Evolution of Interbody Materials in Spine Surgery

A Value-Based Evaluation of New Technologies

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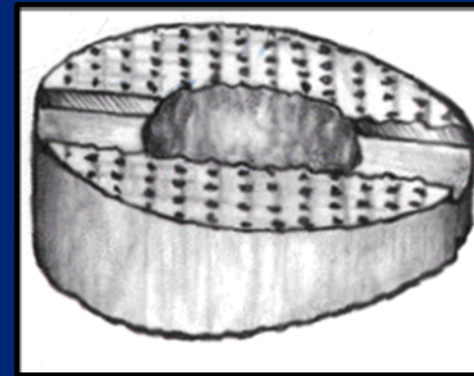
- Ownership/Stock/Options:
  - Providence Medical, Simpirica
- Royalties:
  - Medtronic, Stryker

Overview

- Innovations in Spine Surgery-
  - Patterns of Adoption …and Abandonment
- Incremental Value of New Technologies and Techniques
- Levels of Evidence to Compel/Support Change
- Evidence for novel interbody materials
  - Nanoporous titanium
  - 3D printed Porous Titanium
  - Porous PEEK
  - HA/PEEK

Implant Materials in Spine Surgery



- Interbody Cages
  - Allograft
  - Titanium
    - Porous
    - Acid-Etched
  - PEEK
    - Titanium Coated
    - HA Composites
  - Carbon Fiber
  - HA Coated

Spine Interbody Implants: Material Selection and Modification, Functionalization and Bioactivation of Surfaces to Improve Osseointegration

ORTHOPAEDIC SURGERY
Volume 6, Issue 2
May 2014

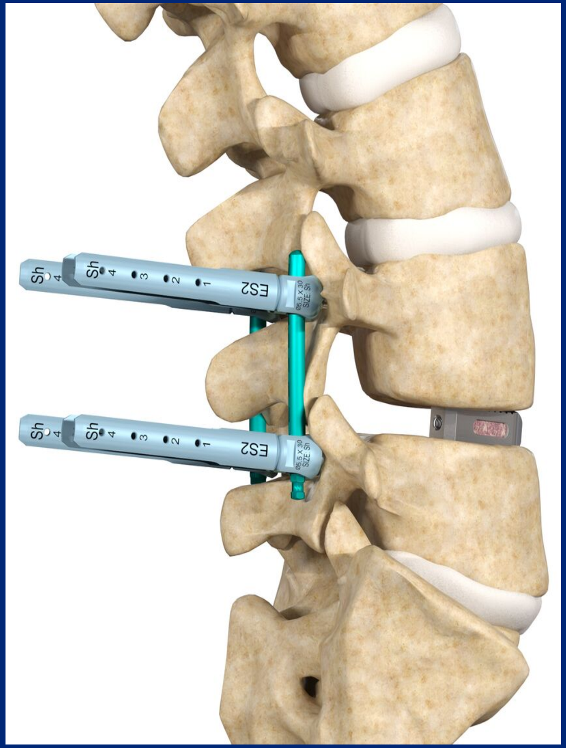
Prashanth J Rao MS, Matthew H Pelletier PhD, William R Walsh PhD, Ralph J Mobbs MS, FRACS

Implant material	Treatment to convert into bioactive material
Titanium	• Rough surface • Modification of surface topography • Heat treatment • Alkali treatment • Removal of Na ions • Porous material conversion • HA coating
PEEK	• Ti composite • HA composite • Calcium silicate composite • Bioglass composite • β-TCP composite

Innovative Interbody Technologies

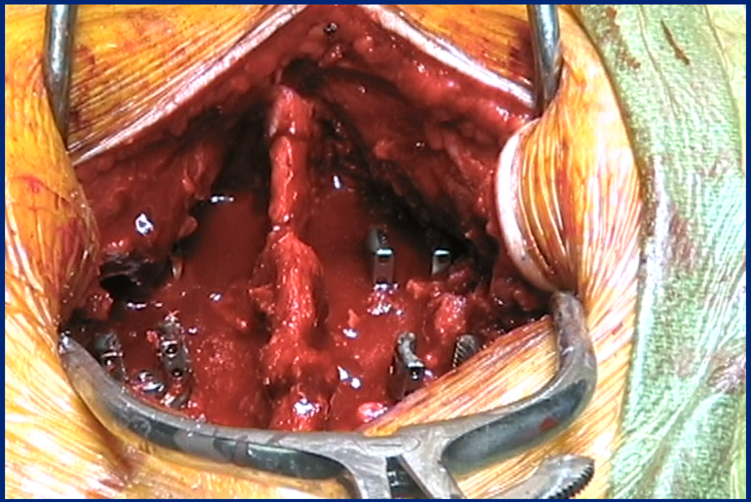
Burden of Proof:

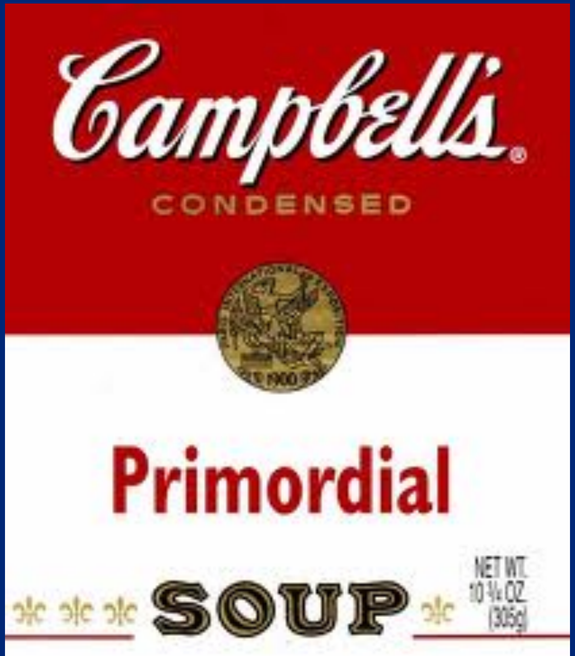
1) Improve Fusion Rates
2) Reduce Cage Subsidence
3) Reduce Cage Migration
4) Reduce Reoperations
5) Improve Clinical Outcomes
6) Cost-effective



Level of Evidence

- Supportive Evidence
  - Preclinical studies
- Compelling Evidence
  - Human clinical trials
  - Comparative Studies

