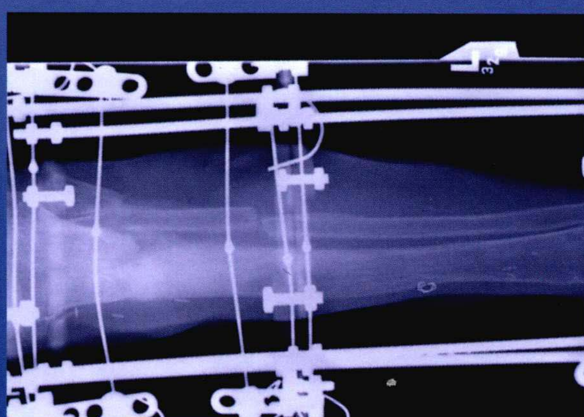



RADIOLOGIC GUIDE TO ORTHOPEDIC DEVICES

EDITED BY Tim B. Hunter, Mihra S. Taljanovic and Jason R. Wild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Radiologic Guide to Orthopedic Devices

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To all those physicians, nurses, technologists, emergency medical technicians, paramedics, ambulance technicians, physical therapists, and other personnel who tirelessly treat and comfort patients with musculoskeletal injuries and deformities.

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Foreword

Lee F. Rogers

The title of this work, *Radiologic Guide to Orthopedic Devices*, is a bit misleading. While the book does indeed fully address the imaging of orthopedic devices, it also describes and illustrates other metallic objects, all forms of foreign bodies that may appear on radiographs. Dental metallic devices are also covered. Thus, in reality, the book is a complete treatise on the subject of imaging metallic objects that may be encountered in radiographs and other imaging of human anatomy.

Countless metallic devices are confronted in the intraoperative, postoperative, and follow-up imaging of orthopedic procedures. Simple generic descriptions such as pin, plate, rod, and screw are commonly used in radiology reports, but more precise terminology is preferred. Devices are best accurately identified by their proper names, i.e., Rush pin, dynamic compression plate, intramedullary rod, cortical screw, etc. Indefinite terminology should be avoided.

Admittedly it is hard, essentially impossible, to remember the correct designation of all but the most commonly encountered hardware. So where does one turn in search of the correct terminology for these devices? There has been no one single source for such information. The search was time-consuming. You had to look through multiple sources online and leaf through books, scientific journals, and the catalogs of the various companies that produced these devices. This problem is now solved by the publication of *Radiologic Guide to Orthopedic Devices* by Hunter, Taljanovic, and Wild. Their book is a veritable compendium, an altogether encyclopedic source on orthopedic devices. Radiographs and diagrams of the various devices are shown and identified by the appropriate terminology.

Two major components of the book are the Gallery of Orthopedic devices and the Glossary of definitions, abbreviations, and acronyms of medical device and procedure terminology.

The Gallery of Orthopedic Devices is designed as a quick reference to identify unfamiliar orthopedic devices found on radiologic examinations. The Gallery consists of radiographs with legends describing and naming the orthopedic device or devices shown for fracture fixation and joint arthroplasty. They are grouped by body region, i.e., upper extremity, lower extremity, neck, and spine. Generic names which apply to the device are found in the legend. To find the proper terminology for the device in question, you simply match up the findings on your radiograph with the appropriate image in the Gallery. It's quick and easy.

The extensive Glossary is a valuable resource of exceptionally useful information regarding terminology; definitions of abbreviations and acronyms used for medical devices and surgical procedures as well as explanations of the many colloquial terms and abbreviations that are frequently heard in conversations and regularly appear on requisitions for radiologic services. The Glossary is easy to use, comprehensive, practical, and highly informative.

A chapter is devoted to the complications of fracture fixation and joint arthroplasty with a review of the subjects and illustrations of various more common complications. Information regarding the imaging of such complications is otherwise difficult to come by and therefore this particular chapter is quite useful and represents a significant contribution to the literature.

Surprisingly, there is similarly an exceptional chapter devoted to the imaging of foreign bodies, another neglected subject in the medical and surgical literature. The chapter covers all forms of foreign bodies: foreign body injuries, foreign body ingestions, and foreign body insertions. The various foreign bodies are fully described and illustrated. Again, this is information that is otherwise hard to come by in a single source.

Metallic objects present problems for either computed tomography (CT) or magnetic resonance imaging (MRI). This important subject is thoroughly presented and illustrated. Metal creates characteristic artifacts and image distortions which, of course, compromise the quality of the examination. Characteristic CT and MRI artifacts are discussed and shown. Steps can be taken to minimize image degradation. Examination protocols for CT and MRI that significantly reduce artifacts and imaging distortions are found in the chapter references at the end of the text. In a separate Nuclear Medicine chapter, artifact and image distortions in Tech 99m bone scanning and FDG PET and PET/CT scans are described and shown.

