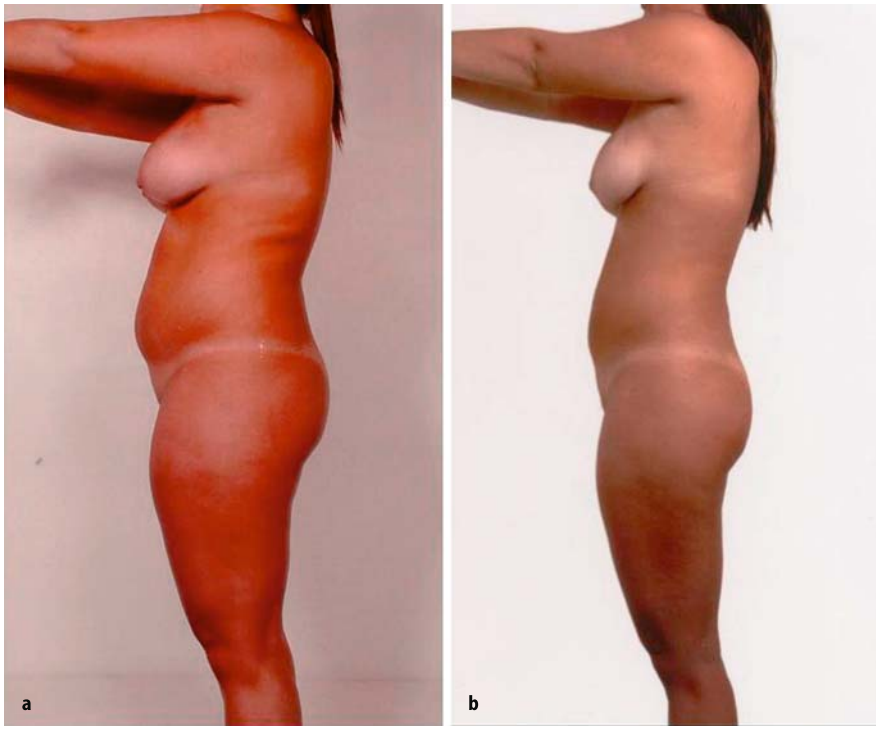

Fig. 54.12. Patient 3: pre- and postoperative at 30 days

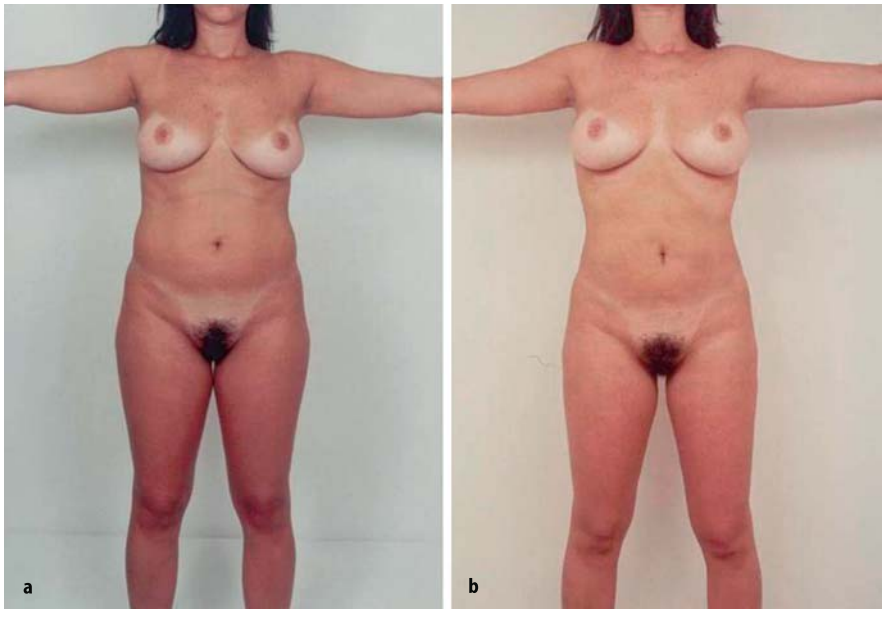

Fig. 54.13. Patient 4: secondary liposuction pre- and postoperatively at 3 months

54.8 Conclusions

VASER is a fat pretreatment device based on the emission of pulsed or continuous ultrasound energy to emulsify fat before its aspiration and works in a complementary way to suction-based aspiration. The lipomioplasty technique focuses on a respect of the anatomy of the body muscles. By moving the cannulae in the same direction as the muscle fibers it is possible to achieve better body contouring with enhanced skin retraction. The sum of these two techniques produces high quality and safe results with decreased irregularities.

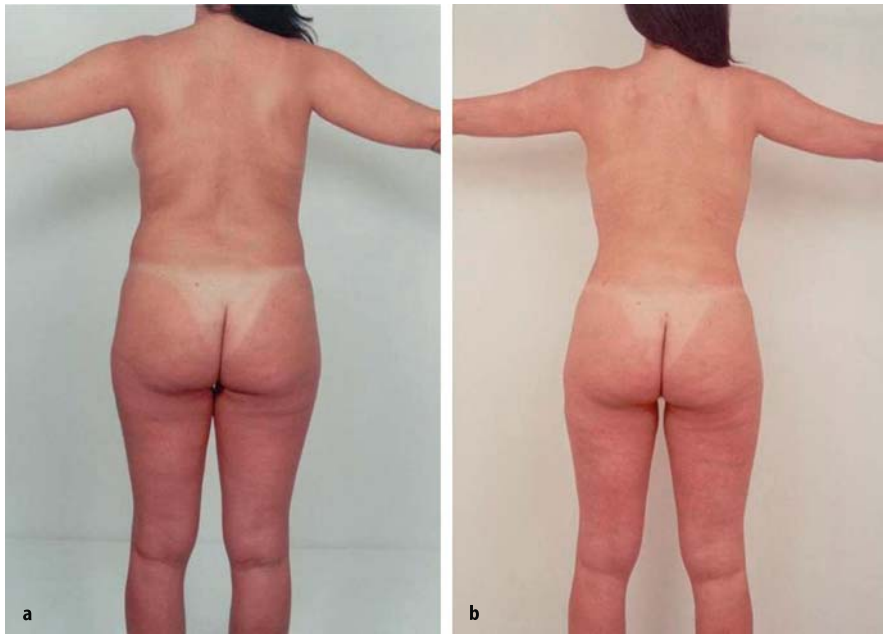

Fig. 54.14. Patient 4: secondary liposuction pre- and postoperatively at 3 months (back view)

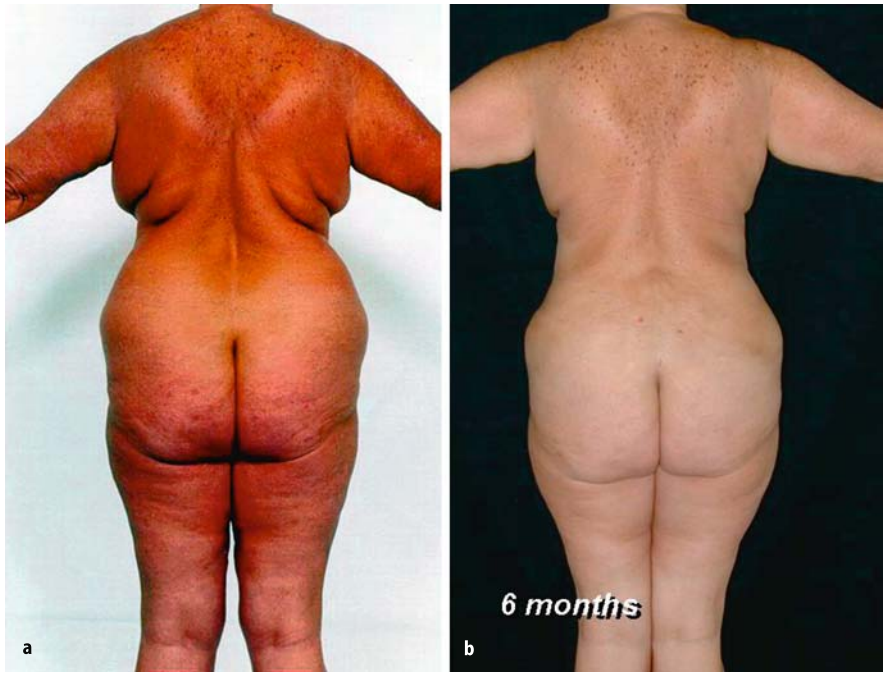

Fig. 54.15. Patient 5: nice skin retraction after 6 months

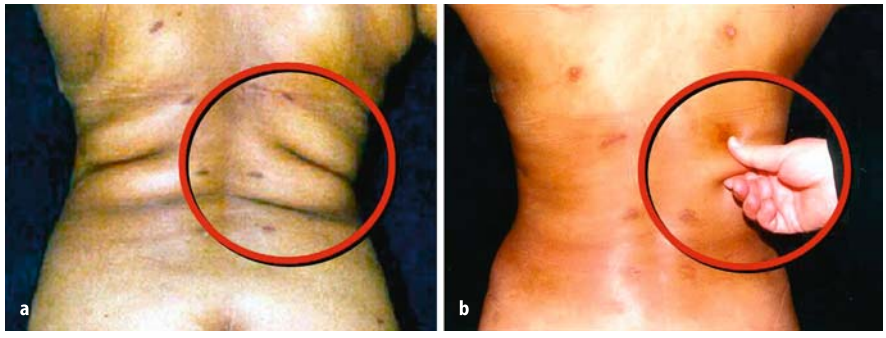

Fig. 54.16. Showing the skin retraction

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Innovation in Plastic and Aesthetic Surgery 55
Lipoplasty

M. Jewell

55.1 Introduction

One of the most remarkable innovations in aesthetic surgery is that of lipoplasty. Mostly, we hear of refinements in surgical technique that merely represent incremental improvements in existing techniques. Lipoplasty, on the other hand, when it was first reported represented a totally new approach for body contouring that had not heretofore been considered. For its inventor, it represented an "a-ha" moment, yet a quarter of a century later, the complete details of this innovation still remain to be discovered [1, 2].

Prior to lipoplasty, the surgical solution for contour improvements was direct excision of areas, with large scars, prolonged recovery time, and unacceptable results for most patients to utilize the existing way that fat deposits were treated before lipoplasty. Disruptions offer better solutions by using approaches never considered formerly to produce better outcomes.

Initially, the announcement of a new form of minimally invasive body contouring surgery produced a lot of excitement for surgeons to learn a new technique. Ultimately, how rapidly lipoplasty was adopted related to providing better, faster, or less-invasive outcomes. While there have been attempts to provide alternative procedures for body contouring with external ultrasound lipoplasty (XUAL), mechanical rollers (Endermologie, LPG Valance, FR), and devices that emit radiofrequency/infrared energy (Thermage, Thermage, Hayward, CA, USA, and Titan, Cutera, Brisbane, CA, USA), surgical lipoplasty remains the procedure of choice for body contouring in most cases. The combination of lipoplasty with excisional body contouring procedures appears to be safe and effective when there is deficient skin tone [3].

55.2 The Evolution of Lipoplasty

It has been an interesting experience to watch both the introduction of lipoplasty technique in the mid 1980s, its adoption by surgeons, and where lipoplasty is today in 2007. The evolution of lipoplasty over the last quarter century has been an interesting mix of incremental improvements regarding technique, wetting solutions, and hardware, and disruptions due to newer lipoplasty technologies [4–6].

Evolutions in the technique of lipoplasty have produced improved outcomes, due to the use of wetting solutions that contain lidocaine and epinephrine. Blood loss has been minimized and recovery enhanced when there is less surgical blood loss and tissue ecchymosis after lipoplasty [7]. Currently, most surgeons are using a variant of the "superwet" technique of infusing between one and one-half to twice the volume of wetting solution to the amount of proposed aspirate. Despite the use of the term "tumescent" technique, very few

surgeons have found benefit with large volumes of wetting solutions.

There have been minor advancements in conventional lipoplasty technology over the large-bore, single port cannulas that Dr. Illouz developed in the late 1970s that were modeled after uterine evacuation cannulas. Cannulas that were designed with sharp cutting edges have proved very damaging to tissue layers. Smaller diameter cannulas with multiple ports were developed that did not inflict as much damage to the collagen tissue matrix. While surgeons were able to perform conventional cannula lipoplasty fairly well, there were still limitations in many areas of the body due to increased collagen content of the tissue matrix and increased resistance to the passage of cannulas through this layer.

55.3 Additional Considerations in Lipoplasty, Beyond Technique

In order for most patients to achieve good to excellent clinical outcomes anywhere in the body it was necessary to consider more than just technology when performing lipoplasty. For this to be accomplished, it was necessary to look beyond plastic surgery and learn from other industries where there exists operational excellence and a process-related approach. In reality, there are similarities to the process of lipoplasty and what occurs in the aviation or automotive industries. Technology certainly has its role, but success in lipoplasty involves a blend of technology, quality improvement, and operational excellence.

55.4 Operational Excellence in Lipoplasty

The concept of how to provide operational excellence and quality improvement in lipoplasty has formerly received minimal thought and action. John Tebbetts, MD, literally dissected the process of breast augmentation, in time and movement studies [8, 9]. In doing this, he found a way to improve the efficiency of the process and improve outcomes. As surgeons, in order to improve quality and safety in lipoplasty our perspective must go beyond the actual performance of the procedure, to encompass a more "holistic" approach that was the entire cycle of care from start to finish.

Plastic surgeons and lipoplasty equipment manufacturers have been focused for years on technical issues rather than how to perform lipoplasty optimally. Conventional approaches to lipoplasty have certain limitations and it is difficult to produce the same quality of outcomes in body areas that have greater collagen content in the tissue matrix layer, i.e., upper abdomen, back and flanks.

55.5 Quality Improvement and Experimentation

We as surgeons when using conventional lipoplasty confront the same problem, case after case as manifested by inefficiencies, irritations, and occasional catastrophes. We fail to engage in problem solving exercises and experiments in order to solve the problems that we face with lipoplasty. When confronted with a situation where the tissue is very fibrous, we as surgeons tend to think that better results can be produced by more aggressive technique versus rethinking how we can better perform lipoplasty in a difficult area with an energy-based technology (UAL, VAL, or PAL) (ultrasonic assisted lipoplasty, VASER-assisted lipoplasty, power-assisted lipoplasty).

A classic example of living with inefficiencies is the matter of vacuum locking that occurs during cannula lipoplasty when the suction tubing fills with aspirated fat and efficiency in aspiration drops due to a lowering of vacuum pressure at the port of the cannula [10]. This equates to sucking liquid out of a closed space. Air is not allowed to enter in order to release the negative pressure. This is no different than what your office nurse experiences when she attempts to draw liquid out of a closed vial with a hypodermic needle and cannot draw more due to the internal vacuum pressure equaling the suction force of the syringe.

Most of us who perform lipoplasty have noticed this vacuum lock phenomenon, yet have not experienced an "a-ha" moment with regards to solving this problem of inefficient aspiration. The solution to this problem is quite simple, and something that we have used formerly in nasogastric tubes, a small air bleed in the line dramatically increasing flow. While this is a simple solution to the problem of inefficient aspiration, it took years to consider the physics of aspiration for a solution to inefficient lipoplasty aspiration [10].

55.6 The Rise and Fall of Ultrasonic Lipoplasty

UAL (ultrasonic assisted lipoplasty) was initially met with enthusiasm in the late 1990s, but fell into disuse because there was not a process by which this technology could optimally function. Surgeons went about performing UAL within the mindset of conventional lipoplasty because they were trained to do it that way in the UAL Taskforce Courses [11]. It was not that UAL was a poor solution for lipoplasty patients, but we as sur-

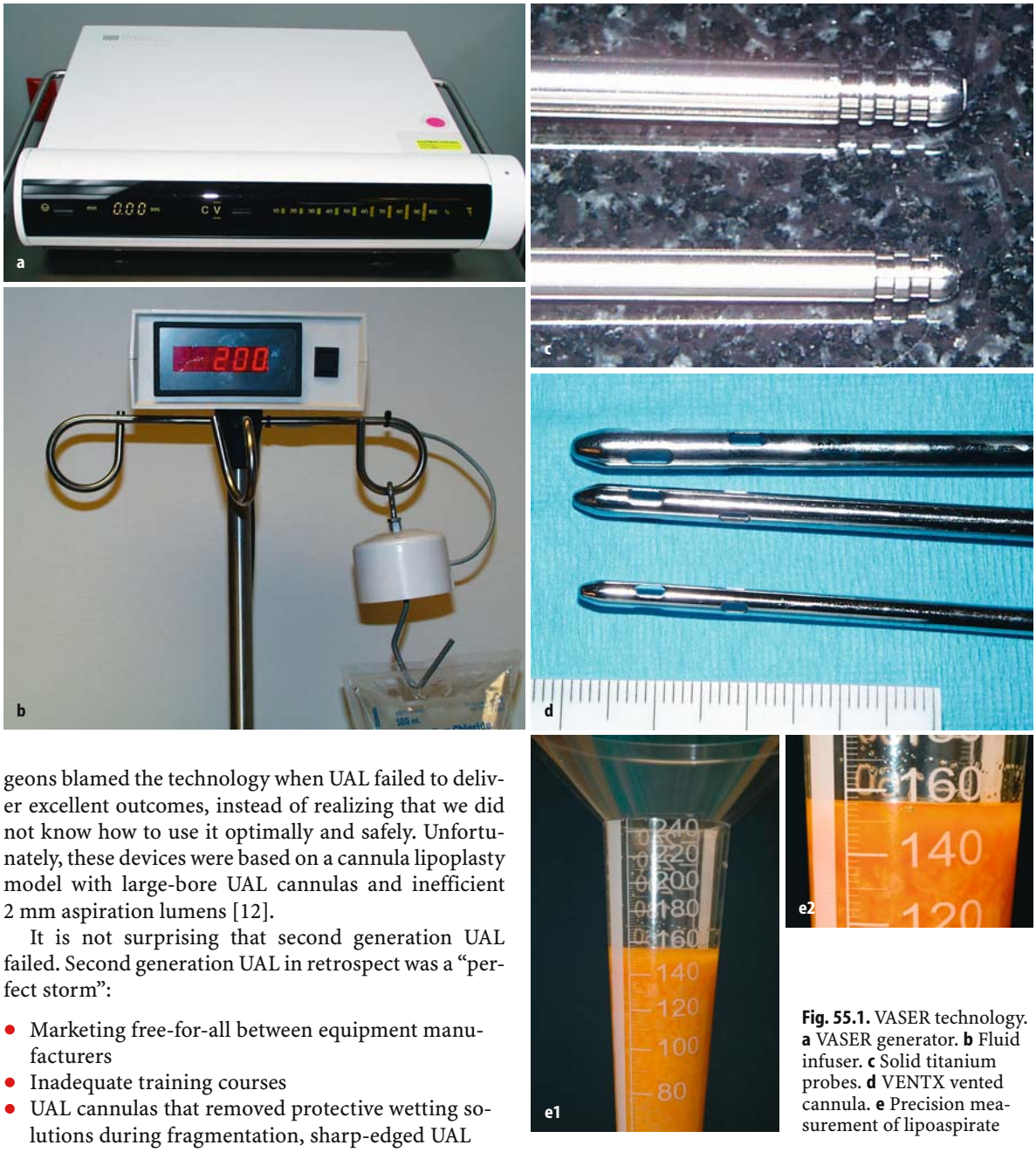

Fig. 55.1. VASER technology. **a** VASER generator. **b** Fluid infuser. **c** Solid titanium probes. **d** VENTX vented cannula. **e** Precision measurement of lipoaspirate

geons blamed the technology when UAL failed to deliver excellent outcomes, instead of realizing that we did not know how to use it optimally and safely. Unfortunately, these devices were based on a cannula lipoplasty model with large-bore UAL cannulas and inefficient 2 mm aspiration lumens [12].

It is not surprising that second generation UAL failed. Second generation UAL in retrospect was a "perfect storm":

- Marketing free-for-all between equipment manufacturers
- Inadequate training courses
- UAL cannulas that removed protective wetting solutions during fragmentation, sharp-edged UAL cannula that cut tissue
- No science whatsoever to determine the optimum power range and length of fragmentation time
- Non-precise measurements of wetting solution infused or fat aspirated

For there to be progress in overcoming the limitations that existed in conventional lipoplasty and second-generation UAL, I felt that it was necessary to look at the entire process, akin to the Toyota Production System, where emphasis is placed on delivering operational excellence and eliminating a work-around culture. This was not a cookbook approach for lipoplasty, but an emphasis on finding ways to improve problems that currently exist.

55.7 More on Quality Improvements in Lipoplasty

If one objectively looks at lipoplasty, it was a crude, imprecise, somewhat brutal form of body contouring that had ill-defined approaches and end points. There was little data that demonstrated safety and quality of out-

comes. There were also unusual clusters of morbidity and mortality when surgeons attempted to use this approach for large volume removal of fat.

The matter of patient morbidity and mortality from a procedure that formerly was considered to be "safe" caused a rethinking of decisions to remove fat volumes greater than 5 liters in a single setting, better monitoring of lidocaine-containing wetting solutions to not exceed 35 mg/kg, and ways to prevent venous thromboembolism during surgery. When these factors were addressed by surgeons, the morbidity and mortality from lipoplasty improved significantly [13–15].

Begging the question, had we really made any progress in a quarter century of lipoplasty when there are:

- Inefficient cannula designs that damage tissue matrix
  - Low-efficiency UAL that primarily deliver heat to tissue as opposed to efficient fragmentation
- Imprecise administration of wetting solutions and aspirate measurement
  - Side-to-side discrepancies in aspirate volume
- Garments with no science whatsoever

Inadequate surgical practices:

- Wrong mindset:
  - "Get it over as quickly as possible"
  - "Large bore 6 mm cannulas work just fine"
  - "I'm satisfied with how I do lipoplasty"
  - "My patients aren't asking for anything fancy"
- Poor aesthetic goals:
  - Spot reduction of fat deposits
  - Failure to treat regional aesthetic units
  - Failure to treat circumferential or three dimensions

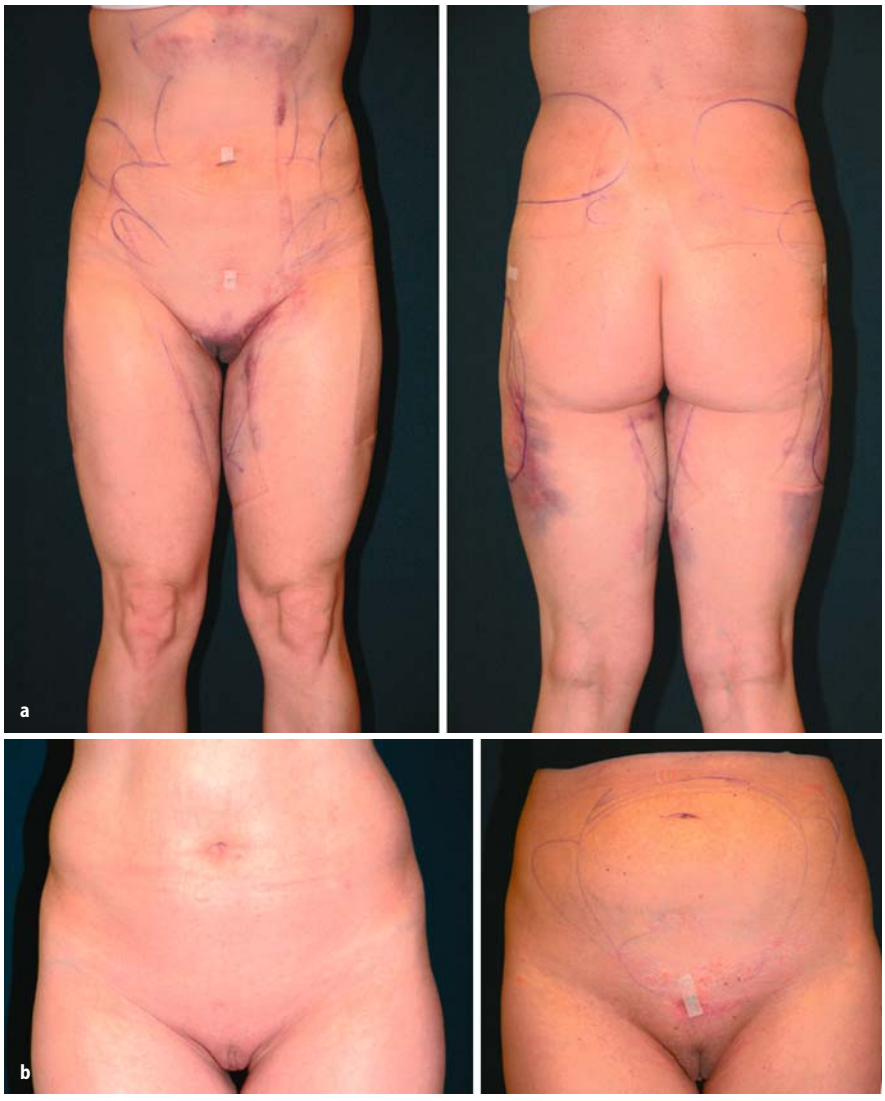

Fig. 55.2. a Patient 24 h post 2,400 cc VASER lipoplasty. There is minimal ecchymosis and pain. **b** No ecchymosis 24 h post 800 cc VASER lipoplasty of abdomen

55.8 Third-Generation Lipoplasty Devices

When I received my first VASER UAL System (Sound Surgical Technologies, Louisville, CO, USA) in 2000, a third generation UAL device that used pulsed ultrasonic energy and solid titanium side-grooved probes, I made a decision to see what would happen if greater attention was paid to each component of the process of ultrasonic lipoplasty in order to improve the quality of outcomes and to lessen the rate of complications. Peter Fodor, MD, and Ewaldo Bolivar DeSouza Pinto, MD, also received the initial VASER devices. We conducted the initial Pilot Clinical Study regarding the VASER.