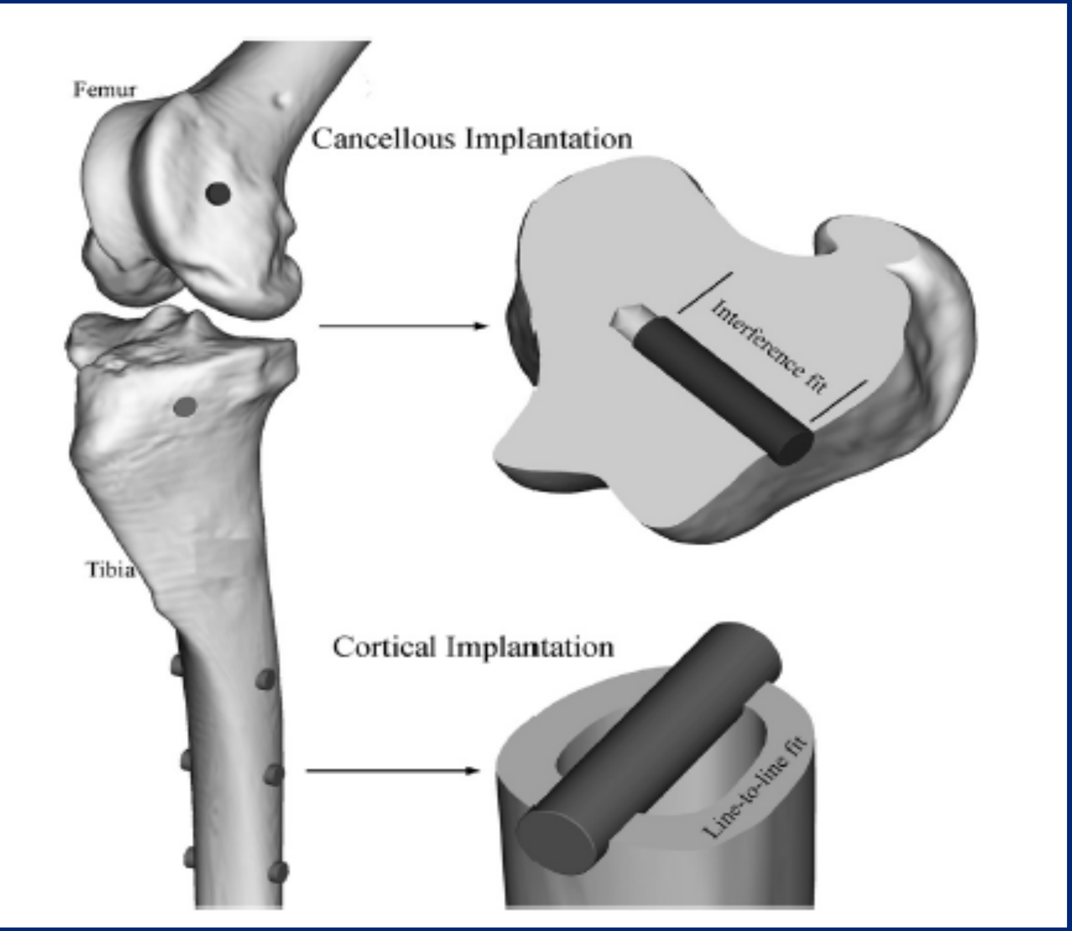


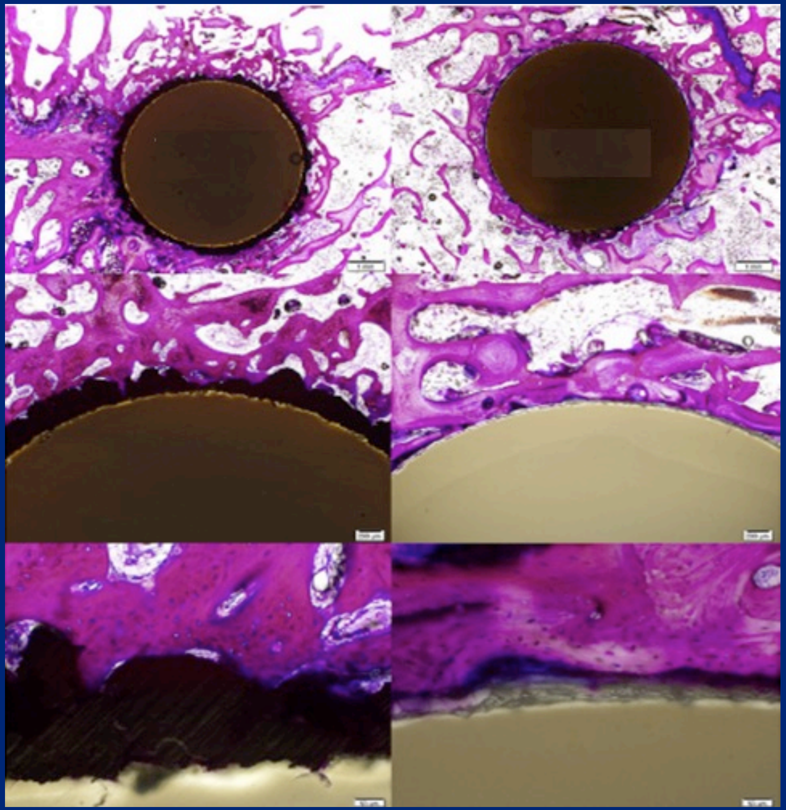


Levels of Proof

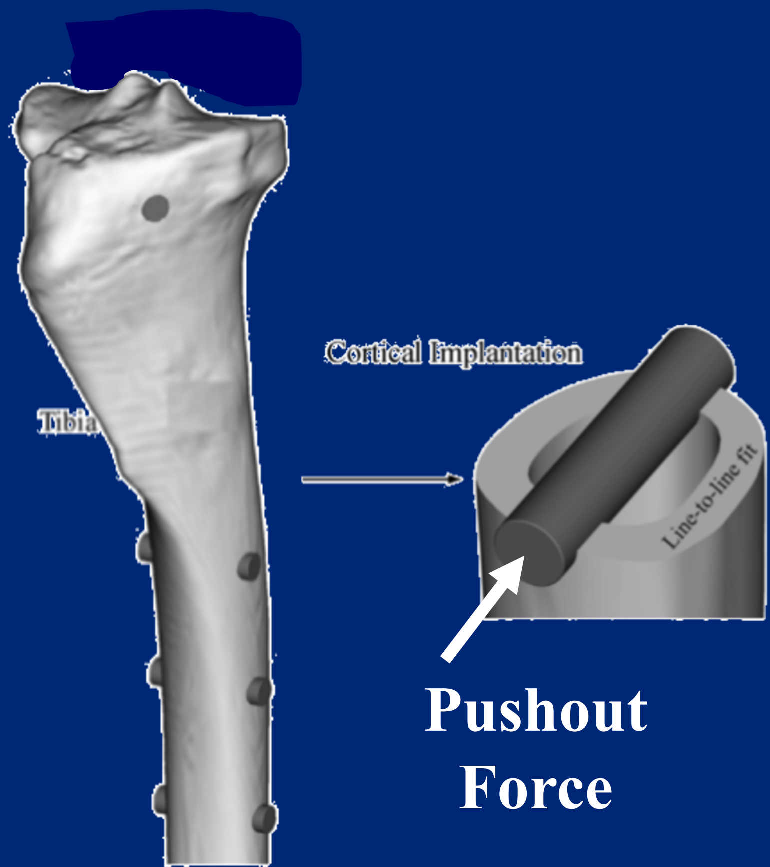
- Beyond a Reasonable Doubt
  - Randomized prospective clinical trial
- Preponderance of evidence
  - Preclinical studies
  - Prospective cohort studies;retrospective review
  - Clinical experience

