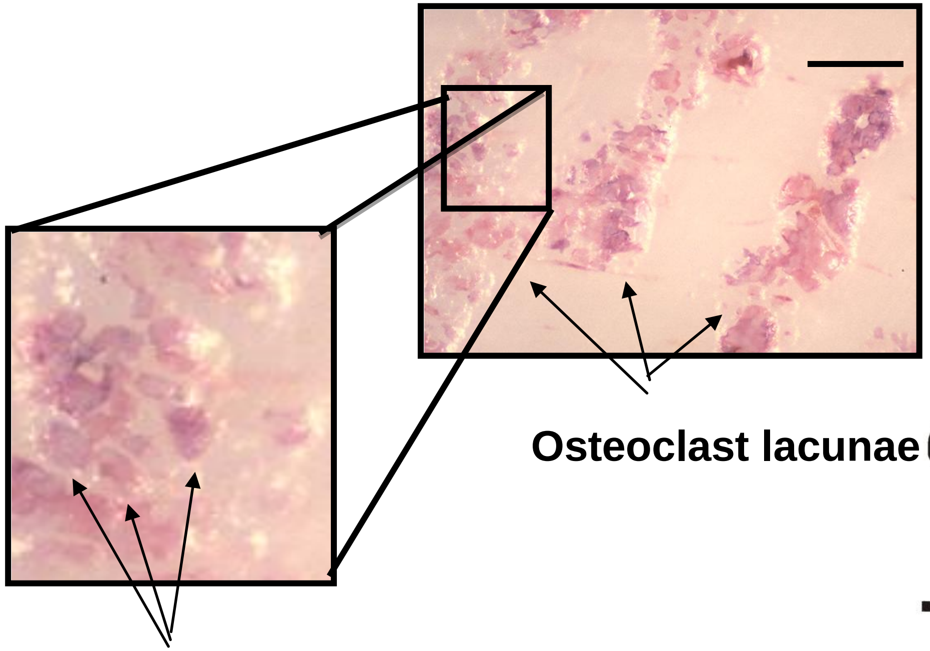
Surface Matters

Adam Bruggeman, MD
Texas Spine Care Center

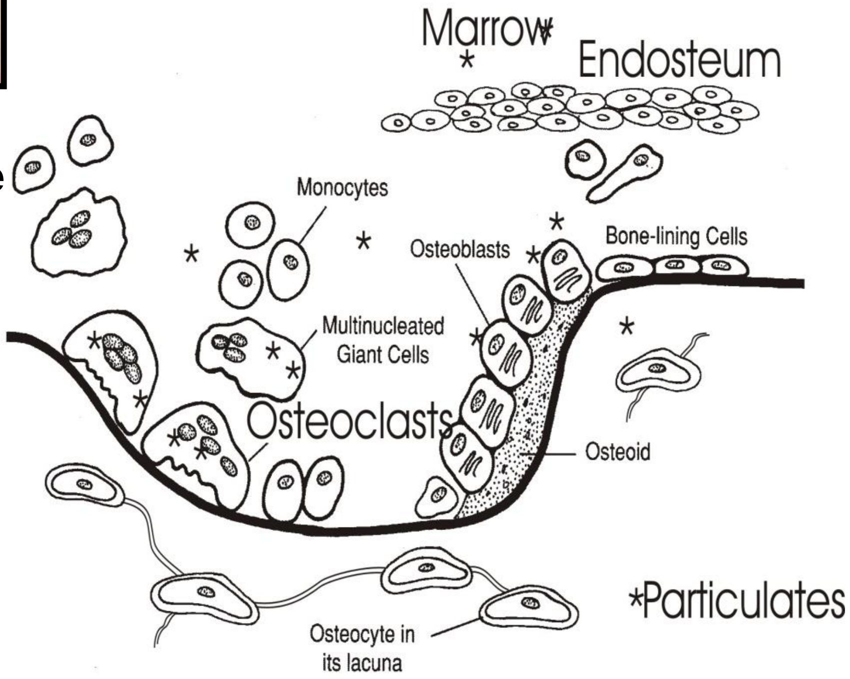
Is surface morphology biologically relevant?

Osteoblasts form bone on a surface that is created and conditioned by osteoclasts.