The VASER, while using ultrasonic energy to fragment fat, like earlier UAL devices, optimized the fragmentation of fat through high-efficiency solid probes [16–18].

55.9 UAL Complications

First, I thought that it was important to look at the data regarding why there were complications reported with UAL and to see if there were root causes that could be corrected. When the published reports of complication for second-generation UAL were analyzed from the 14 papers that had been published, the data confirmed [6] (Table 55.1).

Complications were categorized into nine areas to determine the root cause (Table 55.2).

Table 55.1. Complications

Range of complications	0–100 %
Mean complication (average)	13.5 %
Median complication	4.90 %
Overall complication	7.90 %

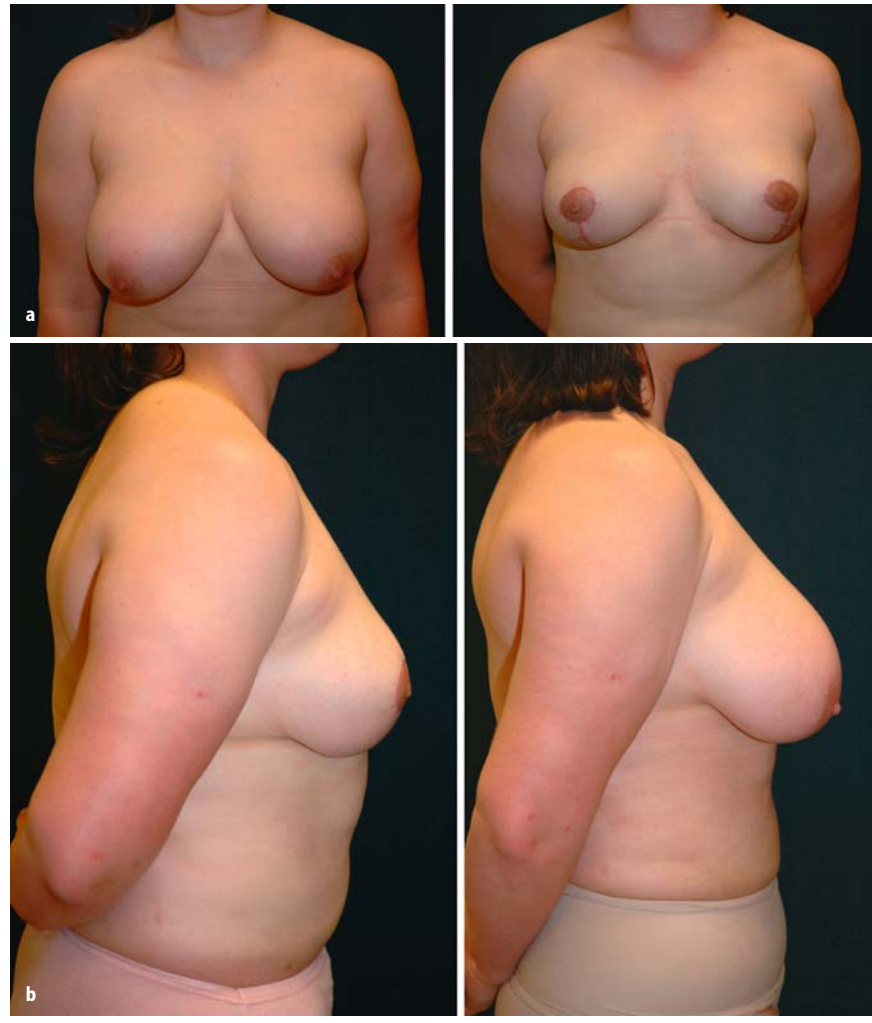

Fig. 55.3. Breast reduction with VASER technique: 850 cc wetting solution/side; 20 min fragmentation time/side; 800 cc lipoaspirate; vertical mastopexy

Table 55.2. Complications categorized into nine areas

Category	Overall incidence	Mean	Median
Sensation change	2.3%	7.0%	0.2%
Seroma	2.2%	4.8%	1.25%
Induration	0.1%	3.6%	0%
Skin necrosis	1.5%	1.6%	0%
Hyperpigmentation	1.2%	0.5%	0%
Prolonged swelling	0.3%	0.3%	0%
End hits	0.1%	0.2%	0%
Burns	0.1%	0.1%	0%
Cellulitis	0.1%	0%	0%

55.10 A Pathway to Improve Quality and Safety in Ultrasonic Lipoplasty

This data confirmed that causes for UAL complications were not a random occurrence, but related to surgeon determined factors:

- Excessive ultrasonic energy applied to tissue
- Inadequate amounts of wetting solutions
- Excessive tissue trauma during aspiration
- Poor surgical technique – burns and end hits
- Ill-defined endpoint regarding tissue fragmentation
- Ill-defined endpoints regarding aspiration

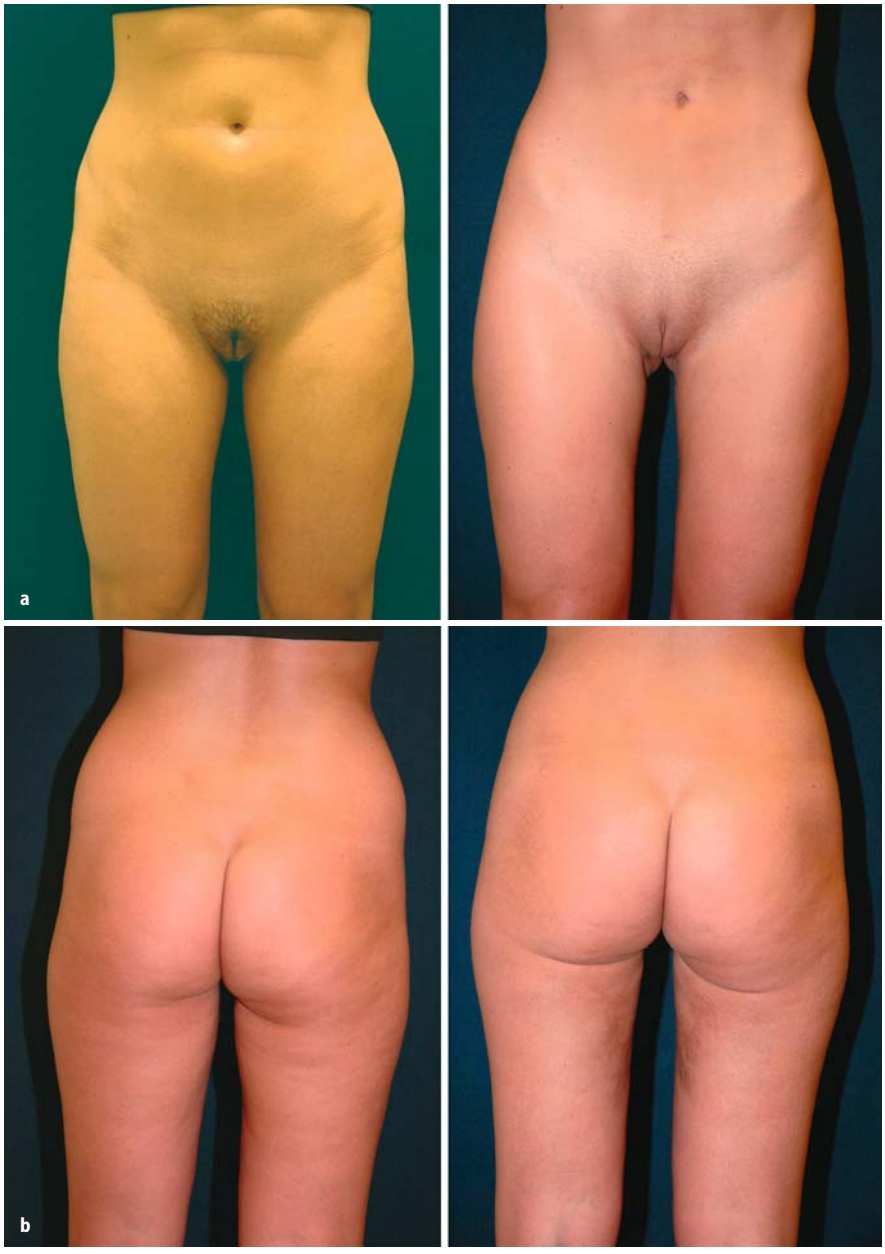

Fig. 55.4. Twelve month follow-up after VASER lipoplasty to upper/lower abdomen, posterior waist, inner and outer thighs 2,600 cc lipoaspirate

Fig. 55.5. Typical VASER lipoaspirate sample, 95 % fat

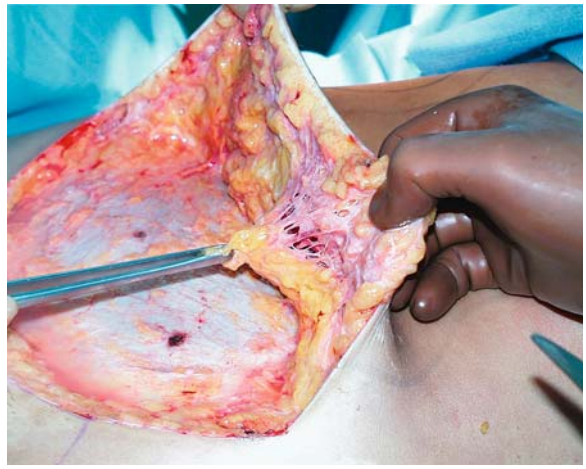

Fig. 55.6. VASER lipoplasty is very effective in the mid-lamellar level, just above Scarpa's fascia. It can be used as a solitary procedure in selected patients, or combined with excisional procedures such as lipoabdominoplasty, body lifts or brachioplasty. The combination of the VASER's pulsed ultrasound and fat-specific aspiration cannula (VENTX) allows for all abdominal layers (superficial, mid-lamellar and sub-fascial) to be safely treated during lipoplasty

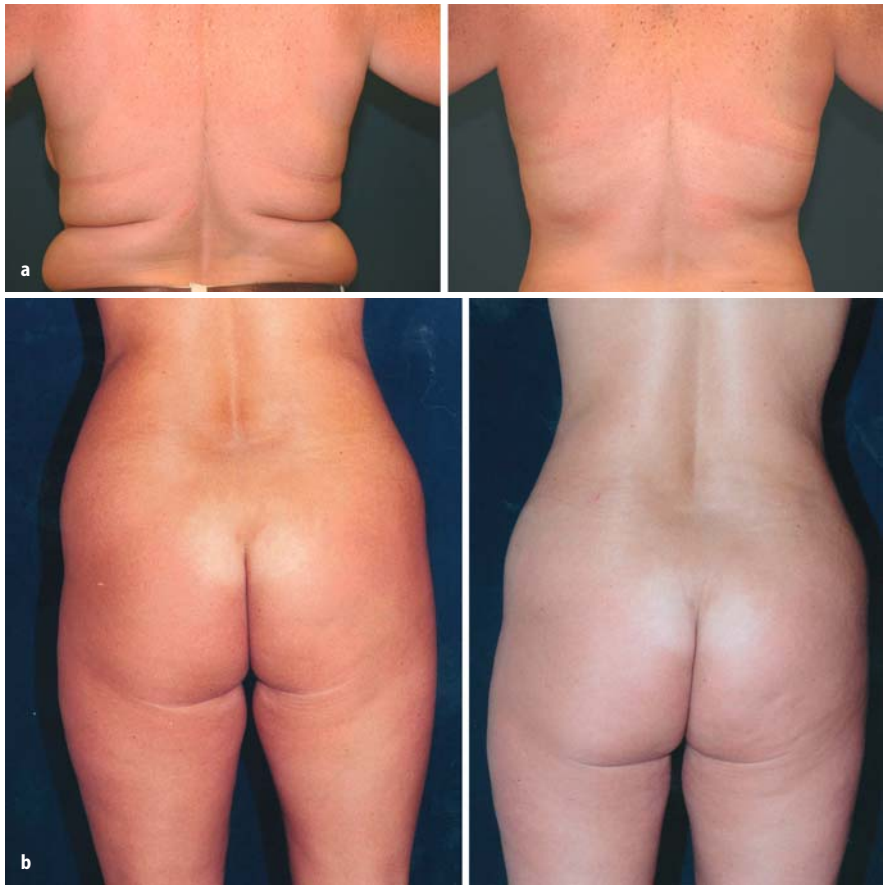

Fig. 55.7. a VASER lipoplasty is effective in fibrous-difficult to treat areas such as back and lumber rolls. **b** Posterior waist VASER lipoplasty before/after

55.11 The Process of VASER Lipoplasty

The cycle of care in lipoplasty from the start to finish involves patient assessment, management of expectations, a surgical strategy, surgical excellence, and aftercare. Documentation of clinical decisions regarding how surgery would be performed and how patient care is delivered documents the quality of lipoplasty outcomes. Forms and worksheets are necessary for planning and performance of lipoplasty [19].

55.12 Wetting Solution Measurements

My approach was to base the amount of fragmentation time on the amount of wetting solution infused into a given tissue area. By this approach, excessive ultrasonic energy is not applied that would otherwise damage the tissue matrix and produce complications as listed above. The Sound Surgical VASER device can measure volume of wetting solution infused to the cc in a given area. This overcame the imprecise manner that was formerly used of a pressure bag of wetting solution and to look for "tissue firmness" clinically. It was safe to infuse wetting solution approximately a range of 1.5 – 2 times the anticipated tissue aspirate from a given area.

55.13 Tissue Fragmentation Time

Excessive application of ultrasonic energy to tissues was also considered as part of a quality improvement process versus extremely long ultrasonic energy times as formerly published. The initial approach was to use 1 min of VASER fragmentation time per 100 cc of wetting solutions infiltrated into a given tissue area. When this guideline was followed, there were no complications in the Initial VASER Clinical Pilot Study paper population that were formerly seen in UAL [6]. Since then, VASER times for tissue fragmentation have increased, 1 min in soft tissue, 2 min in firm tissue areas and 2½ min in the female breast per 100 cc of wetting solution infiltrated into a given area.

The Sound Surgical VASER (Vibration amplification of sound energy at resonance, Sound Surgical Technologies, Louisville, CO, USA) represents a third-generation ultrasonic lipoplasty device that uses side-grooved solid titanium probes versus the hollow UAL cannula from the second-generation devices. The smaller probes require about one-fourth of the energy required in older devices to efficiently fragment fatty tissue. The side grooves of the VASER probes help disperse the ultrasonic energy from the tip area to the sides of the probe in order to diminish the risk of burns. Finally, the VASER probes use pulsed ultrasonic energy versus a continuous application of energy. This allows for efficient fragmentation of fat without excessive heating of the tissue.

55.14 Clinical End Points: Fragmentation

In addition to the clinical guideline of time per 100 cc of wetting solution infiltrated, another end point was that of loss of resistance to VASER probe movement. If it became possible to pass the VASER fragmentation probe with two fingers, before the time limits, it was a safe time to stop. For novices, the initial guideline of 1 min per 100 cc of wetting solution infiltrated into a given area is a good starting point.

The key concept here is to avoid too much ultrasonic energy applied to tissues in order to prevent burns, sensory nerve dysesthesias, and collateral damage to the collagen tissue matrix. Second generation UAL devices that simultaneously fragment tissue and aspirate remove the protective effect of wetting solutions designed to prevent excessive thermal damage to tissue.

55.15 Tissue Evacuation

Tissue evacuation was the next factor to analyze when improving the process of lipoplasty. Besides the problem of vacuum lock, existing lipoplasty cannulas were traumatic to the collagen matrix and damaged blood vessels, lymphatics, and nerves. Smaller bore, vented cannula that were more fat-specific and less prone to damaging the collagen matrix were needed to increase efficiency in aspiration.

Large-sized wall suction canisters are a very inaccurate way to measure the lipoaspirate. A more precise canister system was needed to avoid side-to-side discrepancies in the amount of lip aspirate.

I believe that the process of aspiration is dependent on a keen awareness by the surgeon on the quality and quantity of the lipoaspirate along with a feel for contour changes in the fat deposit. The intended goal of aspiration is to remove fat from treated areas and to spare the residual elements of the collagen tissue matrix (including blood vessels, nerves, and lymphatics). The fat should be aspirated without excessive trauma that will leave blood in the tissue that produces postoperative pain and hyperpigmentation from residual hemosiderin.

Gentle aspiration with a small-bore vented cannula (VENTX, Sound Surgical Technologies) yields a pale-colored lip aspirate. Aggressive techniques with large

bore cannulas or power-assisted devices yield a more bloody aspirate. A simple clinical end point for aspiration is to stop when no more fat is coming out of an area or that the color of the aspirate becomes blood-tinged. It is not necessary to engage in squeezing tissue (sausage rolling) while performing aspiration. This may produce contour irregularities.

55.16 Aftercare, Including Garments and Foam Dressings

Compressive garments and adjunctive techniques to reduce ecchymosis after lipoplasty were another factor to consider. This component of the process of lipoplasty is the least precise and scientific. There is absolutely no data that demonstrates efficacy of compression garments, optimal design, or compression force. Anecdotally, we know that polyurethane foam sheets that are coated on one side with a sticky silicone-based adhesive dramatically reduce ecchymoses after lipoplasty, but there has not been any research into the mechanism of action. Presumably, this material may act in a similar way as taping after a rhinoplasty prevents bruising in the nasal tissue.

Foam has remained a mainstay in my personal lipoplasty technique. I have for the most part abandoned conventional lipoplasty compressive garments (corsets) and use commercial body shaper garments one or two sizes larger than the patient would wear normally. These inexpensive garments appear to work, yet are more difficult to apply when a patient is under general anesthesia than the garments that have side zippers.

55.17 General Anesthesia Vs. IV Sedation

The need for general anesthesia for lipoplasty also remains to be studied. From a surgeon's perspective, it allows for efficiency in the performance of lipoplasty, yet adds risk to the procedure regarding venous thromboembolism, hypothermia, and PONV (postoperative nausea and vomiting), besides increased cost. Lipoplasty performed with warmed, buffered, local anesthetic-containing wetting solutions [20] under conscious sedation or deeper monitored anesthesia care (MAC) may be safer, but slower.

55.18 Expanded Applications for VASER Lipoplasty

Once the initial pilot clinical study confirmed that the approach for VASER lipoplasty (VAL) was safe, additional applications were considered in areas that formerly were considered off-limits for UAL. This included arms, inner thighs, face and submental area/jaw line, and harvesting of fat for autologous fat transfer. VAL can be successfully use in male gynecomastia with and without tissue resection. The use of ultrasonic surgery devices in the female breast remains controversial, yet UAL, VAL, and Harmonic Scalpel (Ethicon Endo Surgery, Cincinnati, OH, USA) can be effectively used, with appropriate informed consent. VAL appears to work well in combination with excisional body contouring procedures, such as limited abdominoplasty, standard abdominoplasty, lipoabdominoplasty, body lifts, and brachioplasty, in my experience. It is possible to use this technology in a discontinuous fashion for undermining and freeing up of zones of tissue adherence for the purpose of mobilizing tissue.

Hoyas and Millard have developed a high-definition multiplanar VAL approach that enhances surface contour by emphasizing regional muscle group definition. This approach appears successful in the use of superficial VAL, without the serious complications reported in superficial UAL and conventional cannula lipoplasty [22]. This appears to be a technique that should be performed by surgeons that are experienced in the safe use of VASER lipoplasty.

55.19 Discussion

From this discussion, there are a variety of elements regarding technology, physics, and process of lipoplasty that could be improved to change the quality of patient outcomes. These consist of Precision, Finesse, Safety, and Technology. Success in performing contemporary lipoplasty involves the following elements:

- Patient Satisfaction Pays
  - Improve the quality of the experience for the patient
  - Treat anatomic areas to enhance body contours
- Patient Safety Pays
  - Diminish re-op incidence = professional liability concerns
  - Excessive resection = long-term lipoplasty defects that require body lifts or fat grafts to correct
  - What is the role and benefit of general anesthesia for lipoplasty?
- Precision Pays
  - Role of measurements (spreadsheets and data forms), precise technique, observance of clinical end points, and quality improvements
- Technology Pays
  - Avoidance of former UAL/SAL complications

- High efficiency solid probes; vented cannula minimize tissue matrix trauma
- Tools and techniques trump the Surgeon (most lipoplasty complications relate to surgeon-related factors)

While surgical lipoplasty remains a mainstay of body contouring surgery, there are even newer technologies that are being researched to utilize high-intensity focused ultrasonic energy (HIFU) from an external transducer through the skin to disintegrate fat deposits. Pharmacologic approaches to body fat reduction are also being researched in order to obtain data regarding safety and effectiveness. Predicatively, the future may involve a combination of lipoplasty technologies, merged with imaging and computer modeling.

Our personal journey as professional surgeons has shown that there is often more to consider than just technique and that management of the entire cycle of care allows for better quality and safety versus being preoccupied with surgical technique. Take the time to look at how you perform lipoplasty in 2007 and ask yourself if you are really at the state of the art, versus repetitively performing lipoplasty of yesteryear. You future will be bright if you can adopt a mindset of quality improvement, precision, finesse, and safety in lipoplasty. It comes down to your personal examination of the entire process to make it better and safer.