Pre-Clinical Comparisons

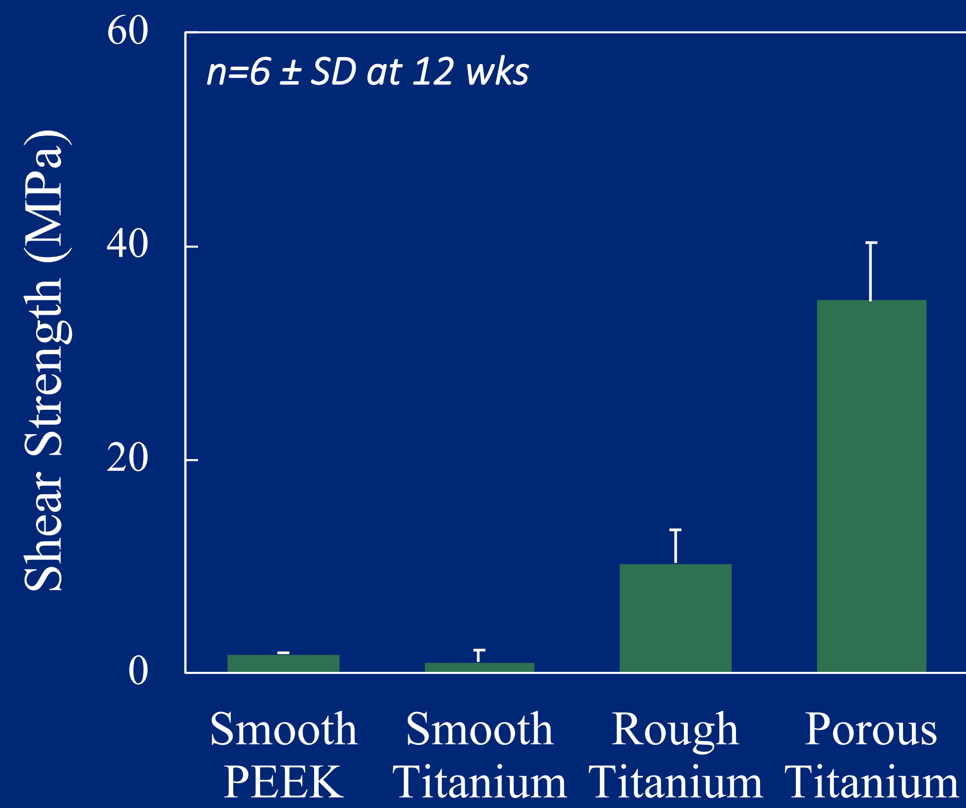




3D Printed Porous Titanium



Sheep, Male, 18 m.o.



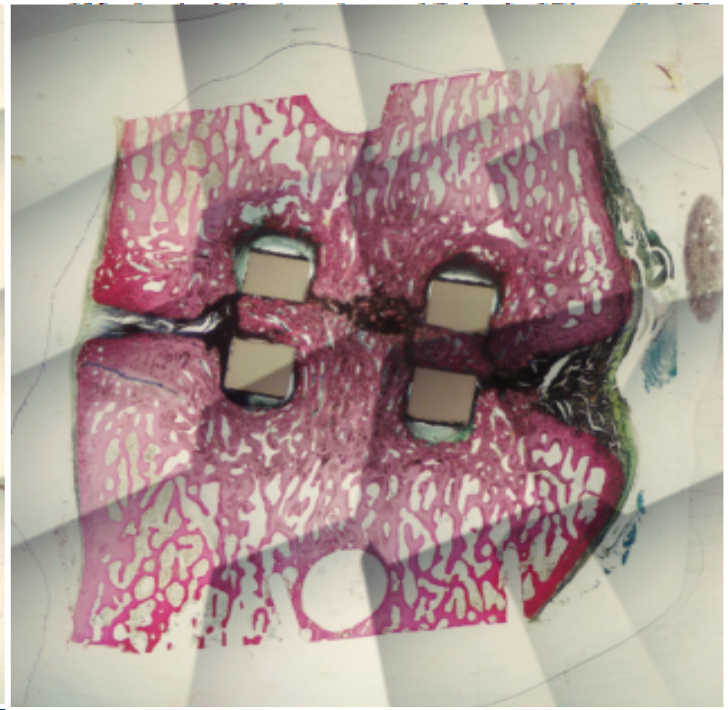
Svehla, JBMR (2000); Walsh, Spine (2015)

Bony ingrowth potential of 3D-printed porous titanium alloy: a direct comparison of interbody cage materials in an in vivo ovine lumbar fusion model

The Spine Journal 18 (2018) 1250–1260

Kirk C. McGilvray, PhD[a,*], Jeremiah Easley, DVM[b], Howard B. Seim, DVM[b], Daniel Regan, DVM, PhD[a], Sigurd H. Berven, MD[c], Wellington K. Hsu, MD[d], Thomas E. Mroz, MD[e], Christian M. Puttlitz, PhD[a]

AVS UniLIF PEEK Cage: 16 weeks post-op



Competitive Ti Plasma Sprayed PEEK Implant: 16 weeks post-op

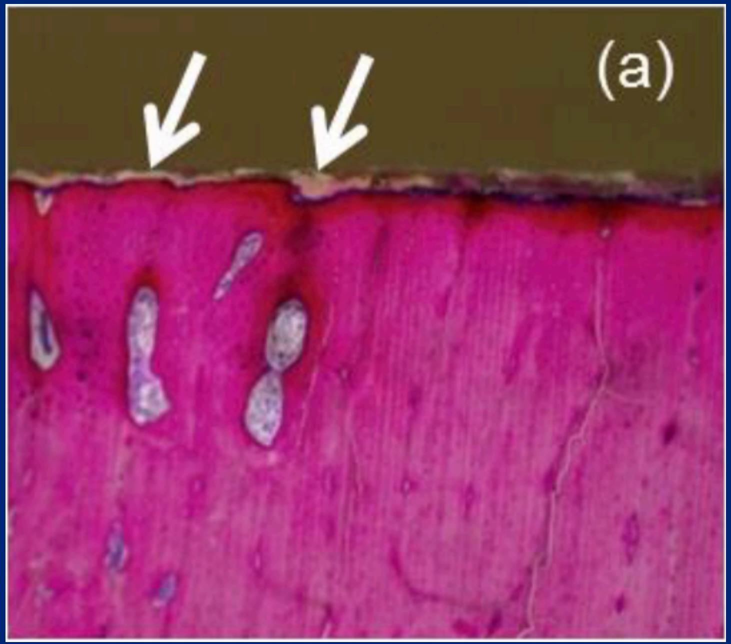
TRITANIUM PL Cage: 16 weeks post-op

Results presented are preliminary data from study. Final results to be available at conclusion of the study

