Three-Dimensional Imaging for Orthodontics and Maxillofacial Surgery

Edited by
Chung How Kau
BDS, MScD, MBA, MOrth, PhD, FDS, FFD (Ortho), FAMS (Ortho)
Professor and Chairman
Department of Orthodontics
University of Alabama at Birmingham School of Dentistry
Birmingham
Alabama
USA

Stephen Richmond
BDS (Sheffield), DOrth, RCS, MScD, FDS, RCS (Edin), FDS, RCS (Eng), PhD (Manchester)
Professor of Orthodontics and Head of Applied Clinical Research and Public Health
Department of Applied Clinical Research and Public Health
University Dental Hospital
Cardiff University
Heath Park
Cardiff
UK
Three-Dimensional Imaging for Orthodontics and Maxillofacial Surgery
Three-Dimensional Imaging for Orthodontics and Maxillofacial Surgery

Edited by
Chung How Kau
BDS, MScD, MBA, MOrth, PhD, FDS, FFD (Ortho), FAMS (Ortho)
Professor and Chairman
Department of Orthodontics
University of Alabama at Birmingham School of Dentistry
Birmingham
Alabama
USA

Stephen Richmond
BDS (Sheffield), DOrth, RCS, MScD, FDS, RCS (Edin), FDS, RCS (Eng), PhD (Manchester)
Professor of Orthodontics and Head of Applied Clinical Research and Public Health
Department of Applied Clinical Research and Public Health
University Dental Hospital
Cardiff University
Heath Park
Cardiff
UK
List of Contributors vii
Preface x

Part 1: IMAGING, DIAGNOSTIC, AND ASSESSMENT METHODS

1 The Legalities of Cone Beam Imaging
   Kenneth Abramovitch, Christos Angelopoulos, and Randall O. Sorrels 3
2 Three-Dimensional Surface Acquisition Systems for Facial Analysis
   Chung How Kau 11
3 Diagnostic Imaging
   Nicholas Drage and John Rout 29
4 Diagnostic Oral Pathology with Computed Tomography
   Jerry E. Bouquot 73
5 Three-Dimensional Diagnosis and Treatment Planning of Dentoalveolar Problems
   Lutz Ritter, Jörg Neugebauer, Robert Mischkowski, Martin Scheer,
   and Joachim E. Zöller 89
6 Referencing and Registration of Three-Dimensional Images
   Lucia H.S. Cevidanes, Martin Styner, and William R. Profitt 112
7 Averaging Facial Images
   Alexei Zhurov, Stephen Richmond, Chung How Kau, and Arshed Toma 126

Part 2: APPLICATIONS, PHYSIOLOGICAL DEVELOPMENT, AND SURGICAL PROCEDURES

8 Studying Facial Morphologies in Different Populations
   Chung How Kau, Stephen Richmond, Alexei Zhurov, Jeryl D. English, Maja Ovsenik,
   Peter Borbely, and Wael Tawfik 147
9 A New Clinical Protocol to Plan Craniomaxillofacial Surgery Using Computer-aided Simulation
James J. Xia, Jaime Gateno, and John F. Teichgraeber 159

10 Controversial Issues in Computer-aided Surgical Planning for Craniomaxillofacial Surgery
James J. Xia, Jaime Gateno, and John F. Teichgraeber 171

11 Predicting and Managing Surgical Intervention in Craniofacial Disharmony – a Biomechanical Perspective
Stephen Richmond, Liliana Beldie, Yongtao Lu, John Middleton, Brian Walker, Andrew Cronin, Nicholas Drage, Alexei Zhurov, and Caroline Wilkinson 180

12 Understanding the Facial Changes Associated with Postoperative Swelling in Patients Following Orthognathic Surgery
Chung How Kau, Stephen Richmond, and Andrew Cronin 198

13 Visualizing Facial Growth
Stephen Richmond, Alexei Zhurov, Arshed Toma, Chung How Kau, and Frank Hartles 207

14 Use of Digital Models/Dental Casts and their Role in Orthodontics/Maxillofacial Surgery
Kelvin W.C. Foong 226

15 A Custom-fitting Surgical Guide
Richard Bibb, Dominic Eggbeer, Alan Bocca, Peter Evans, and Adrian Sugar 239

Part 3: MOVEMENT AND FACIAL DYNAMICS

16 Assessment of Facial Movement
Hashmat Popat, Stephen Richmond, David Marshall, Paul L. Rosin, and Lanthao Benedikt 251

