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The hierarchical structure of osseointegration - multiscale and multimodal assessment of the bone-implant interface

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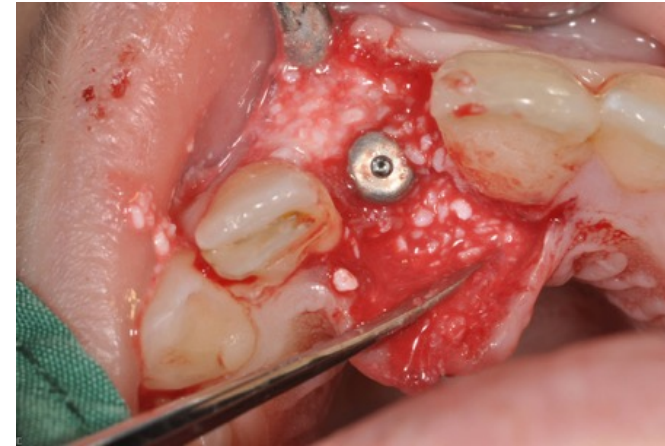
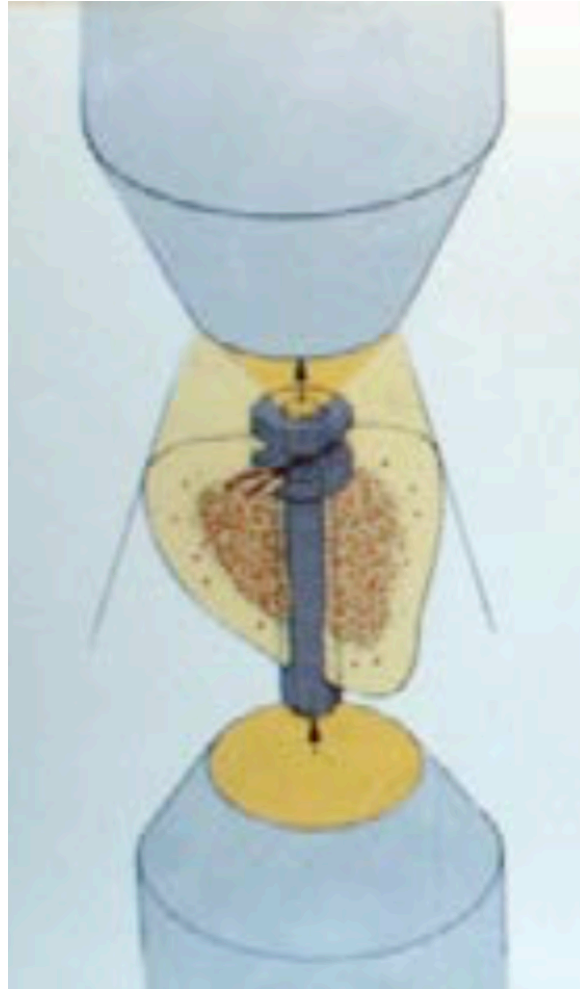
I have no actual or potential conflict of interest in relation to this presentation!



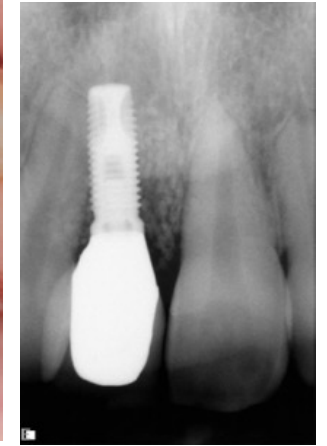
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Prof PI Brånemark
1929-2014

