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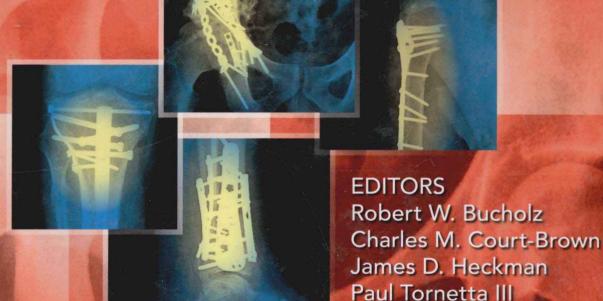
## **VOLUME ONE**

ROCKWOOD AND GREEN'S

## FRACTURES INADULTS

SEVENTH EDITION

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ASSOCIATE EDITORS Margaret M. McQueen

William M. Ricci



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## **ROCKWOOD AND GREEN'S**

# FRACTURES IN ADULTS

**VOLUME 1** 

## SEVENTH EDITION

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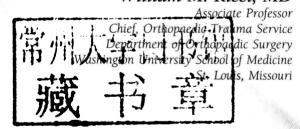
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We dedicate this Seventh Edition of *Rockwood and Green's Fractures in Adults* to Charles A. Rockwood, Jr, MD, and David P. Green, MD, who served as our inspiration and mentors for carrying on the revision and update of this textbook.

To Marybeth for her unwavering support over the years,

RWB

To Susan for her encouragement and understanding.

IDH

To my family for their help and support.

**CCB** 

To my mother, Phyllis, who found the best in people, had compassion for all, and whose insight, guidance, and love have always made me believe that anything is possible.

PT3

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## **PREFACE**

The 7th edition of Rockwood and Green's Fractures in Adults continues with the changes that were instituted in the 6th edition. In this edition there are four more chapters and 53 new authors drawn from three continents and ten different countries. Eleven new chapters focus on topics that have not been covered in separate chapters in previous editions of Rockwood and Green. To allow us to cope with the advances and changes in Orthopaedic Trauma, Paul Tornetta has become an Editor, and Margaret McQueen from Edinburgh and Bill Ricci from St Louis have been appointed Associate Editors. All three are accomplished orthopaedic trauma surgeons and their complementary interests and areas of expertise have greatly assisted the production of the 7th edition. In addition, many of the new authors represent the next generation of orthopaedic trauma surgeons who will be determining the direction of trauma management over the next two or three decades.

Orthopaedic trauma continues to be an expanding discipline, with change occurring more quickly than is often realized. When Drs. Rockwood and Green published the 1st edition in 1975, there were virtually no orthopaedic trauma specialists in most countries, fractures were usually treated nonoperatively, and mortality following severe trauma was considerable. In one generation the changes in orthopaedic surgery, as in the rest of medicine, have been formidable. We have worked to incorporate these changes in this edition. The continuing importance of wartime and severe civilian injuries is reflected in new chapters on gunshot and wartime injuries, the principles of mangled extremity management, bone and soft tissue reconstruction, and amputation. There is expanded coverage in this edition of the inevitable complications that all orthopaedic surgeons have to deal with, and we have included new chapters that discuss systemic complications, complex regional pain syndrome, infection, nonunion, and malunion. We have also separated distal tibial fractures into pilon and ankle fractures.

The other area of orthopaedic trauma that is expanding quickly, particularly in the developed countries, is the treatment of osteoporotic (or fragility) fractures. These fractures are assuming a greater medical and political importance, and orthopaedic implants are now being designed specifically to treat elderly patients. It is likely that this trend will continue over the next few decades; many of the chapters in this edition reflect this change in emphasis.

The changes in the 7th edition are highlighted by the altered presentation of the book. Many of the operative pictures and diagrams are now in color, as are all the tables. This edition is strengthened by the inclusion online of 20 new videos of surgical procedures done by Drs. Tornetta, Ricci, and Schmidt. Twelve additional videos will be created in the next year. The user will be able to download clips from these videos for lectures and presentations. We have also made available videos of many surgical approaches useful for trauma procedures. Two features that we have not changed are the Pearls and Pitfalls and the Authors' Preferred Treatment, these features having been present in the last edition. It is perhaps a paradox that we ask our authors to emphasize Level 1 evidence in the form of randomized double blind studies but we promote the authors' preferred methods, which is Level V evidence! However, we continue to believe that it is the function of Rockwood and Green to feature the world's leading orthopaedic trauma surgeons and to listen to what they say.

> Robert W. Bucholz James D. Heckman Charles M. Court-Brown Paul Tornetta, III

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SECTION ONE

# GENERAL PRINCIPLES: BASICS





## BIOMECHANICS OF FRACTURES AND FRACTURE FIXATION

Allan F. Tencer

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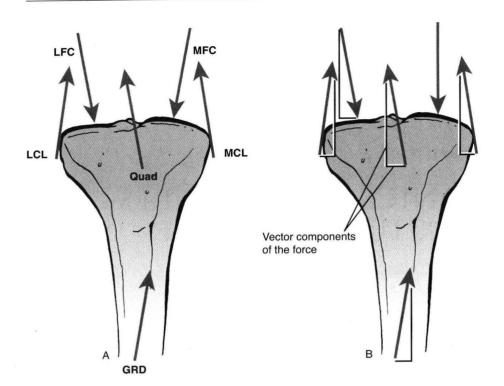
#### INTRODUCTION