55.20 Research Opportunities

As you can understand from this list, lipoplasty is not a mature technique and there is still the need for more research to work on these unanswered questions. Oddly, despite the great number of lipoplasty procedures that have been performed since inception of this technique, there still exists abundant opportunities for basic and clinical science research in this area. While there is widespread clinical use of this technique and excellent clinical outcomes, little has been done to understand the following:

1. Histological changes of tissue following lipoplasty, including energy-based lipoplasty devices?
2. What is the ultimate cannula design that will be the most specific for fat and least injurious to the collagen tissue matrix?
3. What is the role of garments after lipoplasty and necessary amount of compression?
4. What is the mechanism by which foam dressings diminish ecchymosis after lipoplasty?
5. To what extent can skin retraction be safely produced by lipoplasty techniques?
6. How much lidocaine is really needed in wetting solutions?
7. What is the long-term effect of using ultrasonic lipoplasty (UAL, VASER-assisted lipoplasty) for breast reduction procedures?
8. How to use lipoplasty technique to facilitate non-contiguous soft tissue undermining for incisional body contouring procedures (the “lipoabdominoplasty” and body lifts)?
9. Predictive modeling of amounts of fat aspirate based on imaging of tissue areas?
10. What is the role of the so-called “zones of adherence” and tissue layers in the clinical performance of lipoplasty?
11. How safe is lipoplasty performed in situations of minimal sedation or monitored anesthesia care over general anesthesia?

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Abdominoplasty and Body Lift

VIII

Adhesion Stitches to Avoid and to Treat Seroma 56

R. Baroudi, F.R. De Almeida

56.1 Introduction

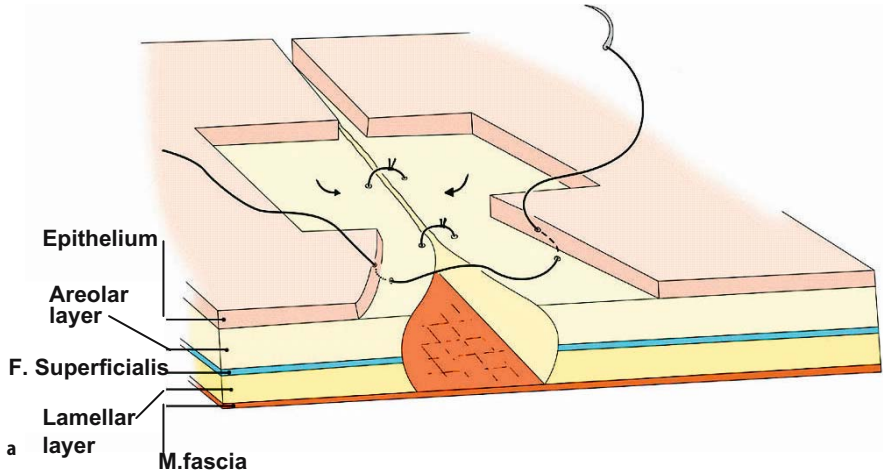
Hematomas and seromas have been described over the decades by general surgeons and specialists from different areas. At conferences, symposia and congresses, the statistics have not been precise but quite discrepant. In the speciality of aesthetic plastic surgery, the incidence varies from zero to 90 %, according to the speaker's ego, making it impossible obtain real data about this problem. The statistics found in publications on the subject are also variable. In recent meetings on aesthetic abdominoplasty, the numbers have been even more curious, with speakers emphasizing that their methods are more efficient in avoiding seromas. The literature is rich in publications about this problem [6, 9, 21]. Hundreds of articles refer to the presence of seroma in the postoperative period with the presence of dead space as a result of moderate to huge dissections, in particular in the donor areas in reconstructive surgeries [4, 14 – 19]. The different types of procedures used in the postoperative period after seroma detection are well known. The use of fibrin glue and irritant products to provoke the adhesion of the surfaces always associated with the use of vacuum and Penrose type drains has also been described [1, 5, 7, 8, 11]. Unfortunately the results with these procedures have not been efficient in all cases. Sequelae after seroma in the different regions of the body operated on have been described and not always completely resolved. Suction and other types of drains are routine in almost all types of surgeries [13]; even so, the ideal solution, i.e, " zero seroma," has so far never been obtained. Baroudi and Ferreira in 1998 [2, 3] reported their results on "zero seroma" in abdominoplasty, applying the adhesion stitches concomitant with drains. Two years later, the authors confirmed there were no seromas in their cases of aesthetic plastic surgery of the abdomen after the drains had been taken out during routine surgery, for the patient's comfort. These adhesion stitches have been used in all other regions of the body without any type of drain, except for the axillary region after surgical "toilet" in cases of breast cancer. In conclusion in reconstructive and aesthetic plastic surgery the incidence of seroma has been reduced to an irrelevant level. McCarthy et al. [6, 10], O'Dwyer et al. [12] and Zide [20] also report the reduction of seroma with the use of adhesion stitches applied in different types of surgery, skin avulsion, and on the surface of dissected skin flaps and the muscular fascia to eliminate the dead space and its consequences.

56.2 Surgical Technique

For didactic purposes ten different types of surgery have been selected where these stitches are routinely applied.

56.2.1 Suture After Any Type of Skin Resection, with or without Dissection of the Edges and Dead Space

The three most common procedures applied are: (1) the skin suture involves isolated absorbable or non-absorbable stitches applied to the dermis of each edge. When tightened, the local tension and dead space may or may not exist concomitantly, being causes of local ischemia, scar broadness, skin dehiscence, hematoma, seroma, etc. (Fig. 56.1a, b). (2) The use of isolated absorbable 2 to 4.0 adhesion stitches applied with 1 – 2 cm



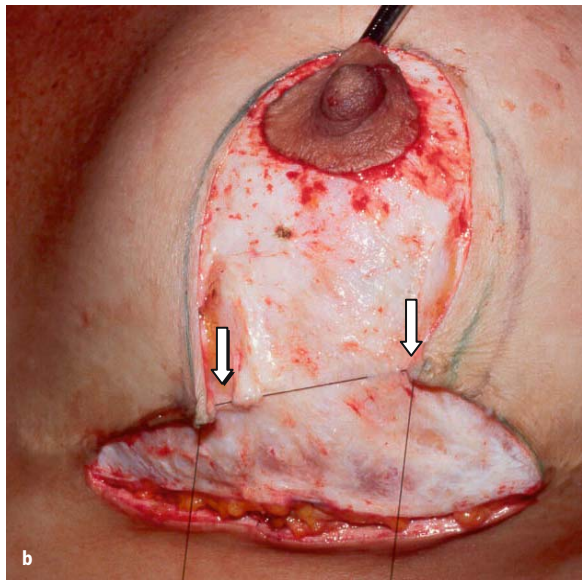


Fig. 56.1a, b. Schematic and surgical aspect of routine skin suture of the dermal edges with isolated absorbable stitches. Very often this type of suture determines the ischemic effect that augments the possibility of dehiscence according to the thickness of the dermis, the region of the suture, the local tension, and even seroma

between them, transfixing or not the superficialis fascia, biting into the subjacent adipose tissue in loops and the dermal-fat edge of each side. When tightened, no dead space should exist below it, otherwise the stitch must be redone (Fig. 56.2a–c). (3) Cases of extensive undermined skin like abdominoplasty, TRAM (transverse rectus abdominal muscle) flap for breast reconstruction, latissimus dorsi, etc., where a similar procedure is applied. Adhesion stitches bite into the subcutaneous tissue and the muscular fascia below. When tightened, all the structures involved in the stitch collapse the dead space. The distance between them may be from 1 to 4 cm according to the region operated on. The reverse leaves the possibility of fragmented dead space, with subclinical localized seroma, very often detected by ultrasound. Finally, when skin dimples persist during the surgery, the stitch must be redone (Fig. 56.3a–c).

56.2.2 Non-extended Mini Abdominoplasty

Non-extended mini abdominoplasty is a limited procedure for the hypogastrium without umbilical mobilization, with or without liposuction and with/without recti muscle plication. After the skin excess resection and other muscular aponeurotic procedures have been performed, the adhesion stitches are placed in lines and columns with no more than 4 cm between them, using

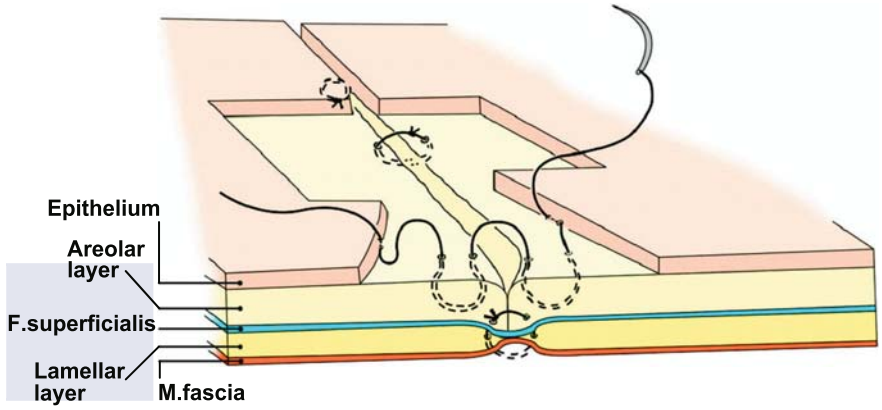


Fig. 56.2a–e. Schematic and surgical aspects of adhesion stitches with isolated absorbable material, applied to the dermis combined with one and more loops that "bite" the subcutaneous tissue including the muscular and superficialis fascia. When tightened all the involved tissues are joined in a block aspect, leaving no "dead space" below. The tension is distributed in a uniform aspect including the dermis.

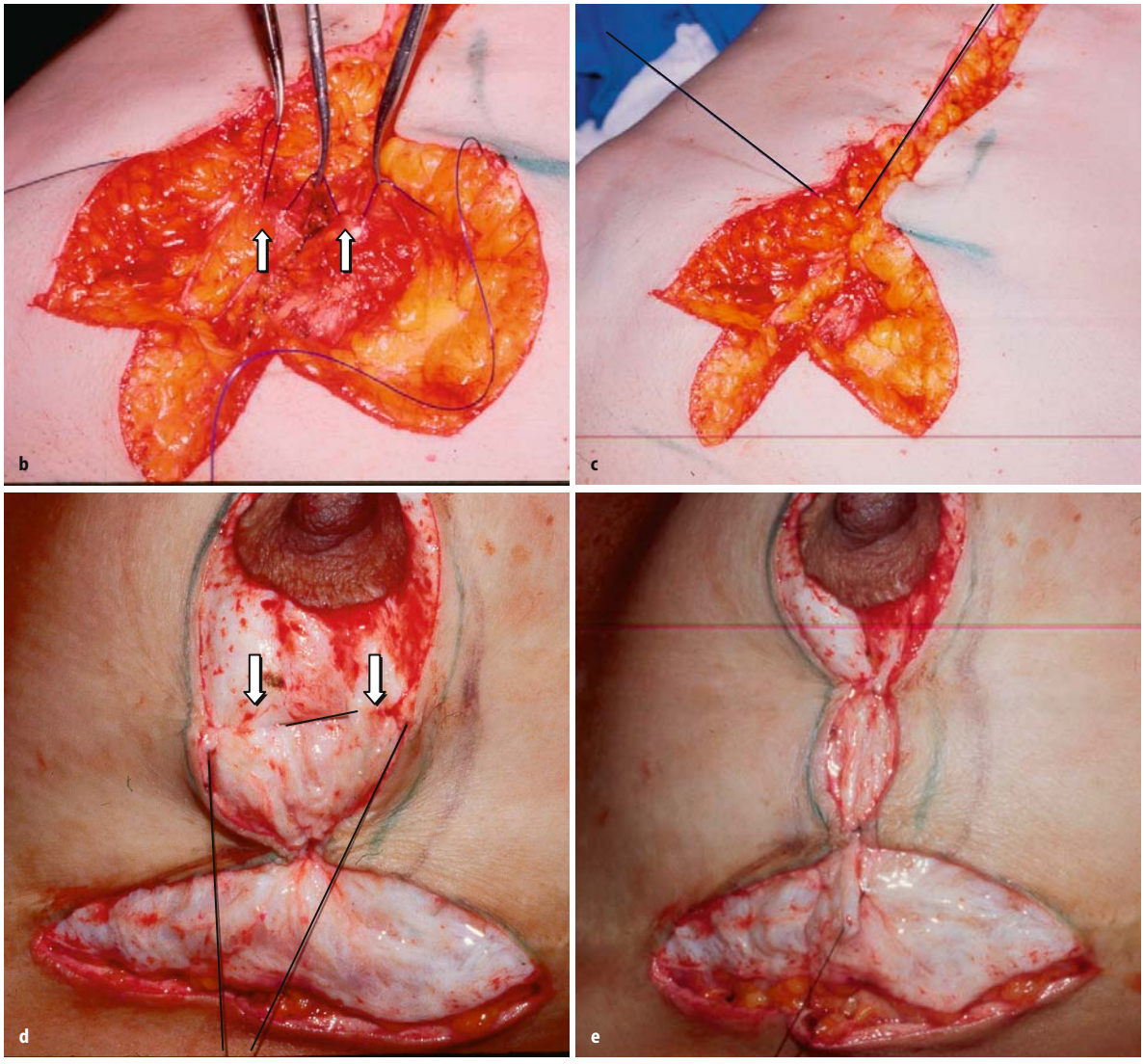


Fig. 56.2. (*Cont.*) Close-up of similar procedure for the suture of the vertical incision of the breast pexy. The stitch bites the dermis of both skin edges and the adjacent glandular adipose tissue, leaving one loop between them. When there is tight and uniform distribution of suture tension, dead space and excessive localized tension applied at the edges is avoided, especially at the T junction

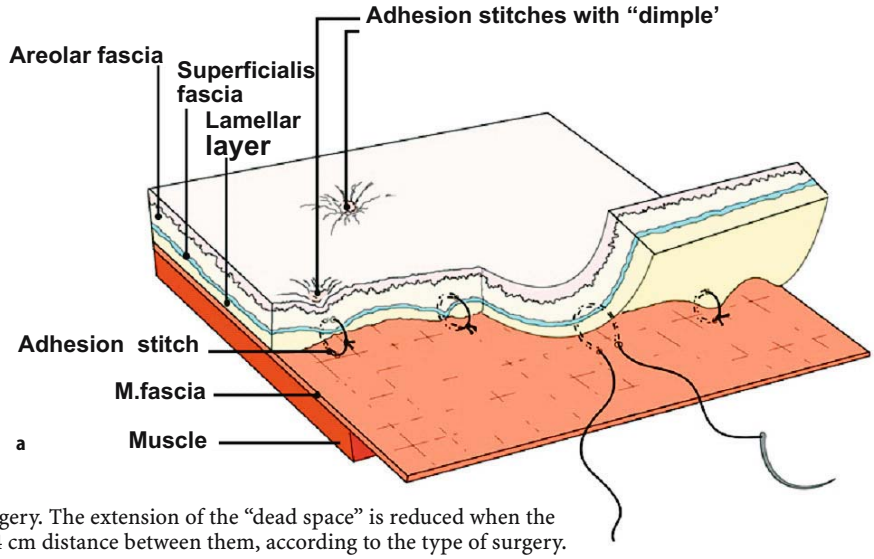


Fig. 56.3. a Schematic aspect of the adhesion stitches. They consist of isolated absorbable material that fixates two dissected cutaneous or non-cutaneous surfaces during the surgery. The extension of the "dead space" is reduced when the stitches are applied with up to 4 cm distance between them, according to the type of surgery.

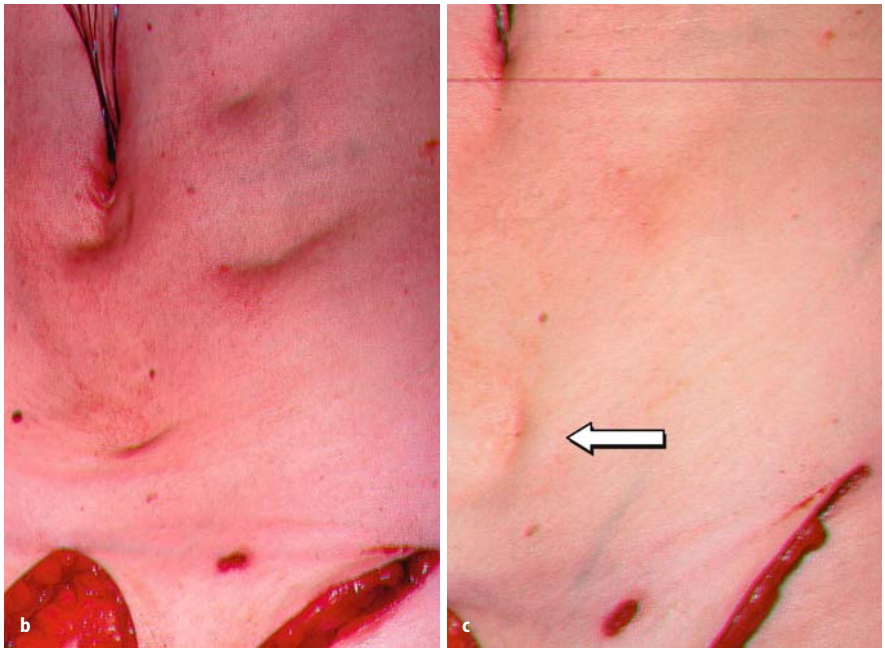


Fig. 56.3. (*Cont.*) In general they involve the subcutaneous tissue and the muscular fascia below, with or without the inclusion of superficialis fascia. Hematoma and seroma are reduced to a maximum by the avoidance of the skin flap sliding and possible dead space. When "dimples" are nitid in the skin (**b**, **c**) they must be removed and redone. Light "dimples" disappear after 2 or 3 days

isolated 2.0 or 3.0 absorbable stitches. In general 20 – 30 are required and take no more than 15 min to place. After each transversal line of stitches, the abdominal skin undermined flap must be stretched downward to estimate its correct position to reach the lower edge incision correctly without tension or to be anchored before it. All the time, evaluate for deep dimples. When evident remove the respective stitch and place another one with less bite volume. The final suture in the intradermal plane follows the surgeon's routine. No Penrose or suction drains are placed. The bandages are free according to each surgeon's routine. In our case, an elastic girdle or abdominal elastic belt is routinely used for 4 weeks (Fig. 56.4a–c).

56.2.3 Mini-extended Abdominoplasty

Mini-extended abdominoplasty, with or without combined liposuction in the same stage, involves skin flap dissection up to the xiphoid. The umbilical stalk is amputated at its base, maintaining the skin connection. After the recti muscle plication, isolated absorbable 2 or 3.0 adhesion stitches, with no more than 4 cm between them, are placed in lines and columns from the

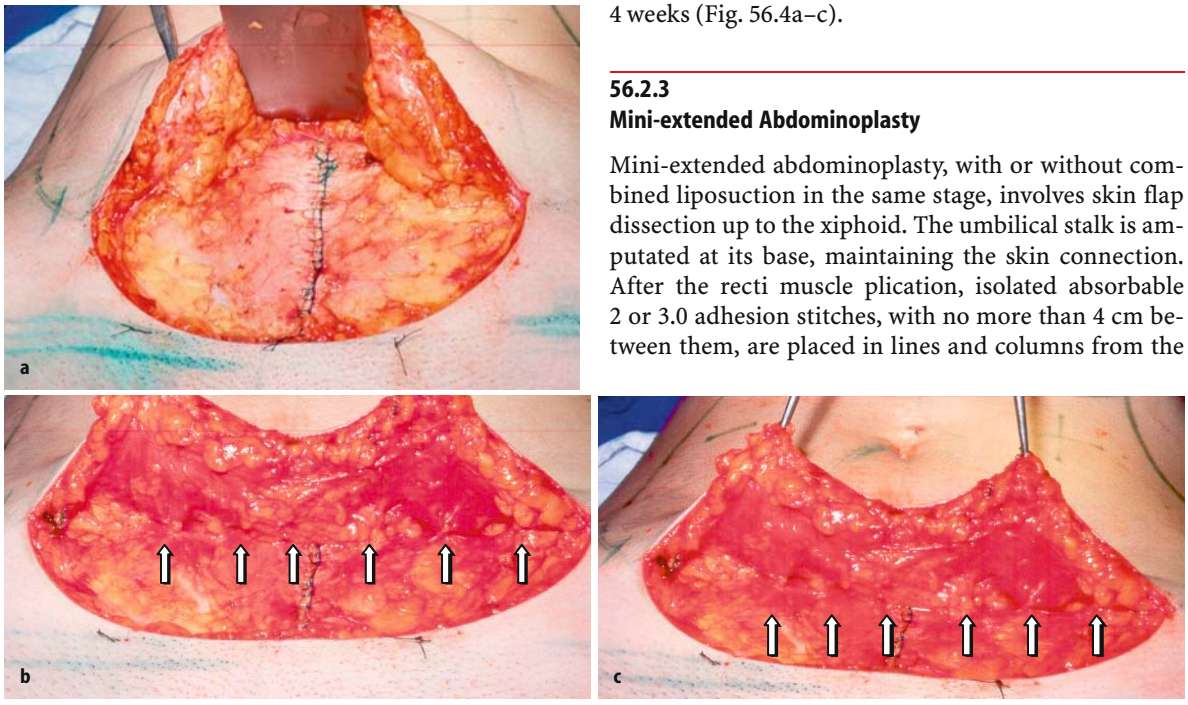


Fig. 56.4. a Non-extended mini abdominoplasty, with limited dissection up to the umbilical level without its mobilization, and recti muscular fascia plication. **b**, **c** Adhesion stitches are applied in lines and columns, 4 cm distant from each other. The undermined skin flap is anchored to the muscular fascia in all its extension, including incision at the edges. No drains are required

xiphoid down to the pubic incision. In general 30–35 stitches are applied and the time spent is around 20–25 min. At the umbilicus level these distances are also respected, because the stitches required to fixate the umbilicus again in its new position are considered a type of adhesion stitch. No drains are required. After one or two stitches in transversal lines are applied, the skin flap is stretched downward to estimate its correct position by the end of the process, to close the pubic suture line. Bandages have no specific use. Each surgeon's routine may be different. In general we use a micropore to cover the low transversal suture line, an abdominal gauze pad and an elastic girdle or even an abdominal belt (Fig. 56.5a–e).