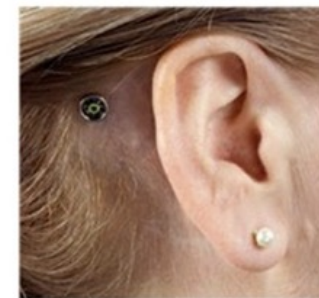


1. Titanium implant



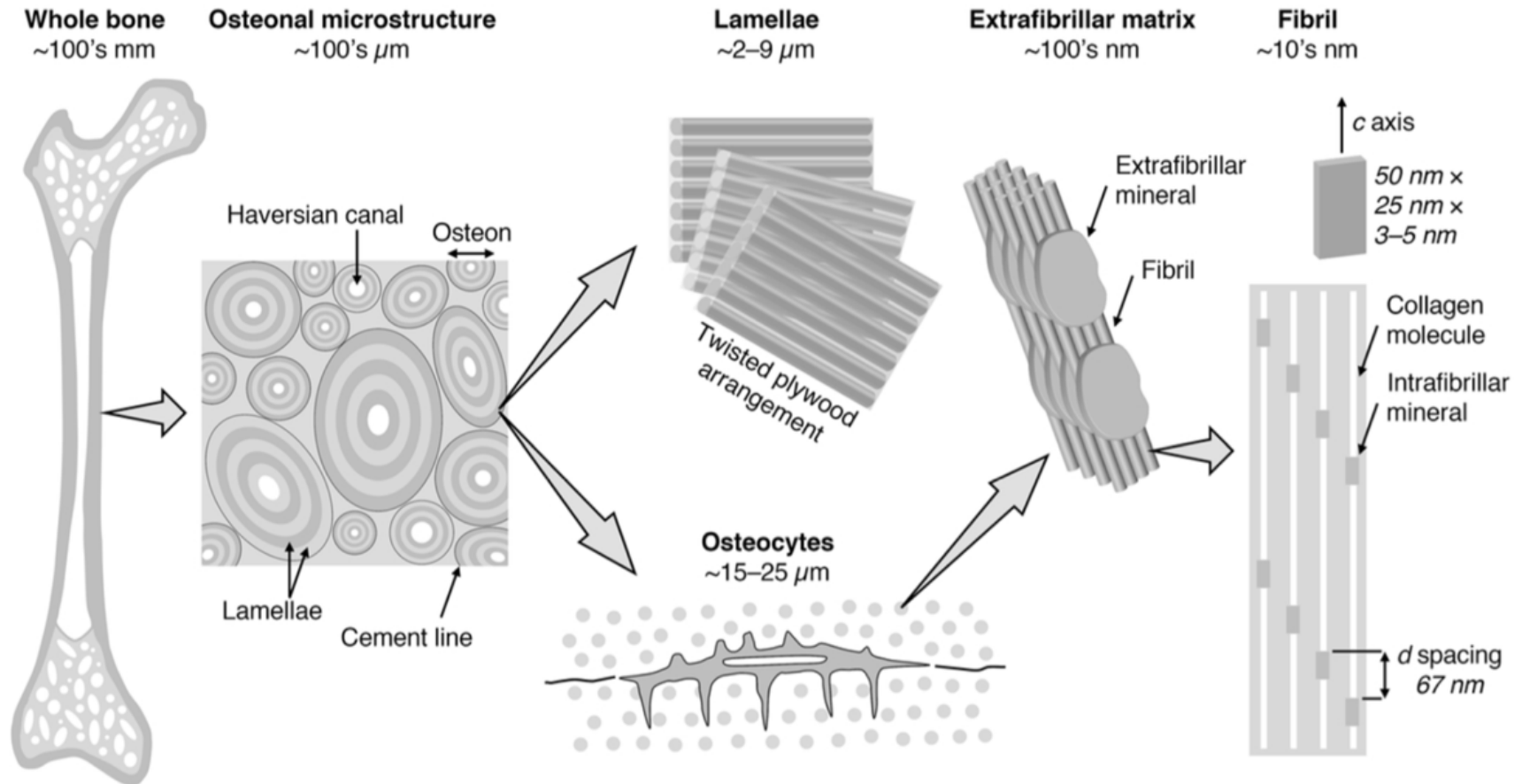
2. Abutment

3. Sound Processor





Bone tissue

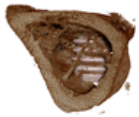




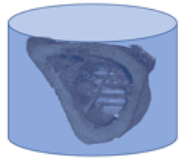
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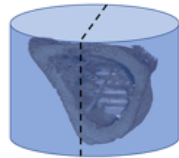
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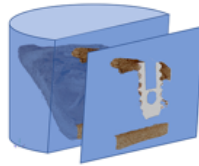
Resin embedding



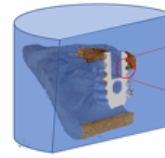
Dividing



Ground-sectioning



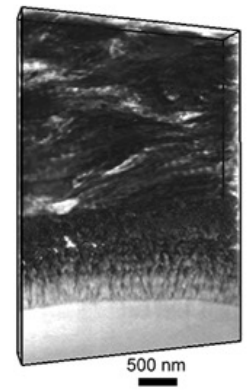
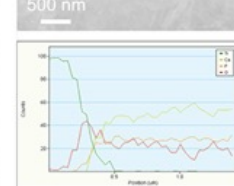
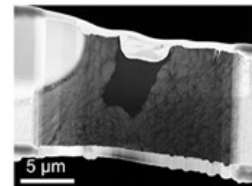
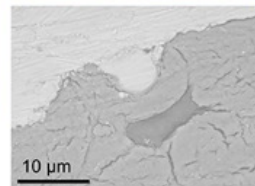
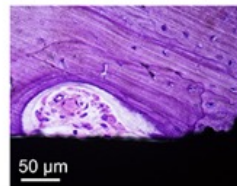
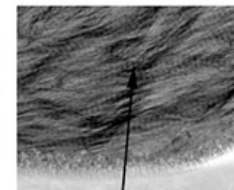
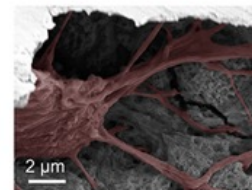
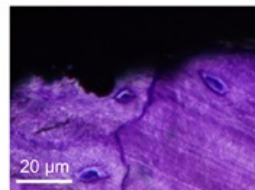
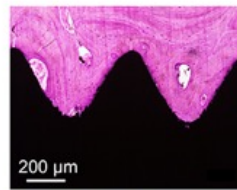
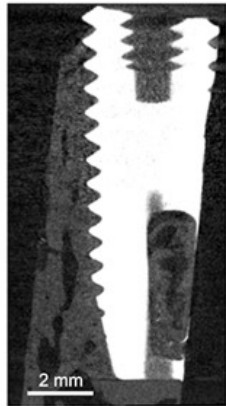
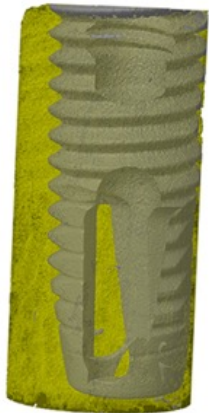
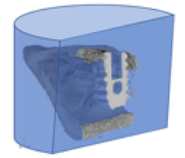
Polishing