Who is the audience for this work? Who might find the book useful in their everyday practice? If you are an orthopedic surgeon or a radiologist who performs and interprets musculoskeletal imaging, your practice would be facilitated and enhanced by the presence and use of the *Radiologic Guide to Orthopedic Devices.* While primarily written for radiologists and orthopedic surgeons, emergency medicine physicians may also find this book of value in hospital emergency departments. The book would also be a useful reference in radiology and orthopedic billing services and medical insurance offices.

This work is an outstanding contribution to a long-neglected subject in the orthopedic and radiologic literature. Drs. Hunter, Taljanovic, and Wild, and their associate authors, Drs. Choudhary, Gurman, Light, Kuo, and Melville, are to be commended for their efforts.

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Acknowledgments

The successful completion of a book is the result of multiple, usually unselfish contributions from many persons, most of whom do not receive the recognition or thanks they justly deserve.

In this short section I hope to recognize and thank many who have contributed so much to the completion of this work and apologize to those whom I have inadvertently overlooked.

First, I need to thank the Co-editors Mihra S. Taljanovic and Jason R. Wild, whose expertise, time, and effort were requisite for the construction and completion of this work. Any omissions or significant errors herein are my own. I also need to acknowledge and thank the authors whose work is found in Hunter T.B., Bragg D.G., eds., *Radiologic Guide to Medical Devices and Foreign bodies*. St Louis, MO: Mosby–Year Book, 1994. That book was the stimulus for the present book, and much of the material in that book – images, glossary, and orthopedic treatment discussion – was extracted, updated, and corrected, where necessary, for the present work. Every effort was made to provide full credit and proper citation for any previous work used. Every effort was made to obtain proper permission for use of images previously published in print or electronically. I own the full copyright to the *Radiologic Guide to Medical Devices and Foreign Bodies.*

I need to specifically thank the chapter authors for this book – Gagandeep Choudhary, Pablo Gurman, Philip Kuo, Rick Light, and David Melville. They provided splendid chapters in a timely fashion and helped correct my editorial errors. They even remained friendly toward me despite periodic badgering to turn in their manuscripts or answer questions from the publisher. What counts most is the high quality of their work, which I believe is unique and not found anywhere else.

Any chapter errors or omissions are mine. I should note there is very little reward for being a chapter author for a scientific work. Academia hardly recognizes this effort when considering promotion and tenure, and there is certainly no financial reward for such an undertaking. The reward for writing a chapter is the pleasure one feels for contributing to scientific knowledge and understanding and for helping one's friend or colleague (the editor) in constructing a book.

I have to thank the webmasters and authors of the hundreds of websites I used in obtaining information and references for the book. I did my best to properly cite and acknowledge such information throughout the book. I profusely apologize for any omission in this regard.

This entire manuscript concerns medical apparatus, specifically that dealing with orthopedic disease and treatment. Medical device manufacturers actually produce the devices which save lives and help alleviate pain and suffering. Caring physicians, nurses, and other important healthcare providers are literally at the patient's bedside, and medical researchers constantly expand our scope of knowledge. Both of these groups are requisite for the advancement of medicine. However, the benefits of modern medicine would be of no use to any of us if pharmaceuticals and medical devices were not designed, tested, manufactured, evaluated for safety, and put on the market by medical device manufacturers and pharmaceutical companies. Their important role in our well-being should be acknowledged. In addition, many manufacturers graciously gave me permission to display images of their products. This was usually the result of a local manufacturer's representative taking a great deal of time and effort to acknowledge my request for images and permission and going out of his or her way to get that permission for me. These professionals certainly deserve my thanks.

Finally, I need to acknowledge and thank to my fullest Nicole Liberty and Amy Jennings. Nicole, who is a web design and application consultant, provided the template and structure for the websites (www.MedApparatus.com and www.OrthoApparatus.com) which are associated with the book. She tutored me on the nuances of computer programs used to construct the website and the accompanying images for the website and book. She is a superb internet technology specialist with extensive experience and a good sense of humor and extreme patience when teaching an elderly editor new tricks.

Amy Jennings, Administrative Assistant in the Department of Medical Imaging at the University of Arizona, literally put together the book you see before you. Like Nicole, she kept her sense of humor and patience when dealing with an elderly book editor. She was a godsend to me. Without her invaluable help, the book would not have been in a useful form for submission to Cambridge University Press. What you see is also the hard work of many at Cambridge who took the Word files for the book and put them into a printed and electronic form I hope will delight and enlighten the reader.

Tim B. Hunter

Contents

Chapter 1

Radiologic Guide to Orthopedic Devices and Miscellaneous Foreign Bodies

An Introduction

Tim B. Hunter

There are a large number of medical devices visible on everyday radiographs and on cross-sectional imaging – computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound exams (US) – as well as Nuclear Medicine studies. Many devices (electrocardiographic leads, pulse oximaters, Foley catheters, and IV lines) are used to monitor a patient's condition. Other devices (fracture fixation plates and screws, Kirschner wires, and joint arthroplasties) have therapeutic uses (Figure 1.1).

