

Implants in Orthopedy



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Abstract

Orthopedics is a branch of surgery that deals with disorders and conditions that involve the musculoskeletal system. Orthopedic surgeons use surgical and non-surgical agents to treat musculoskeletal trauma, spinal diseases, sports injuries, degenerative diseases, infections, tumors, and congenital disorders.

Keywords: Orthopedics; Bone; Ligament; 3D; CT

Introduction

The quality of human life can be dramatically improved with the use of biomaterials [1]. Rapidly advancing technologies are allowing new and improved biomaterials to be developed with unprecedented performance behaviour.

Biomedical Engineering

There has been significant improvement in technologies to reconstruct musculoskeletal defects as a result of trauma or disease [2]. During the last few decades, there has been widespread use of bone-banked, processed skeletal allografts to reconstruct large deficits of bone and cartilage with outcomes at intermediate follow-up providing 85% satisfactory results. However, there still is a significant incidence of nonunions and graft failures, which usually require additional surgical intervention and result in additional morbidity. Additionally, the cost and availability of graft materials and some immunological issues still have not been completely resolved. Although great strides have been made to improve materials and surgical techniques, the failure rate in these younger patients still approaches 10% in long-term follow-ups. The ultimate goal of any treatment that addresses musculoskeletal tissue loss is the restoration of the morphology and function of the lost tissue. The recent emergence of a new discipline, defined as tissue engineering, combines aspects of cell biology, engineering, materials science, and surgery with the outcome goal to regenerate functional skeletal tissues as opposed to replacing them. Repair and regeneration of skeletal tissues are fundamentally different processes. In many situations, scar, which is the result of rapid repair, can function satisfactorily, such as in the early phases of bone restoration. By contrast, regeneration is a relatively slow process that ultimately results in a duplication of the tissue that has been lost. Regeneration is rarely seen in adults but is evident

in very young children. Such regeneration appears to recapitulate some of the key steps that occur in embryonic development. Our approach to musculoskeletal tissue regeneration is to use principles of tissue engineering that are based upon the premise that there are important constituents that distinguish the fetal environment from that in adults and by mimicking aspects of these fetal microenvironments, we can engineer the restoration of adult tissue. The basic component of any tissue engineering strategy is the use, either in combination or separately, of cells, biomatrices or scaffolds/delivery vehicles, and signaling molecules that provide the biological cues for the progression of cellular differentiation and its site-specific functional modulation. Significant issues remain for each component that must be addressed to develop successful and realistic tissue engineering treatment strategies. Central to our strategies is the need for cells. Significant issues that remain include the source of these cells, the number and density, and, most important, their age, phenotypic character, and developmental potency. We have put forth the hypothesis that mesenchymal stem or progenitor cells possess the appropriate developmental potential, are responsive to local cueing, and are capable of ultimately differentiating into the appropriate required phenotype. By contrast, adult differentiated cells are generally less responsive to mechanical and biological cues and may not be available in the appropriate quantities to achieve the desired tissue density.

Tooth

Tooth is a biological organ originating from ectomesenchymal cells composed of enamel, dentin, and viable pulp tissue which is altogether called as tooth organ [3]. These tissues usually arise from the interaction of oral epithelium and mesenchyme of cranial neural crest.

Bone

As a highly specialized and dynamic tissue, bone is characterized by its mineralized matrix, rigidity and hardness with certain degree of elasticity [4]. Bone provides support and protection to internal organs and also aids in locomotion.

Ligament

Ligaments are specialized connective tissues whose biomechanical properties allow them to adapt to and carry out the complex functions required of the body [5]. While ligaments were once thought to be inert, it is now recognized that they are in fact responsive to many local and systemic factors which influence their performance within the organism. Injury to a ligament results in a drastic change in its structure and physiology and may resolve by the formation of scar tissue, which is biologically and biomechanically inferior to the ligament it replaces. T1 weighted images are particularly useful at demonstrating the normal anatomy [6]. Ligaments will appear black against the adjacent fat which will be white. In case of injury, T2 weighted images will show edema in the soft tissues and if fat suppression is used then this can easily be differentiated from fatty structures. Therefore, T2 weighted images with fat suppression, or perhaps more sensitively, Fast STIR images should be employed. Because the anatomy of the lateral complex is variable, the choice of imaging planes is difficult. True axial images are particularly useful for looking at both the anterior and posterior tibiofibular ligaments. The anterior talofibular ligament will also be seen on most axial images although arguably an oblique axial running along the plane of this ligament may be more precise. Much more difficult is the calcaneofibular ligament. This is unfortunate as it is the most structurally important and therefore where we would like to image most accurately. The calcaneofibular ligament runs in oblique plane from the calcaneus running anteriorly and superiorly to the fibula. The angle varies with individuals and the shape of the hind foot. It is very difficult to judge the inclination of the best imaging plane to produce a true axial of this ligament. It is common that axial images will show the ligament on multiple slices, and it is difficult to follow its integrity even with MIP reconstructions. Alternative strategies are to place the foot in an equinus position, which elevates the calcaneus, making the calcaneofibular ligament a more horizontal structure. In this position a true axial is more likely to show the calcaneofibular ligament in its full length, but this may be a difficult position for the patient to achieve and hold, particularly if the ankle is painful. Therefore, it may be easier to examine the foot in a neutral position and incline the imaging plane with the anterior margin more cranial. The difficulty is how to assess the degree of angulation that would be required for an individual. Careful palpation of the ankle and judgement of the imaging plane by the examining technician or radiographer may assist. True 3D volume imaging of this region has an advantage that reconstructions can be made in different planes. However, 3D volume is most effectively achieved using gradient echo imaging and the contrast between the ligament and the adjacent structure

is not as effective as it is on spin echo imaging. Therefore, 3D volume images are more difficult to interpret.