Focused ion beam



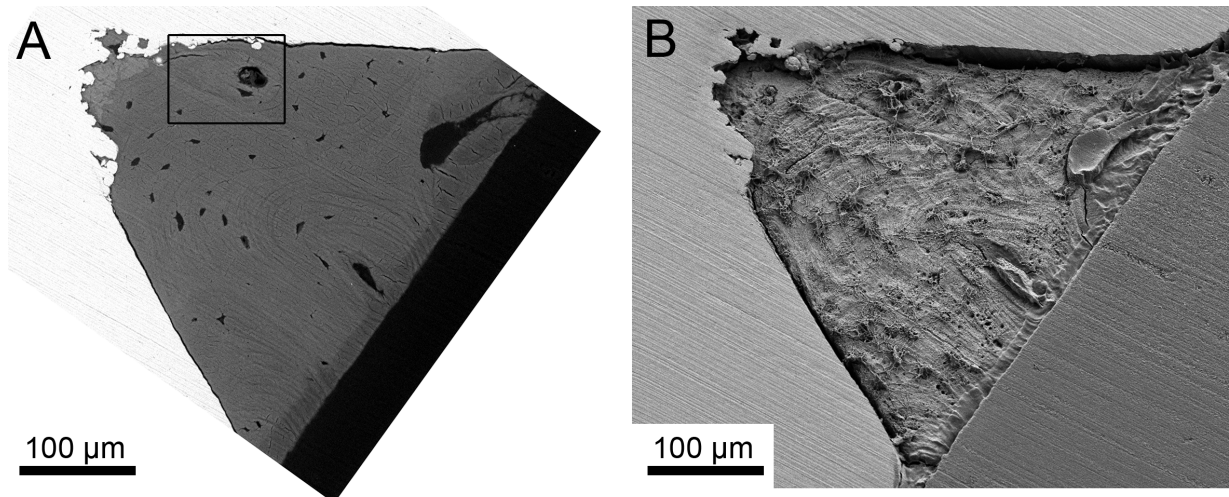
Resin cast etching

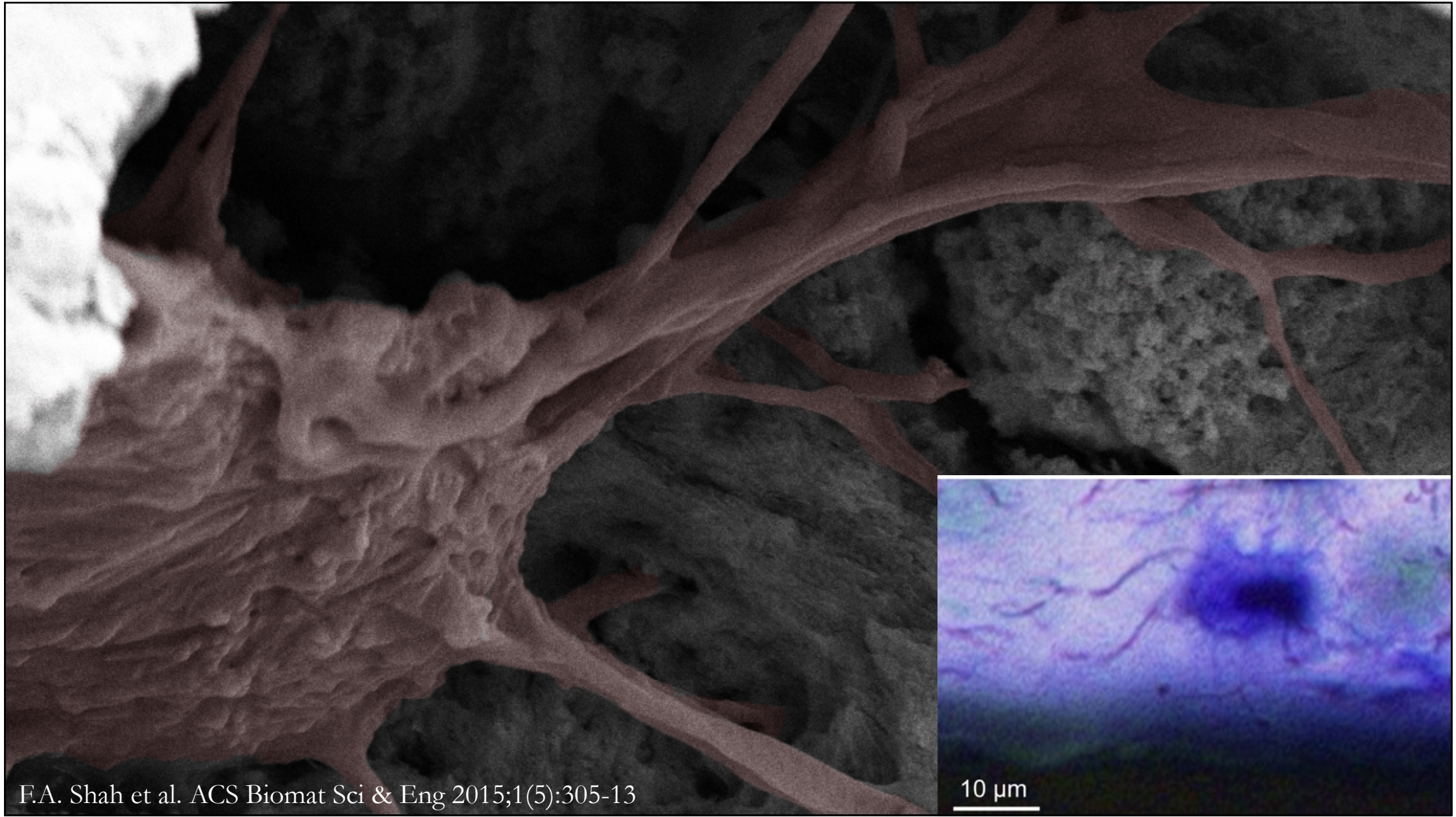




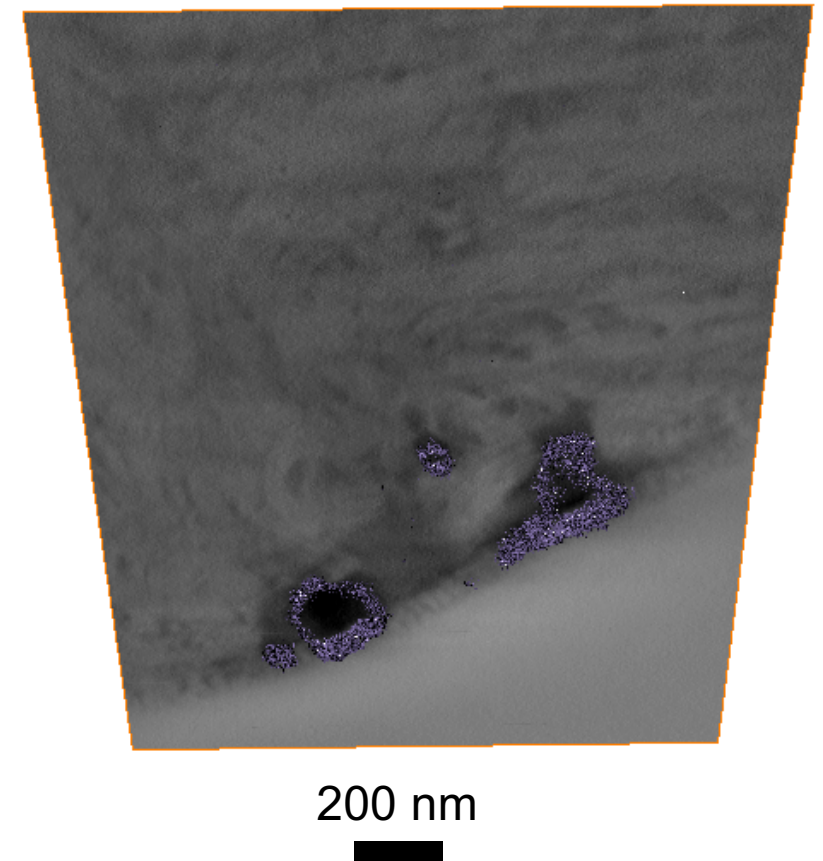
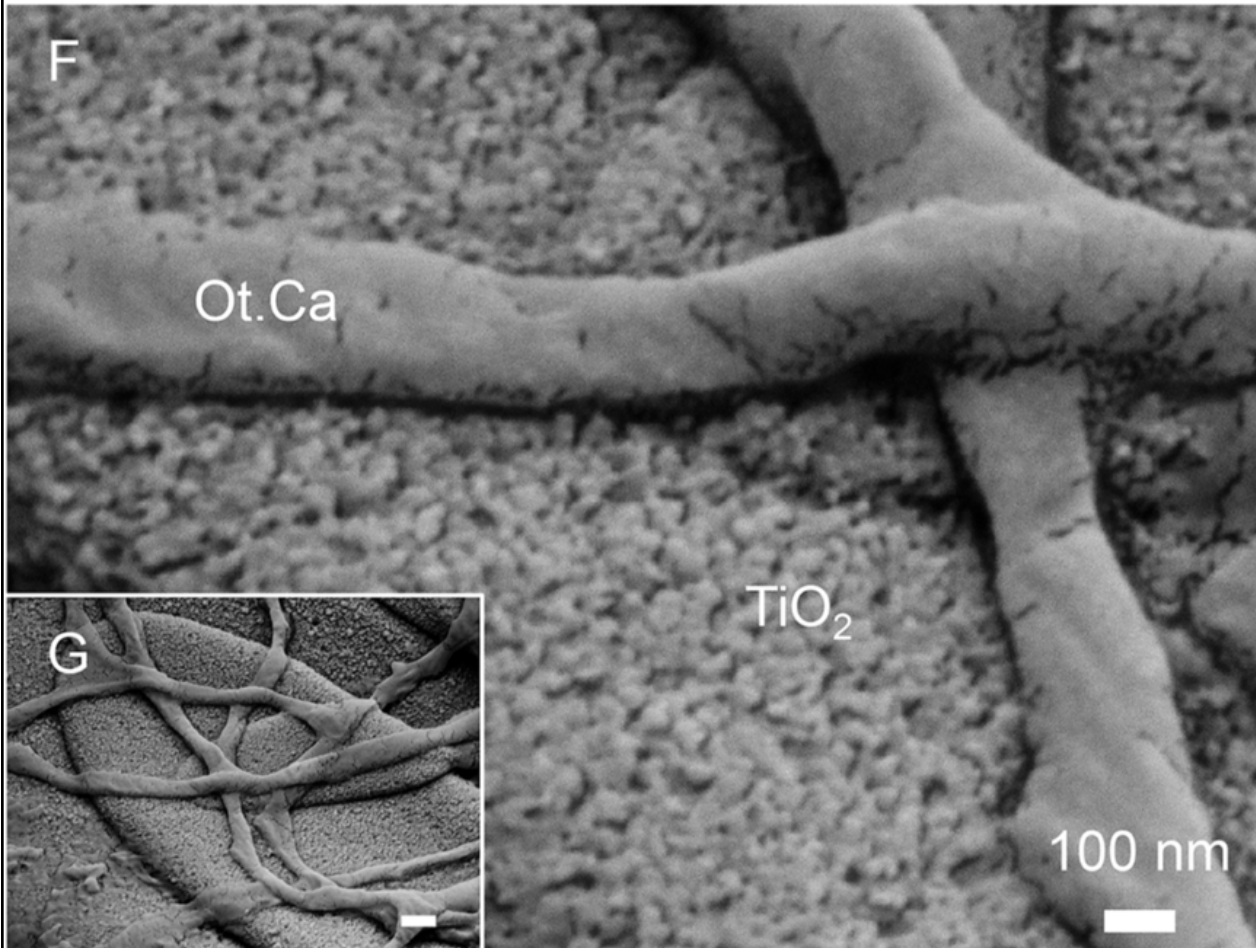
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Does cells exist close to the implant and do
canaliculi reach the implant surface?