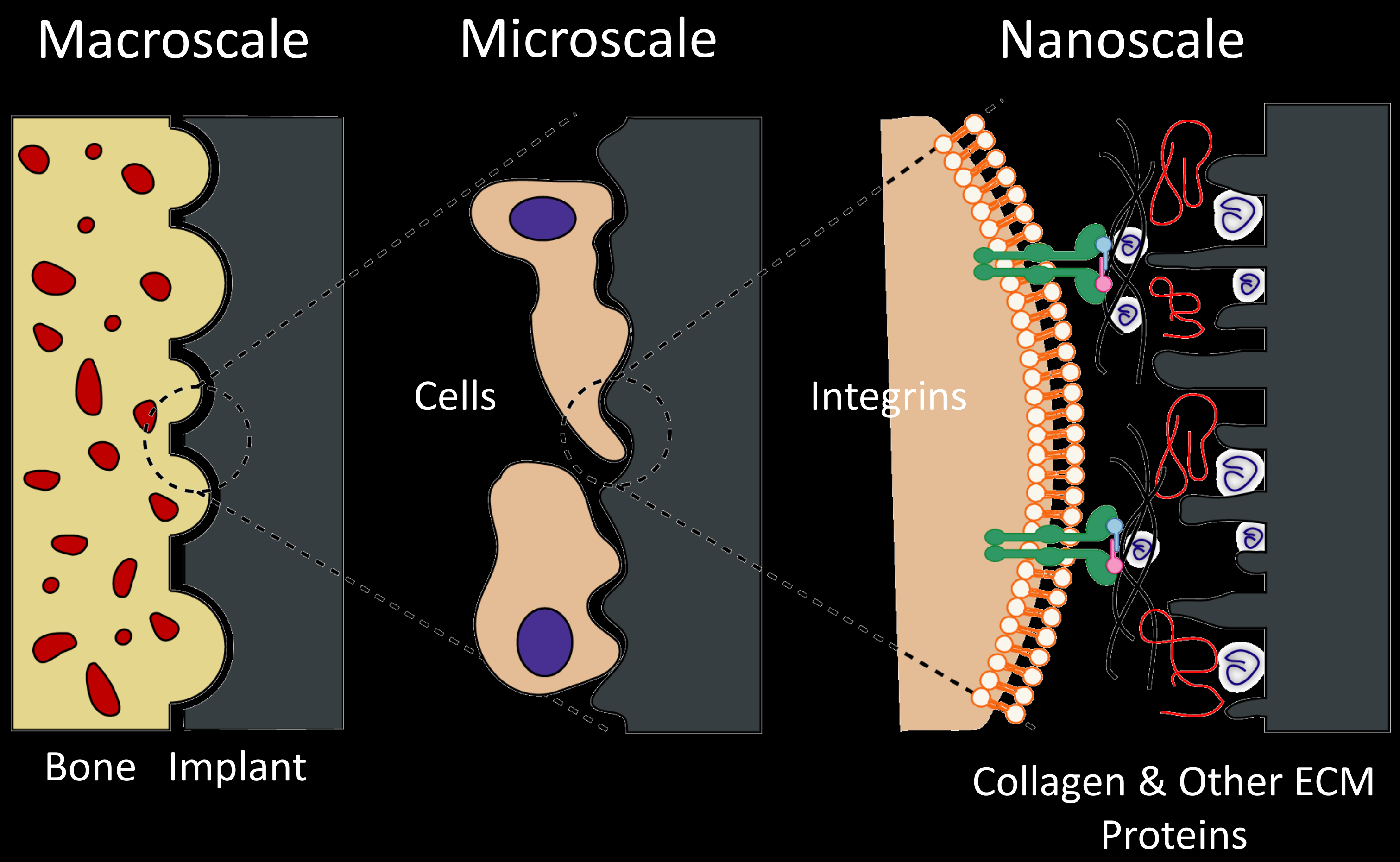


Osteoclast lacunae

Alkaline phosphatase positive osteoblasts

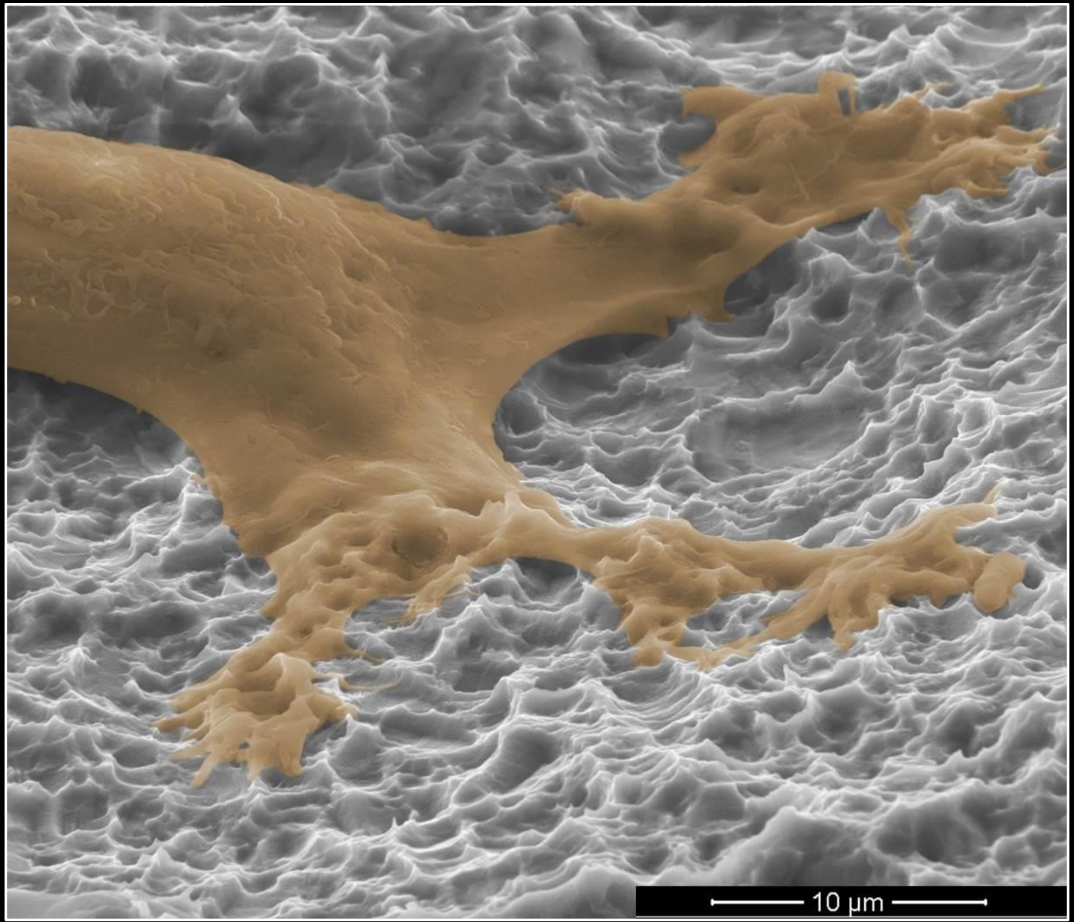


Bone Structural Complexity



What is it that cells like?