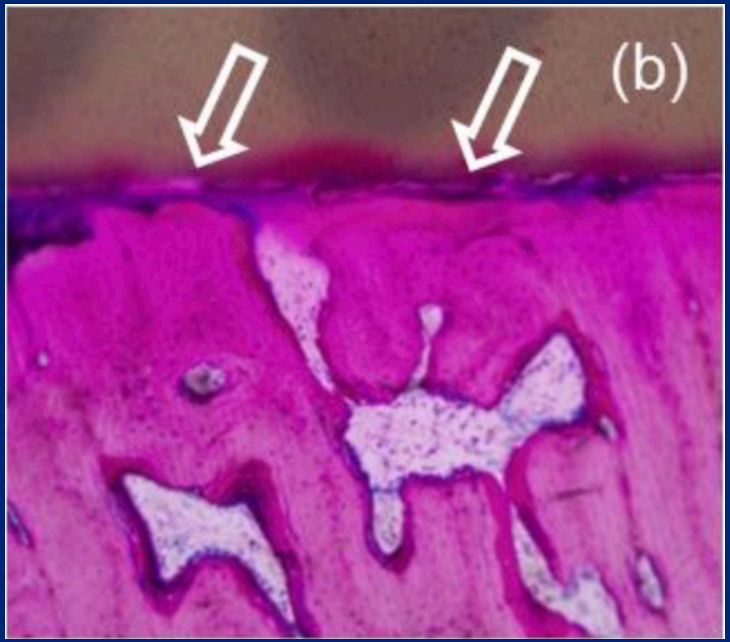
HA PEEK

- Composite material of 80% PEEK, 20% Hydroxyapatite integration
- Structural and mechanical properties of PEEK combined with osteoconductive properties of HA
- No coatings or laminate
- Hydroxyapatite
  - Osteoconductive biomaterial used to enhance bone apposition
  - Chemical crystal structure similar to bone

Osteoconductive Surface



Natural PEEK

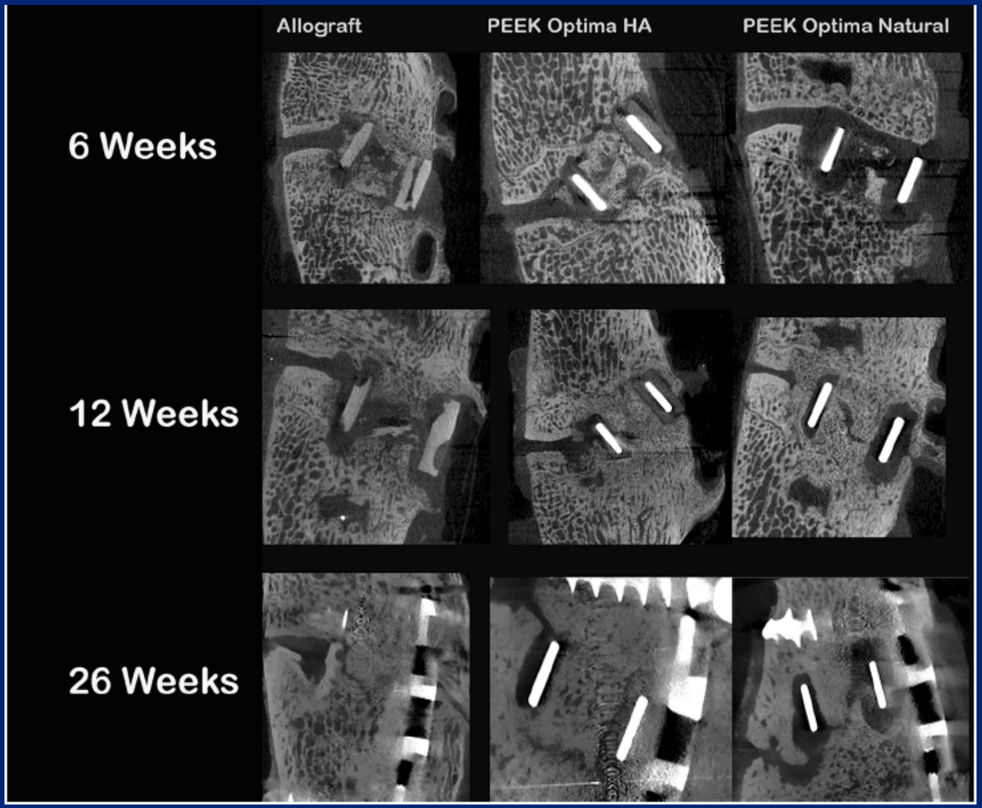


HA PEEK

The above images compare the two products showing a 4 week histology in sheep of (a) Natural PEEK, and (b) HA infused PEEK. Solid and open arrows show gaps and areas of direct bone contact respectively.
With the HA infused PEEK (b), a more consistent and continuous degree of direct bone contact is observed.

Pre-Clinical Outcomes

- Micro-CT showed direct bone contact at implant interface with HA PEEK
- More mature fusion histology with HA PEEK compared to PEEK or allograft implant.



SPINE Volume 40, Number 6, pp 399-404

Spine

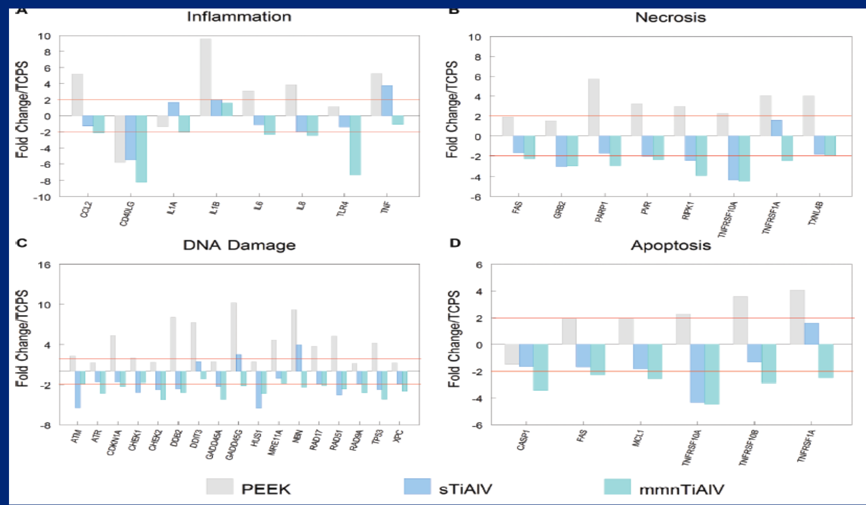
EPIDEMIOLOGY

Implant Materials Generate Different Peri-implant Inflammatory Factors

Poly-ether-ether-ketone Promotes Fibrosis and Microtextured Titanium Promotes Osteogenic Factors

Rene Olivares-Navarrete, DDS, PhD,* Sharon L. Hyzy, MS,* Paul J. Slosar, MD,† Jennifer M. Schneider, MS,‡
Zvi Schwartz, DMD, PhD,*§ and Barbara D. Boyan, PhD*¶

- Biological Environment adjacent to titanium is more favorable to bone formation than PEEK



“Nanotechnology exploits the unique advantage of *direct interaction with cells* on a molecular level.”