Canaliculi and surface contact

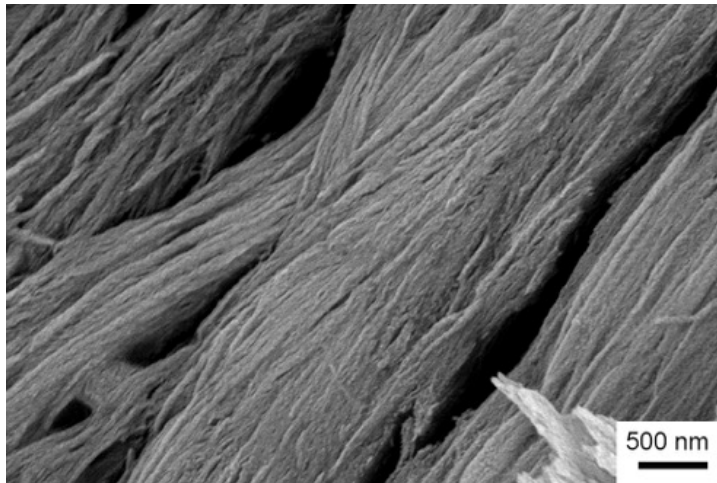




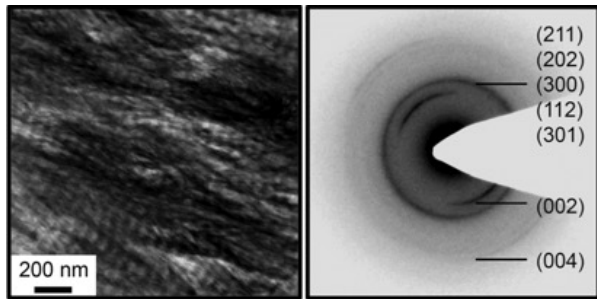
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How does the interface look at the nanometer resolution?

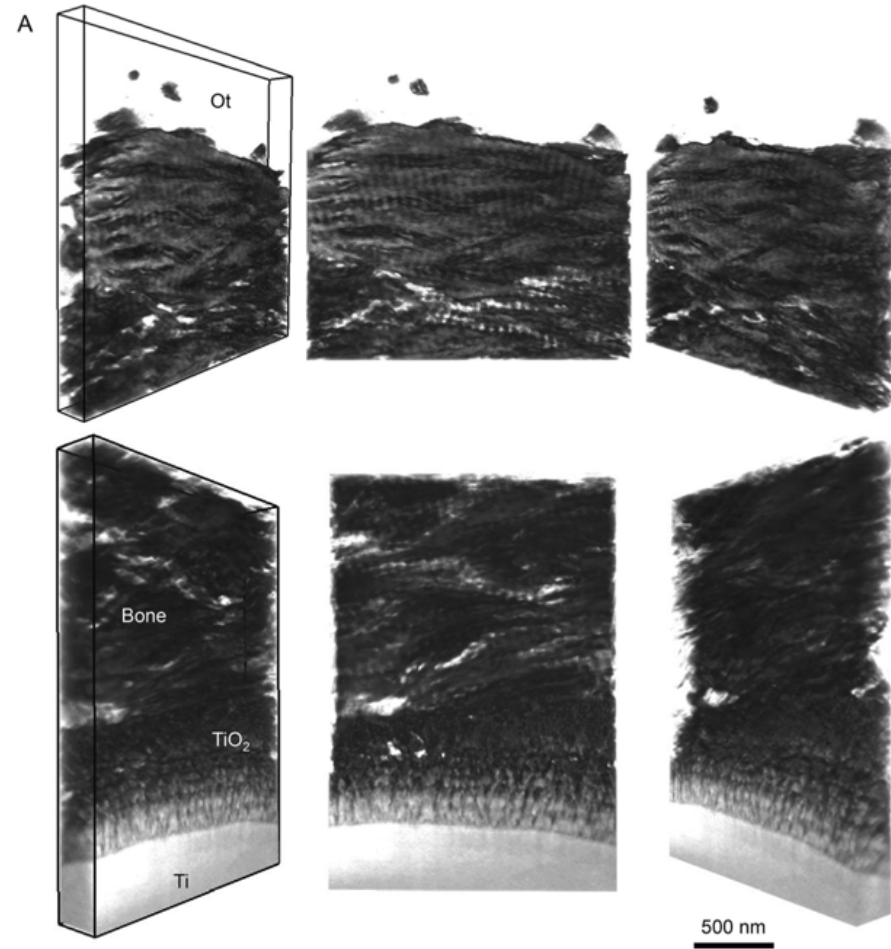
Electron Tomography: Nanoscale Bone – Implant Interaction