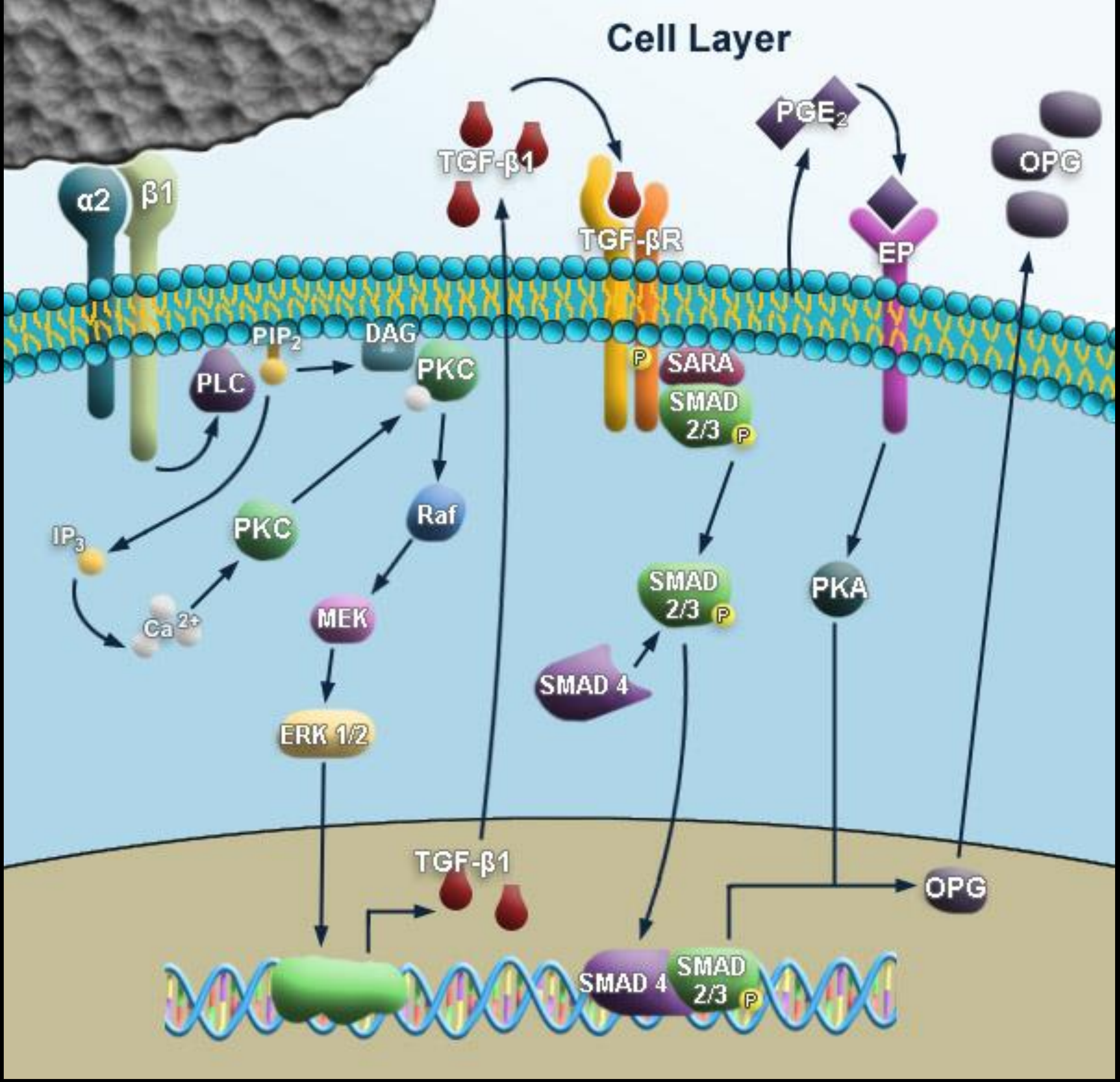
- Complex microtextured surfaces
- Craters that are 30-100 μm wide
  - Macro
- Pits that are 1-3 μm wide
  - Micro
- Peaks that are “pointed” with a regular shape
  - Nano



MSC interacting with a roughened Ti surface.

Image Courtesy of Dr. Robert Brown, Department of Bioengineering, Penn State University

How can the surface have an effect?