56.2.4 Abdominal Low Transversal Pubic Incision

After the skin flap dissection at the hypo- and epigastrium, the umbilical mobilization, recti muscle plication and the resection of skin excesses, the adhesion stitches are applied in a similar way as described for extended mini abdominoplasty. Surgically, the abdominal skin flap excesses should be resected before the adhesion stitches are applied. We highly recommend 40–45 stitches and even 50. The time required is no longer than 30 min (Fig. 56.6). These stitches transfix the muscular fascia below and the skin flap subcutaneous tissue, biting into (or not) the skin superficialis fas-

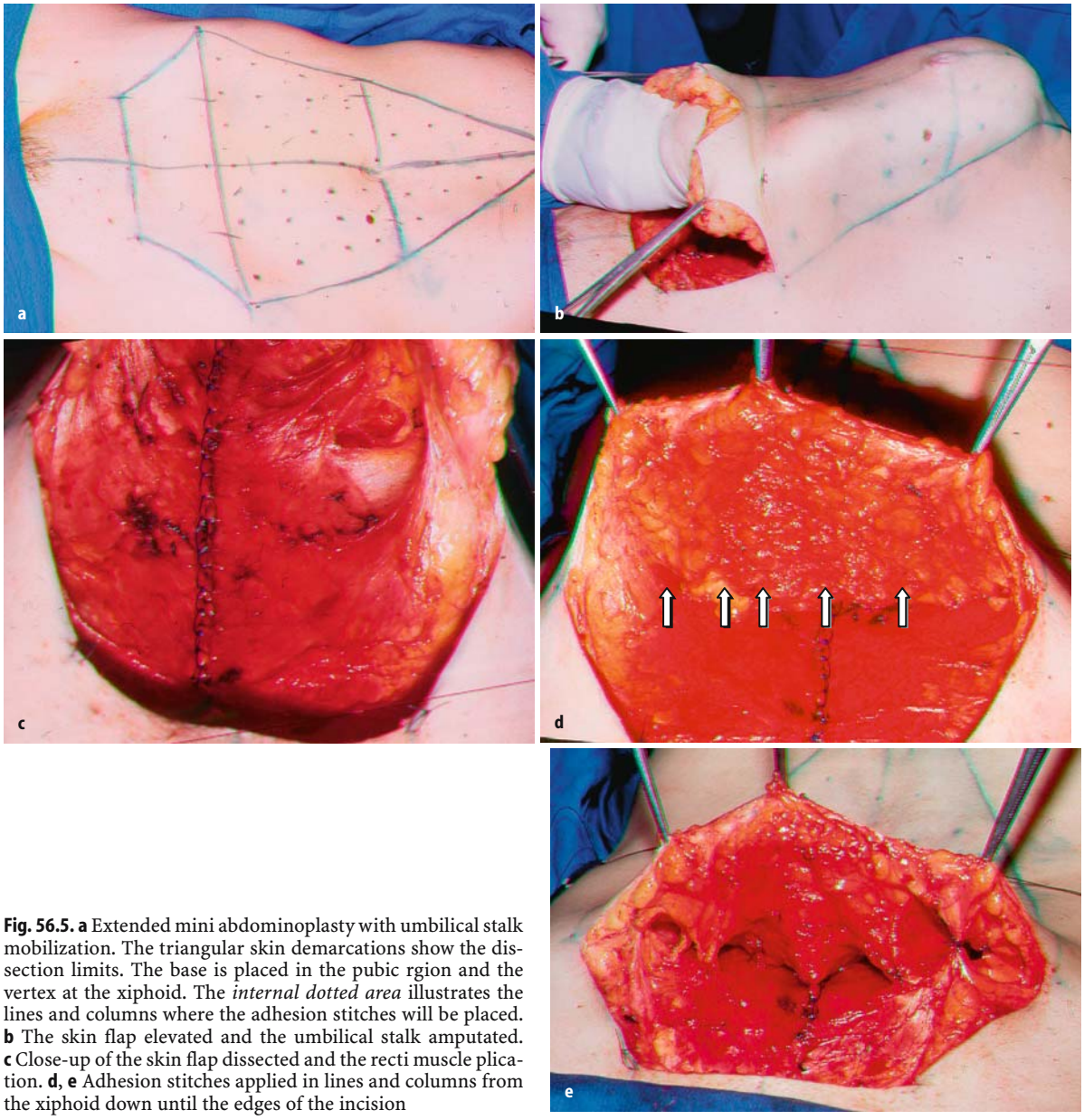


Fig. 56.5. a Extended mini abdominoplasty with umbilical stalk mobilization. The triangular skin demarcations show the dissection limits. The base is placed in the pubic rgion and the vertex at the xiphoid. The *internal dotted area* illustrates the lines and columns where the adhesion stitches will be placed. **b** The skin flap elevated and the umbilical stalk amputated. **c** Close-up of the skin flap dissected and the recti muscle plication. **d, e** Adhesion stitches applied in lines and columns from the xiphoid down until the edges of the incision

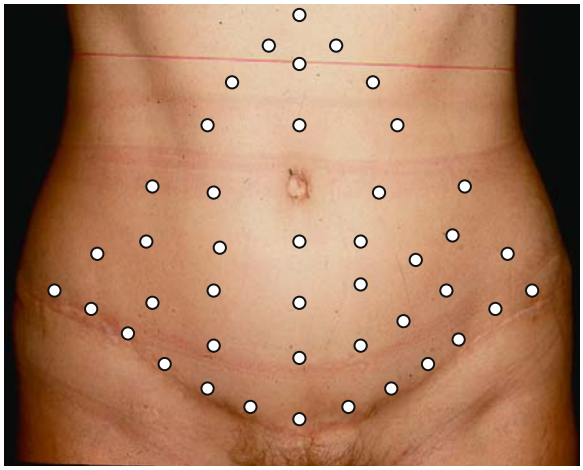


Fig. 56.6. Illustrative aspect of the skin projection of the adhesion stitches after low transversal pubic abdominoplasty with umbilicus mobilization (from 35 to 45 stitches). No drains are required

cia. The presence of evident "dimples" implies removal of the respective stitch and substitution by another with less voluminous bite. Mild dimples disappear spontaneously after no more than 3 days. Again, from the xiphoid down, after each two horizontal lines of adhesion stitches have been placed, the skin flap is stretched downward to estimate its correct position to reach and adapt with the lower transversal incision edge of the transversal skin incision. These stitches are applied in all its extension. The umbilicoplasty is performed according to the routine procedure, when the adhesion stitches reach its level. Again no drains are required (Fig. 56.7a–e). To conclude, adhesion stitches are also applied in the abdomen for breast reconstruction by TRAM flap.

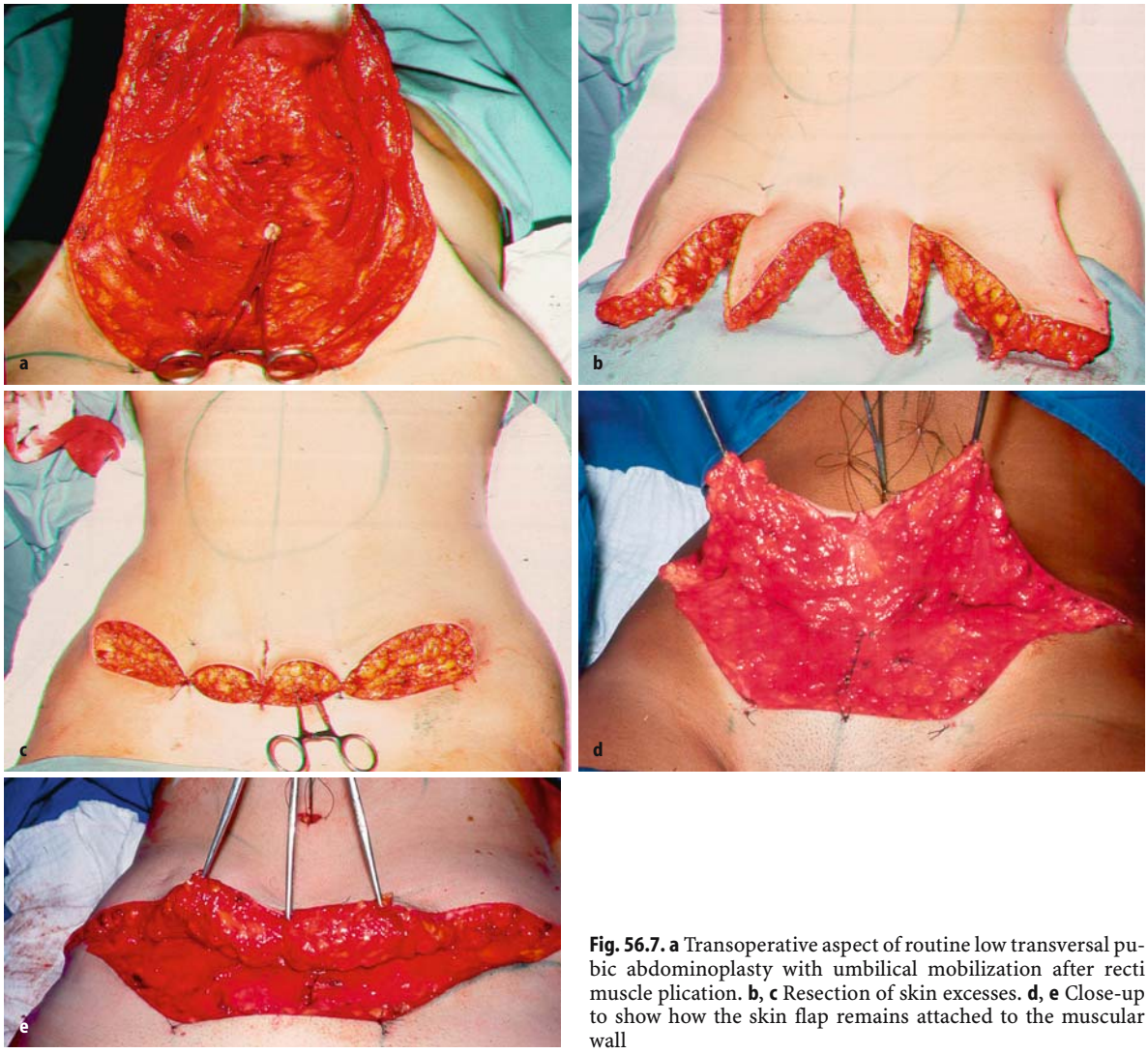


Fig. 56.7. a Transoperative aspect of routine low transversal pubic abdominoplasty with umbilical mobilization after recti muscle plication. **b**, **c** Resection of skin excesses. **d**, **e** Close-up to show how the skin flap remains attached to the muscular wall

56.2.5
Breast Reconstruction by Latissimus Dorsi Flap

Isolated absorbable 2 or 3.0 adhesion stitches are applied in lines and columns in the all dissected area extension, with no more than 4 cm between them, similarly to already described. No drains are required (Fig. 56.8a–g).

56.2.6
Axilla

The dead space left after the surgical "toilet" in the axillary region during the mastectomy for cancer can be reduced in its volume, with isolated absorbable 0 to 2.0 adhesion stitches, applied selectively in the muscle

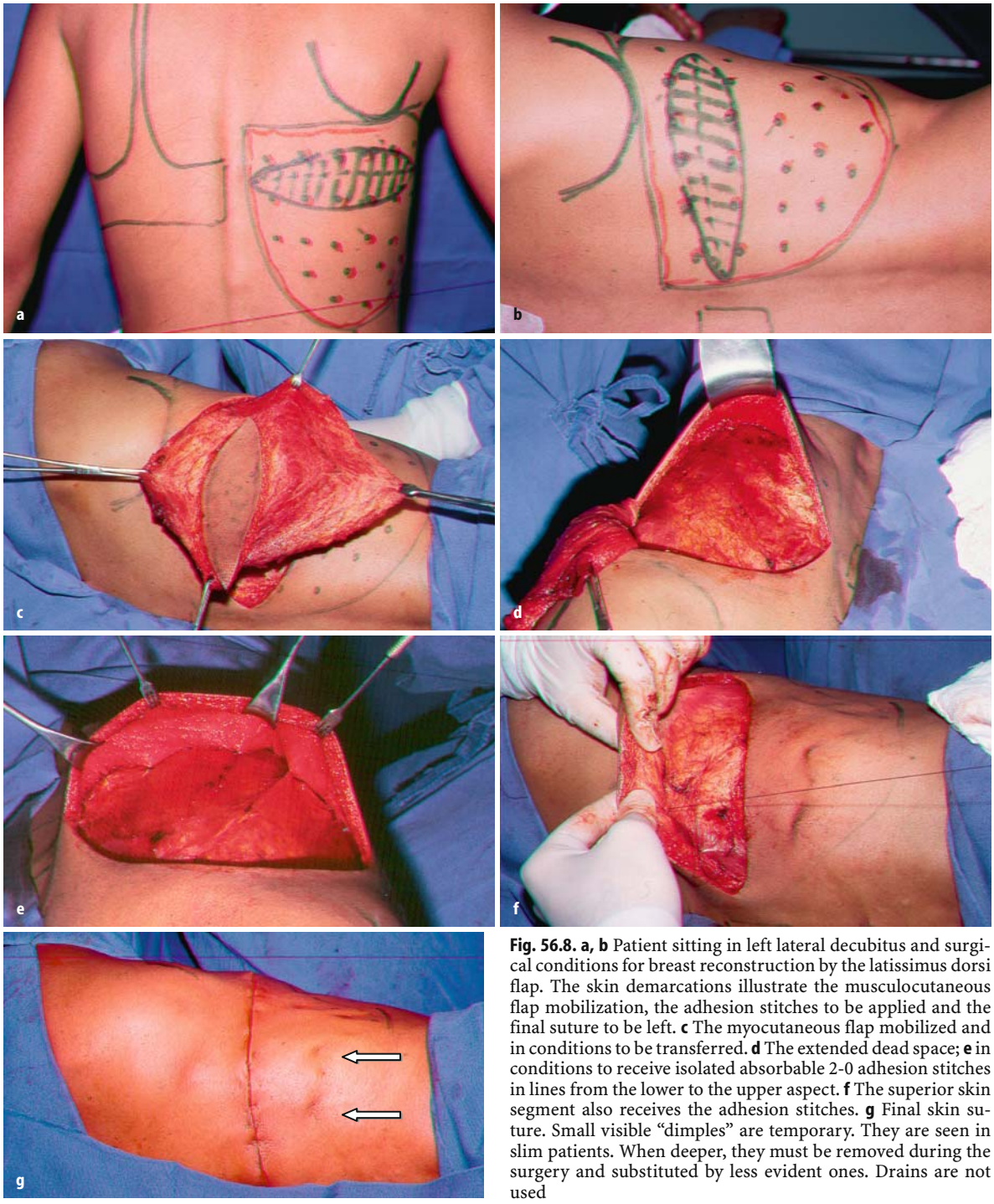


Fig. 56.8. a, b Patient sitting in left lateral decubitus and surgical conditions for breast reconstruction by the latissimus dorsi flap. The skin demarcations illustrate the musculocutaneous flap mobilization, the adhesion stitches to be applied and the final suture to be left. **c** The myocutaneous flap mobilized and in conditions to be transferred. **d** The extended dead space; **e** in conditions to receive isolated absorbable 2-0 adhesion stitches in lines from the lower to the upper aspect. **f** The superior skin segment also receives the adhesion stitches. **g** Final skin suture. Small visible "dimples" are temporary. They are seen in slim patients. When deeper, they must be removed during the surgery and substituted by less evident ones. Drains are not used

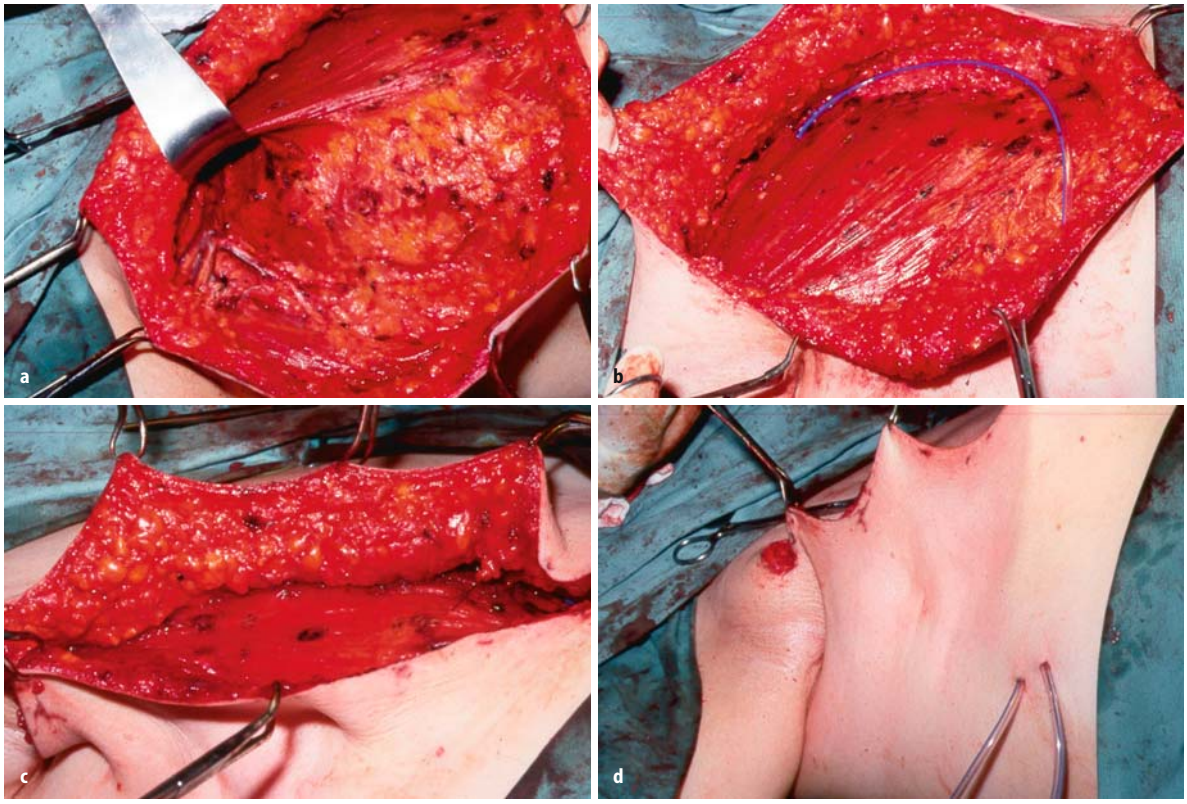


Fig. 56.9. a Close-up of the anatomic aspect after surgical axillectomy for breast cancer. The upper arm initially abducted 90° is adducted to 45° to reduce the dead space. Isolated absorbable 2-0 adhesion stitches are applied among the tissues after dissection involving muscles and their respective fascia. **b**, **c** Suction drains are inserted in the axillary pit, transfixing the musculocutaneous space (**d**) to merge through the skin. Drains are still in use because the dead space is not completely eliminated. On the other hand, the volume and the drainage period are reduced significantly

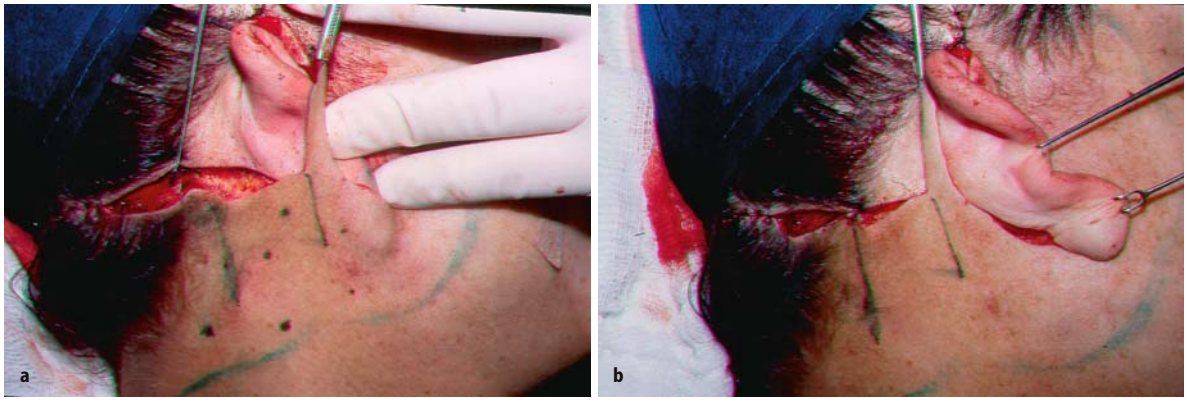


Fig. 56.10. In the face lift after skin undermining, hemostasia and resection of skin excesses, adhesion stitches are applied in the retroauricular region. **a, b** The retroauricular undermined skin flap is stretched by a Kocher clamp. Two parallel ink lines on the skin guide where the adhesion stitches should be placed for better positioning of the skin flap at the final suture

aponeurotic structures, after the upper arm is placed in adduction. There is no standardization and the number of stitches is different from case to case. The important thing is the maximum reduction of the dead space. Suction drains are used in this region (Fig. 56.9a–d).

56.2.7 Rhytidectomy

The pre- and postauricular dead space after skin excess resection receives isolated absorbable 4.0 adhesion stitches, in different numbers, but always following the procedures already described. In the preauricular re-

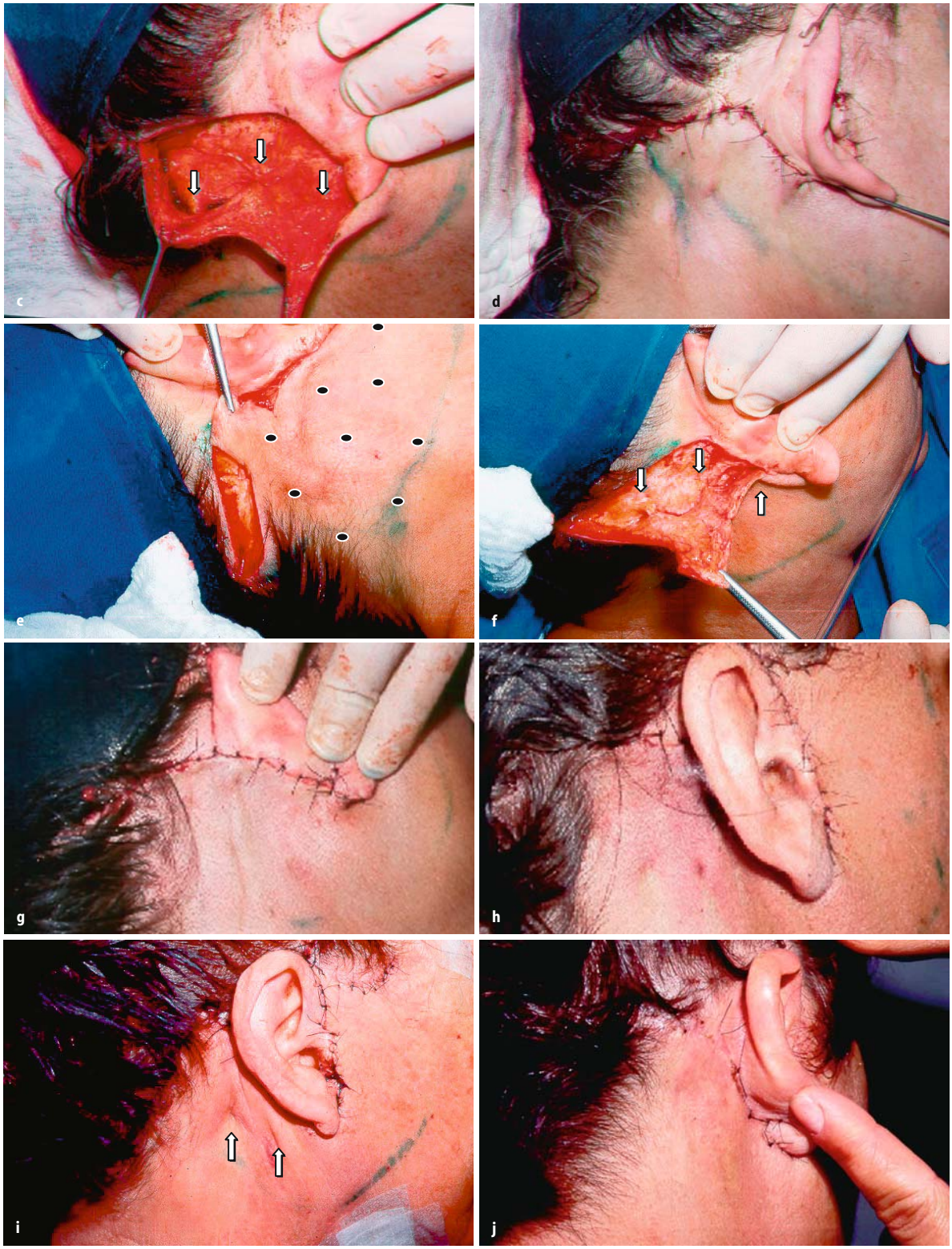


Fig. 56.10. c Close-up of the isolated absorbable 4-0 adhesion stitches in the skin shows how they remain distant from each other (six to nine stitches). **d** The skin flap final suture. **e, f** Another illustrative case, showing a similar procedure. **g, h** Routine aspect at the end of the surgery and 24 h postoperative period, to show the skin adhesion to the retroauricular muscle–aponeurotic plane. **i, j** Rarely, a serum-hematic small collection is present between the stitches, absorbable during the subsequent 5-day postoperative period. No puncture or drains are required

gion, three to four stitches are applied at the sideburn projection, and also three to four others in front of the ear and 1 – 2 cm distant from it. Minimal dimples can be acceptable; conversely, if one is evident, its stitch should be removed and replaced by another with less bite volume. In the postauricular region the number of stitches goes from six to nine, according to the extension of the dead space. After the skin excess resection, two provisional stitches hold the flap in its definitive position. Two parallel ink lines demarcate the scalp skin as a reference for application of the stitches to replace the flap again in its position (Fig. 56.10a–j). The provisional stitches are then removed and the skin flap eversion exposes the local muscle aponeurosis. The stitches are placed with 2 – 3 cm between them, from the limit of the undermining to the upper segment of the skin flap. Step by step, after each stitch is applied, the skin flap is repositioned to evaluate its correct situation according to the two lines before the final suture of the edges. No drains are used.

