Titanium-PEEK Interbody Implants

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Disclosure: Employed by Aesculap, Inc.

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Implant Surface Technology

Composition
- PEEK
- Porous PEEK
- Titanium
- Titanium – PEEK
- Femto-surface?

Manufacturing methods
- Additive
  - 3D printed
  - Vacuum Plasma Spray (VPS)
- Subtractive
  - Acid-etched
  - Molded/Machined

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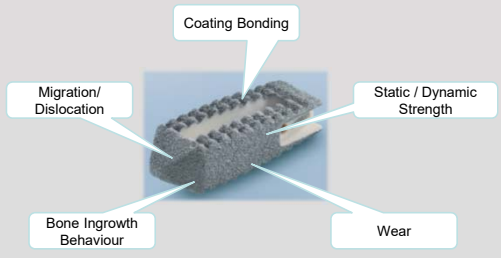
Ti-PEEK: Important properties



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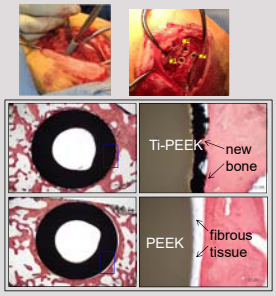
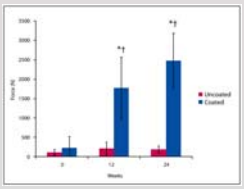
Ti-PEEK Bone In-growth/Osseointegration: Sheep implant model





- Significantly higher pull out strength at 12 and 24 weeks.
- Bony apposition and new bone formed significantly greater at 24wks.

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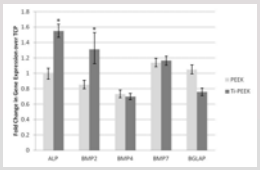
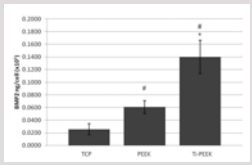
Bone Ingrowth/Osseointegration: *In vitro* models





Bone Formation

Early phase → Late phase		
Growth (proliferation): BMP's	ECM development: ALP, Type I Collagen	Mineralization: BMP's, Osteocalcin
PEEK →		
Ti-PEEK →		

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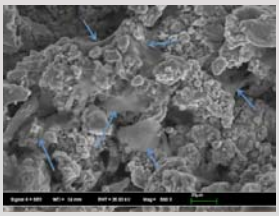
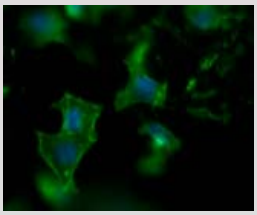
Cell adhesion on Ti-PEEK: SEM and confocal fluorescence





Pre-osteoblasts growing for 3 days on Ti-PEEK spine implant sections: *SEM 1000X (left panel), fluorescence microscopy (right panel) after staining (phalloidin, actin cytoskeleton, green; DAPI, cell nuclei, blue). (Bar = 50 µm)*

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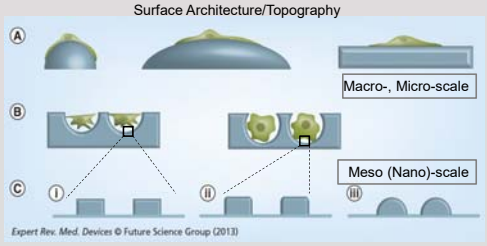
Cell-Implant Surface Biology

Surface Architecture/Topography



10^{-3} mm → 10^{-6} µm → 10^{-9} nm

Spinal Biologics

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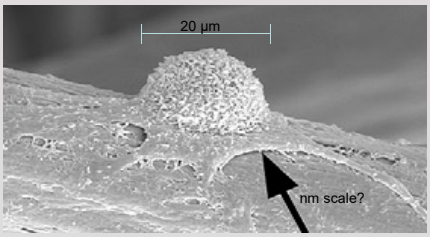
Cell-Implant Interaction: Scale



What's happening at the submicron, nanometer level?

Spinal Biologics

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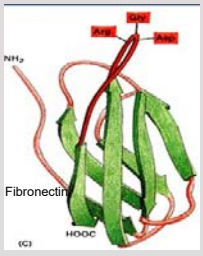
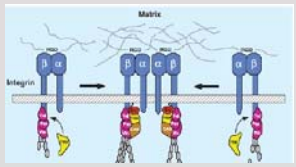
1984: Discovery of "RGD" Cell Adhesive motif – diverse range of ECM proteins (Pierschbacher and Ruoslahti, Nature 1984)



Fibronectin



1985: Discovery of RGD receptors, "Integrins" (Pytela, Pierschbacher, Ruoslahti, Cell 1985)

Distinct integrins → cell type/ECM → cell response

Spinal Biologics

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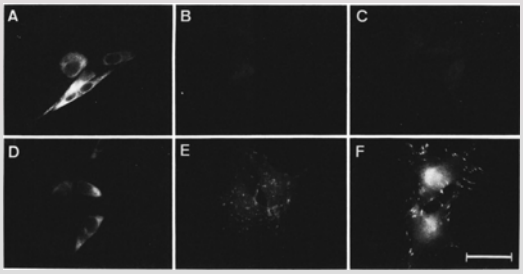
1987: Integrin expression and cancer (Spiro and Cheresh, JBiol Chem 1987)