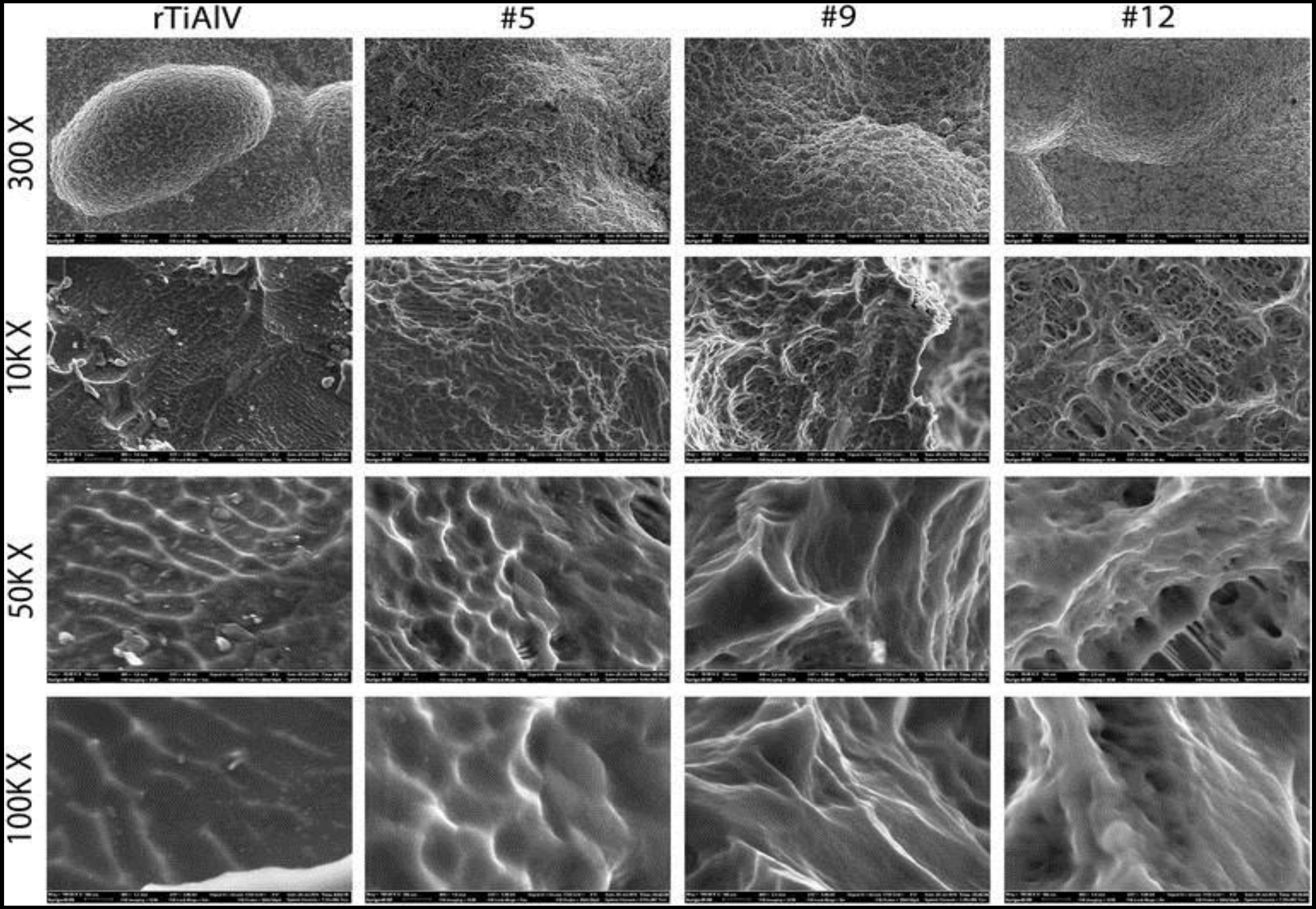


Annals of Biomedical Engineering, Vol. 42, No. 12, December 2014 (© 2014) pp. 2551–2561
DOI: 10.1007/s10439-014-1108-3

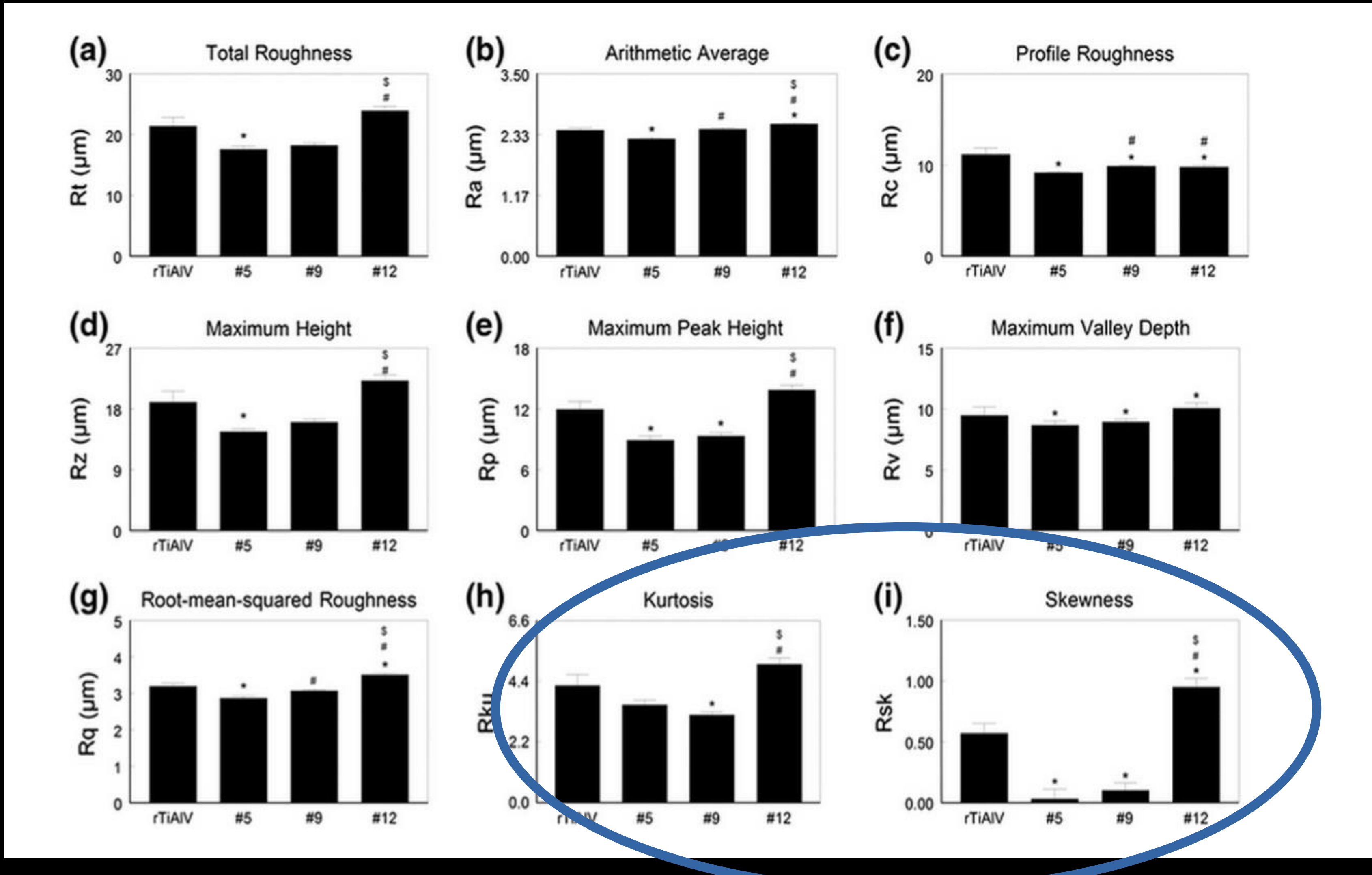
Osteoblast Lineage Cells Can Discriminate Microscale Topographic Features on Titanium–Aluminum–Vanadium Surfaces

RENE OLIVARES-NAVARRETE,[1] SHARON L. HYZY,[1] MARK E. BERG,[2] JENNIFER M. SCHNEIDER,[2] KELLY HOTCHKISS,[1] ZVI SCHWARTZ,[1,4] and BARBARA D. BOYAN[1,3,4,5]