17 Facial Actions for Biometric Applications
Lanthao Benedikt, Paul L. Rosin, David Marshall, Darren Cosker, Hashmat Popat, and Stephen Richmond 267

18 Nonrigid Image Registration Using Groupwise Methods
Kirill Sidorov, David Marshall, and Stephen Richmond 286

19 Three-Dimensional Developments for the Future
Stephen Richmond and Chung How Kau 301

Appendix 1: Sample of Informed Consent for Imaging Procedures 305
Index 307

See the supporting companion website for this book: www.wiley.com/go/kau
List of Contributors

Ken Abramovitch, Department of Diagnostic Sciences, University of Texas Health Science Center at Houston Dental Branch, Houston, TX, USA

Christos Angelopoulos, Columbia University Dental School, New York, USA

Liliana Beldie, Arup Campus, Blythe Valley Park, Solihull, Birmingham, West Midlands, UK

Lanthao Benedikt, School of Computer Science, Cardiff University, UK

Richard Bibb, Department of Design and Technology, Loughborough University, UK

Alan Bocca, Centre for Applied Reconstructive Technologies in Surgery (CARTIS), Maxillofacial Unit, Morriston Hospital, ABM University Health Board, Swansea, UK

Peter Borbely, 1072 Budapest, Rackoczi ut 4, Hungary

Jerry E. Bouquot, Department of Diagnostic Sciences, University of Texas Health Science Center at Houston Dental Branch, Houston, TX, USA

Lucia H.S. Cevidanes, Department of Orthodontics, UNC School of Dentistry, Chapel Hill, NC, USA

Darren Cosker, School of Computer Science, University of Bath, UK

Andrew Cronin, Consultant in Maxillofacial Surgery, University Dental Hospital, Cardiff, UK

Nicholas Drage, Consultant in Dental and Maxillofacial Radiology, University Dental Hospital, Cardiff, UK

Dominic Eggbeer, Centre for Applied Reconstructive Technologies in Surgery (CARTIS), National Centre for Product Design & Development Research (PDR), University of Wales Institute Cardiff (UWIC), Cardiff, UK

Jeryl D. English, Department of Orthodontics, M.D. Anderson, Houston, TX, USA

Peter Evans, Centre for Applied Reconstructive Technologies in Surgery (CARTIS), Maxillofacial Unit, Morriston Hospital, ABM University Health Board, Swansea, UK

Kelvin W.C. Foong, Department of Preventive Dentistry, Faculty of Dentistry, National University of Singapore, Singapore
Jaime Gateno, 6560 Fannin Street, Suite 1228, Houston, TX, USA

Frank Hartles, Department of Applied Clinical Research and Public Health, University Dental Hospital, Cardiff University, UK

Chung How Kau, Department of Orthodontics, University of Alabama at Birmingham, Birmingham, AL, USA

Yongtao Lu, Institute of Theoretical, Applied and Computational Mechanics (ITACM), Research Office, Cardiff School of Engineering, UK

David Marshall, School of Computer Science, Cardiff University, Cardiff, UK

John Middleton, Biomaterials/Biomechanics Research Centre, Wales College of Medicine, Cardiff Medicentre, UK

Robert Misckowski, Department for Craniomaxillofacial and Plastic Surgery and Interdisciplinary Outpatient Department for Oral Surgery and Implantology, University of Cologne, Germany

Jörg Neugebauer, Department for Craniomaxillofacial and Plastic Surgery and Interdisciplinary Outpatient Department for Oral Surgery and Implantology, University of Cologne, Germany

Maja Ovsenik, Department of Dental and Jaw Orthopaedics, Medical Faculty, University of Ljubljana, Slovenia

Hashmat Popat, Department of Applied Clinical Research and Public Health, University Dental Hospital, Cardiff University, UK

William R. Profitt, Department of Orthodontics, UNC School of Dentistry, Chapel Hill, NC, USA

Stephen Richmond, Department of Applied Clinical Research and Public Health, University Dental Hospital, Cardiff University, UK

Lutz Ritter, Department for Craniomaxillofacial and Plastic Surgery and Interdisciplinary Outpatient Department for Oral Surgery and Implantology, University of Cologne, Germany

Paul L. Rosin, School of Computer Science, Cardiff University, UK

John Rout, Consultant in Dental and Maxillofacial Radiology, Birmingham Dental Hospital, Birmingham, UK