Trending in Orthopedics

Applied Nanotechnology and Nanoscience in Orthopedic Oncology

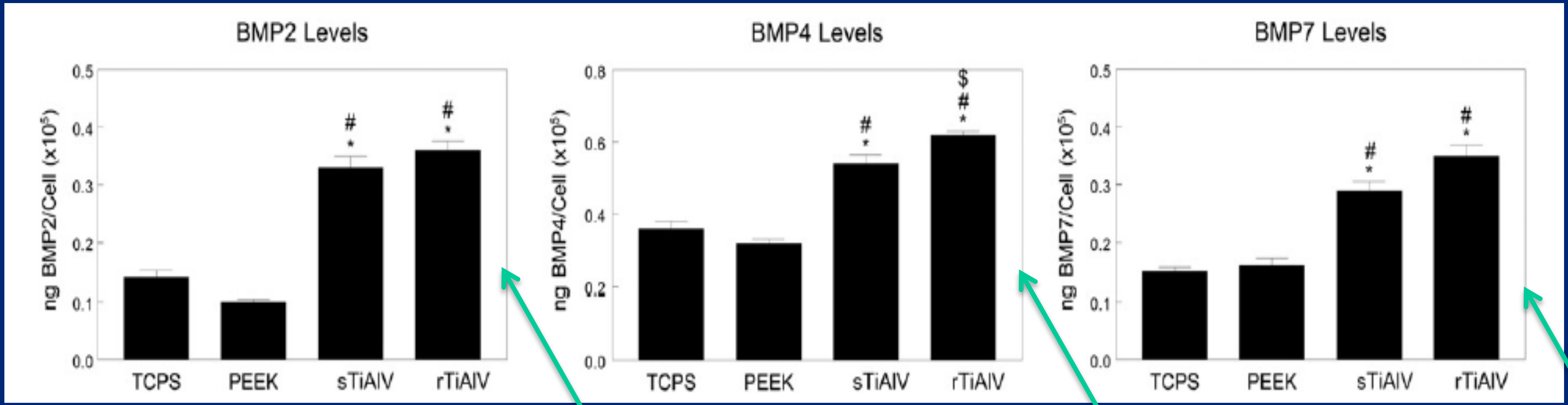
Olga D. Savvidou, MD; Ioanna K. Bolia, MD, MSc; George D. Chloros, MD; Stavros D. Goumenos, MD; Vasileios I. Sakellariou, MD; Evanthia C. Galanis, MD; Panayiotis J. Papagelopoulos, MD, DSc

Nano-Structured Titanium

- Biologically Inspired implant surface which can be “sensed” by *Individual* Cells to
- Drive Osteoblastic Differentiation
- Leading to rapid bone formation and osseous integration

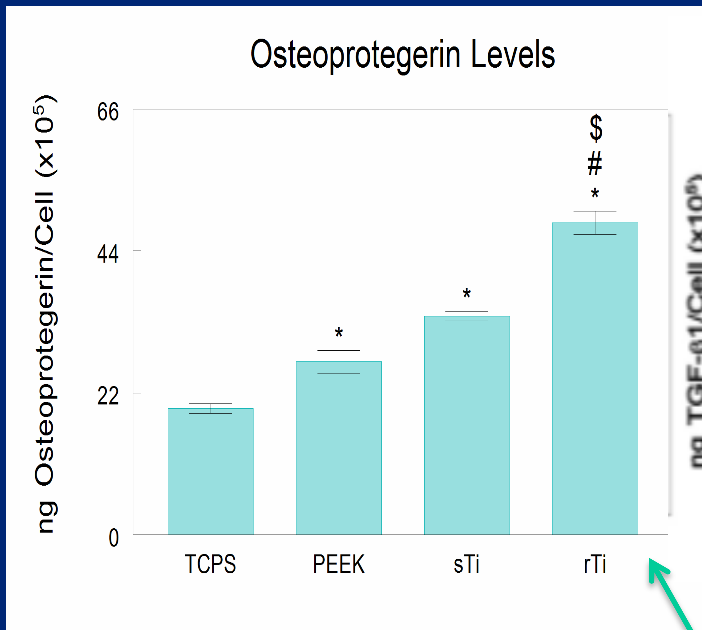
Up-regulate Osteoblasts - TGF-B1, BMP-2,4,7

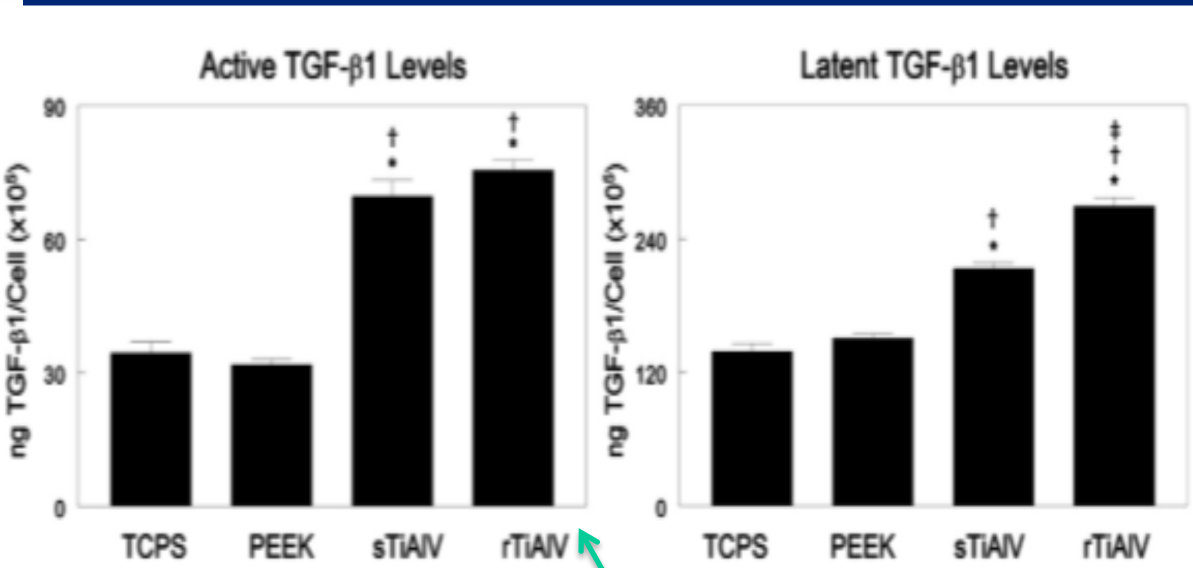
Physiologic BMP production



TCPS = Tissue Culture Polystyrene
sTi = Smooth Titanium
rTi = Roughened Titanium (Micro scale)

