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Hip Joint Restoration

Worldwide Advances in Arthroscopy, Arthroplasty, Osteotomy and Joint Preservation Surgery

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Preface

Those of us who treat patients with hip pain know that the surgical treatment of hip disease has undergone tremendous growth during the last decade. Prior books on the hip have either addressed arthroplasty, in providing prosthetic solutions for end-stage hip arthritis, or focused on minimally invasive arthroscopy of the hip. Many of them were technical treatises. Yet hip surgery has moved on greatly from the days when all that might be offered was fracture fixation or arthroplasty and, for the younger patient, the instruction to wait until they had reached sufficient age to justify a prosthesis. The thrust of most surgeons in the twenty-first century is to achieve as much benefit as possible for the patient while keeping surgical trauma to a minimum. Fulfillment of this ambition requires an understanding of new concepts and new procedures, as well as new training to accompany them.

The authors of this book believe that hip disease presents as a spectrum of symptoms and pathology, and so any comprehensive text must include the accurate diagnosis and treatment of both the biologic and the prosthetic hip. With the explosion of information on hip disease in the literature, particularly in the treatment of younger patients, the authors felt that it was time for a comprehensive treatise on this subject. Arthroscopy of the Hip, according to many, is the fastest growing specialty area within orthopedics. Accordingly, an extensive amount of this book is devoted to determining proper surgical indications as well as knowledge of surgical techniques and outcomes for the expanding number of surgical procedures in this area.

This book is divided into 16 parts. Pathology within the hip is best understood in contradistinction to normal growth and development. Early chapters also focus on discerning extra-articular from intra-articular etiologies of hip pain. Digital imaging, including CT, MRI, and ultrasound, has immensely increased our diagnostic understanding of the joint and the periarticular soft tissues. At times, MR imaging may disclose combined issues in pathology such as intra-articular loose bodies in combination with osteonecrosis of the hip or, similarly, an acetabular labral tear in combination with abductor muscle attenuation.

The spectrum of treatment of hip disease importantly includes hip osteotomies, whether of the femur or the acetabulum, or in combination. Knowledge of these procedures and their indications is a critical prerequisite for successful outcomes, especially in young patients. However, some young patients do require total hip arthroplasty, typically secondary to osteonecrosis, tumors, trauma, or collagen disease. Several chapters are devoted to the latest evidence-based information on bearing surfaces, and implant selection as well as surgical techniques.

A critically important area for increased understanding is patient outcomes following hip arthroscopy, osteotomy, or total joint replacement. Importantly, world experts in validated outcome measures and quality of life indicators are authors of chapters in this book. Another unique feature of this volume is a section describing the growth and development of hip arthroscopic surgery in each of the world's continents, authored by experts in each of these geographical areas. Finally, there is an entire section devoted to research and future developments. The robustness of the information as well as the development in these areas adds significantly to the depth of knowledge contained within this book.

There has never been such an exciting time to be a specialist in hip surgery, nor such a time to feel so proud. This book brings together a large number of specialists in the field, each of whom has given up valuable hours to prepare their text. As editors we are enormously grateful to them. Our authors are excellent clinicians, respected practitioners, but, more than anything, good personal friends. So join us on the tidal wave of surgical development shown on these pages, the tidal wave in the surgical treatment of hip disease.

In conclusion, this book has been a truly collaborative effort but would never have been possible without the tireless efforts of Connie Walsh, Miranda Finch and Kristopher Spring at Springer whose expertise, patience, and attention to detail have been vital. We also profusely thank our colleagues and fellow members of ISHA (The International Society of Hip Arthroscopy) who have pitched in as authors and section editors to share their knowledge and understanding of hip disease in making this work an important treatise. And finally, we thank our spouses and families for their support and understanding during this extensive endeavor.

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Abbreviations

ADL	Activities of daily living
AIIS	Anterior inferior iliac spine
ASIS	Anterior superior iliac spine
AVN	Avascular necrosis
BMP	Bone morphogenic proteins
BW	Body weight
CMI	Core muscle injury
COPD	Chronic obstructive pulmonary disease
CT	Computerized tomography
DEXRIT	Dynamic external rotatory impingement test
DGS	Deep gluteal syndrome
DHS	Dynamic hip screw
DIRI	Dynamic internal rotatory impingement test
EMG	Electromyography
FABER	Flexion, abduction, external rotation
FADDIR	Flexion adduction internal rotation test
FAI	Femoroacetabular impingement
GRF	Ground reaction force(s)
HHS	Harris hip score
HHSm	Modified Harris hip score
HPI	History of present illness
iHOT	international hip outcome tool
IPI	Iliopsoas impingement
ITB	Iliotibial band
L	Left
MAHORN	Multicenter arthroscopy of the hip outcomes research network
MFCA	Medial femoral circumflex artery
MRI	Magnetic resonance imaging
NAHS	Nonarthritic hip score
NSAIDS	Nonsteroidal anti-inflammatory drugs
OA	Osteoarthritis
ON	Osteonecrosis
ONFH	Osteonecrosis of the femoral head
PRP	Platelet rich plasma
R	Right
ROM	Range of motion
SCFE	Slipped capital femoral epiphysis
SI	Sacroiliac