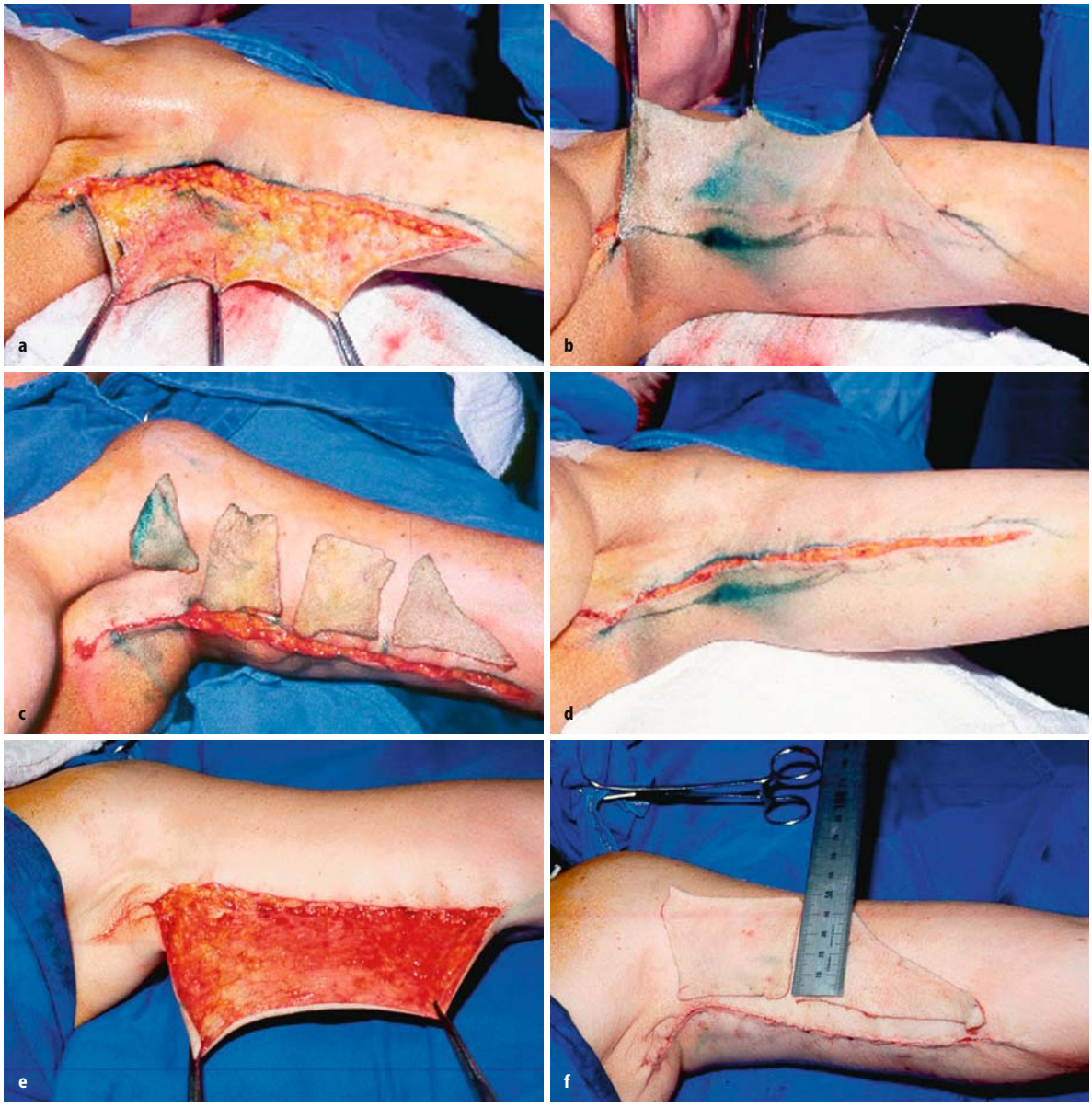
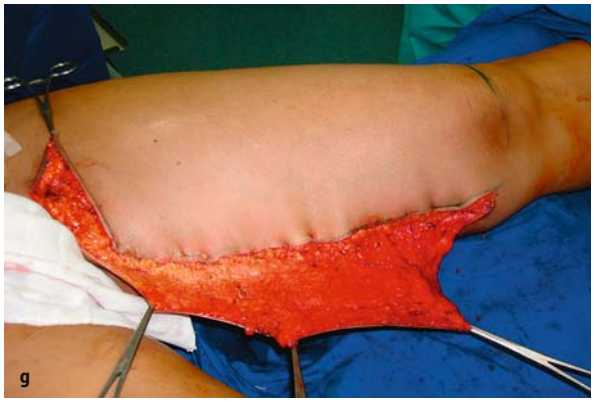
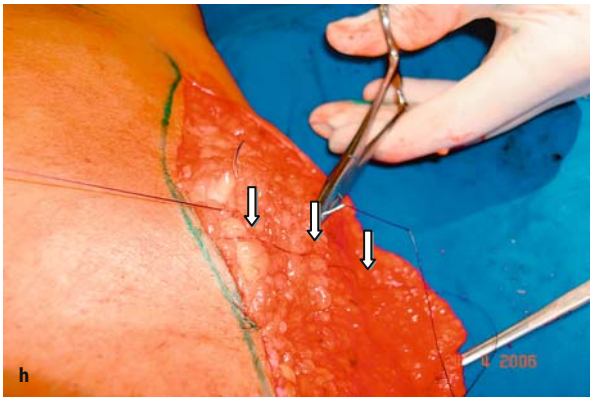


Fig. 56.11a–d. Brachioplasty at the dermal skin level dissection, extended to the limit of the amount to be resected. Adhesion stitches transfix the dermis of the skin incision, then the dermis at the limit of the dissected skin, and in "loops" the subcutaneous tissue between these two limits is transfixed. When tightened, the dermis and the subcutaneous tissue are joined in a block without dead space below. The distance between the adhesion stitches is no more than 1.5 cm. After the resection of the skin excess, the final suture follows the routine method. **e**, **f** Another similar illustrative procedure





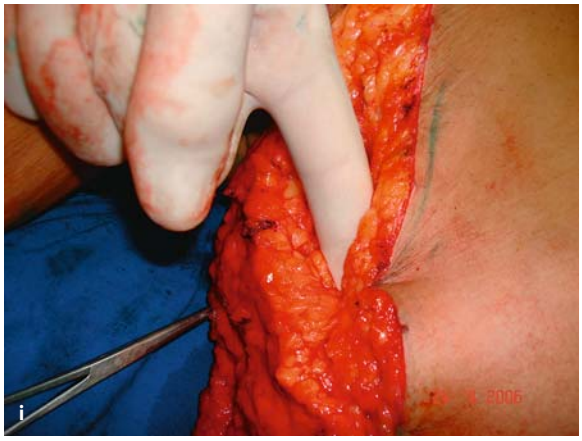


Fig. 56.11. (*Cont.*) In the axilla, the suture follows a similar routine, without a specific type of resection of excess. **g**, **h** In the thighplasty, similar procedures are applied. The adhesion stitches follow similar criteria described for brachioplasty, where the suture line transfixes the subcutaneous tissue in loops. **i** When tightened no dead space is left

56.2.8 Arms and Thighs

Arms and thigh plasties are similar regarding the dissection of skin excess and the resection of excesses. The adhesion stitches are also placed similarly to as already described to close the skin edges after resection. For all the incision absorbable isolated 2 and/or 3.0 stitches transfix the non-dissected skin edge, the dermis of the dissected skin flap and finally the in loop-like aspect, biting one and more times into the subcutaneous tissue between them. When tightened, the dermis and subcutaneous tissue involved are joined, leaving no dead space, and with the knot facing down (Fig. 56.11a–h). Then the skin excesses are resected and the final suture concluded according to the surgeon's routine.

56.2.9 Gynecomastia

Glandular gynecomastia requires glandular resection, after which a dead space is always present with the natural risks of hematoma and seroma according to the volume of tissue resected. In our practice, after the glandular removal, we leave a thin glandular pad below and with the same size of areola (no more than 3 mm thick). Adhesion stitches similar to those described for other regions are placed to eliminate the dead space below. In cases of even larger gynecomastia, these stitches are also applied in the surrounding spaces with fat tissue only.

56.2.10 Organized Seroma

There are four main types of organized seroma:

1. Small hard nodules detected by touch that can be treated with local heat and massage with the hand or with electric massager, that disappear after several sessions (Fig. 56.12a–c).
2. Hard fibrous nodules treated with cannula that create several tunnels in different directions to release the hardness (Fig. 56.13a–d).
3. Thick and hard-shelled fibrosis with a cavity and blood inside. Surgical resection is the only solution (Fig. 56.14a–d).
4. Organized seroma with a cavity delimited by a thin pseudo-membrane. The problem is solved with adhesion stitches to collapse the dead space without removing the pseudo-membrane (Fig. 56.15a–d).

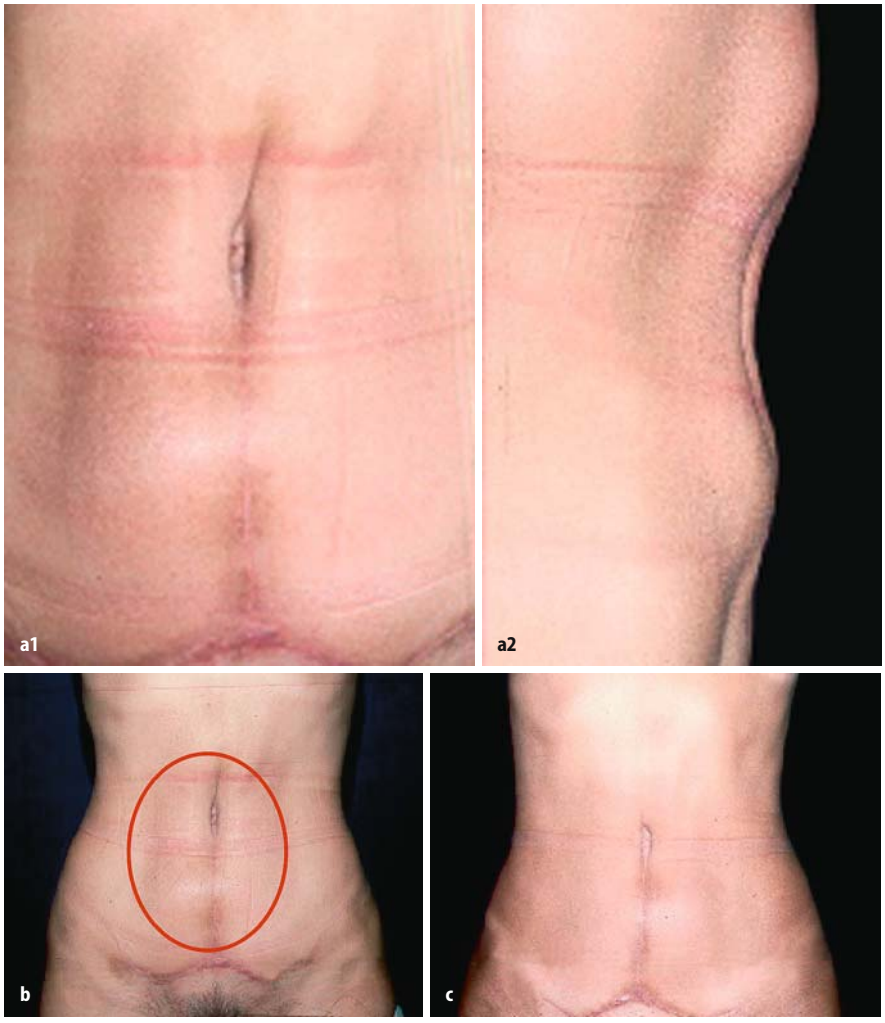


Fig. 56.12. a Two months postoperative period after inverted T abdominoplasty shows two organized seroma bilaterally placed near the vertical midline scar. **b**, **c** After several sessions of local heat and massage, the bulging and hard skin reaction is reduced completely

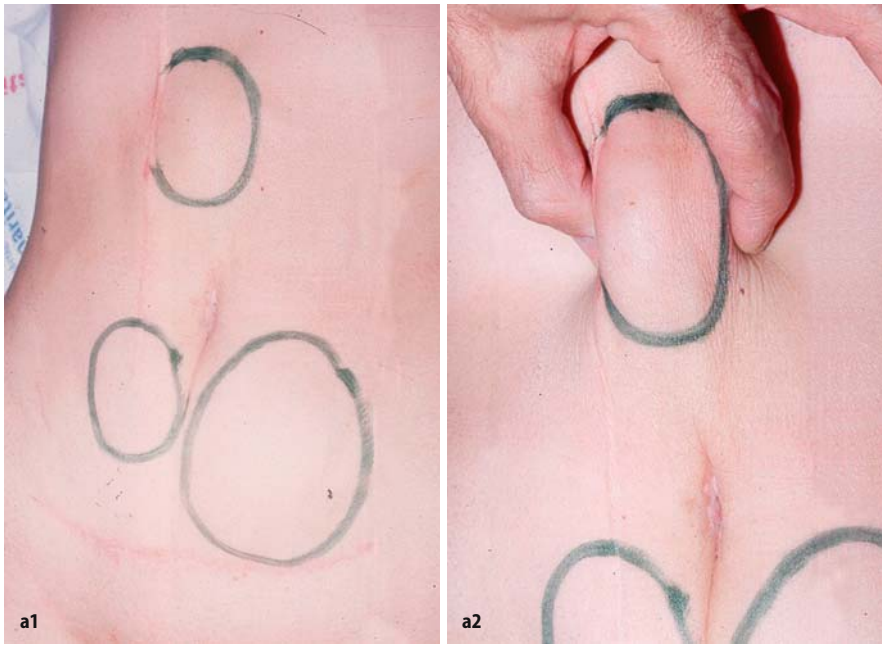


Fig. 56.13. a Four months postoperatively after mini extended abdominoplasty there are three hard nodules in the skin after fibrotic reaction after segmented seroma.

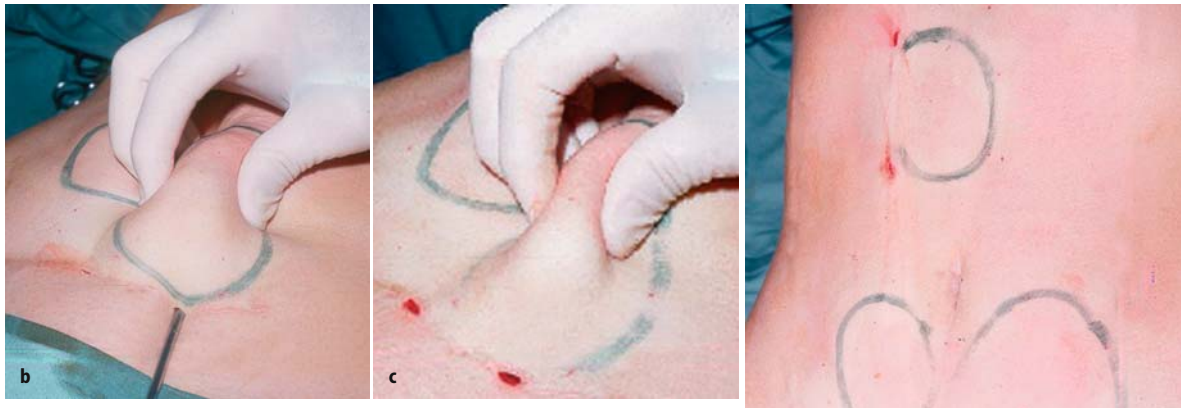


Fig. 56.13. b–d Several tunnels with a 2-mm cannula performed in a criss-cross orientation fragmented and released the fibrosis

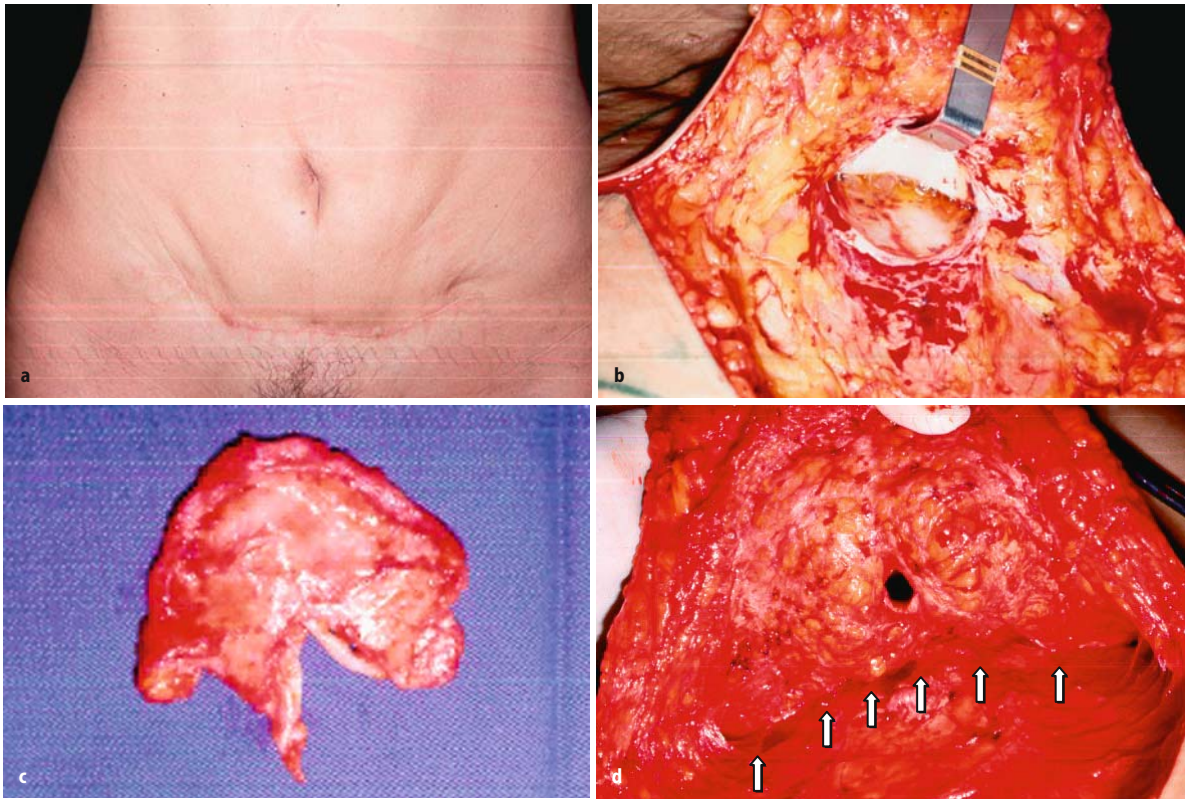


Fig. 56.14. a Patient submitted for a previous mini abdominoplasty presents a bulging and wrinkled hypogastrium with evident unaesthetic aspect. **b** Abdominal skin flap dissection up to the xiphoid shows an organized and hard fibrous seroma with a cavity inside. **c, d** The capsule is resected completely and adhesion stitches are applied within similarly to the conventional abdominoplasty

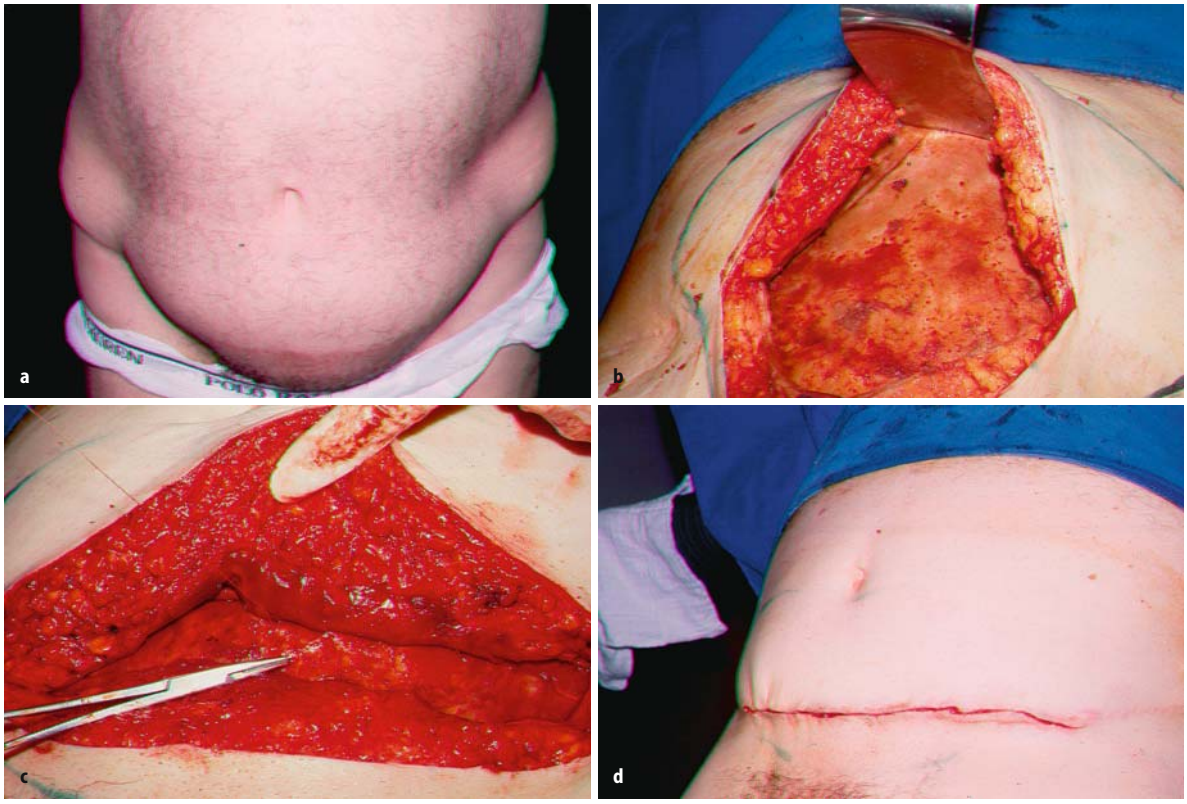


Fig. 56.15. a A 62-year-old male patient, 4 months postoperatively after abdominoplasty, shows a bulging hypogastrium from a voluminous seroma bursae. Successive punctures, fibrin and other glue materials injected were unsuccessful in eliminating the problem. **b**, **c** Transoperative aspects show the serous pseudo-membrane and adhesion stitches placed a distance of 3 cm from each other, without the membrane resection. **d** Final routine suture, without recurrence of seroma

56.3 Discussion

In 1996 we started to present the use of adhesion stitches at scientific meetings, and in 1998 we made our first publication, but there is still a limited receptivity by plastic surgeons and in the different surgical specialities to the method. The use of drains represents a significant lack of confidence in the value of adhesion stitches in avoiding hematoma and seroma. Unfortunately, so far these unpleasant problems have been seen more frequently in the patients of reluctant surgeons who do not want to change their routine. In the last few years, credibility has increased continuously, in particular among surgeons with frequent seromas in their cases. Presently, the number of surgeons in Brazil and abroad who are using these stitches in their surgical routine is quite significant. We have selected different types of aesthetic and reconstructive surgery, to describe how we have standardized the use of adhesion stitches, in relation to the distance between them, their types, etc. The time required differs according to their number, the region operated on and the surgeons' training. Comments on different surgeries illustrate these aspects.

