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17.1 Introduction

Bone repair is a subject of intensive investigation in reconstructive surgery (for review, see [1]). Current approaches in skeletal reconstructive surgery use biomaterials, autografts or allografts, although restrictions on all these techniques exist. These restrictions include donor site morbidity and donor shortage for autografts [2], immunological barriers for allografts, and the risk of transmitting infectious diseases. Numerous artificial tissue substitutes containing metals, ceramics, and polymers were introduced to maintain skeletal function [3]. However, each material has specific disadvantages, and none of these can perfectly substitute for autografts in current clinical practice. The use of biomaterials is a common treatment option in clinical practice. One important reason for the priority of tissue grafts over nonliving biomaterials is that they contain living cells and tissue-inducing substances, thereby possessing biological plasticity. Research is currently in progress to develop cell-containing hybrid materials and to create replacement tissues that remain interactive after implantation, imparting physiological functions as well as structure to the tissue or organ damaged by disease or trauma [4].

Bone tissue engineering, as in most other tissue engineering areas, exploits living cells in a variety of ways to restore, maintain, or enhance tissue functions [5, 6]. There are three principal therapeutic strategies for treating diseased or lost tissue in patients: (1) in situ tissue regeneration, (2) implantation of freshly isolated or cultured cells, and (3) implantation of a bone-like tissue assembled in vitro from cells and scaffolds. For in situ regeneration, new tissue formation is induced by specific scaffolds or external stimuli that are used to stimulate the body’s own cells and promote local tissue repair. Cellular implantation means that individual cells or small cellular aggregates from the patient or a donor are injected directly into the damaged or lost region with or without a degradable scaffold. For tissue implantation, a complete three-dimensional tissue is grown in vitro using autologous or donor cells within a scaffold, which has to be implanted once it has reached
“maturity” [7–9]. In this chapter we give some details of all of the above-mentioned strategies and present alternatives to extracorporal approaches that are important in clinical decision-making. Furthermore, it is mentioned that some of the techniques described here are clinically combined with extracorporal tissue-engineering methods.

17.2

Bone Repair Strategies

The use of autologous bone in bone defect reconstruction can be considered to be the gold standard. There are two classical ways to repair bone defects by use of autologous cells: one utilizes mechanisms of defect repair by enhancement of the local host cell population, while the other is based on transplantation of grafted bone (Fig. 17.1).

Augmentation of the host cell population can effectively be used to improve the healing of bone lesions. The ability to repair or reconstruct lost bone structure by this technique critically depends on the condition of the defect site. If the soft and hard tissues of the defect site are healthy, expansion of host cells is often successfully applied. In circumstances of impaired defect conditions such as wound infection and tissue necrosis or irritation, however, cellular augmentation of the local bone cell population will probably fail.

17.3

Membrane Techniques

Membrane techniques can be used to improve defect healing by ingrowth of local host cells in the defect site (Fig. 17.2). This kind of defect repair procedure (guided bone regeneration) is mainly used in maxillofacial surgery to repair bony defects in the maxilla and mandible. The principle of guided bone regeneration (GBR) is to effectively separate bone tissue from the soft tissue ingrowth by a barrier [10]. The application of the principle of GBR has proven to be successful in a number of controlled animal studies and clinical trials [11–13]. The healing pattern has been shown to involve all steps of de novo bone formation including blood clot formation, invasion by osteoprogenitor cells, and their terminal differentiation into osteoblasts. Under these circumstances the produced extracellular matrix finally mineralizes to form woven bone and later is remodeled into lamellar bone [14]. The success of GBR critically depends on the defect size and geometry.