Down-regulate Osteoclasts – TGF-B1, OPG (Osteoprotegerin)





TCPS = Tissue Culture Polystyrene

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rTi = Roughened Titanium (Micro scale)

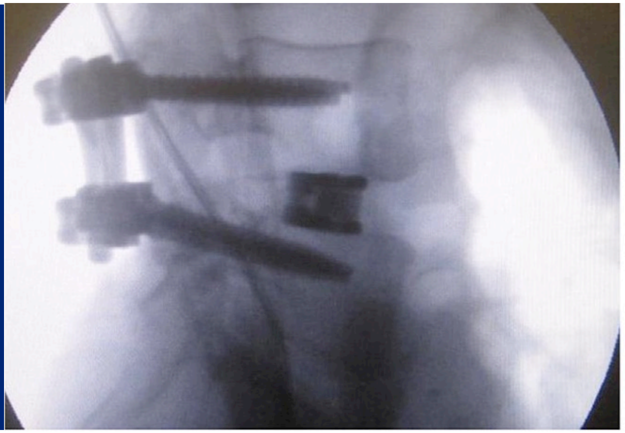
International Journal of Spine Surgery 7 (2013) e95–e100

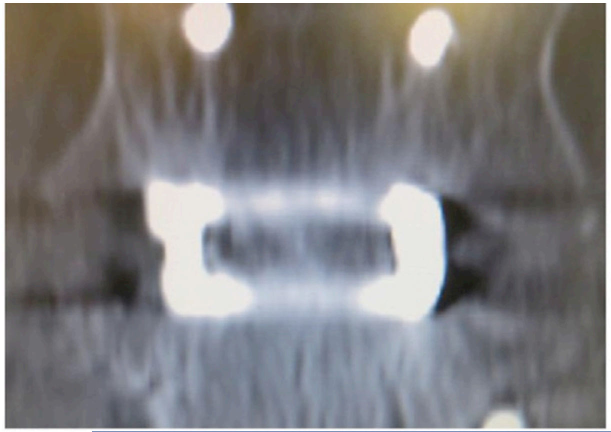
Transforaminal lumbar interbody fusion rates in patients using a novel titanium implant and demineralized cancellous allograft bone sponge

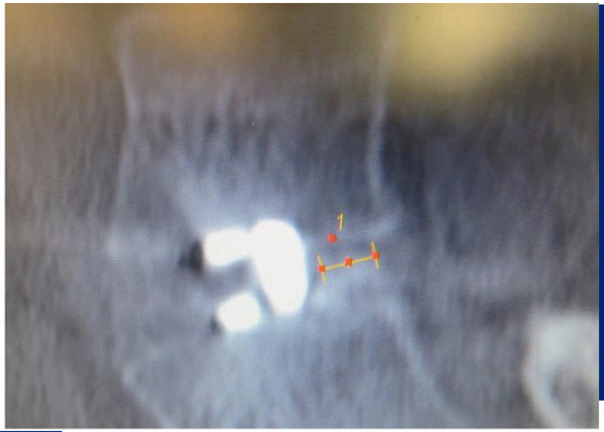
Gerard Girasole, MD[a,*], Gerard Muro, MD[a], Abraham Mintz[a], Jason Chertoff, MD, MPH[b]

[a] *Orthopaedic and Sports Medical Center, Trumbull, CT*

[b] *Department of Internal Medicine, University of Florida College of Medicine, Gainesville, FL*







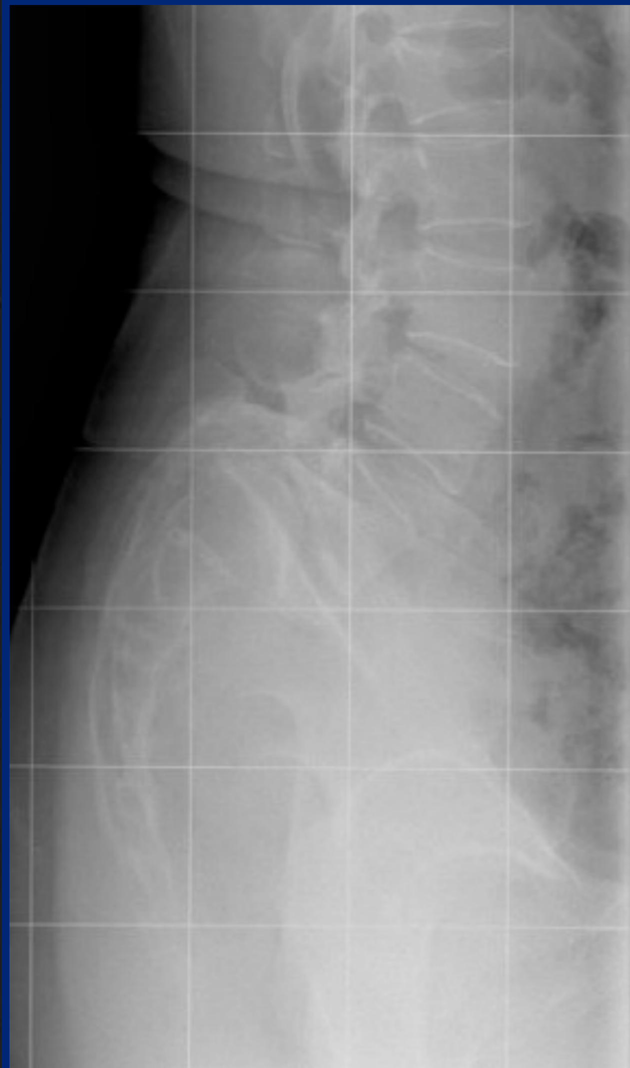
Grading system

	Points	
Spacer margins	0	Any evidence of subsidence or lucency around the cage
	1	Tightly marginated with both endplates without bone resorption or subsidence
Bone within cage	0	Lucency within cage similar to nonossified disc
	1	Increased density within spacer beyond that of nonossified disc space suggestive of trabecular bone
Bone bridge between endplates	0	No bony bridging between endplates
	1	< 0.5 cm bridge on either sagittal or coronal reconstruction
	2	≥ 0.5 cm bridge on either sagittal or coronal reconstruction

