Classification of Bone Regeneration and Graft Materials

Regenerating lost supporting periodontal structure has become an accepted goal in dental treatment today. An intricate part today includes bone grafting therapy. Patients are becoming more aware of grafting as a treatment modality and are demanding better predictability, fit, function and esthetics. Today, with the introduction of advanced bone grafting techniques and sophisticated bone replacement graft materials, it is possible to increase the volume, width and height of bone in deficient areas enough to regenerate supporting periodontal tissues around questionable teeth and place implants in ideal positions and angulation resulting in more acceptable and predictable restoration.

Bone replacement graft materials have played an important part in regenerative dentistry for many years and today we are introduced to a host of new technology that will continue to improve the predictability and success rate of grafting procedures. There are four basic divisions of bone grafts: autogenous bone; allographic bone; alloplastic bone; and enographic bone.

The ideal bone replacement graft material has always been autogenous bone. Autogenous bone forms bone by osteogenesis, osteoconduction and osteoinduction. Osteogenesis refers to matter that is capable of forming bone directly from osteoblasts. An osteoinductive material is capable of inducing the transformation of cells into osteoblasts and enhancing bone growth. Osteoconduction is a material that permits bone apposition from existing bone.

Autogenous bone is bone from the same individual and has long been considered the “standard” in bone replacement graft materials. It consists of two components, a natural anatomical structure and scaffolding for support and cellular invasion and a component of primarily Type-1 collagen, providing pathways for vascularity and resilience to the bone. The vitality of the autogenous graft may vary in its duration, some lasting a shorter duration than desired. It is harvested from the same individual therefore a second surgical wound site must be available and utilized. The use of autogenous bone, however, avoids the possibility of antigenicity and the possible immunologic rejection.

Allografts are grafts from individuals from the same species. A major advantage is that the material is readily available without an additional surgical donor site procedure from the patient. It is solely the organic component of material bone. It does not produce the inorganic calcium or scaffolding necessary for bone regeneration. The harvested allographic bone must be processed to guarantee safety. There are three main divisions: (a) frozen (b) freeze-dried and (c) freeze-dried demineralized. They come in different forms: particulate gels, putties, and others, to ease handling of the material.

Synthetic grafts are termed alloplasts. They aid in the repair of osseous defects and to enhance osseous ingrowth. The chemical composition, physical form, and differences in surface configuration result in varying bioreabsorbility. The commercial graft material, alloplast’s porosity, solubility and density determine the resorption of calcium phosphate based graft material.

Xenograft graft material is derived from another species. It is a graft material with the organic component totally removed. With their removal, concerns of immunological reaction or sensitivity to the xenograft bone is negated. The remaining inorganic bone graft provides a natural architectural structure and an excellent source of calcium. The inorganic material can also maintain the physical dimension of the augmentation until the remodeling of bone.

Bone replacement graft materials have been striving for years to meet the standard set by autogenous bone. Originally, synthetic hydroxylapatites were used when adequate amount of autogenous bone was not available. Synthetic, dense, nonresorbable hydroxylapatites are osteoconductive, non-inflammatory and permit bone apposition from existing bone. They do not form bone nor will they increase the volume of vital bone in a deficient area.

Synthetic hydroxylapatites have limited indications. Augmentation for conventional dentures is an acceptable indication for this material. However, since the ceramic form of this dense material does not resorb or remodel, implant placement through a grafted site is impossible, limiting its value.

Synthetic hydroxylapatite is also available in a resorbable form. Hydroxyapatite is the principal inorganic component of natural bone and, as it resorbs, provides a readily available source of calcium in osteogenic sites. It is an osteoconductive material composed of very small/ non-fused crystals with extremely high surface areas. Synthetic, resorbable hydroxylapatite is a material of choice in four-wall defects, such as extraction sockets. Without grafting, ridge resorption will occur resulting in loss of the buccal/lingual dimension of the ridge.

The introduction of xenografts, with calcium phosphate bone replacement, to the dental market was significant clinical alternative. Some xenografts such as anorganic bovine-derived bone material (ABM) offered the mechanical and architectural component of natural bone that had been lacking in the synthetics. Since it is a natural form of hydroxylapatite, it provides a source of calcium essential for bone formation. This material alone as a xenograft, does not satisfy all of the attributes by establishing the “standard” of autogenous bone.