This book and the website www.medapparatus.com are designed to help physicians and other healthcare workers identify and understand the indications and uses for common orthopedic apparatus visualized on everyday imaging studies. The book also identifies and discusses many of the potential complications associated with orthopedic instrumentation.

It is not important to know the specific name for a given device, as the names and the variations for medical apparatus are endless. What is important is to recognize the presence of a medical device and understand its generic function. It is important to be familiar with a device's normal appearance and be able to identify when it is abnormally positioned, abnormally functioning, or has a life-threatening complication. For more information about a specific illustrated device, please see any associated references listed for the device.

Orthopedics is the surgical specialty devoted to the diagnosis and treatment of diseases and injuries affecting the musculoskeletal system (Orthopedic Surgery/Introduction). The range of conditions addressed by modern orthopedics involves trauma, degenerative diseases, congenital diseases, metabolic diseases, sports injuries, and tumors related to the musculoskeletal system – bones, joints, muscles, ligaments, tendons, and connective tissue supporting structures. Modern orthopedics overlaps with many other surgical and non-surgical specialties, particularly in regard to the treatment of spinal disorders, tumors of the extremities and trunk, and traumatic injuries to the hand.

The French physician and writer Nicholas Andry (1658–1742) coined the word "orthopaedics" from Greek words meaning straight "orthos" and "child" (paideion). In 1741 he published *Orthopaedia: or the art of Correcting and Preventing Deformities in Children*" (Orthopedics University of Colorado; Nicholas Andry). Until the early part of the twentieth century, orthopedics was part of general surgery, with much of orthopedic treatment devoted toward correcting bony deformities caused by ricketts, tuberculosis, and congenital scoliosis. Treatment of fractures was limited until the introduction of x-rays in the early twentieth century. Internal fixation of fractures did not get widely accepted until the mid-twentieth century through the work of Robert Denis (1880–1962). The first practical use of "rods" and "nails" to treat long bone fractures was by Gerhard Kuntscher (1900–1972) in 1940 while he served in the German army. The Kirschner wire (K-wire) was developed by Martin Kirschner (1879–1942), a German surgeon, who introduced the use of wire skeletal traction in 1909.

There are two common spelling for "orthopedics": ***orthopaedics*** and ***orthopedics***. Both are correct. The shortened form, orthopedics, is favored in the United States, while the more classic form, orthopaedics, is favored in Britain. Many universities and higher education departments in the United States favor the classic spelling as does the American Academy of Orthopaedic Surgeons (AAOS). *This website and its associated book have no classical pretensions and will use the common United States spelling for orthopedics.*

The devices presented and discussed are categorized by body site (Neck and Spine; Dental Devices) or orthopedic use (Fracture Fixation; Joint Arthroplasty). They are also displayed online as part of a **gallery of medical devices** which consists of simple radiographs and line drawings that illustrate a multitude of common orthopedic devices found in daily practice. The gallery is designed as a quick reference for those wishing to identify an unfamiliar medical device found on a radiologic study. Sometimes, a specific trademark name is shown for a particular device, but most of the devices illustrated are given generic names which apply to the device shown as well as to similar devices. This gallery can be found at http://medapparatus.com/Gallery/Gallery_Introduction.html.

With regard to the head, neck, and spine, there are few orthopedic devices associated with the skull other than tongs for cervical spine traction (Figure 1.2). However, considerable orthopedic apparatus can be found in the cervical, thoracic, and lumbar spine for treatment of fractures, degenerative spinal conditions, spinal tumors, and spinal infections (Figure 1.3). This apparatus ranges from spinal braces to spinal fixation hardware and spinal cord stimulators.

The largest array of orthopedic apparatus involves fracture fixation (Figure 1.4, Figure 1.5). This ranges from external stabilization with wraps, splints, and casts to internal traction and