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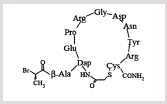
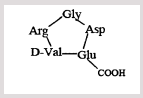
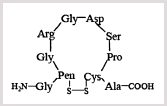
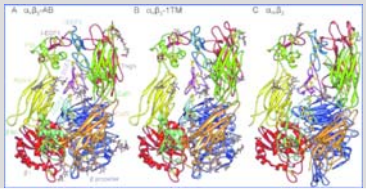
1988-90: RGD conformation and flanking sequences dictate integrin specificity (Pierschbacher and Ruoslahti, J Biol Chem 1987, Telios Pharmaceuticals, Inc.)









Spiro Biologics

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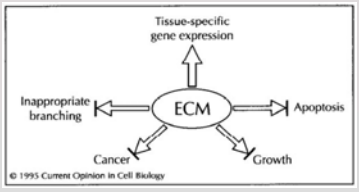
1990: Extracellular matrix composition regulates cellular differentiation (Streuli and Bissel, JCell Biol 1990)



Firm understanding of the language used in cell – ECM communication and how to manipulate it.

Spiro Biologics

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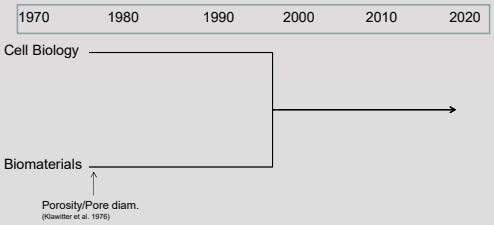
1984-2017: Convergence of basic cell biology principles with biomaterial/device concepts



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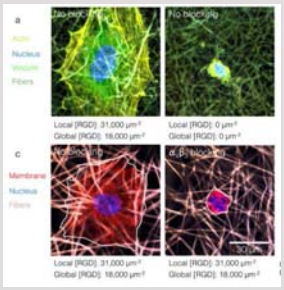
2016: RGD density and integrin clustering on biomaterials
(Benitez et al. Integr Biol 2016)



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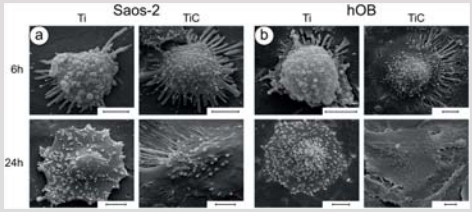
2016: Nano-clustered Titanium/Graphitic carbon (TiC)
(Longo et al. PlosOne 11(3) 2016)



Conformation of cell adhesive motifs (nanoscale) influenced by composition and topography of implant surface → dictates cell response → tissue formation.

Summary

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- Surface properties of implants recognized as an important determinant of device success.
  - **Composition** (PEEK, Ti, CoCr, collagen…)
  - **Architecture/Topography** (2D, 3D, porous, smooth, rough…macro, micro, meso (nano) scale)
  - **Mechanical properties** (hard, soft, compressible, elastic…)

Surface textures at the macro-, micro- and nano-scale level have significant influence at the cellular level.

- Support cell adhesion by binding proteins from serum/tissue fluid
  - **Influences conformation of ECM protein / cell adhesion motifs**
- Dictate cell shape, growth characteristics, differentiation, inflammatory response

Deep roots in basic cell biology/tissue engineering disciplines

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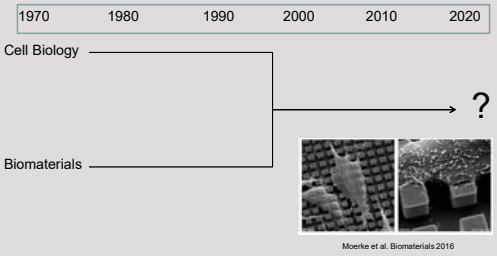
1984-2017: Convergence of basic cell biology principles with biomaterial/device concepts



Moerke et al. Biomaterials 2016

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Porous Titanium Surface Technology

20 year of clinical presence with Ti-PEEK, 30 years with porous titanium surface enhancements

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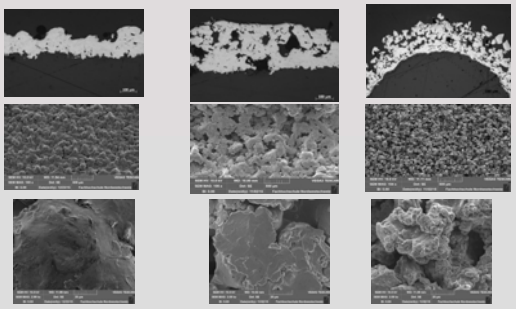
Titanium – PEEK: Not all the same…



Surface Dynamics | APS Materials | Orchid/Allehenia

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Thank You

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