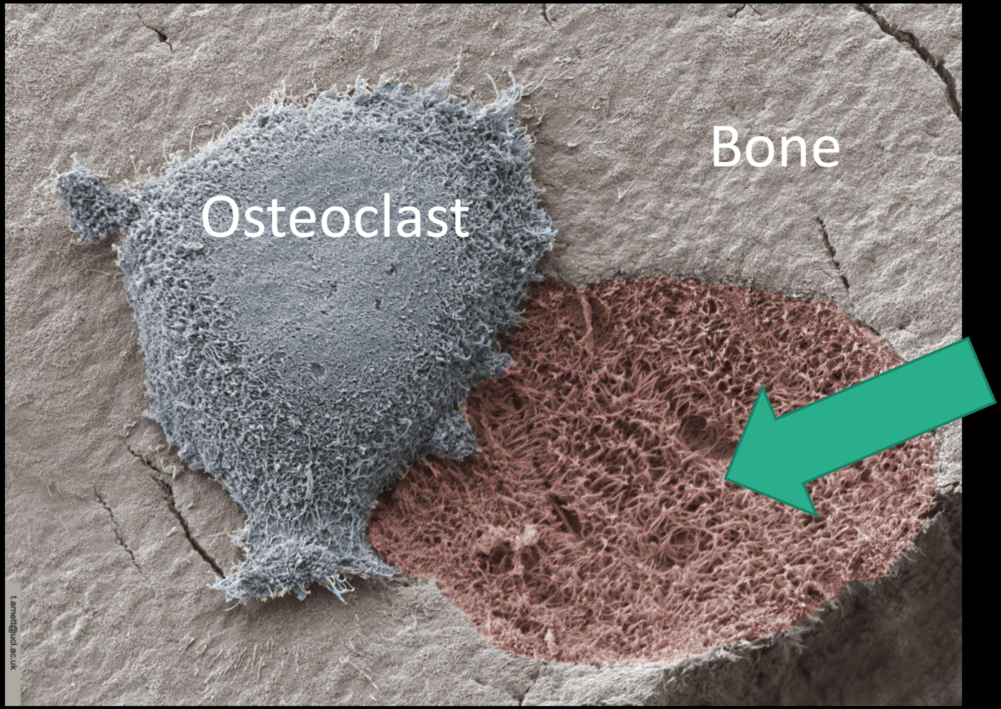
[1]Department of Biomedical Engineering, Virginia Commonwealth University, Richmond, VA, USA; [2]Titan Spine LLC, Mequon, WI, USA; [3]Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology, Atlanta, GA, USA; [4]Department of Periodontics, University of Texas Health Science Center at San Antonio, San Antonio, TX, USA; and [5]School of Engineering Virginia Commonwealth University, 601 West Main Street, Suite 331a, Richmond, VA 23284, USA


rTiAlV
#5
#9
#12
300 X
10K X
50K X
100K X

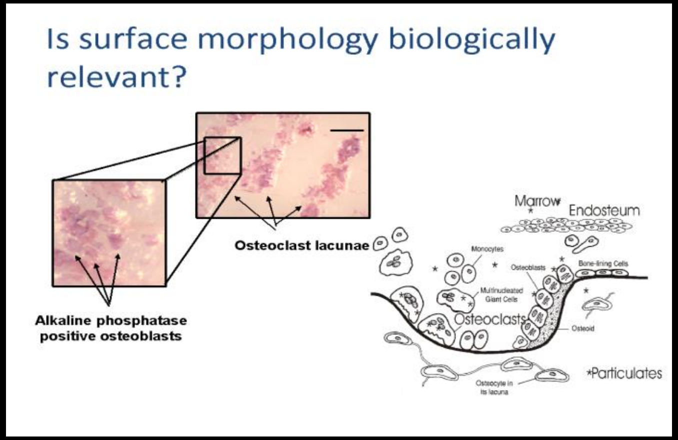
- Multiple surface characteristics were measured
- Only two parameters showed significant differences
  - Low Skewness (deep valleys)
  - High Kurtosis (sharp peaks)



Morphology of an osteoclastic pit



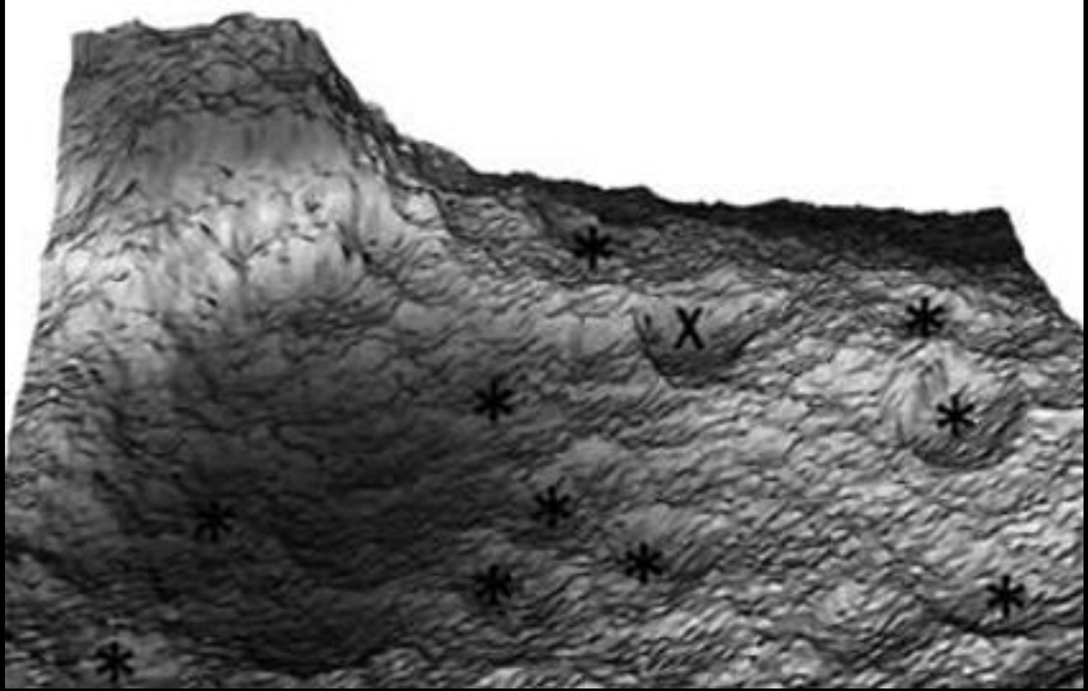
By kind permission of Tim Arnett (t.arnett@ucl.ac.uk) & Javier Manzano, UCL.