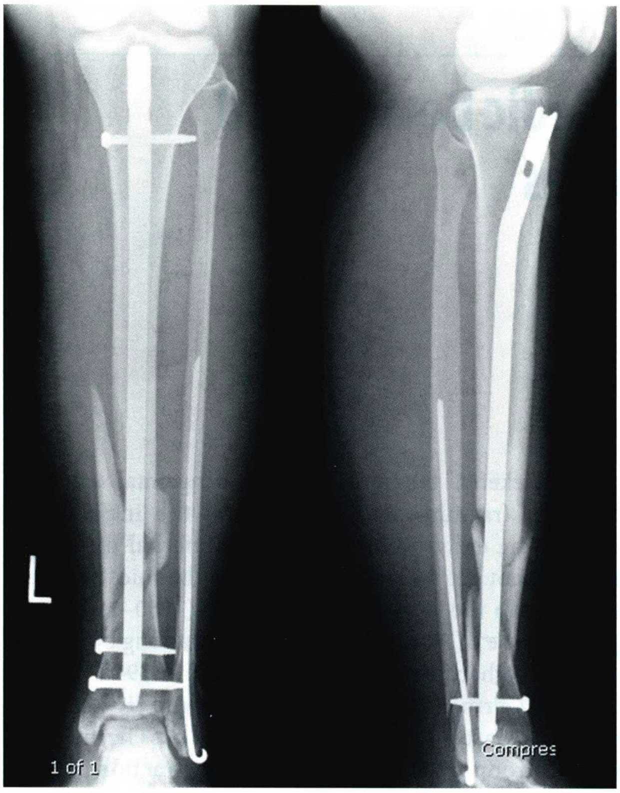

Figure 1.1 Intramedullary tibial nail and fibular Rush rod for stabilization of left distal tibial and fibular fractures (from Taljanovic *et al.*, 2005).

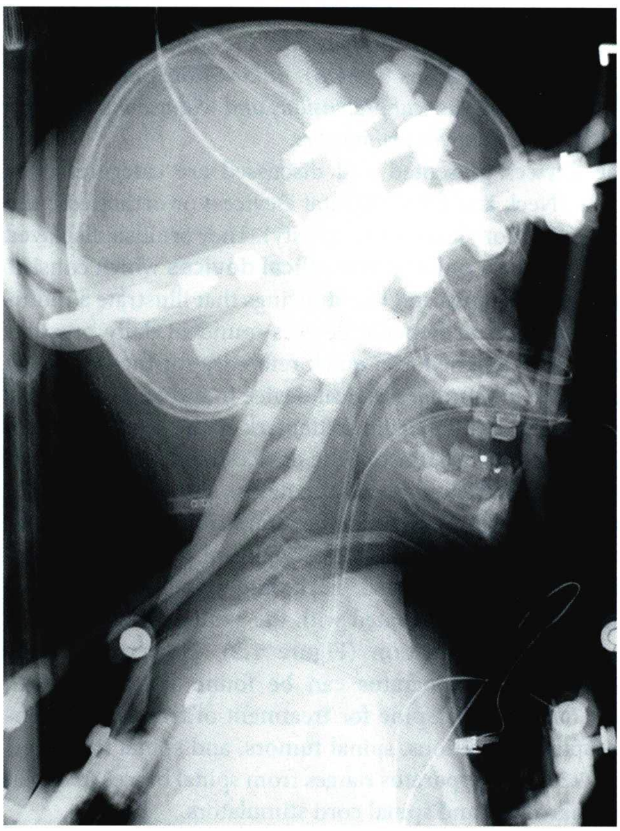

Figure 1.2 Child with severe intracranial and cervical spine injuries with bilateral cranial stabilization tongs, an endotracheal tube, an oroogastric tube, and a feeding tube entering via the nose. From Hunter *et al.*, 2004.