Reconstruction

A mechanically stable and bioactive substance would dramatically change the practice of reconstructive fields, such as orthopedic, plastic and oromaxillofacial surgery [7]. Percutaneous procedures with injectable, bioactive and resorbable cements could replace invasive treatments of acute fractures, chronic nonunions, and critical-sized bone defects. Management of soft tissue defects that also require mechanical strength, such as rotator cuff patches, anterior cruciate ligament (ACL) reconstruction, and cartilage or meniscal repair could likewise be performed with minimally invasive procedures and incur little functional loss during recovery.

For this reason, there has been considerable research in nanotechnology, which considers the biomaterial properties such as chemistry, charge, wettability, and surface roughness. These determine the extracellular protein interactions and mediate cell interactions at the tissue/matrix interface, which are critical for biocompatibility and longevity of the implant. In vitro research of surface morphology has suggested the importance of nanometer roughness. Up to four times the calcium-mineral deposition occurs when osteoblasts were cultured for 28 days in the presence of ceramics with grain sizes below 100 nm, compared with conventional alumina surfaces. Even greater osteoblast performance has been reported in grain sizes below 60 nm. This has been correlated to osteoblast interactions with vitronectin, which shares a linear dimension of approximately 60 nm. Multiple techniques are now being explored, such as e-beam lithography, polymer demising, chemical etching, cast-mold techniques and spin casting to fine-tune surface characteristic for optimal biologic interactions. In addition, three-dimensional (3D) printers can construct 3D organic-inorganic composite matrices with a defined internal architecture. These have also demonstrated osteoblast ingrowth and proliferation in vivo.

3D

Obviously, the use of the computer and associated software has benefited the orthopedic surgeons in other aspects, such as preoperative planning, preoperative 3D imaging, intraoperative computer navigation in total joint and spine surgery, besides trauma surgery, more recently, virtual intraoperative impingement and stability testing in ACL reconstruction in the field of sports medicine [8].

CT

Computed tomography, or CT, greatly facilitates 3D viewing of the internal morphology of soft tissue and skeletal structures [8].

Clinical Pathways

The adoption of clinical pathways in patient care has grown from the necessity of providing consistently high quality of

care for an increasing demand for clinical services [9]. Clinical pathways are structured multidisciplinary care plans that detail the essential steps in the care of patients with specific clinical problems. Clinical pathways provide hospitals with a consistent template for patient care by creating a predetermined standardized approach to care that should be adhered to by each member of the healthcare team. Clinical pathways are especially suited to the high volume and elective nature of much of orthopedic surgery. In our specialty quality and efficiency must be optimized. To help achieve this clinical pathways are used as standard protocols. Each process, in a clinical pathway, is followed in order to ensure that the desired end results are achieved. The pathway also ensures that each patient is receiving optimum levels of care pre, intra-, and postoperatively. Clinical pathways are evidence based using the common international experience but must be adapted to the culture of any given hospital. Clinical pathways are effective because they standardize care, help develop measures for prevention of patient discomfort and harm and provide ongoing performance measures that promote effective and useful change in practice.

Adoption of clinical pathways can be met with skepticism and resistance from any member of the multidisciplinary team involved in patient care. Because clinical pathways standardize care they reduce reliance on individual decision making or traditional approaches to care. Every effort must be made in adopting new clinical pathways to educate and inform the multidisciplinary team of the evidentiary basis on which the principles of the new pathway are based. Physician, nursing, and administrative champions must work together to develop and institute new pathways. The process should be communicated in a completely transparent manner. The thought processes involved should be clearly documented, and every member of the patient care team must be trained and oriented to the new process. Following implementation documentation of important clinical indicators should be monitored and regular reports of outcome must be communicated back to the hospital staff. The pace of implementation must be geared to the tolerance of the staff at each individual hospital. Often implementation should be conservative with realistic expectations. As success is garnered more progressive modifications to the pathway based on real outcomes can be pursued. It is critical that the clinician champions involved in this process be sensitive and realistic as well as willing to devote their time and energy to the process.

Education

At a time of groundbreaking medical advances in the diagnosis and treatment of arthritis and musculoskeletal diseases, patient education has become an essential component in providing comprehensive care and in achieving positive clinical outcomes [10]. These advances, coupled with novel education delivery systems such as the Internet, have created consumer demand for information from patients, their families, and the general public.

Conclusion

Traumatological implants are used for the surgical treatment of fractures, deformities, and tumor diseases of the bones. In addition to products intended for the fixation of long bone fractures, trauma implants for the shoulder, hand, pelvis and hip are also produced. It should certainly be noted that innovations in orthopedics and traumatology serve to complement and enhance existing implants thereby improving the final outcome for patients. The basis for making an implant is a doctor's request for making such an implant and a CT scan in order to precisely shape the bone that needs to be replaced. Such implants are created in close collaboration with the surgeon-operator with whom each individual feature is analyzed and coordinated. After the doctor agrees on the final design, the implant is produced by additive manufacturing technology, popularly called 3D print technology, which represents a revolution in the production of medical implants because of its speed, accuracy, and economy.

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