Martin Scheer, Department for Craniomaxillofacial and Plastic Surgery and Interdisciplinary Outpatient Department for Oral Surgery and Implantology, University of Cologne, Germany

Kirill Sidorov, School of Computer Science, Cardiff University, UK

Randall O. Sorrels, Abraham, Watkins, Nichols, Sorrels, Agosto & Friend, Houston, TX, USA

Martin Styner, Department of Orthodontics, UNC School of Dentistry, Chapel Hill, NC, USA

Adrian Sugar, Centre for Applied Reconstructive Technologies in Surgery (CARTIS), Maxillofacial Unit, Morriston Hospital, ABM University Health Board and Swansea University, Swansea, UK

Wael Tawfik, National Research Center, Dokki, Cairo, Egypt

John F. Teichgraeber, 6560 Fannin Street, Houston, TX, USA
Arshed Toma, Department of Applied Clinical Research and Public Health, University Dental Hospital, Cardiff University, UK

Brian Walker, The Arup Campus, Blythe Gate, Blythe Valley Park, Solihull, Birmingham, West Midlands, UK

Caroline Wilkinson, School of Media Arts and Imaging, Duncan of Jordanstone College of Art and Design, University of Dundee, UK

James J. Xia, 6560 Fannin Street, Suite 1228, Houston, TX, USA

Alexei Zhurov, Biomaterials/Biomechanics Research Centre, Wales College of Medicine, Cardiff Medicentre, Cardiff, UK

Joachim E. Zöller, Department for Craniomaxillofacial and Plastic Surgery and Interdisciplinary Outpatient Department for Oral Surgery and Implantology, University of Cologne, Germany
When we embarked on this project, we appreciated that a wide range of disciplines would be involved in developing acquisition systems and software analysis packages for a host of applications for medical, medically allied, entertainment, and military/security groups. In fact, three-dimensional imaging potentially is of interest to all and certainly has the potential to have an impact on everyone in daily life.

We took a clear initiative to build a text that is not only informative, illustrative, and applied, but also provides the latest in state-of-the-art technology. The book is set out in three sections – (1) diagnostic and assessment methods, (2) applications, physiological development, and surgical procedures, and (3) movement and facial dynamics – to cover clinical interest in the craniofacial complex not only for dentists, specialists, and specialties related to dentistry, but also for other professions that deal with the craniofacial complex, such as speech therapists and psychologists.

We have chosen a group of authors world-renowned in their field, and their topics cover a wide range of applications representing different levels of sophistication, experience, and knowledge. The chapters are well illustrated to facilitate knowledge and skills transfer. Each chapter is well referenced to enable interested readers to facilitate their understanding and build a foundation of knowledge. Certain chapters direct readers to utilize open-sourced, readily available software, commercially available packages, and also the mathematical theory behind problem-solving.

This book addresses a gap in the applications of three-dimensional imaging in dentistry and allied health professionals. We hope that we have derived a blend of topics that will be of interest to the novice as well as to experts in different disciplines.

Stephen Richmond
Chung How Kau
Part 1

Imaging, Diagnostic, and Assessment Methods
INTRODUCTION

When a patient requires an imaging procedure, there are several underlying scenarios that are part of the process. These events have a complicity of legal implications. The legal implications may vary from one jurisdiction to another, regardless of whether one is referring to national, state/provincial, county/parish, city, or municipality. The intent here is to describe legal processes that can establish guidelines consistent with good quality healthcare delivery.

Imaging procedures are required to evaluate the presence or absence of a disease state or to perform the craniofacial morphometric analyses necessary to develop dentoalveolar and craniofacial treatment plans. The latter are frequently indicated to evaluate craniofacial esthetic and functional relationships.

The indications for a cone beam computed tomography (CBCT) scan are usually associated with some degree of morbidity, hence there is an element of risk associated with either performing or abstaining from the procedure. These associated risks may be from either the physical harm from the procedure, the potential morbidity of a misdiagnosis, or the potential morbidity from a failure to diagnose. Physical harm from imaging procedures is related to the harmful biologic effects of ionizing radiations. These risks are very low and are discussed in another chapter. Legal issues associated with misdiagnosis and a failure to diagnose, as well as disclosure and informed consent and adequate documentation, are discussed here.

EDUCATION AND TRAINING

The utilization of any diagnostic procedure, including cone beam imaging, should be ordered and performed based on a sound knowledge of the potential diagnostic yield of the procedure. Due to the