In reduction mammaplasty, for example, the stitches anchor the breast already mounted on the major pectoralis muscle fascia, avoiding the use of drains. Their number depends on the surgeon's criteria and the type of surgery. We have been using 2 or 3.0 isolated absorbable stitches. No hematomas have been detected in the immediate or mediate postoperative period. In the axillectomy with ample surgical "toilet," there is a great limitation to completely eliminating the dead space. Surgeons who routinely use suction drains and only skin sutures without adhesion stitches report they need 2 or more weeks of drainage and that there is evident local fibrosis. In cases like these, with adhesion stitches, suction drains are placed, but a reduced drainage period of 4–5 postoperative days is always reported. With the use of more recent technology such as the "sentinel ganglion" evaluation, the axillectomy is less aggressive and more selective with a better and more rapid healing period. In the conventional low pubic transversal incision abdominoplasty, the time required to apply 40–45 stitches is around 20–25 min. Surgeons who use this procedure but with no more than 10–15 stitches and suction drains still report seromas. On the other hand, all report that the drainage has become signifi-

cantly reduced, dropping to less than 40 cc after the 2nd day of the postoperative period, when the drains are removed. Effectively there is a reduced number of stitches, with more than 4 cm between them. This procedure allows for a fragmented type of seroma formation, even with the use of an elastic girdle. The adhesion stitches allow patients to be freely seated in a normal position such as when working at a computer, playing cards or playing the piano, without the risk of the skin flap sliding or not "gluing" to the muscular fascia below even when wearing the girdle. This orientation offers better comfort to patients during the first postoperative week, instead of the requirement to be in a position of recline or slightly bent forward when walking as used to be recommended by the great majority of doctors. Another significant improvement in the immediate postoperative period after rhytidectomy is the use of these stitches in the retroauricular region. No more than six to nine stitches is required, taking around 10 min for each side. When the skin flap is too thin, small dimples below the stitch should be avoided. When present and evident, it should be removed and replaced by another with a less aggressive bite. We had rare superficial dermal necrosis with local ischemia below the stitch, healing by secondary intention, leaving a 2- to 3-mm-diameter achromic area, which was never complained of by the patients. In the temporal and preauricular regions these stitches are also applied. In the other surgeries described and different regions of the body, the use of these stitches follows the same criteria, with the scope of collapsing the dead space and avoiding sliding to the dissected surfaces. Finally when there is an organized seroma that does not disappear after several punctures and irritant products to make the surfaces glue, the solution is the surgical opening and the use of adhesion stitches following the described principles, without surgical resection to the pseudomembranes. This detail avoids bleeding and the surfaces adhere naturally. Over the local area of the seroma, according to the region, an extracompressive bandage with tailored sponge material the size of the area is applied over the 3 – 5 days immediately postoperatively. The patients is able to remove it for hygienic necessities.

In conclusion, the use of drains combined with adhesion stitches is a reflection of the surgeon's insecurity about the credibility of the method. Only with time will this attitude improve. We particularly believe that main cause of this situation is the distance and time required for the application of more stitches. Several more minutes taken during surgery will bring all the benefits of avoiding the presence of seroma, the time required in the office to perform the punctures and the eventual necessity of submitting the patient to surgery again. We have had the opportunity to resolve situations like this in patients operated on twice for seroma problems after routine abdominoplasty, where the doctor had removed the pseudo-membrane without applying adhesion stitches. Lawsuits against doctors with regard to the sequelae of seromas have become a reality. Without time prevision, future lawsuits due to the sequelae of seromas where no adhesion stitches were applied in the dead space in the area operated on will characterize malpractice, negligence and imprudence.

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Lipoabdominoplasty

57

R. Graf, D. Pace, L.G. Neto, L.R. Araujo, R.C. Damasio, R. Rippel, T. Al-Yafi

57.1 Introduction

Lipoabdominoplasty is a technique that combines liposuction with reduced undermining and traditional abdominal skin flap resection. The wide undermining of the abdominal flap is the most common cause of complications such as skin necrosis, seroma and hematoma. These complications can be reduced using an abdominoplasty technique with limited undermining and preservation of perforators to the flap, including the periumbilical vessels, which are kept intact, providing a better blood supply to the flap.

Avelar, in 1985, described a technique of liposuction associated with abdominoplasty for patients with prominent abdomen with fat deposits supra- and infraumbilicus and muscular laxity, and in 2000 he described abdominoplasty without undermining and removal of fat was done through liposuction with only skin resection in the lower abdomen [1, 2].

Matarrasso [11, 12], in 2000, described the combination of liposuction with abdominoplasty as a way to preserve the blood supply to the abdominal flap to minimize the undermining of the flap.

One of the most interesting newly described techniques is abdominoplasty with selective undermining of the abdominal flap, using liposuction of the entire abdomen, including the infraumbilicus and flanks, developed by Saldanha [13, 14]. This technique consists of suctioning the subcutaneous fat of the entire abdomen and resection of the infraumbilicus skin and remaining subcutaneous fat, undermining the midline between the medial edges of the rectus abdominus for muscle plication, therefore preserving most of the blood supply to the abdominal wall.

In order to prove the integrity of the perforators and the safety of this procedure, a study was performed with Doppler flowmetry, which is an important non-invasive diagnostic method, to evaluate the flow capacity of the vessels that nourish the abdominal flap [9]. Ultrasound combined with Doppler flowmetry was used to detect, evaluate and quantify the blood flow. A Doppler flowmetry study of the abdominal wall was performed before the surgical procedure and on the 15th postoperative day of lipoabdominoplasty.

In a series of 20 patients the blood supply of the lower and upper abdominal wall was evaluated and also the superior and inferior epigastric arteries and their respective myocutaneous perforators were also evaluated [9]. This study confirmed the preservation of the perforator arteries in the periumbilicus area and right upper quadrant after abdominoplasty with liposuction and reduced undermining. Liposuction did not affect the perforators more than 1 mm as demonstrated by Doppler flowmetry in the postoperative period. There was an increase in the caliber of the arteries of 9 %, and a flow increase of 56 % of the branches identified. This increase may have occurred due to surgical trauma that generated vasodilatation and a decrease of minor perforators.

The patient selection for this technique is based on the classification of Bozola, who classified the abdomen on a clinical basis, suggesting a specific treatment for each type [6]: type I: fat deposit, normal musculoaponeurotic layer and no excess skin; type II: mild skin excess, normal musculoaponeurotic layer, fat may or may not be in excess; type III: mild skin excess, laxity of the infraumbilical area of the musculoaponeurotic layer, fat may or may not be present; type IV: mild skin excess, laxity of the infraumbilical area of the musculoaponeurotic layer, fat may or may not be in excess; type V: large skin excess, laxity of the musculoaponeurotic layer with or without hernias, fat may or may not be in excess.

The lipoabdominoplasty technique with traditional abdominal flap resection is indicated for types III–V according to Bozola's classification.

57.2 Operative Approach

57.2.1 Markings

The skin is marked with the patient in the standing position. The midline and the suprapubic inferior line are marked, and extended laterally towards the anterior superior iliac spine, observing previous scars and natural creases to place the future scars. The superior line is marked according to Baroudi's technique [3, 4], using the bicycle handlebar incision. The areas to be suctioned are marked up to the inframammary crease superiorly and laterally to the flanks (Figs. 57.1, 57.2).

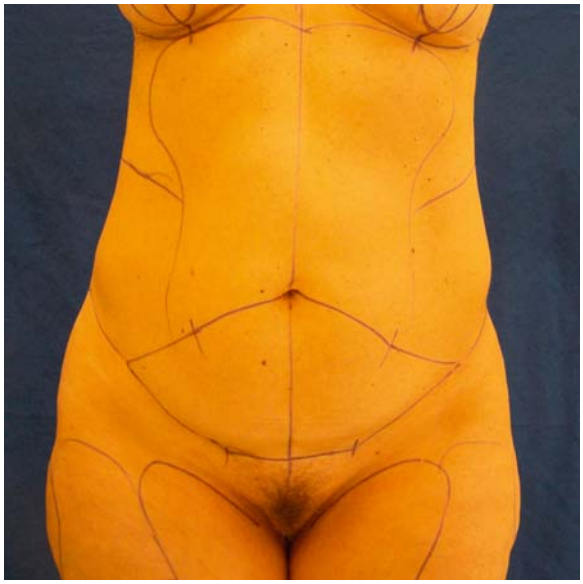

Fig. 57.1. The markings. The area marked below the umbilicus will be resected and the area marked above the umbilicus will be liposuctioned. The drawings show the areas of liposuction on the flanks, inner and lateral thighs

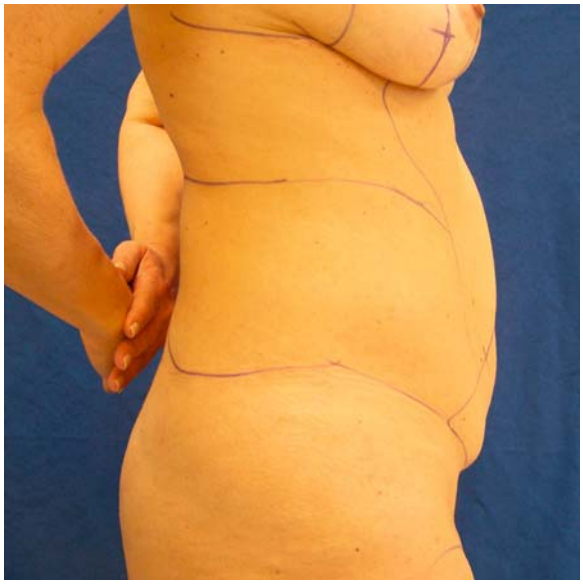

Fig. 57.2. Markings of liposuction areas. Lateral position

57.3 Technique

Surgery is done with the patient under epidural anesthesia in most cases, or general anesthesia in some selected patients. Infiltration for liposuction is done with 1:500,000 adrenaline solution and the superwet technique is used. The procedure is performed with 3.0 and 3.5 mm Mercedes cannulas beginning in the deep layer of fat and later superficially in the flanks and upper abdomen, except for the area above the umbilicus (Fig. 57.3). No suction is done at the lower abdomen. After the liposuction, the lower abdomen flap is under-

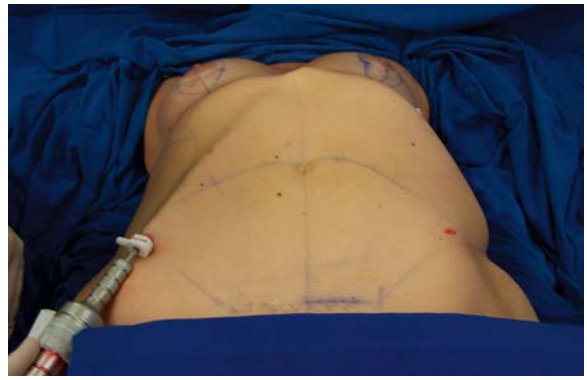

Fig. 57.3. Liposuction of the upper abdomen

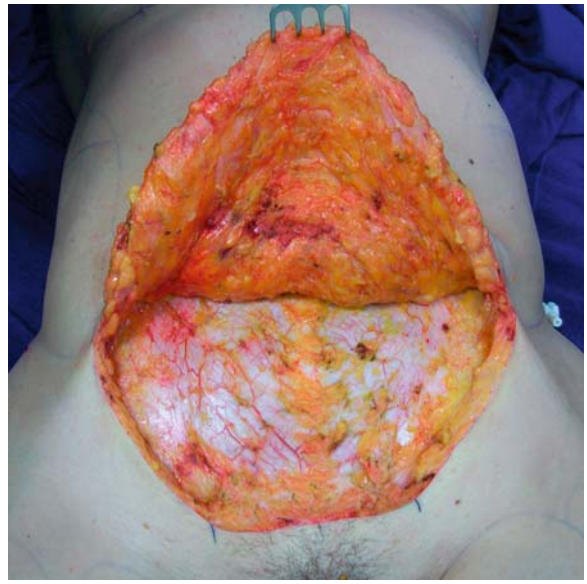

Fig. 57.4. The lower abdomen flap is undermined up to the umbilicus

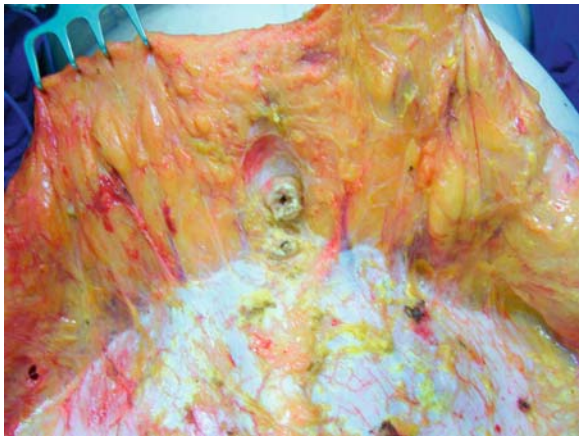

Fig. 57.5. The umbilicus is released

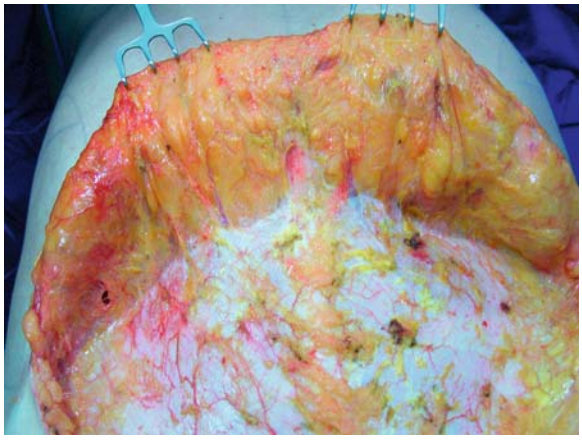

Fig. 57.6. The perforator vessels are preserved

mined up to the umbilicus (Fig. 57.4), and the skin around it is incised as well. The umbilicus is transected near its base (Fig. 57.5).

The limited supraumbilical undermining is done in the midline, until 1.5 cm lateral to the medial border of the rectus abdominus muscle bilaterally up to the xiphoid appendix, allowing adequate fascia plication and at the same time preserving the perforators. In the lower abdomen, plication is also performed with black nylon 0 continued sutures, down to the pubis (Figs. 57.6 – 57.9). The umbilicus skin is resected from the abdominal flap (Fig. 57.10).

The patient is placed in the Fowler position (semiseated) and sutures placed from Scarpa's fascia down to the rectus's fascia for flap fixation to the abdominal wall as in Baroudi's technique. This is done from the xiphoid appendix down to the umbilicus in the midline. Next, the abdominal flap traction and resection is performed (Fig. 57.11), and after the neoumbilicus is created by defatting the area of the new position of the umbilicus and fixed to the aponeurosis with 3.0 Monocryl (Figs. 57.12 – 57.14), Baroudi's sutures are also done down to the pubic area (Figs. 57.15 – 57.17). This ap-

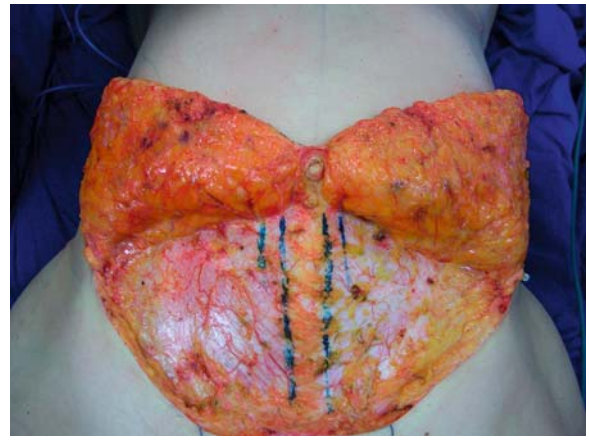

Fig. 57.7. The infraumbilical undermining. The inner marks represent the medial border of the rectus abdominus muscle. The lateral marks are 1.5 cm lateral to the medial border of the rectus abdominus muscle

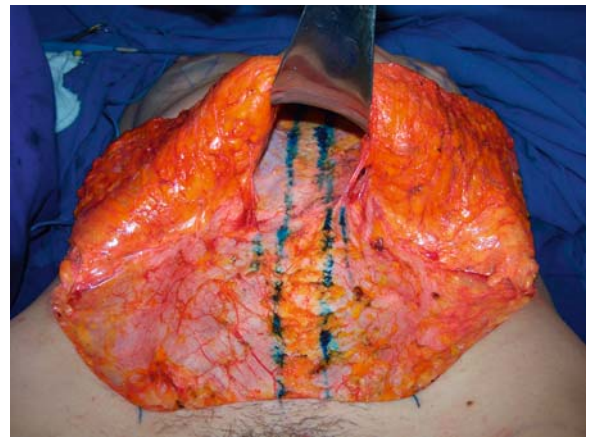

Fig. 57.8. The supraumbilical undermining. The inner marks represent the medial border of the rectus abdominus muscle. The lateral marks are 1.5 cm lateral to the medial border of the rectus abdominus muscle. Note the reduced undermining in the upper abdomen

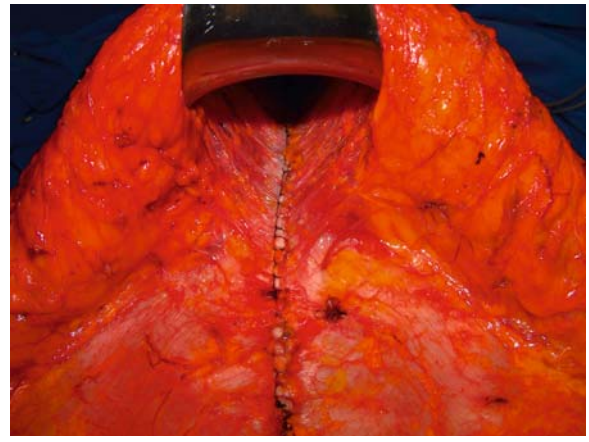

Fig. 57.9. The plication of the rectus aponeurosis is performed with 0 nylon to the xiphoid appendix down to the pubis. Note that there is no undermined area after the plication

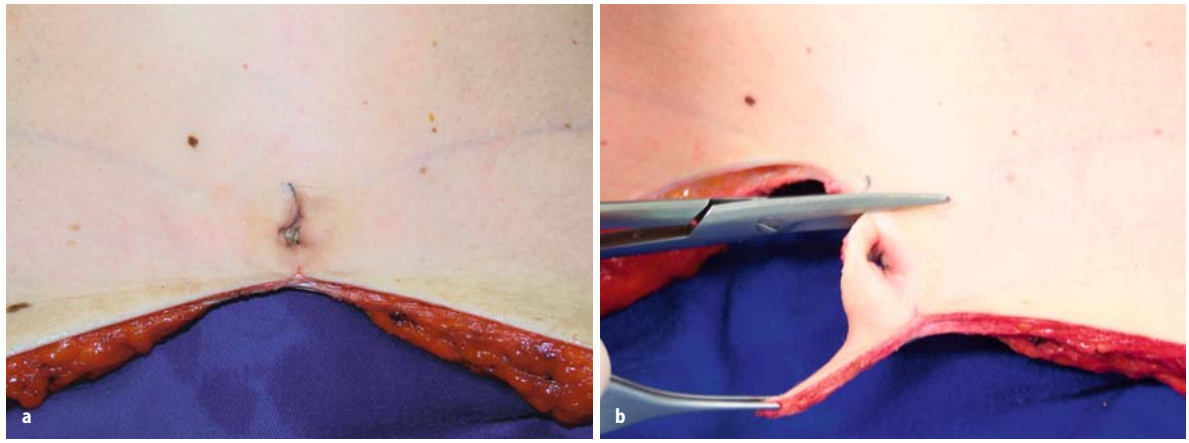

Fig. 57.10. a The umbilicus in the abdominal flap. **b** The resection of the umbilicus from the abdominal flap

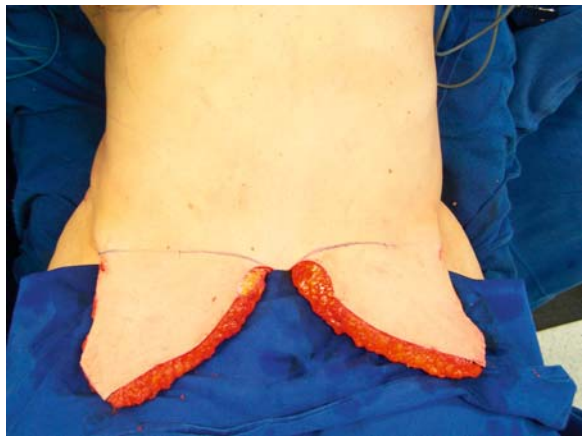

Fig. 57.11. The abdominal flap traction and resection is performed

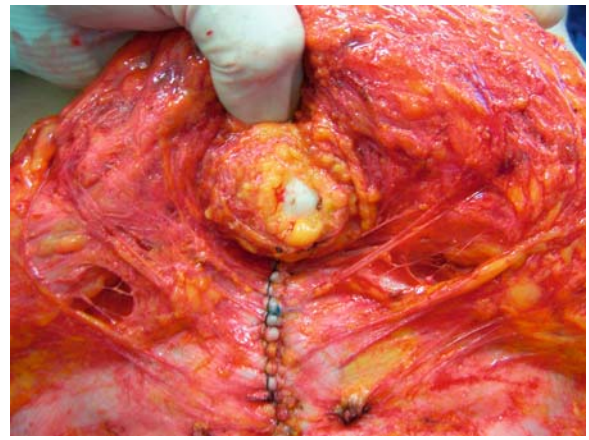

Fig. 57.12. The fat around the new umbilicus is removed exposing the dermis

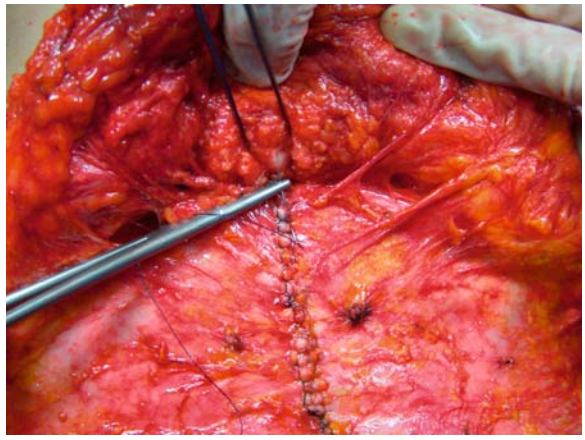

Fig. 57.13. Stitches with 3.0 Monocryl are done between the dermis and aponeurosis

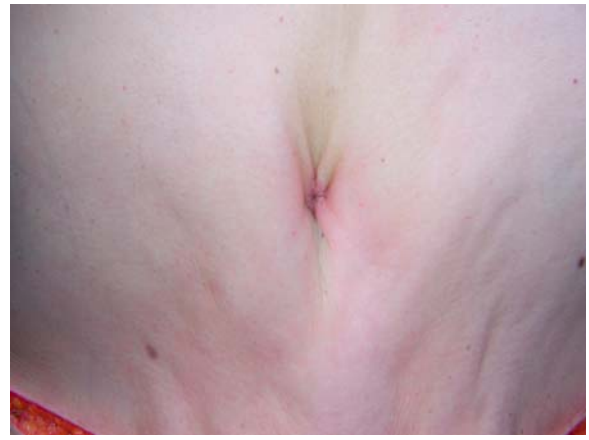

Fig. 57.14. The final aspect of the umbilicus

proach helps the flap fixation and therefore to keep the final scar in a lower position, and also to prevent seromas.