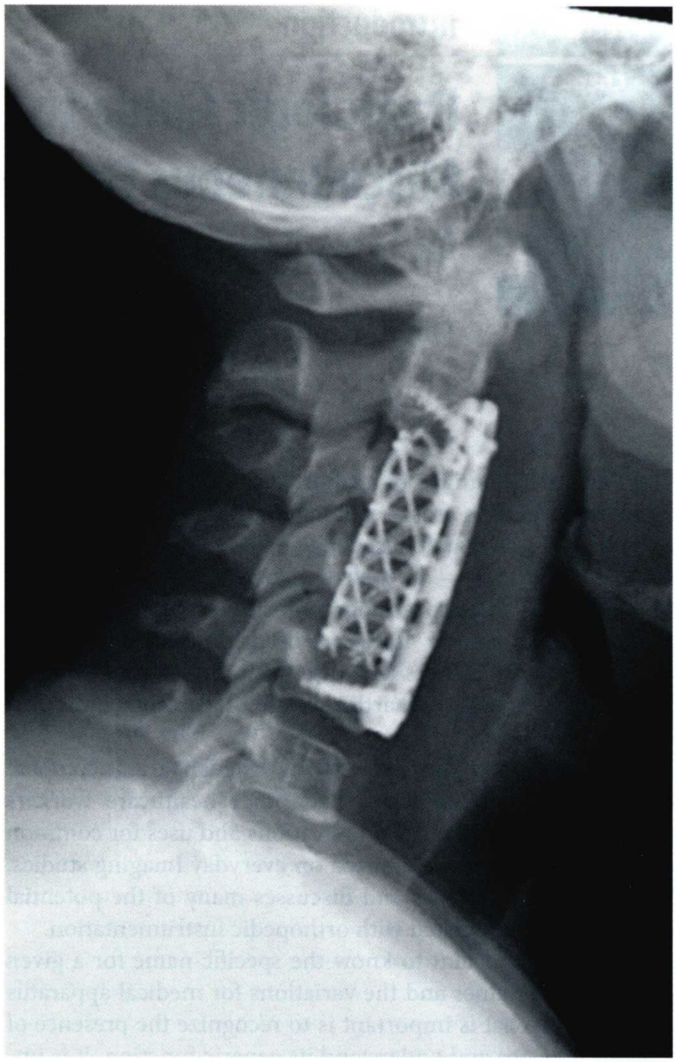

Figure 1.3 Cervical spine fusion cage and anterior cervical fixation plate.

fixation with wires, pins, plates, screws, rods, and nails. Bone grafts and bone substitute material is extensively used for fracture treatment.

Modern bioengineering coupled with advanced surgical techniques has enabled the orthopedic surgeon to offer a large selection of prosthetic joints (joint arthroplasty) for painful, poorly functioning native joints that have end-stage inflammatory or degenerative arthritis (Figure 1.6). The most successful joint arthroplasties are for the hips and the knees, but successful arthroplasty is also being performed for the shoulder and the small joints in the hand. There is the expectation that more successful joint prostheses will soon be available for the elbow, wrist, and ankle. Limb salvage prostheses successfully replace joints destroyed by tumor or removed due to extensive surgical resection for a life-threatening neoplasm (Figure 1.7).

Medical devices used for orthopedic applications as well as numerous other applications (heart valves, pacemakers, central indwelling catheters, subcutaneous ports, hernia repair mesh, etc.) rely on an armamentarium of modern biomaterials compatible with human tissue chemically,

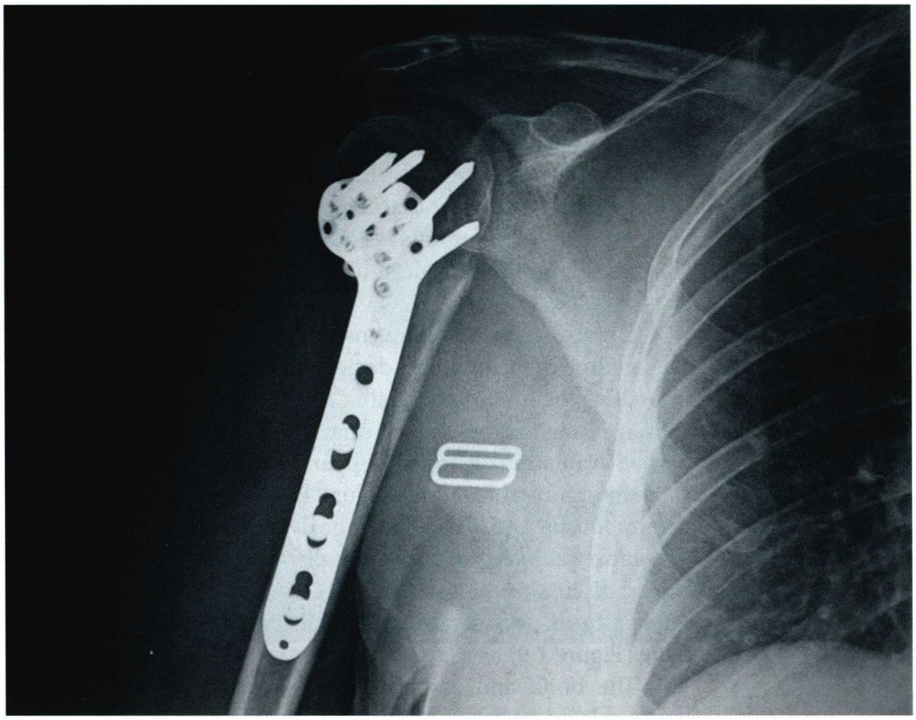

Figure 1.4 Humerus periarticular locking plate.

Figure 1.5 Short hip nail with helical (spiral) blade in femoral neck. From Taljanovic *et al.*, 2005.

Figure 1.6 Unipolar hip arthroplasty (endoprosthesis) with a cemented femoral component. From Taljanovic *et al.*, 2005.

