New Approaches in the Treatment of Critical-Size Segmental Defects in Long Bones

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Segmental defects in long bones are frequent entities in musculoskeletal surgery. Their etiology includes high-energy trauma, gunshot, deformity correction or iatrogenic resection of infected or neoplastic bone lesions. The treatment of large diaphyseal bone deficiencies presents a formidable clinical challenge. The standard treatment modalities such as distraction osteogenesis, vascularized bone transfer, or cortical allografts exhibit extremely high complication rates, and frequently culminate in limb amputation or major functional deficits. Recent efforts to develop new treatment modalities for segmental bone loss have resulted in designing new metallic and biodegradable nonmetallic implants that incorporate novel osteogenic, -inductive, and/or -conductive bone healing augmentation materials, thereby further enhancing the efficacy of the treatment applied.

The objective of the presentation is to briefly review the limitations of the currently applied standard treatment modalities for segmental bone defects, provide insight into the specific treatment challenges, and present the animal and initial clinical results of new alternative treatment approaches that involve the application of bioresorbable polylactide membranes or cylindrical titanium mesh cages.

In a sheep critical-size segmental tibial defect model, bioresorbable microporous and microporous-perforated polylactide membranes were applied in single tube and/or tube-in-tube configurations. Defects covered with the membranes without bone graft resulted in a nonunion at 16 weeks. Bone healing was observed in defects covered with perforated membranes packed with autograft. The presence of perforations improved bone graft reconstitution. Defect healing was more efficacious for the tube-in-tube membranes. The double perforated membranes permitted less autograft to be used. Restricting bone formation to the space between the two membranes resulted in formation of the “neo-cortex” with a defined thickness.

In a canine critical-size segmental femoral defect model, cylindrical titanium mesh cages were used in combination with allograft. The cage with supplementary IM nail fixation provided excellent initial mechanical stability that permitted unrestricted weightbearing. The cage-allograft construct resulted in an immediate restoration of the defect continuity and permitted uniform reconstitution of the allograft and subsequent defect healing. The new bone formed within and around the mesh cage was histologically and mechanically mature exhibiting of 73.8% and 83.4% torsional stiffness and strength compared to the contralateral intact femur. The defects treated with allograft without the cage culminated with nonunion.

Initial clinical experience with the cylindrical titanium mesh cages in combination with allograft for the treatment of segmental bone defects and arthrodesis has demonstrated favorable results. The cage permitted uniform reconstitution of the bone graft and provided initial mechanical stability for healing to occur without restrictions on patient’s weightbearing. The cage technique offered several advantages: it was a single-stage procedure, utilized existing implants, and did not require specialized surgical skills or equipment. It provided immediate restoration of the osseous continuity, early functional limb recovery and allowed for efficient defect healing to take place.

Perforated polylactide membranes or titanium mesh cages present a viable alternative treatment option for critical-size bone defects. Their specific clinical indications should adhere to the local anatomical and biomechanical constraints of the individual patient.

Keywords: bone defects; bone grafting; polylactide membranes; titanium mesh cage