Xenografts lack an organic, cellular component. In order to be effective, it must be placed in an osteogenic environment that will provide the cellular interaction needed for bone regeneration.

Combining ABM with demineralized freeze-dried bone allograft (DFDBA) will provide two components equal to natural bone. DFDBJ is derived from cadaver bone. It must be thoroughly screened, tested and processed to eliminate adverse impact on the health of the recipient.

Research has shown dramatic variability in the osteoinductive properties of DFDBA. Some donor bone has shown no activity at all and is strictly providing a source of Type-1 collagen to the recipient site. Tissue proven osteoinductive by a bioassay analysis offers a high probability of stimulating growth of bone cells. Even the highest quality, bioassayed DFDBA will not satisfy the two-component model of autogenous bone. DFDBA provides only the organic component and lacks the mechanical structure and architecture of bone.

Over the last two decades, clinicians have learned to utilize bone graft replacement materials which best satisfies the needs of a specific site, patient and treatment plan. Combinations of materials are used, chosen from a wide variety of synthetics, xenografts, and allografts, in conjunction with tissue regenerative barrier membranes (GTR), all with the common goal of simulating autogenous bone.
Positioned as the definitive answer for future osseous regeneration are to the fact that research in recombinant bone morphogenetic proteins (BMP) and tissue-derived growth factors for osseous regeneration has been BMPs are osteoinductive compounds that induce new bone formation. There are at least seven structurally unique BMPs identified that can induce bone formation as well as accelerate the time of bone regeneration. BMPs act as a signal in initiating and regulating specific tissue formation. This activity leads to a series of developmental processes that include chemotaxis, proliferation and differentiation, which result in the transient formation of cartilage (endochondral bone formation) and the production of living bone tissue. At this time, both the technology and the production of the material are quite expensive. The effectiveness of BMPs in inducing new bone formation is a least in part contingent upon delivery of these molecules in a predictable manner. Several different materials that include both natural and synthetic polymers and bioceramics have been evaluated as potential carriers for BMP. To date, collagen has shown the most promise. However, because of the unpredictable nature of collagen metabolism, large variability in the clinical effectiveness of BMP can be expected. While BMPs hold promise as a technologically advanced means for bone regeneration, their arrival in the market place has been long awaited. It may be that approval for use in humans in the United States might be two to three years away.

Incorporation of cellular processes into the design of biomaterials has been approached along other avenues. In October of 1999, an alternate methodology based upon the natural physiology of native bone was approved by the F.D.A. Scientists and clinicians have long recognized the importance of collagen as a biomaterial. It is well known that bone is composed predominantly of collagen and hydroxyapatite. The primary function of collagen is to act as a “scaffold” on which cells can move. While collagen influences cellular processes, the hydroxyapatite provides the structural and morphological support required for cell attachment and cell movement.

The advances in molecular modeling techniques have allowed a close examination of the collagen molecule. Detailed analyses have revealed that a 15-residue amino acid sequence within the α(I) chain of Type-1 collagen is responsible for the cell-binding functions of collagen. This discovery led to the isolation and synthetic fabrication of new synthetic material called P-15. As a first step to mimic the physiological nature of bone, a composite of P-15 and natural anorganic bone mineral (ABM) was examined. ABM/P-15 is a synthetic, collagen-like agent that mimics autogenous bone. The inorganic/mechanical component/ ABM is composed of calcium phosphate and simulates the natural anatomic structure of autogenous bone necessary for cellular movement. The organic component is represented by P-15, the synthetic 15 amino acid peptide that mimics the cell binding domain of Type-1 collagen which modulates cell binding, migrations, proliferation and differentiation.

This material, PepGen P-15 provides a tissue-engineered biomimetic habitat for cells and serves as a bone-like substitute for autogenous bone grafts. In clinical studies, PepGen P-15 demonstrated an increased expression of growth factors-TGF-B as well as BMP-7, the agents associated with osteodifferentiation. PepGen P-15 has been demonstrated and clinically shown to have predictable benefits over other currently marketed bone graft replacement materials (Fig 1&2).

Not only is advancement in the research and development, of bone graft materials exciting however it will eventually offer the ultimate material. Needless to say the bone graft material that most closely resemble the “standard” of autogenous bone and enhances the science of bone repair should be the practitioner’s first choice.

Bibliography