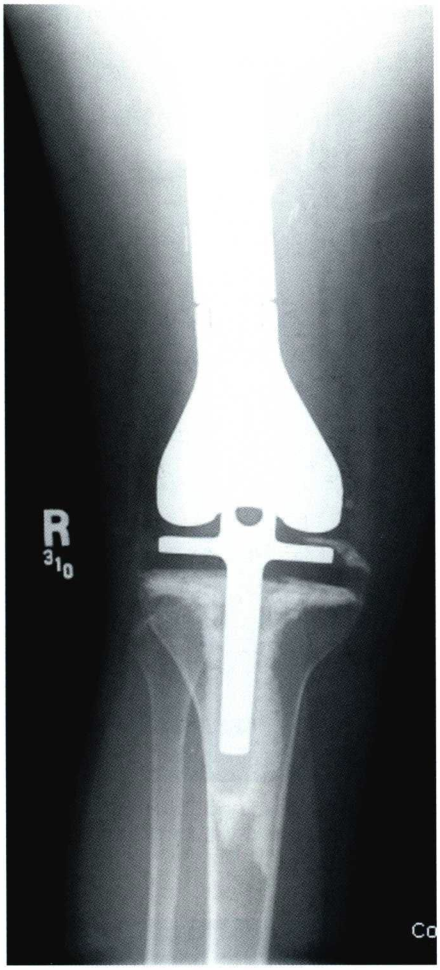

Figure 1.7 Lower limb salvage prosthesis (limb-salvage total knee arthroplasty). From Taljanovic *et al.*, 2005.

mechanically, and pharmacologically. Any material brought into contact with living tissue and used for treating medical and dental diseases is a biomaterial. Biomaterials should have adequate strength, be chemically inert, stable, and not elicit allergenic, carcinogenic, immunologic, or toxic reactions. A detailed study of biomaterials is beyond the scope of the present book and associated website. However, a brief overview of biomaterials is presented to enable the reader to better appreciate the design and functionality of common orthopedic devices.

Dental apparatus is not ordinarily considered part of the collection of orthopedic devices. However, radiologists frequently encounter the teeth, mandible, and maxilla when interpreting head and neck images for trauma or infection or when evaluating orthopedic apparatus placed for cervical spine fixation and stabilization (Figure 1.8). Dental apparatus is not unimportant and is generally poorly understood and evaluated by most radiologists and other physicians. For this reason, a brief discussion of the mandible, tooth anatomy, and dental apparatus is provided as part of this book and associated website (Figure 1.9).

The book and associated website also display and discuss a large number of **foreign bodies** that may be found in patients, either ingested, inserted, or obtained as part of an external injury. Foreign bodies are uncommon, but they are important and interesting (Figure 1.10). Foreign bodies may go unrecognized or mistaken for a normal structure or a normally functioning medical device. They can sometimes simulate orthopedic apparatus, and inadvertent foreign bodies (surgical sponge, broken fixation pin, retained suture needle) can result from an unrecognized surgical mishap (Figure 1.11). Sometimes, what starts out as a useful device may cause

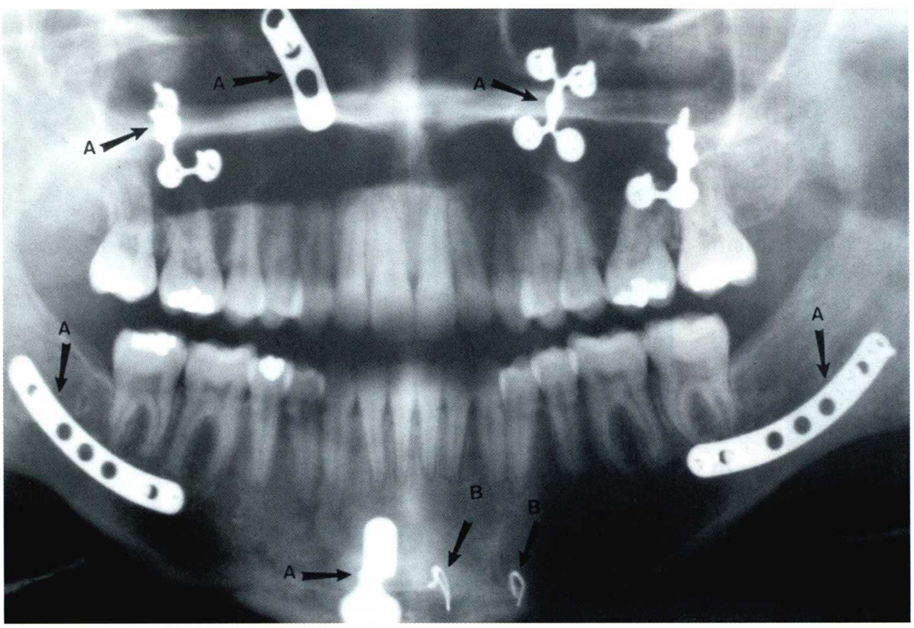

Figure 1.8 Panoramic view of the mandible shows dental plates with screws (A) and bone ligature wires (B). There are multiple dental alloy restorations (amalgam fillings). From Hunter & Bragg, 1994.