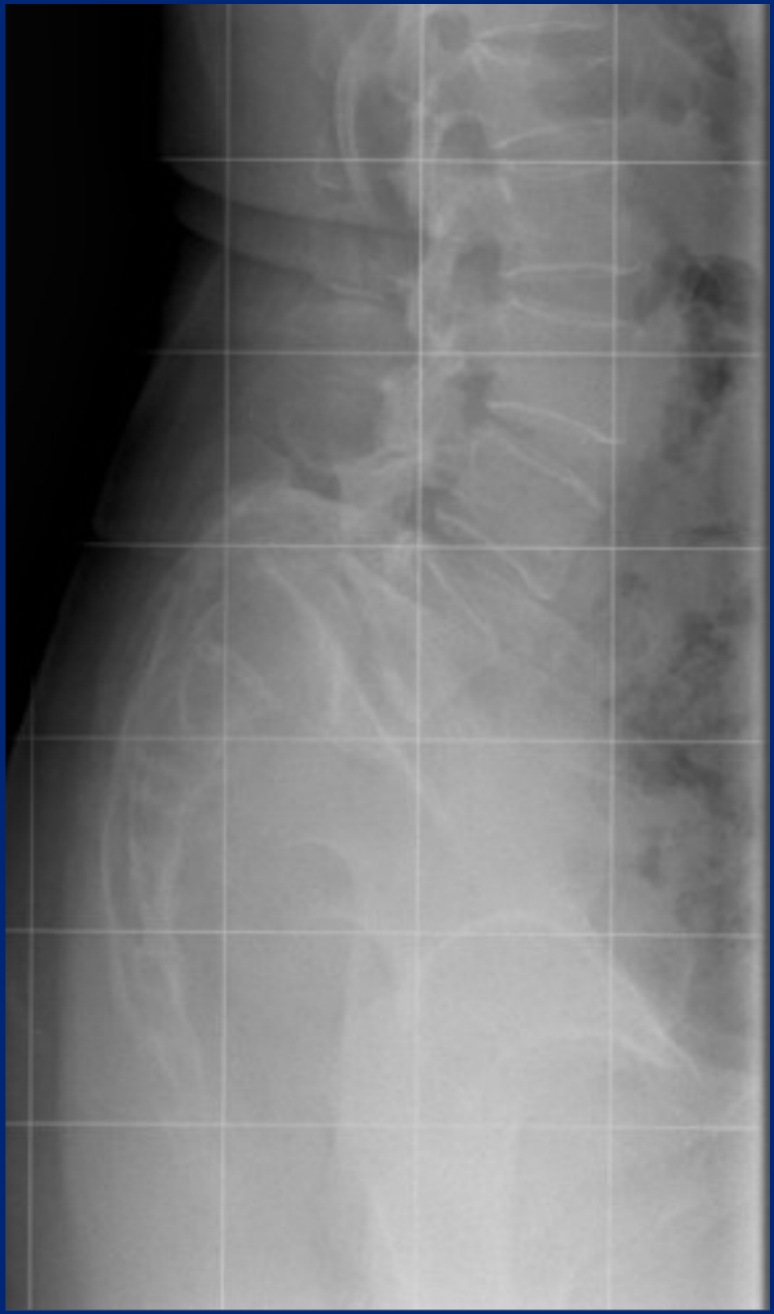
Fusion

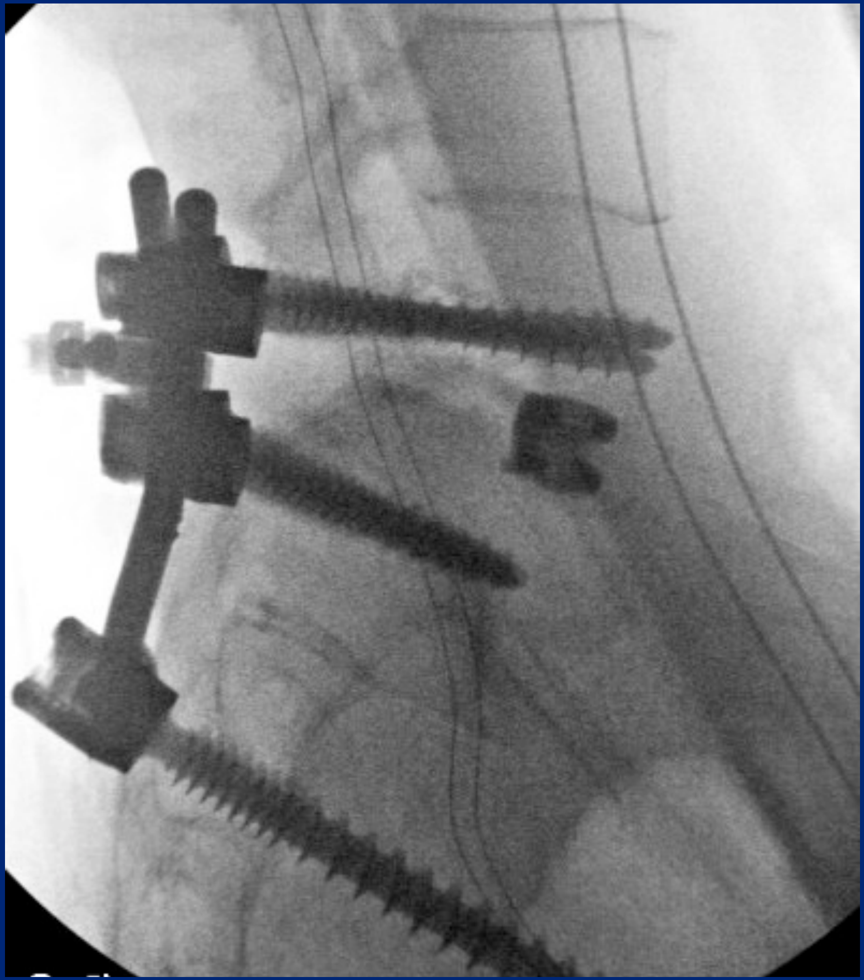
Grade	n	%	Fusion (Y/N)	Fusion %
Six-month cohort				
Grade I	1	2.3	N	0
Grade II	2	4.5	N	0
Grade III	10	22.7	Y	22.7
Grade IV	31	70.5	Y	70.5
Total	**44**	**100**	**N/A**	**93.2**
Percentage Y (fusion rate)				**93.2**
Twelve-month cohort				
Grade I	1	2.6	N	0
Grade II	0	0	N	0
Grade III	9	23.7	Y	23.7
Grade IV	28	73.7	Y	73.7
Total	**38**	**100**	**N/A**	**97.4**
Percentage Y (fusion rate)				**97.4**