F.A. Shah et al. *Calcif Tissue Int.* 2016;98:193



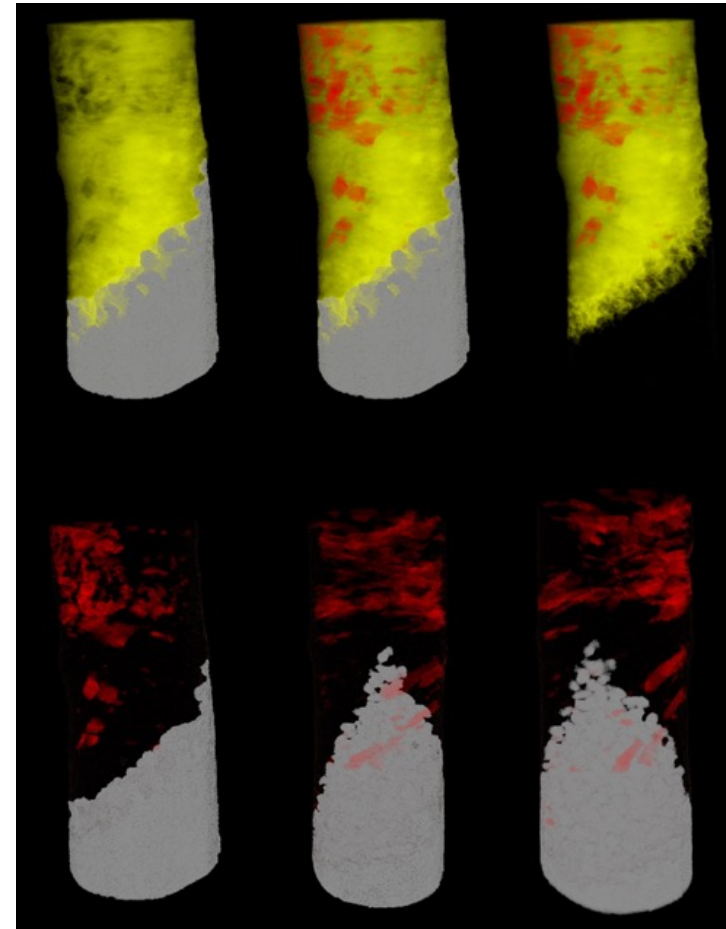
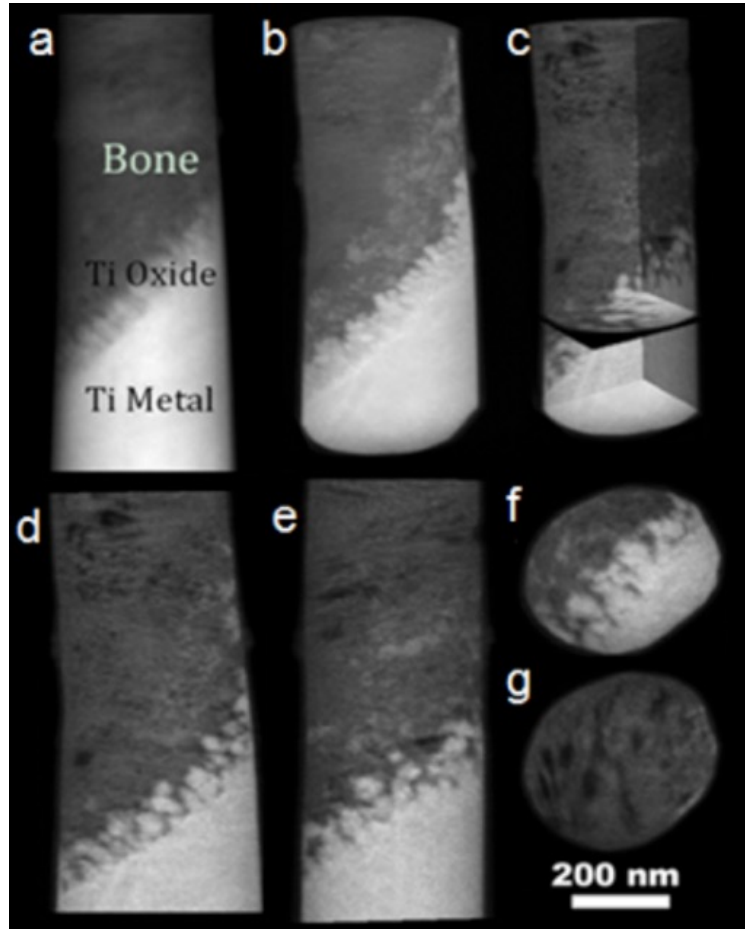
F.A. Shah et al. *ACS Biomater Sci & Eng* 2015;1(5):305-13





