Bone Remodeling in Lumbar Interbody Fusion

- Letter to Editor Regarding "Trabecular Bone Remodelling After Posterior Lumbar Interbody Fusion: Comparison of the Osseointegration in Three-Dimensional Porous Titanium Cages and Polyether-Ether-Ketone Cages" by Segi et al
- Response to Letter to the Editor Regarding the Article Entitled "Trabecular Bone Remodeling After Posterior Lumbar Interbody Fusion: Comparison of the Osseointegration in Three-Dimensional Porous Titanium Cages and Polyether-Ether-Ketone Cages" by Segi et al
- Bone turnover markers are risk factors for endplate injuries during lumbar interbody fusion: a retrospective case-control study
- Trabecular Bone Remodeling after Lateral Lumbar Interbody Fusion: Indirect Findings for Stress Transmission between Vertebrae after Spinal Fusion Surgery
- Feasibility of the Non-Window-Type 3D-Printed Porous Titanium Cage in Posterior Lumbar Interbody Fusion: A Randomized Controlled Multicenter Trial
- Topology Optimization Driven Bone-Remodeling Simulation for Lumbar Interbody Fusion
- Usability of a novel Hounsfield units measurement procedure to quantify intercorporal bone graft remodeling in patients after posterior lumbar interbody fusion: a case series
- Trabecular Bone Remodeling after Posterior Lumbar Interbody Fusion: Comparison of the Osseointegration in Three-Dimensional Porous Titanium Cages and Polyether-Ether-Ketone Cages

Bone remodeling is a crucial process in lumbar interbody fusion (LIF), a surgical procedure used to treat conditions such as degenerative disc disease and spinal instability. Here’s an overview of how bone remodeling impacts the success of LIF:

1. Initial Healing Phase

- **Immediate Post-Operative Period**: Following the interbody fusion, a blood clot forms around the graft site, and an inflammatory response begins. This phase sets the foundation for bone growth.

- **Early Bone Formation**: Within a few weeks, inflammation subsides, and fibroblasts and osteoblasts proliferate at the site. Osteoblasts are responsible for forming new bone tissue, leading to the creation of a new bone matrix and early bone formation.

2. Bone Graft Integration

- **Incorporation of the Graft**: The success of the fusion depends on how well the graft integrates with the surrounding bone. Grafts may be autografts (bone from the patient), allografts (donor bone), or synthetic materials. These provide a scaffold for new bone growth.

- **Remodeling and Ossification**: New bone formation continues as the graft material gradually integrates into the host bone. Osteoclasts break down old bone while osteoblasts form new bone, leading to the gradual replacement of the graft with new bone tissue.

3. Long-Term Remodeling

- **Bone Formation and Strengthening**: Over time, the bone remodels and strengthens as mechanical loads are applied. Ideally, the fusion site should exhibit solid, trabecular (spongy) bone that integrates seamlessly with adjacent vertebrae.
- **Bone Density Changes**: Initially, there may be a decrease in bone density around the fusion site. However, density typically returns to or exceeds baseline levels, influenced by factors such as the patient's health and activity levels.

4. Factors Affecting Bone Remodeling

- **Graft Material**: The type of graft material affects remodeling. Autografts usually have a higher success rate due to their osteogenic properties.
- **Patient Factors**: Age, overall health, and conditions like osteoporosis impact bone remodeling. Generally, younger and healthier patients have better outcomes.
- **Mechanical Stability**: Proper stabilization with implants (screws and rods) is essential for maintaining alignment and reducing complications that might disrupt remodeling.
- **Rehabilitation and Activity**: Post-operative physical therapy and gradual return to activity are important for optimal bone remodeling and recovery.

Bone remodeling in lumbar interbody fusion is vital for achieving long-term success, involving complex interactions between cells and graft material. Managing influencing factors can improve outcomes and ensure a successful fusion.

A study proposes a numerical approach for simulating bone remodeling in lumbar interbody fusion (LIF). It employs a topology optimization method to drive the remodeling process and uses a pixel function to describe the structural topology and bone density distribution. Unlike traditional approaches based on strain energy density or compliance, this study adopts von Mises stress to guide the remodeling of LIF. A novel pixel interpolation scheme associated with stress criteria is applied to the physical properties of the bone, directly addressing the stress shielding effect caused by the implanted cage, which significantly influences the bone remodeling outcome in LIF. Additionally, a boundary inverse approach is utilized to reconstruct a simplified analysis model. To reduce computational cost while maintaining high structural resolution and accuracy, the Scaled Boundary Finite Element Method (SBFEM) is introduced. The proposed numerical approach successfully generates results that closely resemble human lumbar interbody fusion [1)].

Fusion rate

The fusion rate in spinal surgery may vary in relation to the technique, and it remains unknown which surgical technique provides the best fusion rate and surgical outcomes. Lee et al., aimed to compare radiological and surgical results between three surgical techniques used for lumbar interbody fusión.

Seventy-seven patients diagnosed with degenerative lumbar spinal stenosis including spondylolytic lumbar spondylolisthesis. Patients were divided into three groups according to the surgical technique: anterior lumbar inter-body fusion (ALIF, n = 26), transforaminal lumbar inter-body fusion (TLIF, n = 21), and posterior lumbar inter-body fusion (PLIF, n = 30). Various radiological parameters were measured including fusion rates.

Significant changes after surgery were observed in the ALIF group for the percentage of vertebral body slippage, anterior disc height, posterior disc height, segmental, and segmental ROM. The fusion rate on CT scan at the final follow-up was 69.2% in the ALIF, 72.7% in the TLIF, and 64.3 % in the PLIF. The cage subsidence rate 2 years after surgery was 15.4% in the ALIF, 38.1% in the TLIF, and 10% in the PLIF.

ALIF was associated with better restoration of segmental lordosis. The fusion rate on CT scan and with segmental ROM did not differ between the three groups. TLIF was associated with a better post op VAS. PLIF showed the lowest cage subsidence rate. Therefore, it looks difficult to tell which surgical technique is better between the three groups as well as all the surgical procedures being equivocal in terms of fusion rate and outcomes [2).].

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Wang Z, Zhang W, Meng Y, Xiao Z, Mei Y. Topology Optimization Driven Bone-Remodeling Simulation for Lumbar Interbody Fusion. J Biomech Eng. 2024 Aug 28:1-50. doi: 10.1115/1.4066369. Epub ahead of print. PMID: 39196594.
2)
Lee N, Kim KN, Yi S, Ha Y, Shin DA, Yoon DH, Kim KS. Comparison of outcomes of anterior-, posterior- and transforaminal lumbar interbody fusion surgery at a single lumbar level with degenerative spinal disease. World Neurosurg. 2017 Feb 8. pii: S1878-8750(17)30140-7. doi: 10.1016/j.wneu.2017.01.114. [Epub ahead of print] PubMed PMID: 28189865.