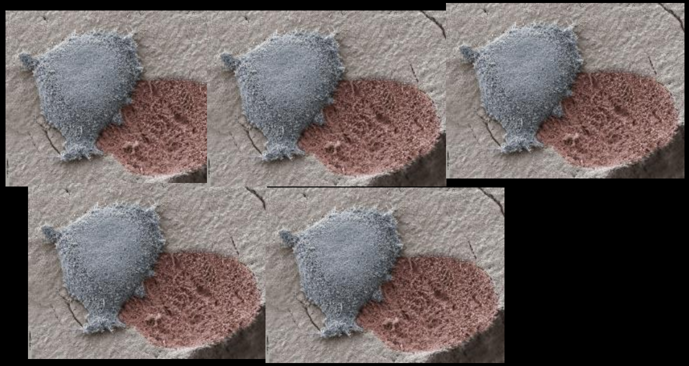


Osteoclastic Pit

Osteoblasts seek these pits out to grow bone in them

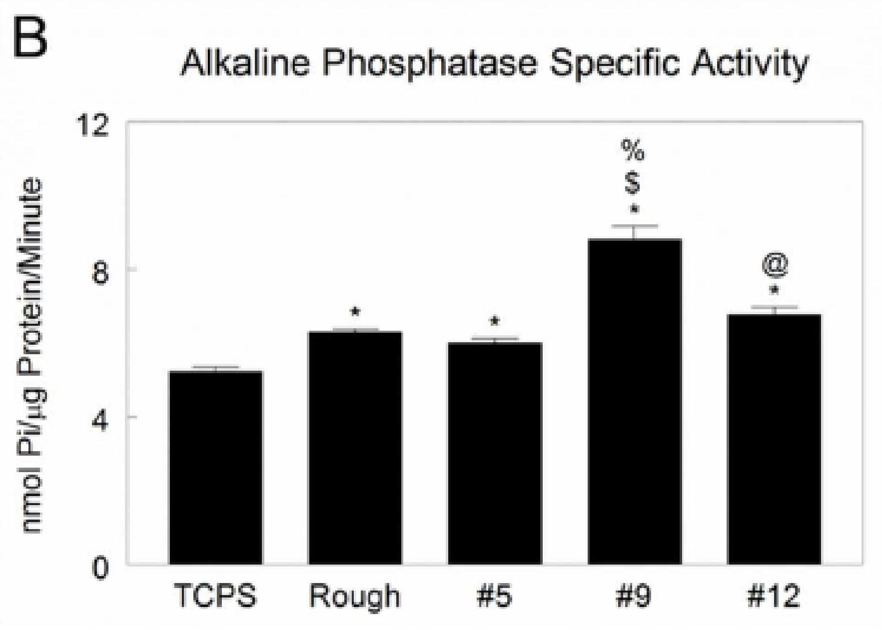
Subtractive Manufactured “Osteoclastic Pits” *