This chapter provides a basic discussion of the concepts of biomechanics, and demonstrates how these concepts can be used to understand the basic functions of bone fracture fixation devices and to avoid clinical problems associated with the mechanics of fracture fixation. Emphasis has been placed on addressing practical problems. First, fundamental concepts of mechanics as they apply to the practice of orthopaedic fracture fixation are explained. This is followed by a short discussion on the mechanical organization of bone, its ability to carry load, and the relationship of applied forces and specific fracture patterns. A discussion of mechanisms of bone and joint injury, including specific mechanisms observed in car crashes is next presented. Description of the mechanics of healing bone follows, which is relevant to understanding the timing of applying progressive load to healing fractures in patients. Finally, the performance of various types of fixation systems is discussed, with emphasis on fixation of difficult fractures, such as the femoral neck and the tibial plateau, and those involving osteoporotic bone. The focus of the discussion is not on comparing the various specific devices available, but rather on demonstrating the common mechanical principles involved in fracture fixation so that potential problems common to various devices can be recognized and avoided.

In the study of biomechanics as it relates to fracture fixation, the fundamental mechanical question remains: is the fixation system stiff and strong enough to allow the patient early mobility, before bony union is complete, without delaying healing, creating bone deformity, or damaging the implant, and yet flexible enough to allow transmission of force to the healing fracture to stimulate union? The issue of which brand of fixation is strongest or stiffest is not specifically addressed because that is not the standard by which different devices should be judged. Within a range of fixation stiffness it has been shown that bone will heal, with the amount of stabilizing callus compensating for more flexible fixation.

#### BASIC CONCEPTS

Before describing the performance of fracture fixation systems, some basic concepts used in biomechanics will be introduced. As Figure 1-1 demonstrates, loads in many different directions may act on a fixed fracture, including body weight, and forces induced by muscle contraction and ligament tension. A *force* causes an object to either accelerate or decelerate. It has *magnitude* (strength) and acts in a specific direction, therefore it is termed a *vector*. However complex the system of forces acting on a bone, each force may be separated into its vector components (which form a 90-degree triangle with the force). Any of several components, acting in the same direction, can be summed to yield the net or *resultant force*. As a simple example, consider the resultant force acting at the shoe/floor interface during ambulation. It can be separated into a vertical force because of



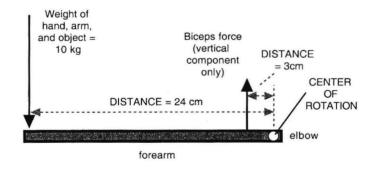
**FIGURE 1-1** Force vectors acting on a long bone during functional use as a result of muscle, tendon, and external forces. A vector indicates that the force has both magnitude and direction. The complex system of forces can be divided into components acting perpendicular and parallel to the ground, or the axis of the bone, then added to arrive at an overall resultant force.

body weight and a horizontal frictional force that produces the forward thrust. Similarly, muscle forces can be separated in the same manner—one force along the axis of the long bone and one perpendicular. The components of the different forces that act in the same direction can be added, and the resultant force acting on the bone can then be found. This concept is important when designing fracture fixation systems because it allows the designer to size the implants so that they can withstand the mechanical loads applied without failure.

The two major loads acting on a long bone are those that cause it to displace in a linear direction (translation) and those that cause it to rotate around a joint center. Muscles typically cause a bone to rotate (e.g., the biceps causes the forearm to rotate, the anterior tibialis causes the foot to dorsiflex). When a force causes rotation, it is termed a moment and has a moment arm. The moment arm is the lever arm against which the force acts to cause rotation. It is the perpendicular distance of the muscle force from the center of rotation of the joint. As shown in Figure 1-2, the moment or rotary force is affected not only by the magnitude of the force applied, but also by its distance from the center of rotation. In the example, two moments act on the outstretched arm. The weight carried in the hand rotates the arm downward, while the balancing muscle force rotates the arm upward. Equilibrium is reached by balancing the moments so that the arm does not rotate and the weight can be carried. Note that to achieve this, the muscle force must be 8 times as large as the weight of the object, arm, and hand because its moment arm or distance from the center of the joint is only one eighth as long.

The basic forces—compression, transverse loading, torsion, and bending—cause bone to behave in predictable ways. A compressive force (Fig. 1-3) results in shortening the length of the bone, while tension elongates it. Torsion causes twisting of a bone about its long axis, while bending causes it to bow at the center. The forces and moments that act on a long bone during functional use produce three basic stresses on the healing

fracture region: tension, compression, and *shear* (as shown previously, all forces can be reduced to their basic components). *Stress*, as shown in Figure 1-4, is simply the force divided by the area on an object over which it acts. This is a convenient way to express how the force affects a material locally. For example, comparing two bones, one with half the cross-sectional area of the other, if the smaller bone is subjected to half the force of the larger bone, the stress experienced by each bone would be the same. Therefore, a smaller woman with less weight



Balance moments to hold arm steady: 24 cm x 10 N = 3 cm x Biceps force Biceps force = 80 N

**FIGURE 1-2** In this example the outstretched arm is a lever. The moment or load that rotates the arm downward around the elbow, the center of rotation, is defined as the product of the weight of the object arm and hand X distance from the elbow (for simplicity the center of gravity of the hand, arm, and object are combined). This moment must be counteracted by a moment in the opposite direction, because of the vertical component of the biceps muscle acting through its lever, which is smaller than the lever arm of the weight arm and hand. The biceps force is then calculated from (10 kg  $\times$  24 cm)/3 cm = 80 kg. The biceps force is much greater than the weight of the object arm and hand because its lever arm is smaller.

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