Wound edges are sutured in a layer-by-layer fashion with 3.0 Monocryl and the skin is closed with 4.0 clear Monocryl and also Dermabond (Fig. 57.18). Suction drainage is not used except if the patient was submitted to a huge liposuction. Compressive dressings are used and Fowler's position is recommended at home for 1 – 2 weeks postoperatively. Dressings are changed every 24 h in the postoperative period.

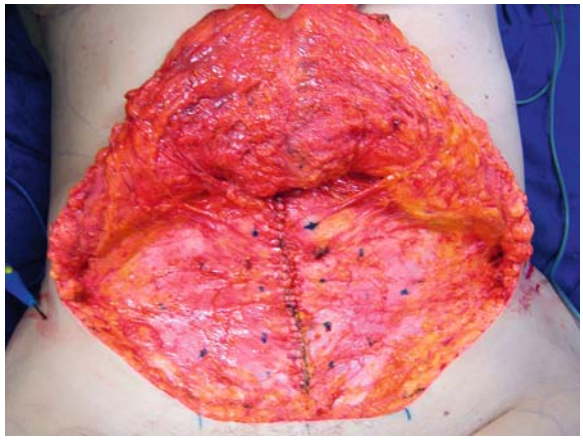

Fig. 57.15. The markings represent the Baroudi's sutures done between Scarpa's fascia and the aponeurosis to prevent collection and dead space

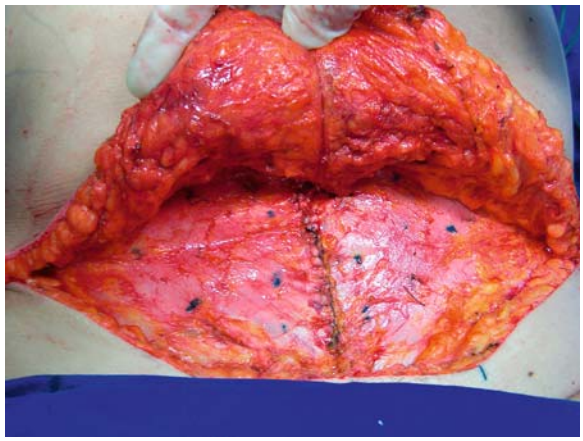

Fig. 57.16. Baroudi's sutures

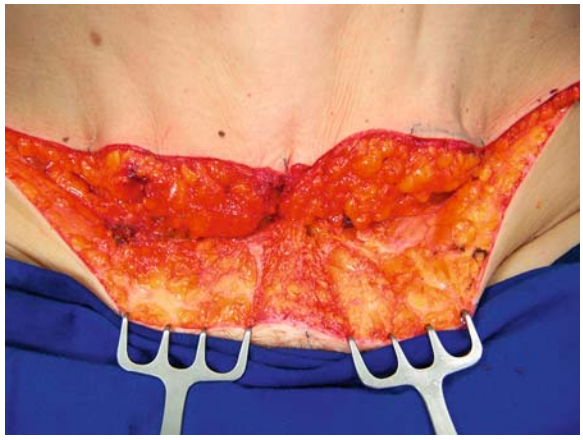

Fig. 57.17. Baroudi's suture in the pubic area to keep the scar lower

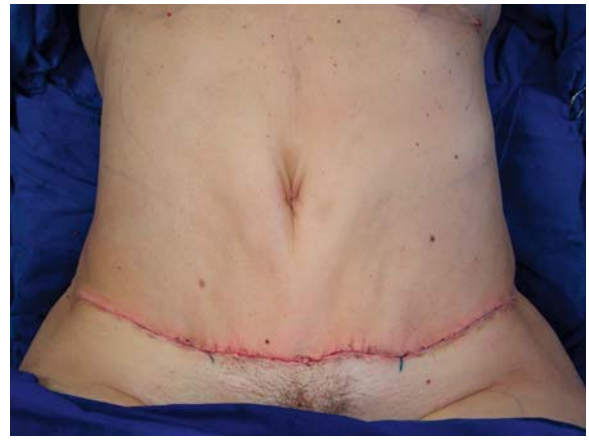

Fig. 57.18. The skin closed

57.4 Postoperative Care

Due to the reduced undermining, postoperative evolution of most patients is very good, and as the perforators are all left intact the blood supply is excellent. For 2 weeks, edema is observed and starts to decrease in 1 – 2 months, improving body contouring significantly. A garment is used for 2 months.

57.5 Complications

Complications are much less likely to occur with this technique, compared to abdominoplasty with wide undermining such as flap necrosis and seroma.

57.6 Results

The lipoabdominoplasty technique can be performed in patients with severe degrees of abdominal laxity. The liposuction improves the body contour and the final results, avoiding the need for secondary procedures such as liposuction for the upper abdominal wall as is done after traditional abdominoplasty (Figs. 57.19 – 57.23).

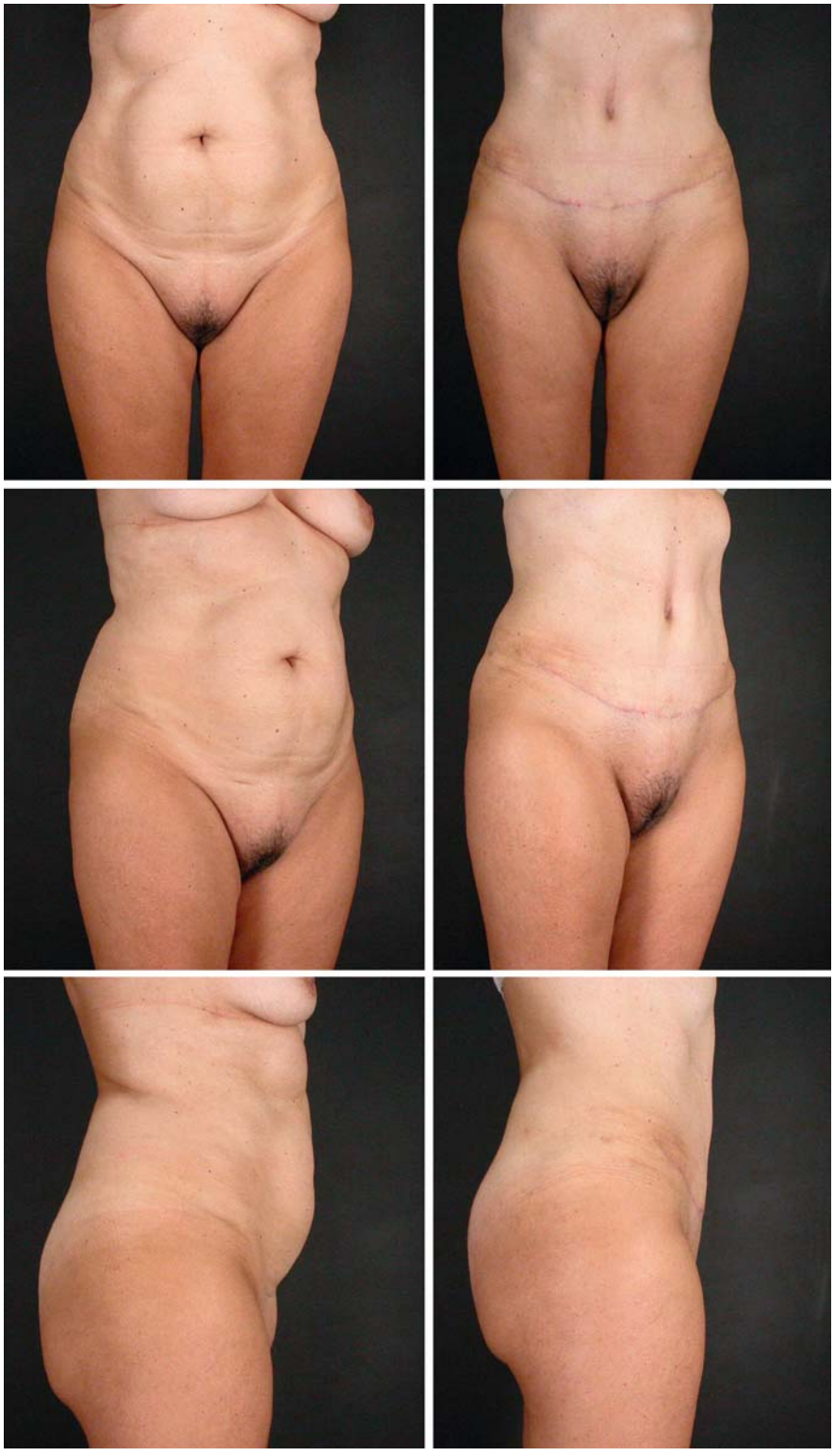

Fig. 57.19. *Left* Preoperative view of a 47-year-old patient. *Right* Postoperative view at 6 months after lipoabdominoplasty, suction on the flanks and back

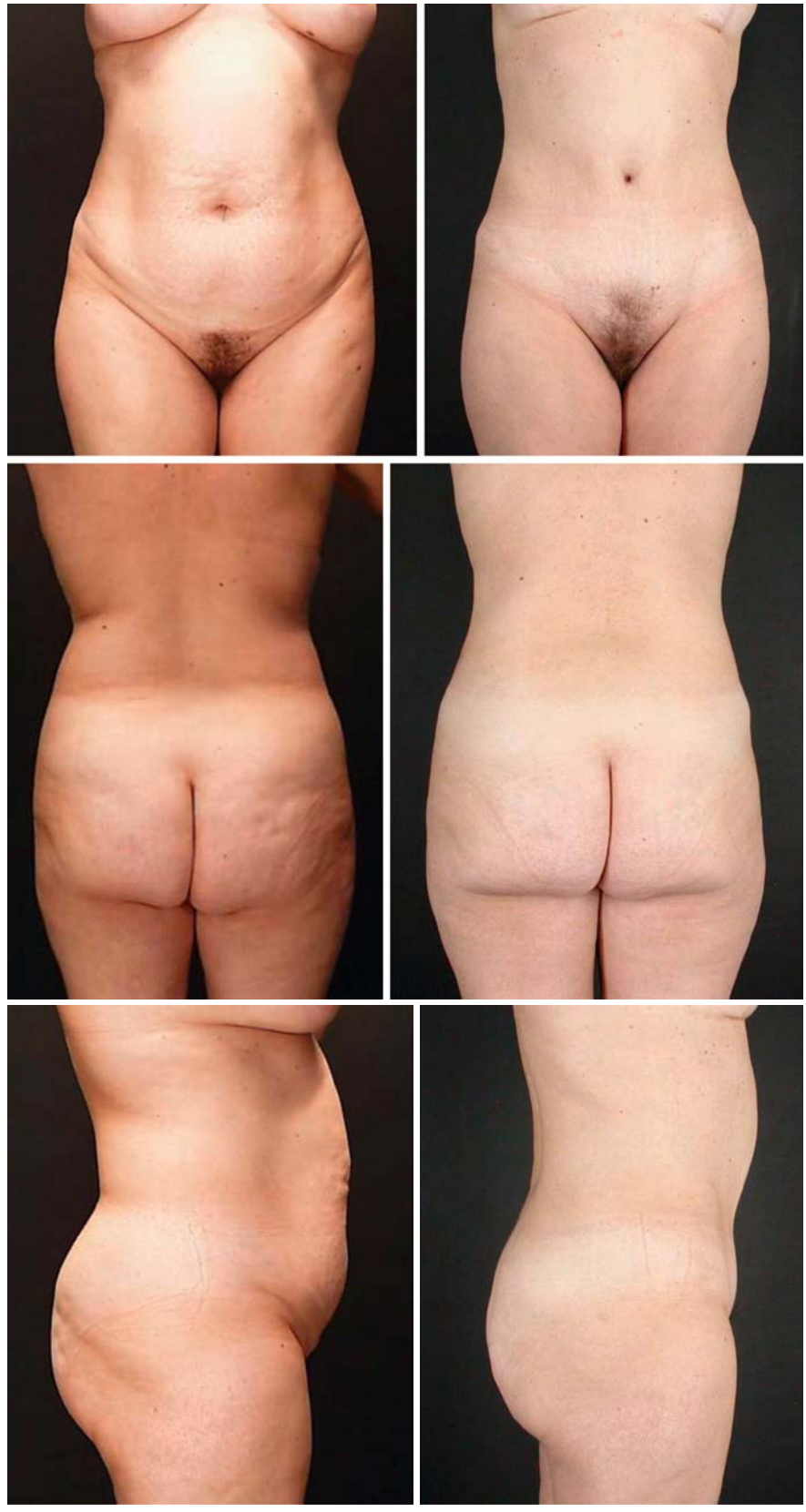

Fig. 57.20. *Left* Preoperative view of a 35-year-old patient. *Right* Postoperative view at 1 year after lipoabdominoplasty, suction on the flanks, back and inner thigh plus fat injection of the gluteal areas

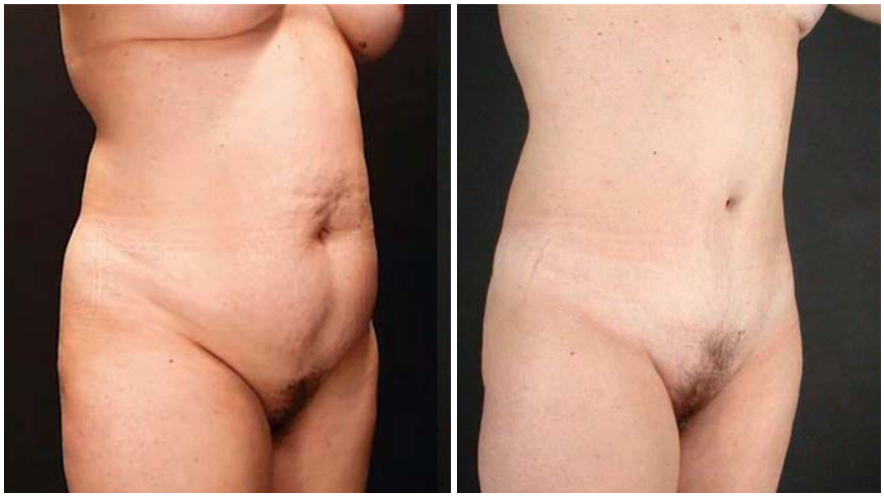

Fig. 57.20. (*Cont.*)

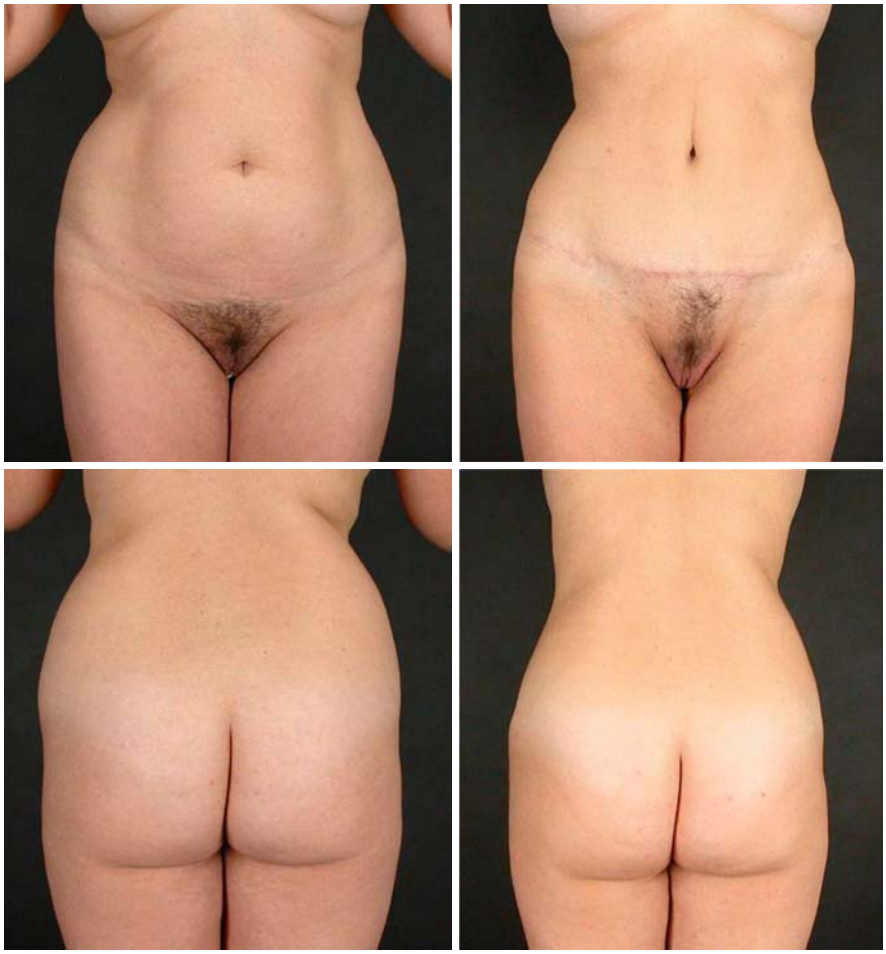

Fig. 57.21. *Left* Preoperative view of a 42-year-old patient. *Right* Postoperative view at 1 year after lipoabdominoplasty, suction on the flanks, back and inner thigh

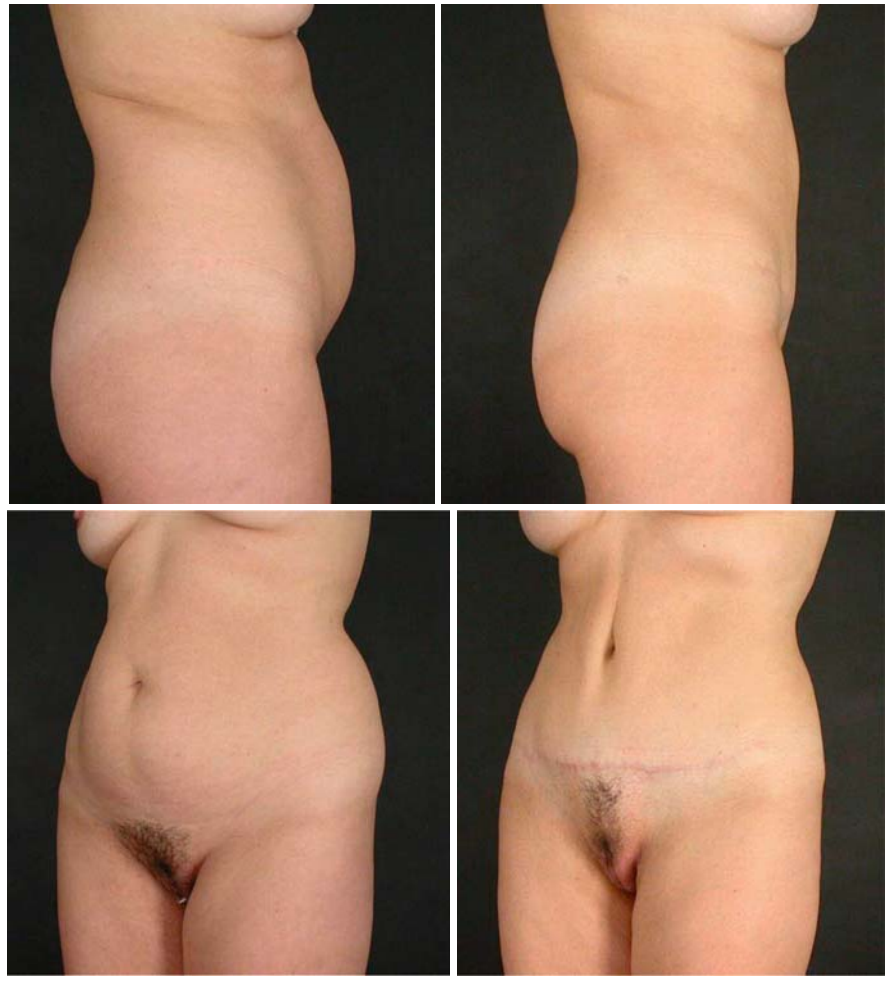

Fig. 57.21 (*Cont.*)

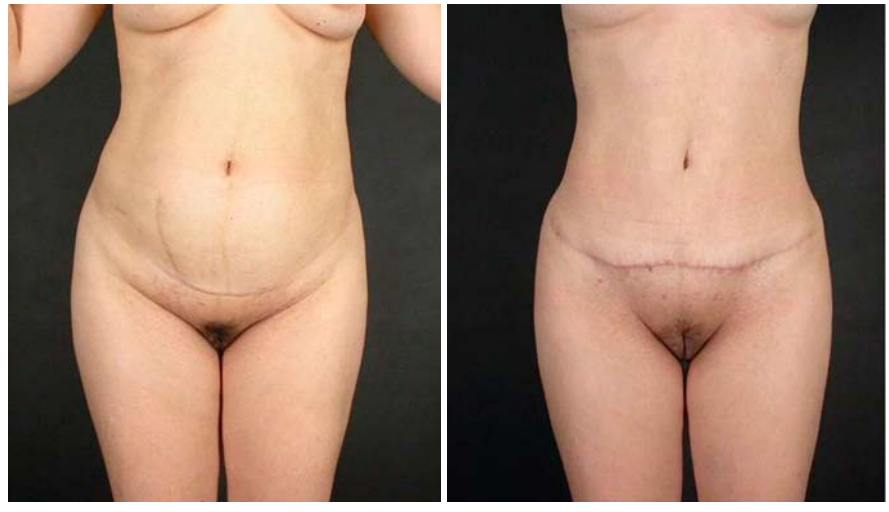

Fig. 57.22. *Left* Preoperative view of a 45-year-old patient. *Right* Postoperative view at 8 months after lipoabdominoplasty, suction on the flanks, back and inner thigh

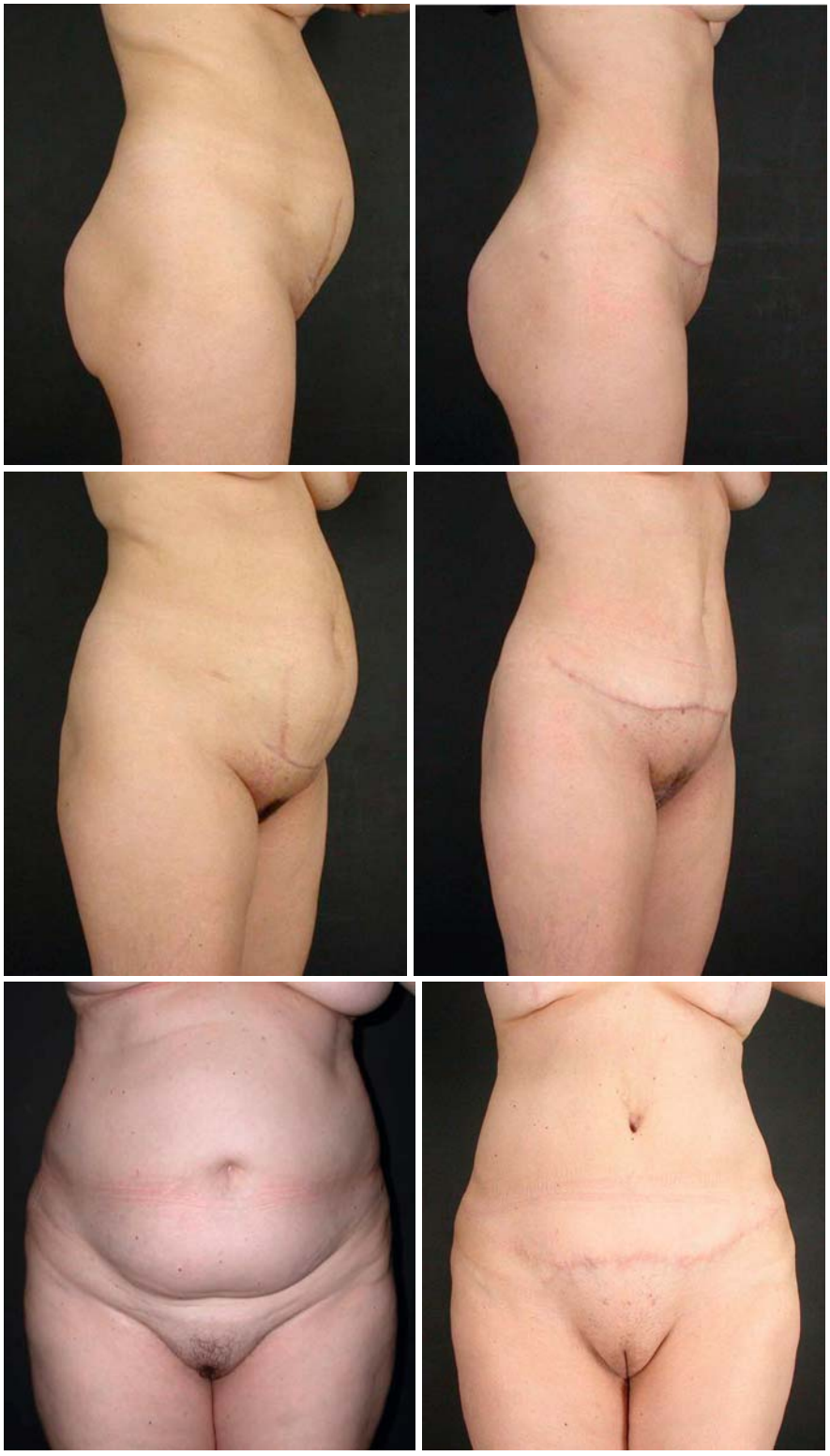

Fig. 57.22 (*Cont.*)