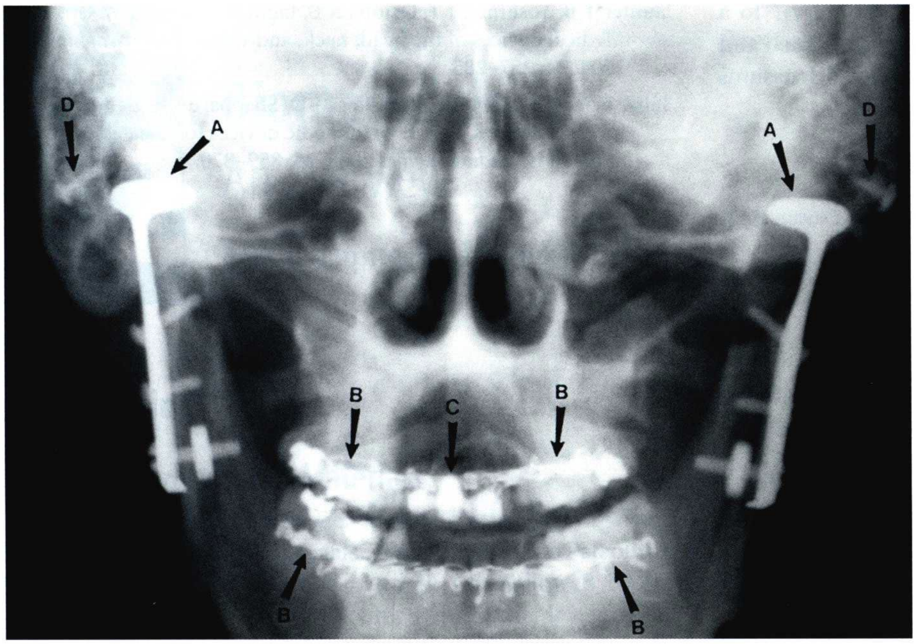

Figure 1.9 Temporomandibular prosthetic condyle implant (A); orthodontic arch bars (B); porcelain veneer dental crowns (caps) (C); fixation screws (bone screws) (D). From Hunter & Bragg, 1994.

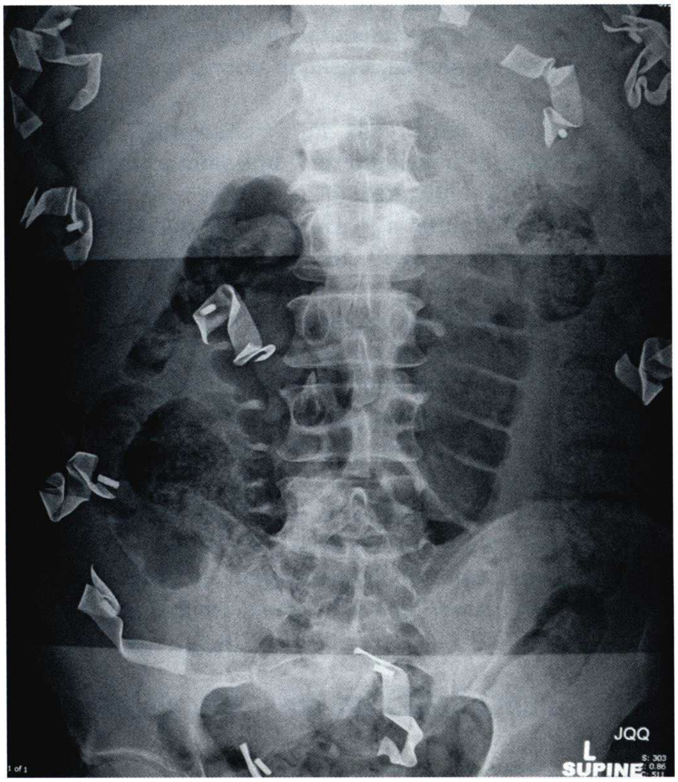

Figure 1.10 Multiple lap sponges in a trauma patient who died at surgery.

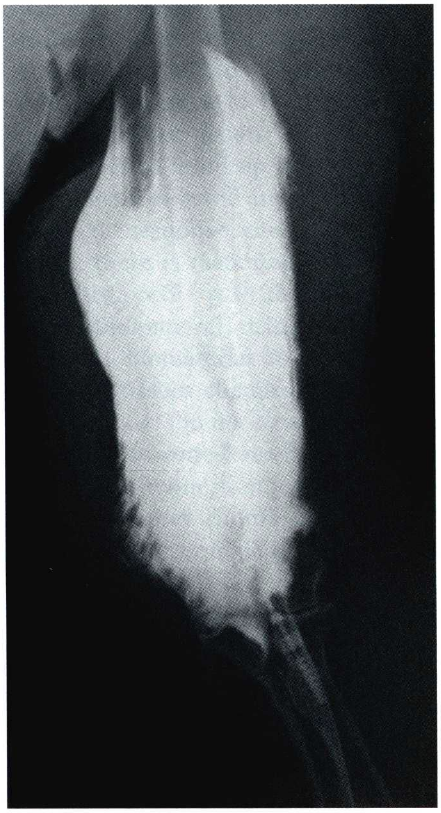

Figure 1.11 79-year-old woman undergoing chest CT study with contrast extravasation from attempted contrast injection in her left antecubital fossa.

problems later (e.g., a surgical sponge left in the abdomen after surgery or a dislocated joint prosthesis).