TFL	Tensor fasciae latae
THA	Total hip arthroplasty
VAS	Visual Analog Pain Scale
WOMAC	Western Ontario and McMaster University

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Joseph C. McCarthy, MD is the chief of Reconstructive Hip and Knee Joint Surgery at Newton Wellesley Hospital, a member of the joint arthroplasty staff at Massachusetts General Hospital, and Associate professor of Orthopedic Surgery at Harvard University, part-time. He is also a clinical professor of Orthopedic Surgery at Tufts University for the past 20 years. He has had a long-standing interest in hip joint preservation and, along with Dr. James Glick, pioneered hip arthroscopy in the United States. This focus included published work on hip anatomy and morphology as well as minimally invasive surgical approaches, development of a dedicated hip distractor and instruments solely for use in hip arthroscopic procedures.

Dr. McCarthy completed his undergraduate education at the University of Notre Dame, during which time he played on the varsity hockey and baseball teams. He then matriculated to Georgetown University medical school. Following a medical internship at Georgetown University Hospital, he completed surgical and orthopedic training at Tufts University in Boston. After residency, he completed a fellowship in hip and knee reconstructive joint surgery at Massachusetts General Hospital under the direction of Dr. William Harris and Hugh Chandler. Subsequently his entire practice career has been in Boston.

During his career he has served the American Academy of Orthopedic Surgeons as a member of the Committee on the Hip, program chair for the Hip Society, and has been on the board of directors for both the AAOS and the orthopedic research and education foundation (OREF). He has also been the chair of the board of specialty societies of the AAOS and chairman of the Shands Society of OREF. He is a founding member of the International Society of Hip Arthroscopy. He is also past president of the American Association of Hip and Knee Surgeons and the International Society of Hip Arthroscopy.

For his research he has received both the Otto Aufranc Award and the Frank Stinchfield Award from the Hip Society and the AAOS. Both of these awards were for work on understanding the acetabular labrum and, when injured, its relationship to degenerative arthritis of the hip joint. Dr. McCarthy has been Director of the biologic hip portion of the Harvard hip/knee course for the past 8 years and has been co-chairman of the AAOS Learning Center hip arthroscopy course for the past 12 years.

Dr. McCarthy has been committed to scholarship in the field of hip preservation, publishing the first validated hip outcomes scoring system for the native hip, as well as been an active member of MAHORN (Multi-center Arthroscopic Hip Outcomes Research Network). Most recently he has authored work on hip joint lubrication and EMG muscle effects associated with acetabular labral tears. Dr. McCarthy has authored over 175 peer-reviewed articles, posters, book chapters, and books.

Philip C. Noble, BE MEngSci PhD was educated in Australia in diverse subjects including Engineering, the Physical Sciences, and Classical Philosophy. After being awarded a Winston Churchill Fellowship in 1979, he traveled throughout Europe, the United Kingdom, and North America and eventually returned to Houston to work in the Texas Medical Center. He was awarded his PhD from the University of Strathclyde in Glasgow, Scotland, where he studied the biomechanics of the hip and hip replacement under the direction of Professor John Paul. He now serves as the Director of Research in the Institute of Orthopedic Research and Education and holds the rank of Professor in the Department of Orthopaedic Surgery at Baylor College of Medicine.

Phil Noble's research interests include the biomechanics of the hip and knee joints and their replacements, the morphometry of human bones, the biology and biomechanics of cartilage, tendon, and ligaments, and the quantitative assessment of clinical outcomes. He has numerous publications related to the hip and is a frequent speaker at national and international conferences. He is also a member of The Hip Society, The Knee Society, The International Hip Society, and The American Academy of Orthopedic Surgeons. Dr. Noble is internationally renowned as a designer and innovator and is the holder of numerous patents. He has participated in the development of more than 20 designs of total hip and knee replacements and associated instrumentation.

Dr. Noble is active in philanthropic activities and is particularly interested in issues related to diversity and underrepresented minorities. He is also committed to mentorship and has been instrumental in the training and development of over 150 postgraduates interested in careers in orthopedic surgery and related research. His recreational interests include foreign travel, gardening, and ornamental glass.

Richard N. Villar, BSc (Hons) MA MS FRCS qualified in medicine at St. Thomas's Hospital in London (UK) before joining the military as the Regimental Medical Officer to the SAS. After leaving the Army he completed his surgical studies in Southampton and Cambridge, joining the consultant staff of Addenbrooke's Hospital (Cambridge) in 1988. It was there that he developed his interest in conservative hip surgery and now has one of the largest experiences of hip arthroscopic (keyhole) procedures in the world.