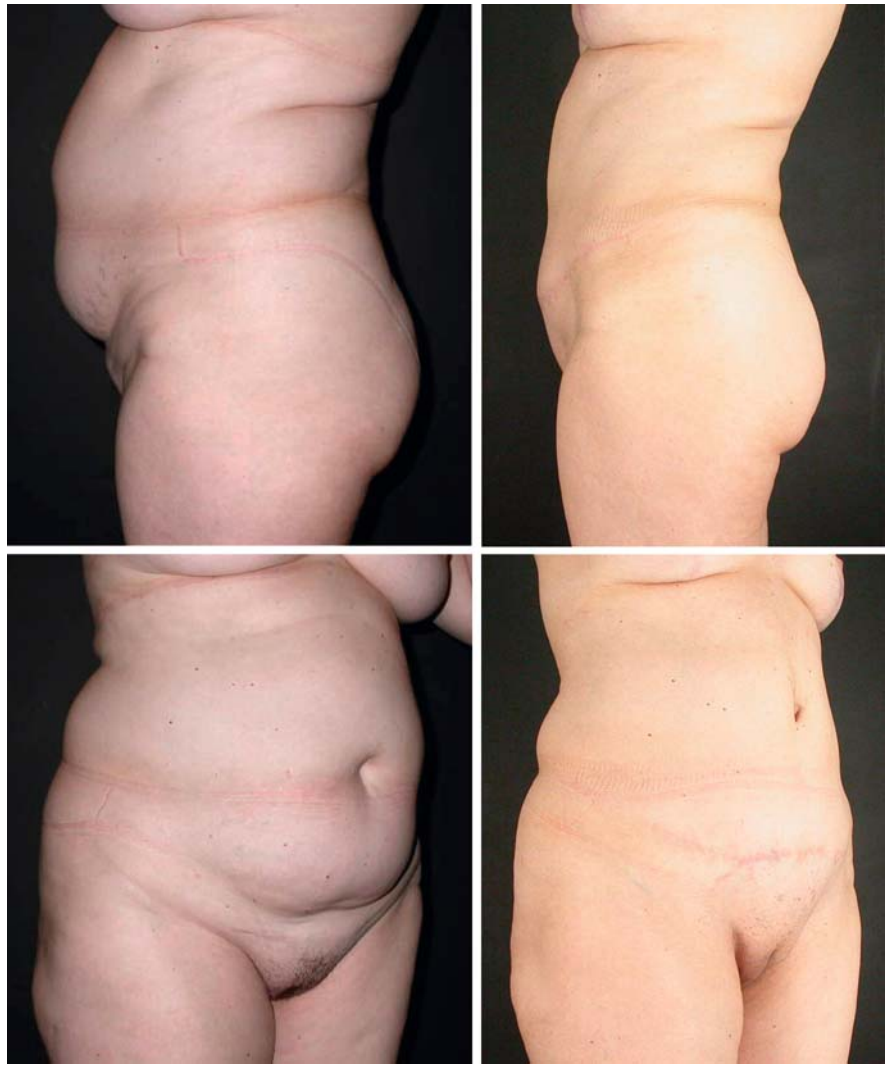

Fig. 57.23. *Left* Preoperative view of a 50-year-old patient. *Right* Postoperative view at 2 years after lipoabdominoplasty, suction on the flanks, back and inner thigh

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58 Lower Body Lift After Massive Weight Loss: Belt Lift

E. Scharnagl, M. Wiedner, F.M. Haas

58.1 Introduction

As the prevalence of overweight in our population continuously increases, the number of morbidly obese individuals is on the rise on the one hand, while on the other, the number of people who go on diets and lose large amounts of weight is also increasing. Experience shows that weight loss due to dietary measures leads, after a latent period, in a high percentage of cases to a return to obesity. This has led to a growing number of centres that offer surgical treatment for obesity in the form of gastric banding or intestinal bypass operations. With these procedures, weight losses of 40 – 70 kg are frequently achieved. As a result of these massive fluctuations in body weight, the skin becomes stretched and falls in folds over the body, causing functional and aesthetic problems. Further, it is rare that these patients achieve a normal weight, even after weight reduction. Rather, it is much more common that they are still considerably overweight.

These problems confront and challenge the plastic surgeon. They open a new chapter in plastic surgery for which our knowledge is very rudimentary and where every operation enables us to learn something new.

A particular problem is the high cost of treatment. From the plastic surgeon's point of view, correction is not just indicated for body regions that may be affected by concomitant disorders such as intertrigo and limited mobility, etc., but for all parts of the body that are misshapened. Providers of mandatory health insurance, however, only cover the costs for the treatment of concomitant disorders. If the patient cannot afford the additional cost of a proper correction, then the surgeon faces the dilemma of refusing to operate, though that is in contradiction to his or her obligation as a physician, or to settle for a compromise, which in the end might end up in court if the result of the operation, regardless of the patient's informed consent, is unsatisfactory.

The fear of very extensive surgery can, for example, lead patients for example to limit themselves to the removal of an apron of abdominal fat. This can lead to a correction in "instalments" if the patient is satisfied with the result and then desires further corrections.

This means that upon the first consultation, the entire body should be inspected. All parts of the body requiring correction should be noted and the options discussed with the patient. An algorithm for the sequence of corrections should be made.

If a whole-body correction is indicated, the belt-shaped body lift is the key operation. With this belt lift, the buttocks and thighs are lifted simultaneously. Only when there is no particular residual lipomatosis of the thighs do we combine the belt lift with a horizontal thigh lift.

As the residual lipomatosis usually involves considerable subcutis weight, a vertical thigh lift is usually to be preferred in these cases.

The belt lift can usually be well combined with a mastopexia or upper arm lift. If folds on the flanks of the thorax or back are to be corrected, a separate operation will be required.

The sequence of corrections remains virtually identical for the whole-body correction in elderly patients with flaccid skin.

58.2 Preliminary Examination and Preparatory Measures

After a thorough physical examination covering condition of the skin as well as the tone of the abdominal wall and any rectal diastasis or hernia, the patient should be comprehensively counselled.

Cardiac and pulmonary function as well as blood chemistry with coagulation status are essential for determining the patient's surgical risk. If there is rectal diastasis or hernia, abdominal sonography and possibly magnetic resonance imaging should be performed. If breast surgery is planned, a mammogram is indicated.

It can be advisable for the patient to have his/her own blood stored for future use if necessary.

An enema is administered the evening before the operation.

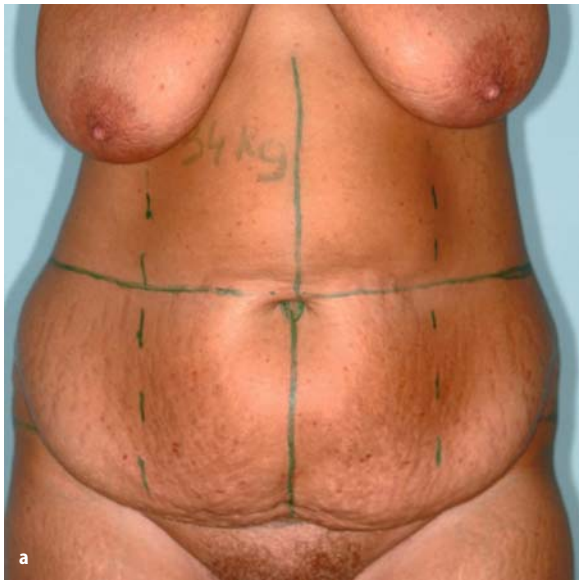
58.3 Planning the Belt Lift

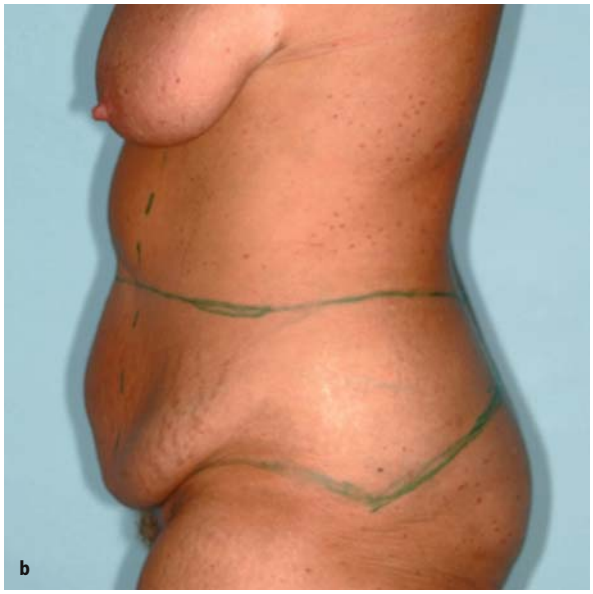
On the evening prior to surgery, the incisions are sketched with a felt-tip pen, taking into consideration the patient's preferences with regard to underwear and swimsuits. Questions often arise and can be answered while this is being done. The conversation with the patient and the sketching of the incisions deepens the understanding of the upcoming operation.

The lower line runs along the ventral side, similar to an abdominoplasty but laterally considerably deeper. It continues on down into the mediolateral line in the direction of the femoral trochanter major, and then rises like a bird's wing above the upper edge of the buttocks up to the mediodorsal line.

The upper line is determined by squeezing together the excessive skin, being sure to apply considerable tension to the skin. The skin of the buttocks and thighs must be raised in the process. The planned extent of the resection is considerable, especially in the area of the mediolateral line.

Finally, paramedian and mediolateral orientation lines parallel to the body axis are drawn (Fig. 58.1a–c).





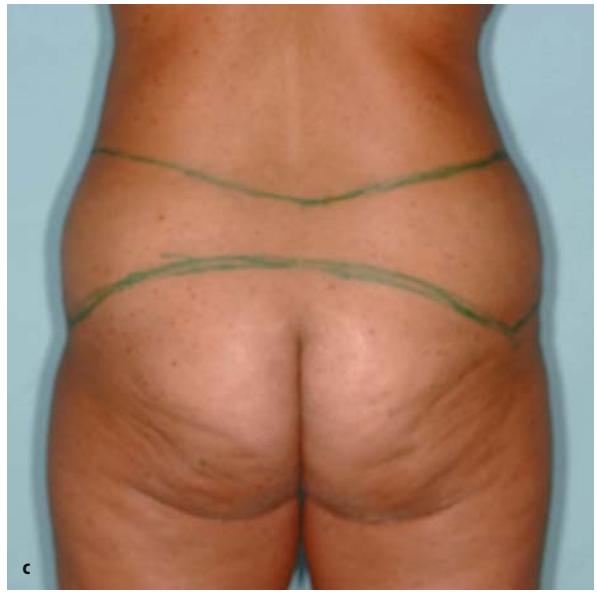
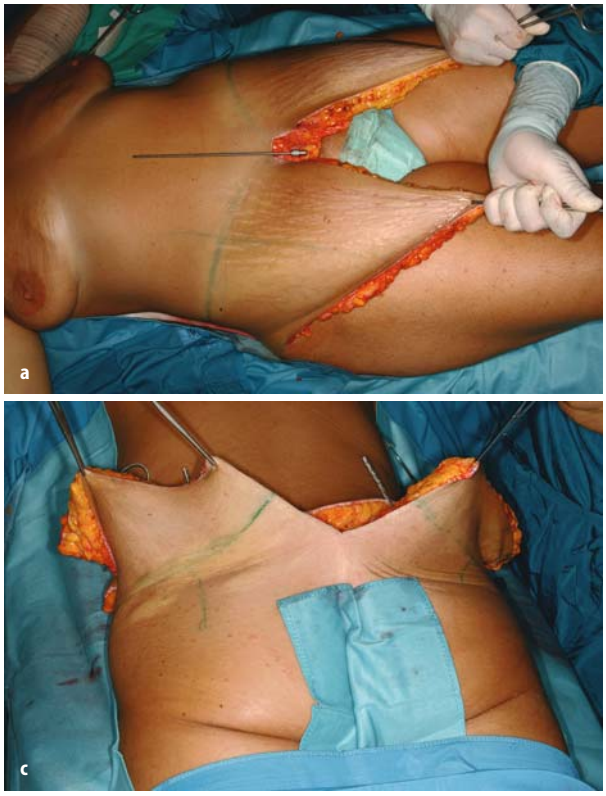


Fig. 58.1. a Female patient who after loss of 34 kg has generally flaccid skin and stretch marks and is still obese. The upper and lower resection lines are marked with felt-tip pen. For later orientation, paramedian vertical lines are also drawn. **b** In the lateral thigh area, the lower resection line deviates far down in the direction of the femoral trochanter. **c** The lower resection line curves above the intergluteal cleft to the contralateral side. The upper resection line takes a bird-wing-shaped course to the contralateral side



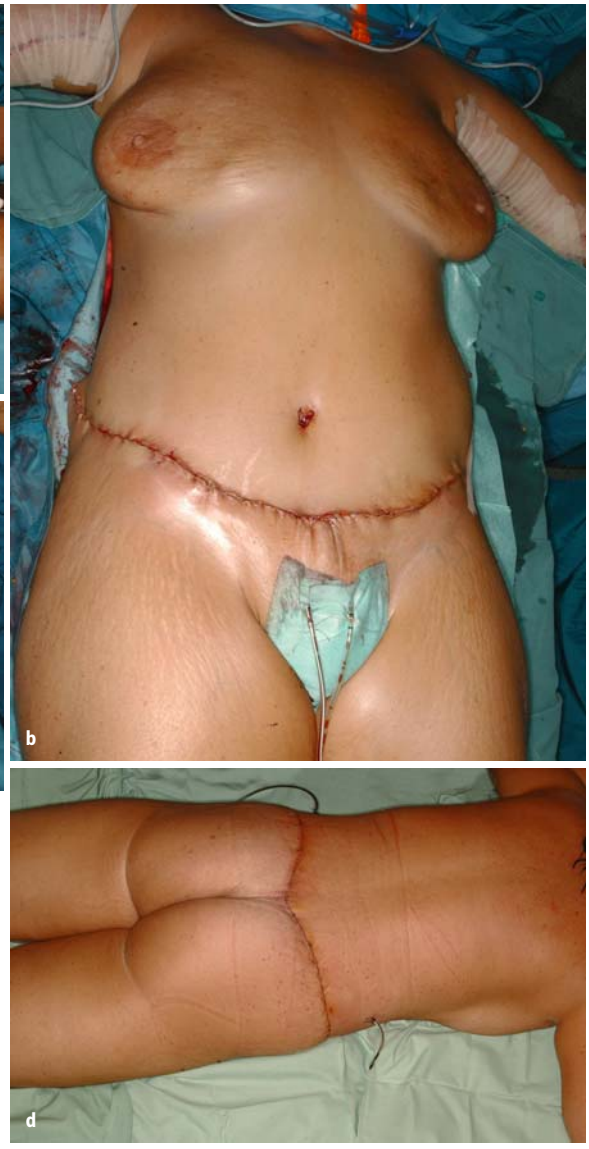


Fig. 58.2. a The abdominal skin flap has been mobilized and the flap has a median notch. **b** After resection of the excess skin, the wound is sutured and the navel is put in place in the form of a wedge. **c** After the patient is turned onto the stomach, a skin and subcutis flap is dissected caudally over the upper incision line. After stepwise notching of the flap, the extent of the resection is determined. **d** The wound is closed under good tension and the scar has the shape of a bird wing

58.4 Belt Lift Operation

To avoid asymmetries, the abdominoplasty is begun with the patient in a supine position. The incisions are made to the mediolateral line. The skin-subcutis flap is only dissected so far laterally as is necessary for mobilization to avoid damage to segmental nerves and vessels. When present, rectal diastases or hernias are closed. If the abdominal wall is flaccid, a vertical or, if necessary, horizontal pursestring suture is applied. The excessive skin is removed and the wound is closed in two layers. After fat resection, the navel wedge is fitted into the median line and sutured into place. A lipomatous mons can be avoided with simultaneous liposuction.

The patient is then shifted to a prone position. An incision is made along the upper marked line and the skin-subcutis flap is mobilized to the marked caudal line, with wide dissection in the direction of the thigh. With step-by-step notches in the flap and adapting sutures under good tension, the final extent of the resection is determined. The wound is sutured in three layers whereby, as with the ventral wound, the deep suture includes the fascia.

Ventral, lateral and dorsal Redon drains are required on each side (Fig. 58.2a–d).

58.5 Adjuvant Treatment

Antibiotics and low-molecular weight heparin are begun during the operation. The patient is mobilized on the first postoperative day. Care must be taken that the lumbar, pelvic and hip areas are immobilized for 3 – 5 weeks.

58.6 Complications

As with abdominoplasty in general, there are often complications but these usually are not serious and are relatively easily treated. A distinction is made between somatic and formal complications.

Common somatic complications include seromas, hematomas, skin necrosis and superficial wound infections, suture and lymph fistulas and localized fatty tissue necrosis, sometimes with secondary calcification. If care is taken not to injure segmental vessels and nerves, extensive deep tissue lesions are rare, but unpleasant hypesthesias cannot always be avoided.

There was a dramatic case of a female patient with a pulmonary artery embolism 10 days after surgery that required lysis, which in turn led to secondary afterbleeding and wound dehiscence. Two weeks after surgery, another female patient unthinkingly bent over, extensively opening her dorsal sutures. A female patient who had lost a lot of weight developed superficial sacral decubitus in spite of optimal positioning.

Because of these serious complications, it is advisable to keep the extent of correction within reasonable limits and preferably to plan a further operation. This can also avoid the need for blood transfusions from other donors.

Formal complications mainly include asymmetries and unaesthetic scars.

58.7 Results

The optical results correlate directly with the body mass index at the time of surgery. As almost all the patients are above the BMI norm, there are limits to what can be expected.

The vast majority of the patients under consideration here considered the optical result of the belt lift to be good to very good and were very satisfied. The operation in many cases was the end of a life phase characterized by physical dissatisfaction due to a shapeless, overweight figure and limited mobility, and the optimistic beginning of a new life phase with restored self confidence and self esteem.

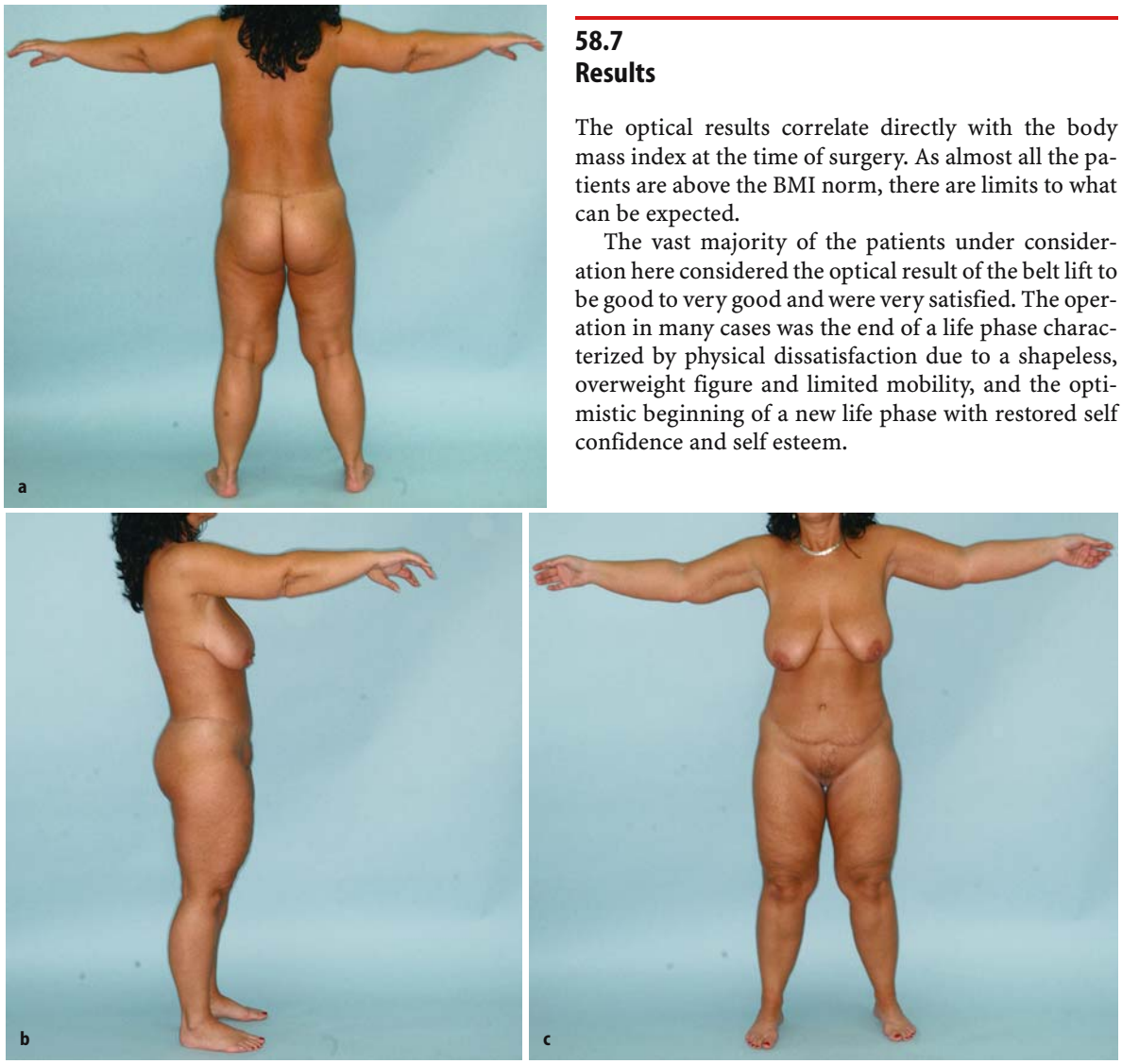


Fig. 58.3a–c. A year postoperatively the body's silhouette is pleasing, in spite of persisting obesity. The upper arms were lifted in the same session. Breast and thighs still require correction. Because of the remaining fatty tissue and its weight, in the thigh-knee region the only lift option will be a vertical incision after liposuction

From the plastic surgeon's point of view as well, the results with patients who have lost massive amounts of weight are good and very effective. When indicated, the operation can be highly recommended (Fig. 58.3a–c).

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