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On-axis electron tomography

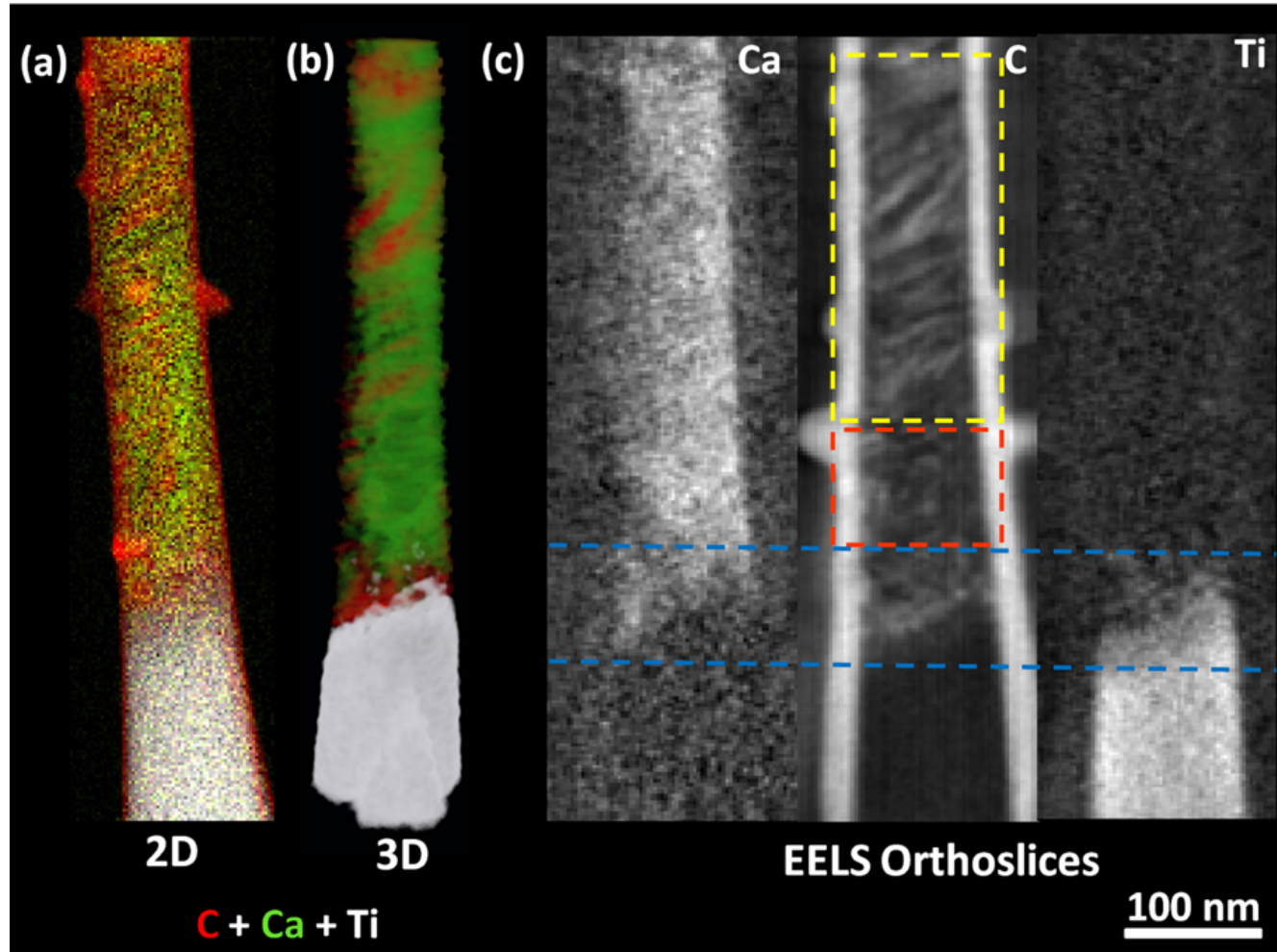


X. Wang et al. ACS Biomater Sci & Eng 2017;3:49-55



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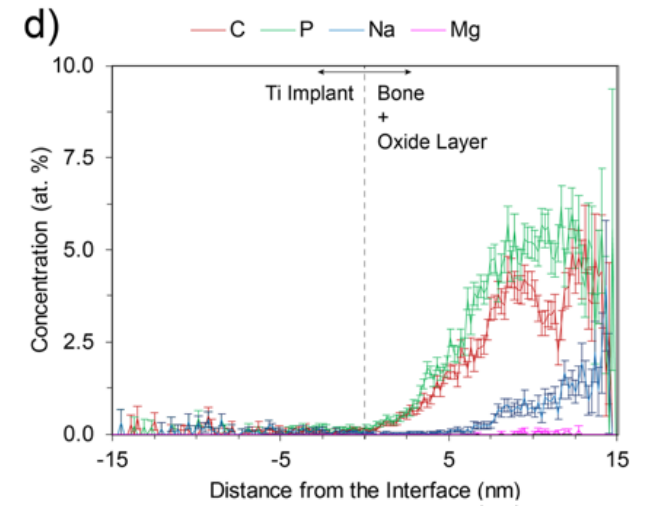
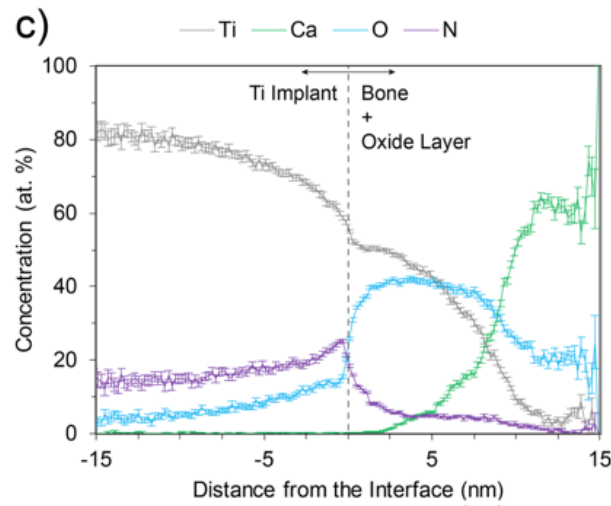
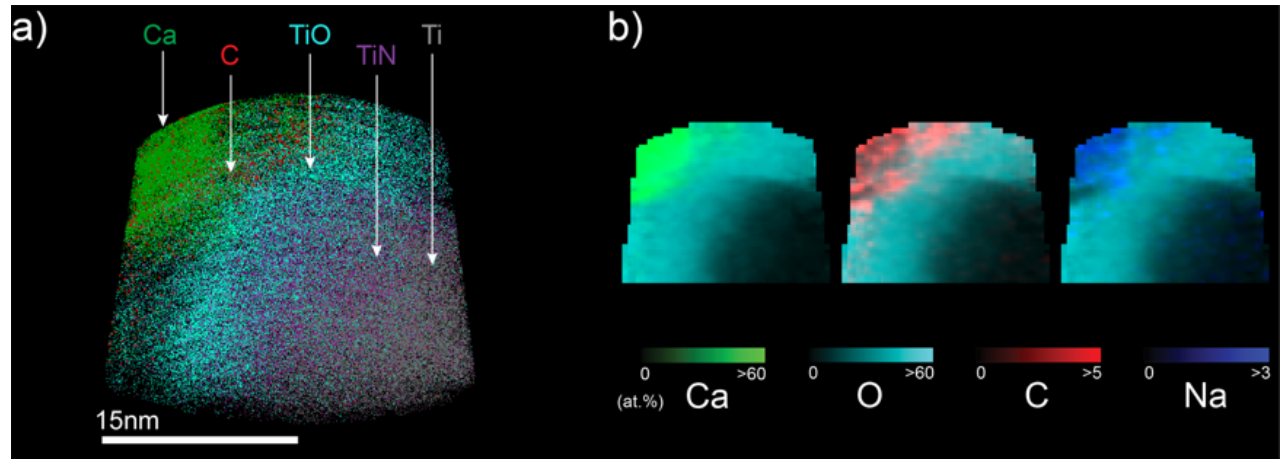
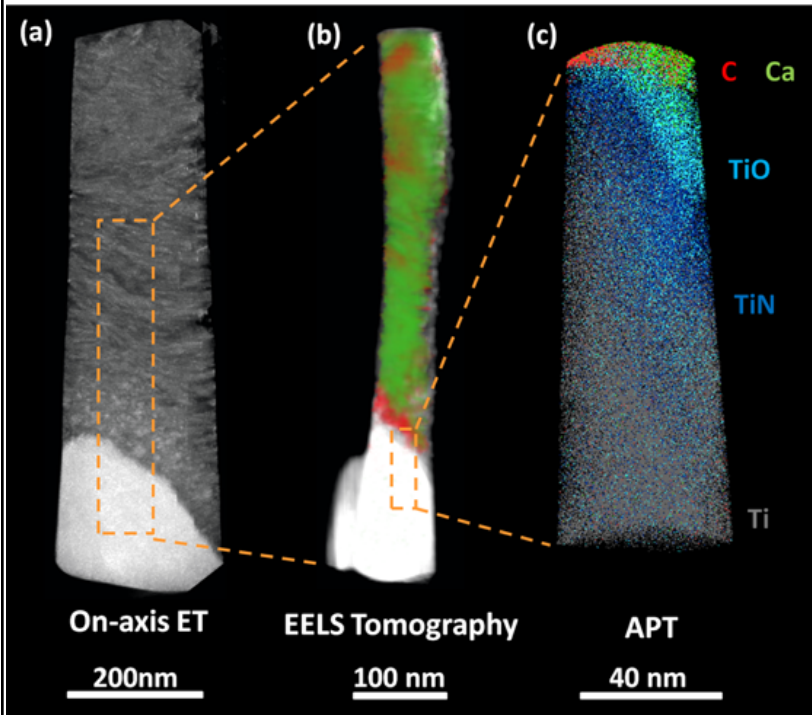
On-axis EELS tomography