Now in independent practice, Richard is a Founding Member, and first President, of the International Society for Hip Arthroscopy. He has served as a member of Council of the British Orthopaedic Association, is an assessor for the General Medical Council, and is a member of the United Kingdom's Disaster Emergency Response Team.

In this latter capacity he was operational in the aftermaths of the Kashmir, Java, and Haiti earthquakes. Richard regards orthopedic surgery as both his profession and hobby.

When not dealing with problematic hips and knees, he can be found either playing his classical guitar or on a mountainside, maintaining his skills as an International Mountain Leader.

Part I

Structure and Function of the Tissues of the Hip (Normal and Diseased)

Richard E. Field

Development of the Hip: Phylogeny and Ontogeny

1

Tom Hogervorst, Karl-Philipp Kienle, and Moritz Tannast

Introduction

The human hip is a conceptually simple ball and socket joint, but functions as part of a complex anatomic unit consisting of the femur, the pelvis and the lumbosacral spine. This unit is highly variable between different species of animals. Human hip evolution is characterized by obligate bipedal gait and encephalization (development of a disproportionately enlarged brain). This makes the female pelvis the only skeletal element that conveys information about these two most peculiar traits of human evolution. It shows both the adaptations that occurred to facilitate a permanent bipedal gait and, at the same time, the adaptations to accommodate the birth of a large-brained baby.

Human hip morphogenesis can deviate from its normal pathway by developmental hip disorders. Common developmental hip disorders such as developmental dysplasia of the hip, slipped capital femoral epiphysis (SCFE) but also femoroacetabular impingement can be explained from an evolutionary perspective. Below, we review relevant aspects of evolution (phylogeny) and human hip morphogenesis (ontogeny) that are relevant to the understanding of hip morphotypes and related hip disorders.

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Evolution of Bone and Locomotion

Mineralized tissues (enamel, dentine and bone) were a major breakthrough in evolution. Calcium carbonate ($CaCo_3$), the common constituent of rock, was always present in ocean water and started being used as reinforcement in organisms about half a billion years ago in the Cambrian era [1]. Since then, fossils demonstrate the calcified remains of life's evolution. But the fossil record will, by definition, always remain incomplete, and it is genetic studies that have revolutionized our understanding of the early stages in evolution of mineralized tissues. For example, a related family of genes that likely arose from a common ancestor produces the mineralized tissues for teeth (enamel, dentine) and skeletons (bone extracellular matrix) [2]. Teeth-like structures probably evolved first, allowing new forms of predation, followed by a dermal exoskeleton of dentine, enamel and bone [3]. Teeth produced big changes in feeding and predation while development of endo- and exoskeletons allowed radical changes in locomotion. Bone likely appeared as an attachment to dentine in scales [2] in exoskeletons. The stunning fossils from the Cambrian era document an explosion in the possible basic structures of bodies (body plans) [4, 5]. The vast majority of these have long gone extinct and the remaining body plans (i.e. at phylum and subphylum level) now show striking *invariability*, for which genetic explanations have been suggested recently [6]. In contrast, within phyla, a spectacular variety in animal form has developed. On the phylum level, the existence of an endo- versus an exoskeleton (e.g. Arthropodae) imparts major differences in function. An exoskeleton affords strength and allows limbs to be longer which enhances both protection and locomotion. An endoskeleton has the advantage over exoskeletons that it frees the skin to function as sensory and thermoregulatory organ.

Already in lobe-finned fishes such as the *Eusthenopteron* (Devonian period [415–375 million years ago]), we find the primordial tetrapod body structure consisting of a longitudinal body axis with four perpendicular appendages. Indeed, their paired breast and pelvic fins have the pattern of our

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limbs today: one proximal (femur and humerus) and two distal bones (tibia/fibula and radius/ulna, Fig. 1.1). Their pelvic fins had what can be interpreted as a proto-femur. Once "on land" a suite of further developments improved locomotion, both in endurance and speed.

Evolution of Tetrapod Gait

The development of terrestrial life forms hinged on the evolution of limbs from paired fins, limbs that, eventually, could bear the animal's weight against gravity (Fig. 1.2). Molecular genetic studies now show the fin to limb transformation can be made by subtle changes in a relatively small number of genetic switches [7], i.e. without the need for extraordinary processes or genetic mechanisms. Amphibians started walking with a sprawling gait, with the limbs still perpendicular to the long axis of the body—as with the paired fins in fish. But on land this requires permanent elevation of the body above the plane of the appendages to prevent contact between the trunk and the ground (Fig. 1.3).