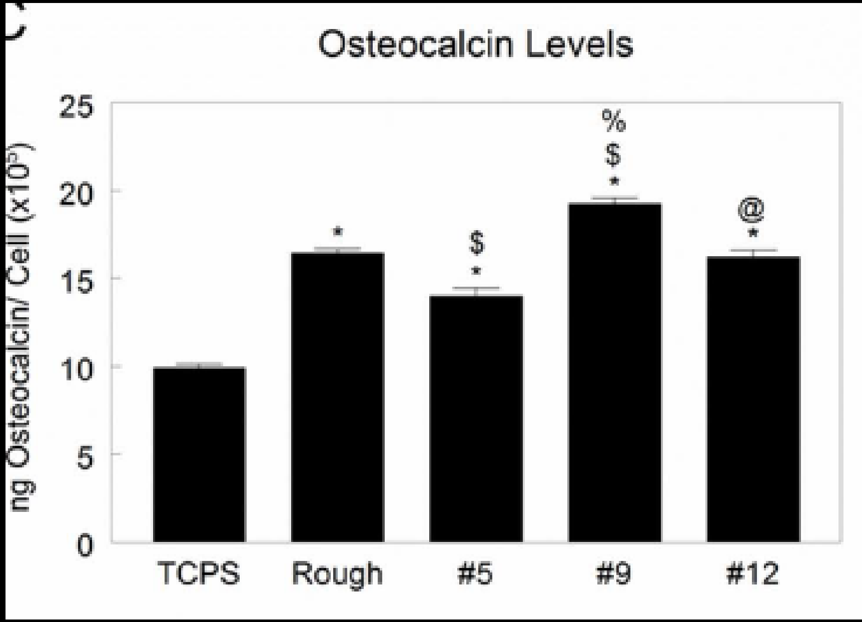




Osteoblasts seek these pits out to grow bone in them

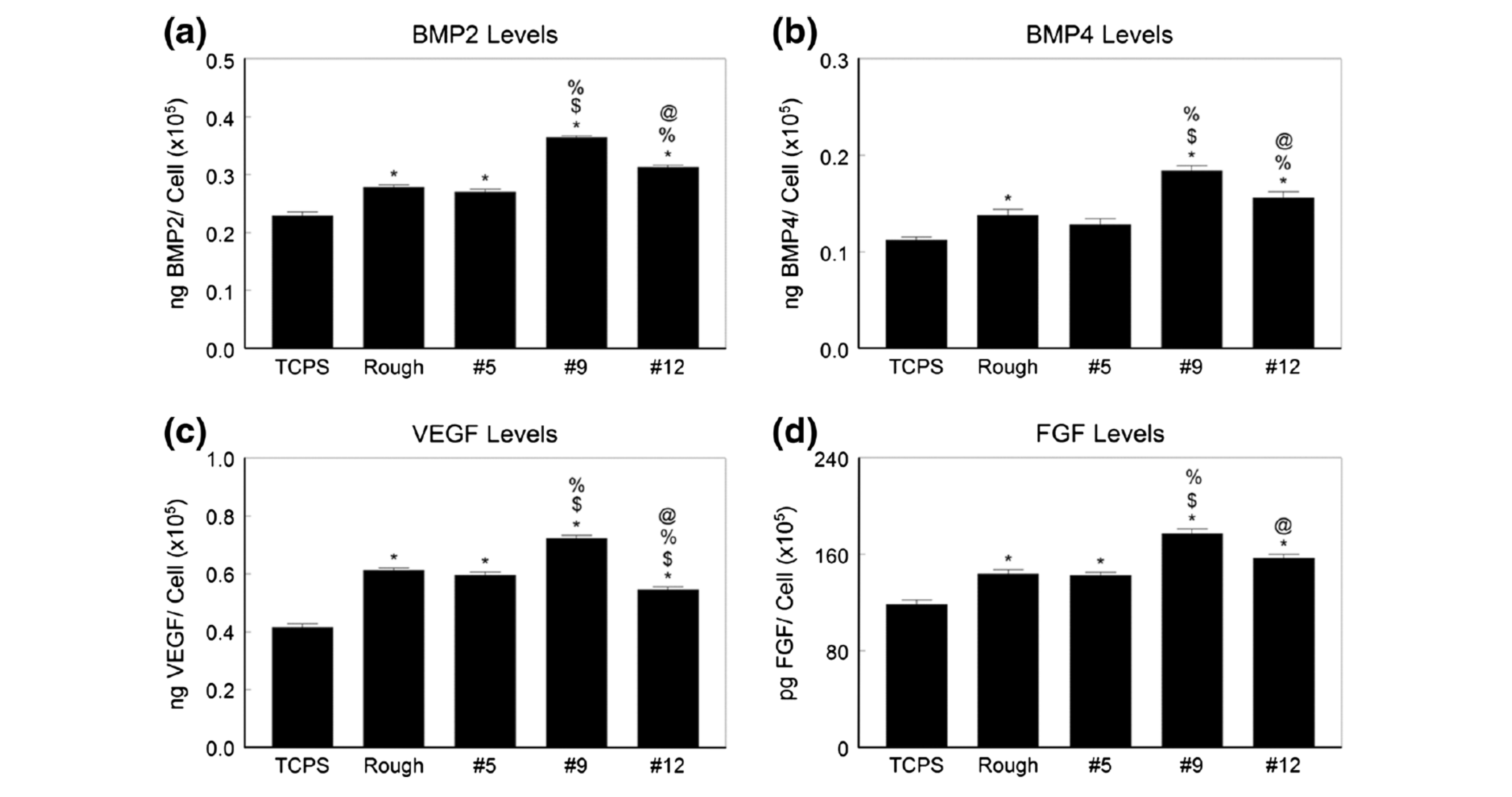
MSCs exhibit greater osteoblastic differentiation on #9.

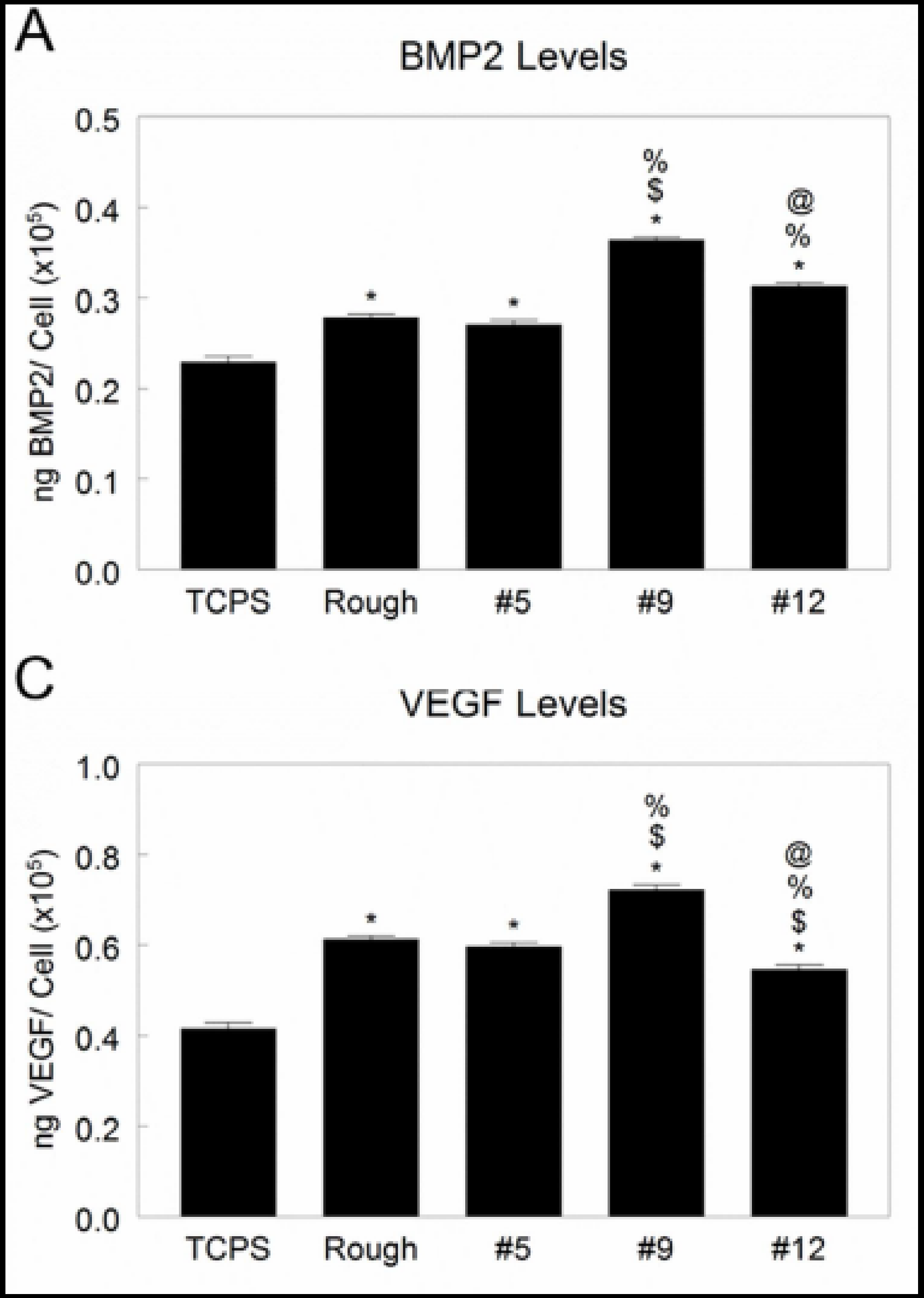




Olivares-Navarrete et al. Ann Biomed Eng. 2014 Dec;42(12):2551-61.
doi: 10.1007/s10439-014-1108-3. Epub 2014 Sep 17.