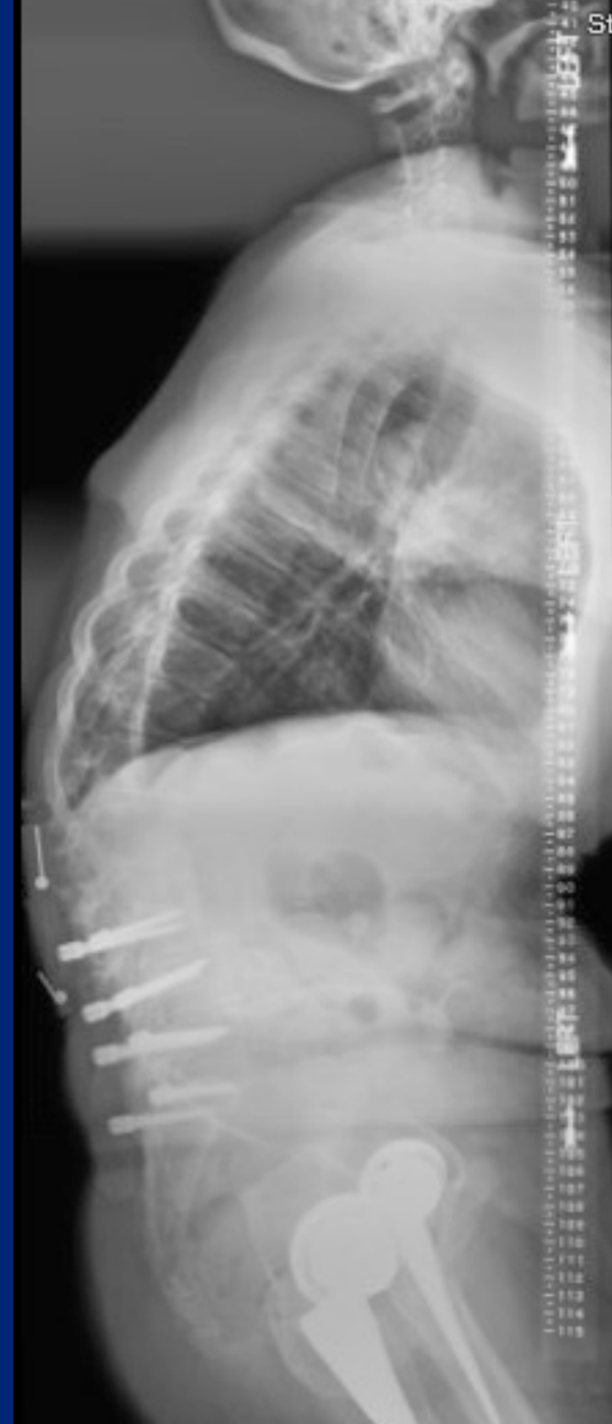
- 53yo female with longstanding lumbosacral pain with bilateral L5 radicular pain
- Fall from ladder (4 feet) with L1 compression fracture
- 3 mos persistent pain to L1 with increase lumbosacral pain and L5 radicular pain
  - Unable to return to work
- DEXA = -2.8
- Non-smoker, BMI=25, Norco- 4/day
- Lives with husband, Disabled as a restaurant worker




H
Desc: CT LUMBAR
F



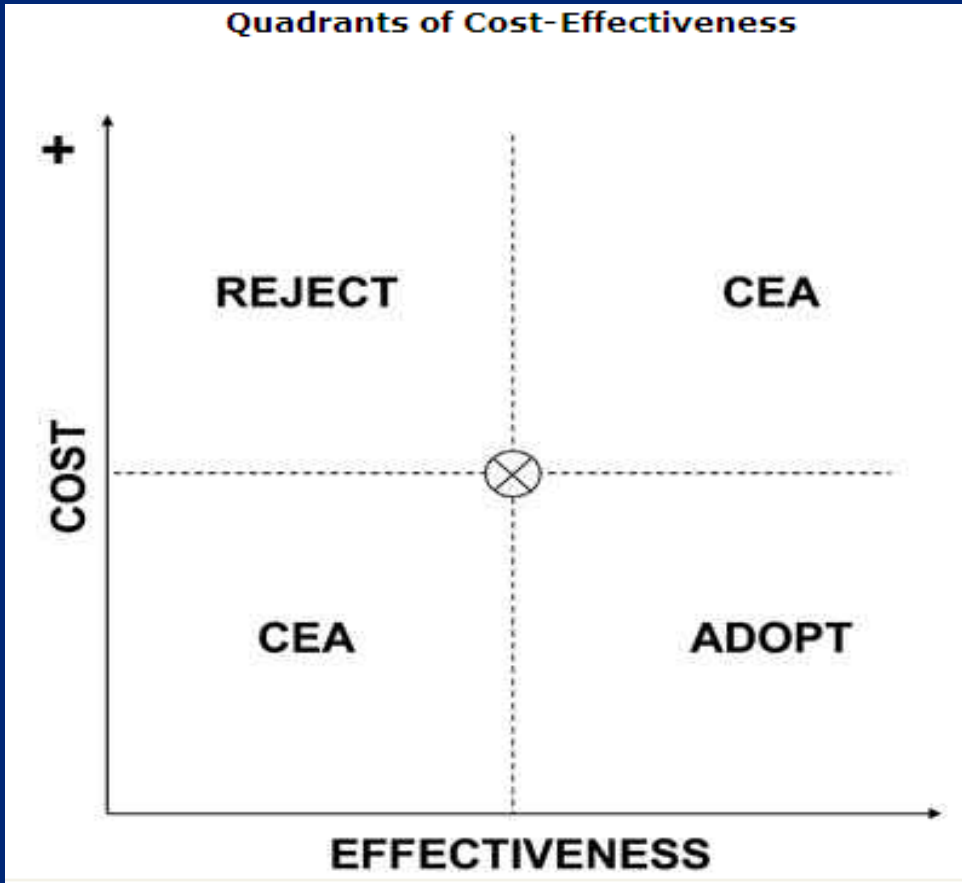





Erect
R

Cost-effectiveness of New Technologies

- Decision analysis in health policy and new technology adoption
- Effectiveness measured in:
  - Implant survival
  - Revision rates
  - Change in Health Status
  - Utility of Intervention



Conclusion

Innovative Surfaces have the opportunity to improve osteointegration of implants and stability and efficacy of interbody fusions

The Ideal Material for interbody fusion:

- Facilitates bone growth / Osteointegration
- Images well across all modalities
- Limited Subsidence
- Cost effective

- Compelling evidence will require direct comparative studies including preclinical modeling and clinical outcomes

UCSF Center for Outcomes Research