Chapter 2
Virtual Bone Surgery

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2.1 Introduction

To become a skillful surgeon requires rigorous training and iterative practice. Traditional training and learning methods for surgeons are based upon the Halstedian apprenticeship model, i.e., “see one, do one, teach one” which is almost 100 years old (Haluck et al. 2000). For bone surgery, students often watch and perform operations on cadaveric or synthetic bones under the tutelage of experienced physicians before performing the procedure themselves under expert supervision. They need to learn and perform material removal operations such as drilling, burring, etc., as shown in Fig. 2.1. Mistakes can lead to irreparable defects to the bone and the surrounding soft tissue during such procedures, which can result in complications such as early loosening, mal-alignment, dislocation, altered gait, and leg length discrepancy (Conditt et al. 2003). The current system of surgery education has many challenges in terms of flexibility, efficiency, cost and safety. In addition, as new types of operations are developed rapidly, more efficient methods of surgical skill education are needed for practicing surgeons (Gorman et al. 2000).

Virtual Reality (VR) is one of the most active research areas in Computer simulation. Virtual reality systems use computers to create virtual environments to simulate real-world scenarios. Special devices such as head-mounted displays, haptic devices, and data gloves are used for interacting with virtual environments to give real-world like feedback to the user. The most important contributing factor to VR development has been the arrival of low-cost, industry-standard multimedia computers and high-performance graphic hardware. VR has been integrated into many aspects of the modern society such as engineering, architecture, entertainment, etc.

The concept of developing and integrating computer-based simulation and training aids for surgery training has begun with VR simulators. VR techniques provide a realistic, safe, controllable environment for novice surgeons to practice surgical operations, allowing them to make mistakes without serious consequences. It promises to change the world of surgical training and practice. With a VR simulator, novice surgeons can train and perfect their skills on simulated human models, and experienced surgeons will be able to use the simulator to plan surgical procedures. VR training also offers the possibility of providing a standardized performance evaluation for the trainees.
Bone surgery is one of the medical applications which can be simulated using VR technology. There exist some surgical simulation tools for orthopedic applications such as knee surgery, but most of them involve only soft tissues. Few have considered the simulation of cutting, sawing, burring, etc., which involve operating on bones as well as on ligaments and muscles. The development of a virtual bone surgery system is very desirable for training surgeons, allowing them to visualize surgical operations simulated with the added sense of touch during the process. As the Minimally Invasive Surgery (MIS) takes a foot-hold in orthopedics, VR technology will become more and more valuable for assisting actual surgery operations. As surgical techniques are developed to sequentially reduce access to the surgical site (via smaller incisions), and instruments and implants are miniaturized to accommodate for these techniques, surgical dexterity and bone preparation and implant positioning will become a less and less forgiving part of the operation. It will be necessary to integrate VR models with images obtained during the actual surgery operations, the so-called Augmented Reality (AR) technology, in order to assist the surgeons in performing the MIS process.

This book chapter reviews the bone surgery simulation systems being developed in various research laboratories and discusses the basic methods and techniques used to develop these systems.

2.2 State-of-the-Art in Surgery Simulation

2.2.1 Current State of Digital Surgery

Previous research on surgery simulation has covered a wide range of operations. Some of the simulators were developed to provide a virtual reality environment as a training tool. The VRMedLab networked facility at the University of Illinois-Chicago (VRMedLab, 2003) was designed to provide an educational resource to otolaryngology surgeons, enabling them to visualize bone-encased structures within the temporal bone using interactive 3D visualization technology.