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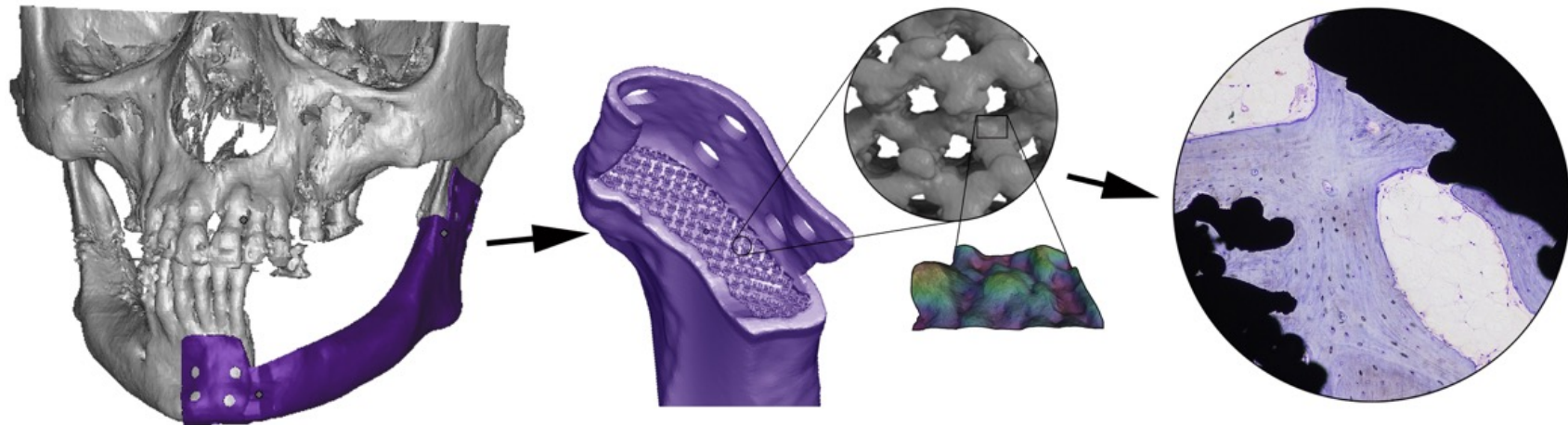
Atom probe tomography





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Additive Manufacturing: How does bone grow into a complex shaped porous implant?





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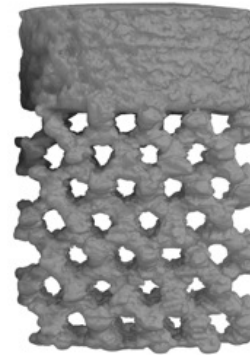
Ti6Al4V



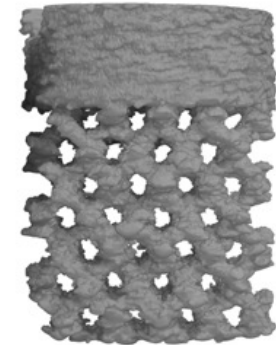
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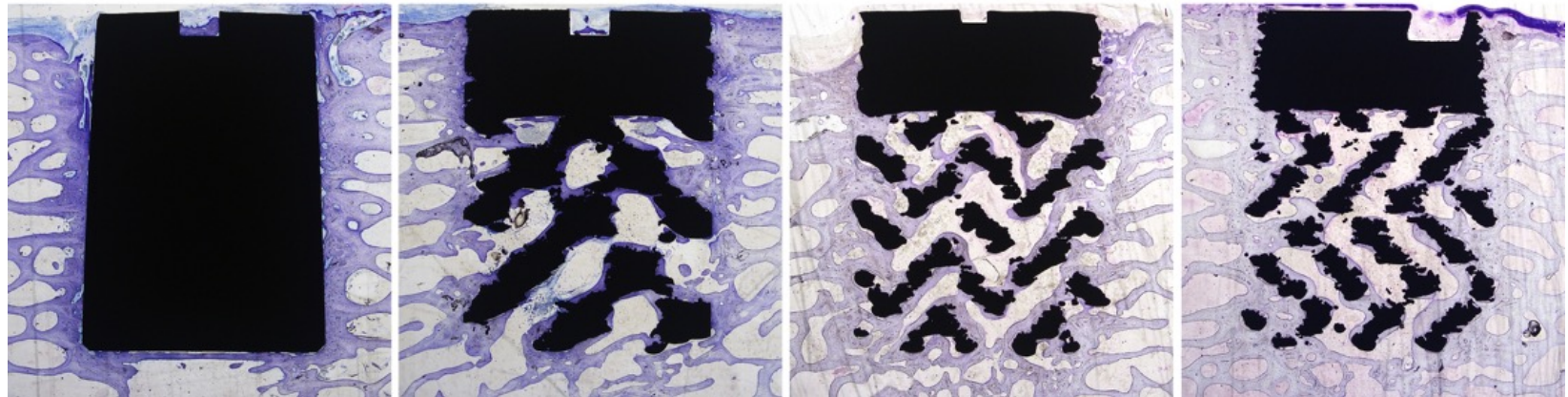
Ti6Al4V



