Bone Graft Options & Biologic Substitutes
The Biology of Bone Grafts
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The need for bone graft and its substitutes has dramatically increased during the past decade because of the increasing incidence of revision arthroplasty. This requires a greater understanding of the biology of bone grafts to choose the correct graft for the intended clinical application.

BONE FORMATION
Bone formation provided by the bone graft can be described biologically as a result of three processes: osteogenesis, osteoinduction, and osteoconduction.  

Osteogenesis occurs when new bone is synthesized by the graft cells or by the host's osteoprogenitor cells, which migrate into the bone graft.

Osteoinduction is a process whereby the bone graft induces the host's osteoprogenitor cells to migrate into the bone graft. This recruitment of the host's cells has been shown to be mediated by induction proteins, low molecular weight peptides, such as glycoprotein, and bone morphogenetic protein.

Osteoconduction is preserved in fresh autografts and processed bone allografts, but is destroyed by autoclaving or high-dose radiation (3.4-4 Mrad).

Osteoconduction is a function provided by all bone grafts. The graft provides a three-dimensional pathway for the host's cells and blood vessels to migrate into the bone graft environment. Bone substitutes also have this function.

BONE GRAFT INCORPORATION
Successful bone graft incorporation requires an effective interaction between the graft and the host's soft tissue. The mechanical stability of the interface between the host bone and graft is critical in determining the outcome of the grafting procedure. Additionally, the graft itself must be able to sustain activity loads for a successful clinical outcome.

The integration of the bone graft into the host bone requires years of remodeling under the influence of Wolff's Law. Ultimately, a successful graft must be revascularized and completely replaced by host tissue. If immediate blood supply is provided to the bone graft, the original graft may survive intact. Bone allografts are modified to reduce their immunogenicity integrate in the host by similar biological processes, but incorporation time is significantly extended and, in many circumstances, the allograft may never be completely replaced by host tissue.

BONE GRAFT OPTIONS
Cancellous autograft remains the gold standard. These grafts are rapidly revascularized. Surface osteocytes survive and are nourished by diffusion, and new bone is seen. Active bone resorption is present throughout the graft, and osteoconduction occurs shortly thereafter. Remodeling, under the influence of weight bearing, results in the complete replacement of necrotic graft bone with viable host bone. Incorporation usually is completed by 1 year postoperatively. Cancellous allografts processed by freezing or freeze drying, which diminishes the host immune response, perform in a similar way except the process is delayed.

Cortical bone grafts, whether autografts or processed allografts, because of their dense structure, must first be invaded by host osteoclasts to allow invasion of Volkmann's canals by capillaries and osteoblasts. Because of this vascular invasion and osteoclastic activity, these grafts are mechanically weaker for the first 6 months to 1 year postoperatively. If bone resorption predominates over bone formation, these grafts may fail under optimum surgical conditions. Remodeling is seen for a prolonged period of time and cortical grafts may remain indefinitely an admixture of necrotic donor bone and viable new host bone. Although bone sterilization by irradiation of up to 3.5 Mrads does not appear to affect the material properties of bone, it may significantly reduce its osteoinduction function and slow graft incorporation.

FIXATION
Stable fixation of the bone graft to
## Comparative Properties of Bone Grafts

<table>
<thead>
<tr>
<th>Bone Graft</th>
<th>Mechanical Properties</th>
<th>Osteoconduct</th>
<th>Inductiveness</th>
<th>Osteogenesis Graft Derived</th>
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<tbody>
<tr>
<td>Autograft</td>
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<td>+++</td>
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<tr>
<td>Cancellous Cortical</td>
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<tr>
<td>Allograft</td>
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<td>Cancellous Frozen</td>
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<td>Freeze-dry Cortical</td>
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<td>Frozen</td>
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<tr>
<td>Freeze-dry Allogenic</td>
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<td>Demineralized Cancellous chips</td>
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The host bone must be provided. Success of the grafting procedure is the result of a complex series of events that depends on the biology of the graft-host interaction. This includes the host immune response to the graft tissue, the mechanical environment of the bone graft-host construct, and most important, the surgical technique. The surgeon must provide a host bed that is well vascularized with excellent soft-tissue cover for the bone graft. Finally, central to this incorporation process is the selection, by the surgeon, of the best bone graft for the intended clinical requirement.

The Table outlines the available bone graft materials and their biological function. The selection of the appropriate bone graft or its substitute based on the biological and mechanical function determines the clinical outcome of bone grafting for primary or revision total joint arthroplasty.

## REFERENCES