A **glossary** is available with many terms and abbreviations used in connection with orthopedic devices as well as medical apparatus in general. Terms and abbreviations like ORIF, POOP, CABG, TENS unit, K-wire, and IM nail may be unfamiliar, depending on one's training, locale, or practice situation. Many terms associated with medical devices are often used inappropriately in the radiologic literature. Sometimes they are misspelled, and frequently they are not properly defined or referenced. In addition, abbreviations have different meanings in different contexts. CT means "computed tomography" to a radiologist, but it can signify "cardiothoracic [surgery]" to a surgeon. Every attempt has been made to adequately spell and define important terms as they arise in the device discussions in addition to their being included in the glossary.

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Chapter 2

Biomaterials
An Overview

Tim B. Hunter and Pablo Gurman

Introduction

Historical Overview of Materials

The history of mankind has been marked by the evolving use of natural and man-made materials. The prehistoric or Paleolithic era ("palaois" = old, "lithos" = stone) was followed by the Neolithic revolution (8000 BC) which led to the development of agriculture. The first civilizations emerged in Mesopotamia between the Euphrates and Tigris rivers. There people began building tools to work the land. They also addressed their medical needs by developing rudimentary medical therapies, including medical devices applied externally or even implanted into the body.

These "biomaterials" for the earliest medical devices were initially simple and were implanted without knowledge of whether they were even biocompatible. A carbon-based material implanted in the skin ("a tattoo") has been found dating to 5000 BC. By 3200 BC there is evidence of the first suture usage.

The development of metallurgy with the first use of copper gave rise to a period known as the "bronze era," accelerating the rate at which humans gained control over nature. By developing techniques to manipulate metals – molding, heating, cracking, and **alloy** development – more advanced tools were created.

By 2000 BC, the Aztecs and Chinese used gold for dental applications. By 1065 BC, the Egyptians built wooden artificial digits to replace lost fingers. By 200 BC, metallic sutures using gold were described, and by 60 AD the Mayans used sea shields as rudimentary dental implants.

Biomaterials: Definition and Classification

A biomaterial can be defined as "a material intended to interface with biological systems for evaluating, treating, augmenting, or replacing a tissue or organ." A biomaterial is thus any substance brought into contact with living tissue for the purpose of treating a medical or dental condition. Biomaterials are usually synthetic and are continuously or intermittently in contact with body fluids (**AZO materials**). Typically, surgical instruments and dental instruments are not categorized as biomaterials. The materials used for external prostheses, such as artificial limbs and hearing aids, are also not considered biomaterials most of the time.

The evolution of biomaterials can be conceptually divided into four generations:

Generation I: Use of inert materials
Generation II: Introduction of interactive biomaterials
Generation III: Introduction of viable biomaterials
Generation IV: Use of tissue engineered/genetic-engineered tissues.

Generation I involved using inert materials intended not to harm. *Generation II* involved materials intended to provide a benefit in addition to the "not to harm" approach of generation I. *Generation III* involved the use of materials capable of acting as scaffolds where biological tissue could adhere to the biomaterial to induce tissue growth. *Generation IV* involves the use genetic engineering and tissue-engineering techniques to build up tissues specifically designed for the host. This is to avoid any unwanted inflammatory or immunological response caused by the biomaterial. In other words, there is matching of the receptor (host) histocompatibility profile with the histocompatibility profile of the donor (biomaterial) using genetic-engineering techniques.

For a biomaterial to be effective it must be compatible with tissues chemically and mechanically (Table 2.1a). Biomaterials should have adequate strength for resisting fatigue – so-called *mechanical compatibility*. They should be chemically inert and stable – so-called *chemical compatibility*, and they should not elicit allergenic, carcinogenic, immunogenic, or toxic reactions – so-called *pharmacological compatibility*.

There are many ways to classify biomaterials. They can be considered either synthetic (man-made) or natural. They can be classified according to their expected duration inside the body (permanent or transient). They are frequently categorized according to their tissue usage (in soft tissue, in hard tissue, or in the blood). They are probably most frequently categorized according to the medical discipline involved in their use. In this regard, the present discussion will center most on the orthopedic applications for biomaterials, but it should be recognized there are important and widespread biomaterial applications for cardiovascular, dental, ophthalmologic, neurosurgical, otolaryngologic, and pediatric conditions.

Implant is a generic term used for any material or device placed *in vivo* for the treatment of a medical or dental condition.