Much heavier loads can be carried by limbs that are vertical than those that are horizontal, and so, vertical limb alignment allowed dinosaurs to grow to a huge size. The emergence of vertical limb positions and rounding of the hip joint also enabled increased stride length, while adoption of an erect posture decoupled walking from breathing. This increased stamina, as running no longer counteracted breathing [8].

Mammalian Hip Types

Mammals display large variation in hip morphology. Conceptually, two types of hip can be distinguished, *coxa recta* and *coxa rotunda* [9, 10], based on differences in *proximal femoral concavity* [11]. Concavity is a compound measure, influenced by the relative dimensions of the femoral head and neck (*head-neck ratio*), the roundness of the femoral head (*sphericity*) and the position of the femoral head relative to the neck [12]. Concavity thus determines the potential for femoral impingement (the acetabular parameters are depth and sphericity). Concavity can be quantified by angular measurements, e.g. alpha [13], beta, gamma and delta angles [12] and linear measurements (offset) or ratios. Coxa recta and rotunda relate to the ossification pattern of the proximal femur [14] and locomotor categories. Specifically, a single coalescence of the proximal femur is seen in coxa recta, whereas separation of the trochanteric and capital epiphysis is seen in coxa rotunda. Typically, coxa recta is seen in runners and jumpers, rotunda in climbers, amphibians and swimmers (Fig. 1.4. horse/walrus). In humans (and in the nonhuman apes), the two epiphyses of the proximal femur separate, i.e. a coxa rotunda ossification pattern. However, some morphotypes of the human hip appear to mimic the normal morphology of species with "coalesced" epiphyses [14], i.e. a coxa recta or "cam-type" hip [15].

Locomotion in the Nonhuman Apes

The nonhuman apes have a varied repertoire of locomotion including arm slinging, climbing, quadrupedal knuckle walking and bipedal walking. The nonhuman apes (chimpanzee, bonobo, gorilla, gibbon, orangutan) do not run bipedally [16], and their bipedal walking is not the true upright walking seen in modern humans. Due to a stiff spine [17], bipedal walking in the nonhuman apes requires flexion in both hips and knees to position the trunk over the feet (Fig. 1.5). Bipedal walking in the nonhuman apes therefore requires constant activity of hip extensors (hamstrings) and

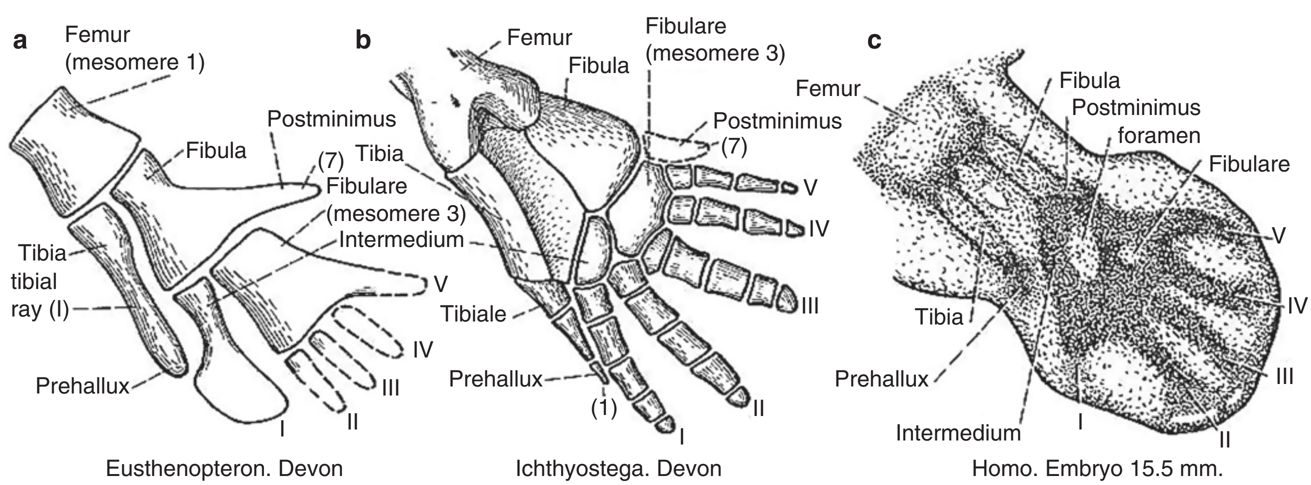

Fig. 1.1 The ancient building plan of (hind) limbs. Eusthenopteron is a lobe-finned fish, Ichtyostega is a *fishapod*, comparable to Acanthostega (Fig. 1.2) From [81] and Hogervorst T, Bouma HW, de Vos J. Evolution of the hip and pelvis. Acta Orthop Suppl. 2009 Aug;80(336):1–39. Reprinted with permission from Informa Healthcare