CoCr

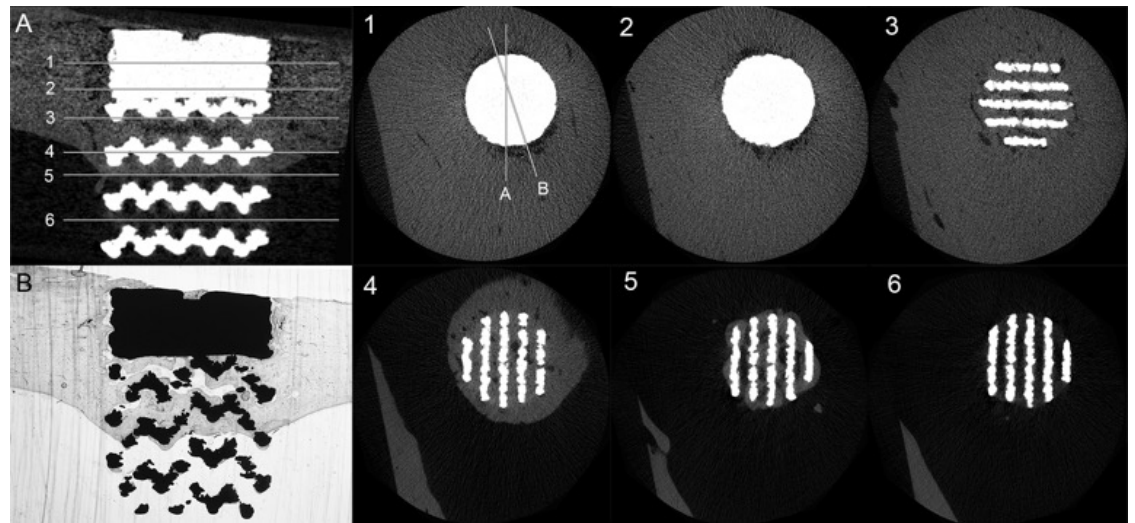
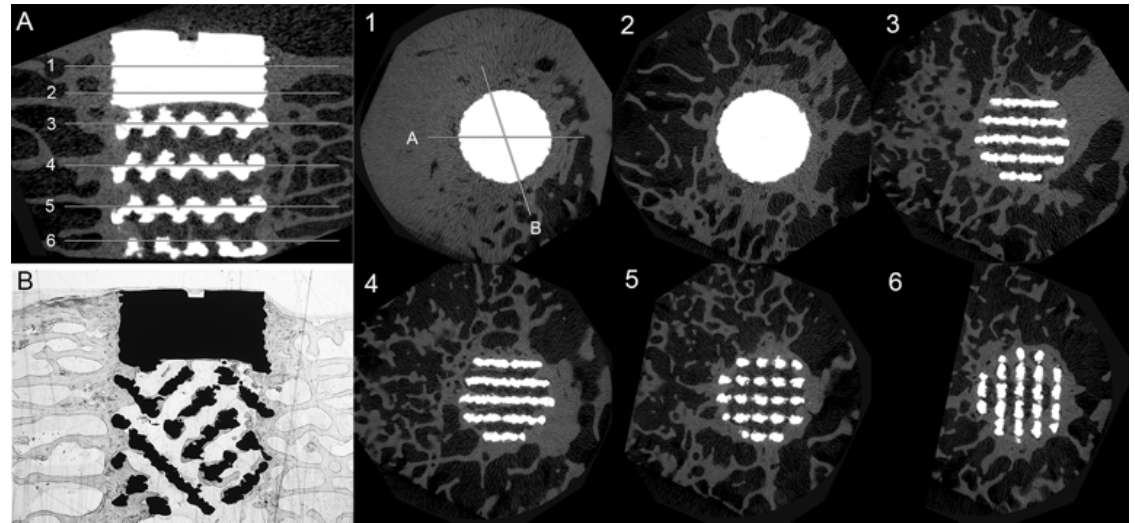


1 mm



Shah et al, Acta Biomater 2016;30:357-67

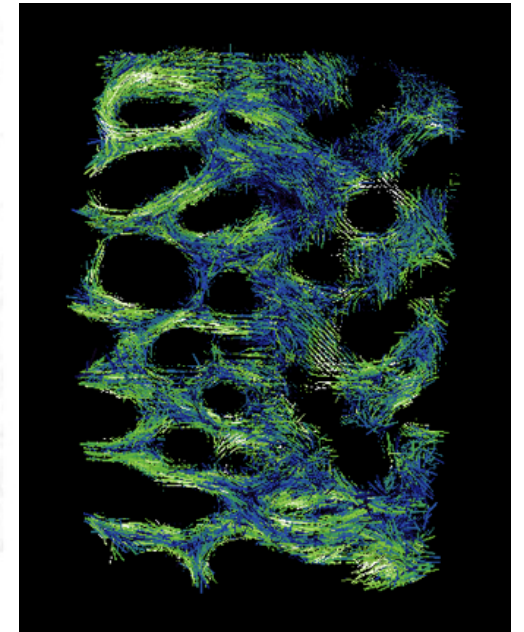
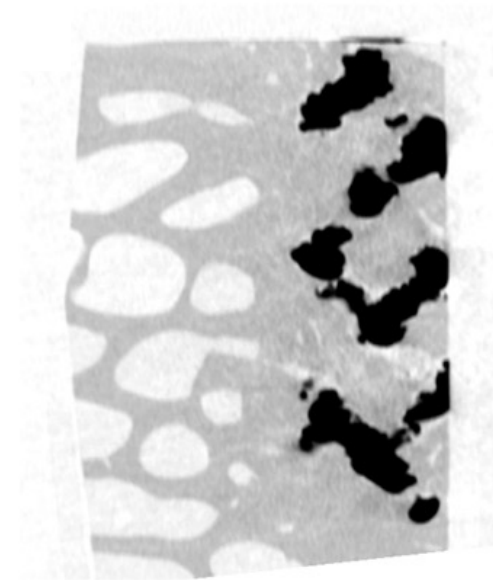
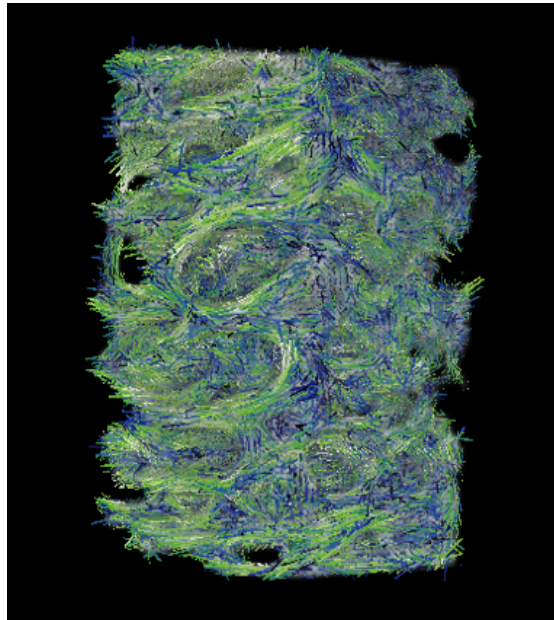
Shah et al, Acta Biomater 2016;36:296-309





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SAXS tensor tomography



T. Grünewald et al. preliminary data



- Vascularized remodeled bone interfacing the implant with interconnected osteocytes via canaliculi network allowing mechanosensing
- Implant surface may act as a surface for coordinated bone formation allowing high quality mechanically competent bone to form
- Porous metal implant seem to guide the bone growth along the struts
- Need for multiscale and multimodal correlative strategies to further understand the structural aspects of osseointegration and the bone maintenance

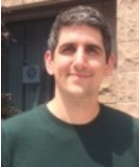


- Shah FA, Ruscsák K, Palmquist A. 50 years of scanning electron microscopy of bone – A comprehensive overview of the important discoveries made and insights gained into bone material properties in health, disease, and taphonomy. *Bone Res.* 2019;7:15 <https://dx.doi.org/10.1038/s41413-019-0053-z>
- Shah FA, Thomsen P, Palmquist A. Osseointegration and current interpretations of the bone-implant interface. *Acta Biomater.* 2019;84:1-15
<https://dx.doi.org/10.1016/j.actbio.2018.11.018>
- Shah FA, Thomsen P, Palmquist A. The impact of implant biomaterials on osteocytes: A literature review. *J Dent Res.* 2018;97(9):977-986
<http://dx.doi.org/10.1177/0022034518778033>



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Dr. Felix Neubergh Foundation

Oticon Medical AB

Arcam AB (now Arcam EBM – a GE Additive company)

Integrum AB



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