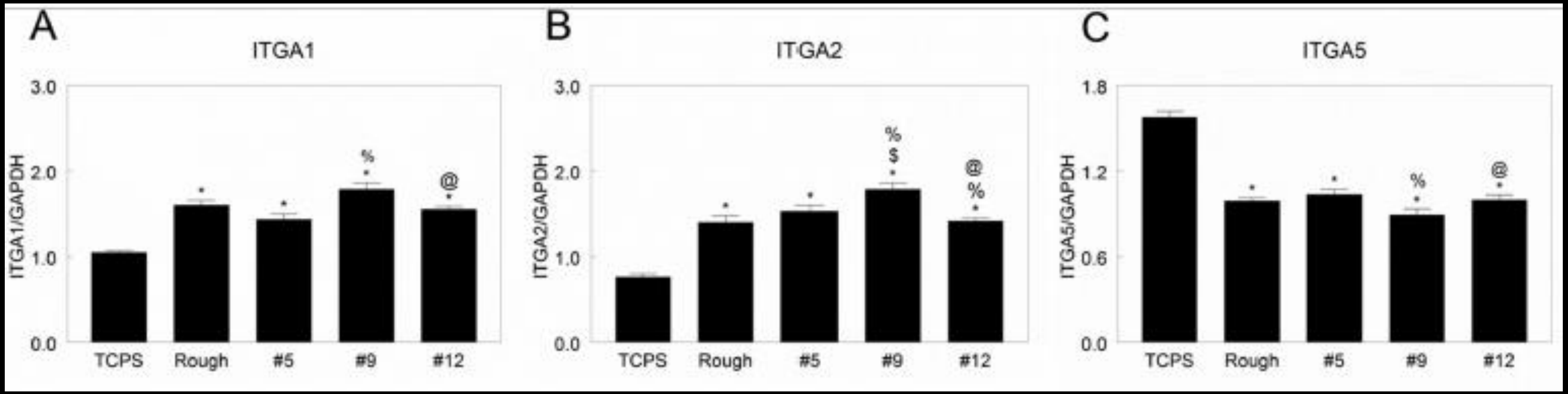
Local factor production by osteoblasts (#9)





MSCs produce more osteogenic factors on #9.

Olivares-Navarrete et al. Ann Biomed Eng. 2014 Dec;42(12):2551-61. doi: 10.1007/s10439-014-1108-3. Epub 2014 Sep 17.

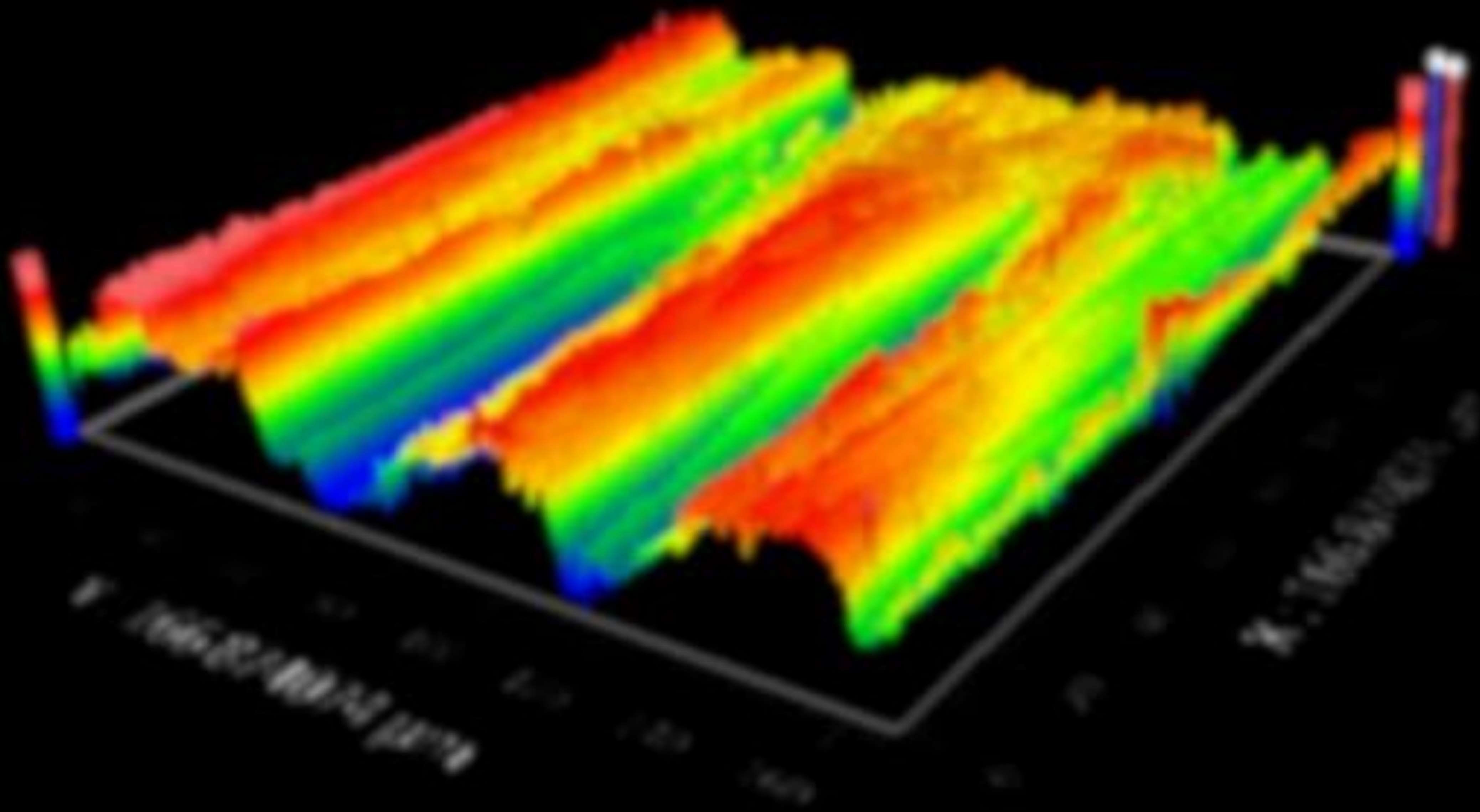


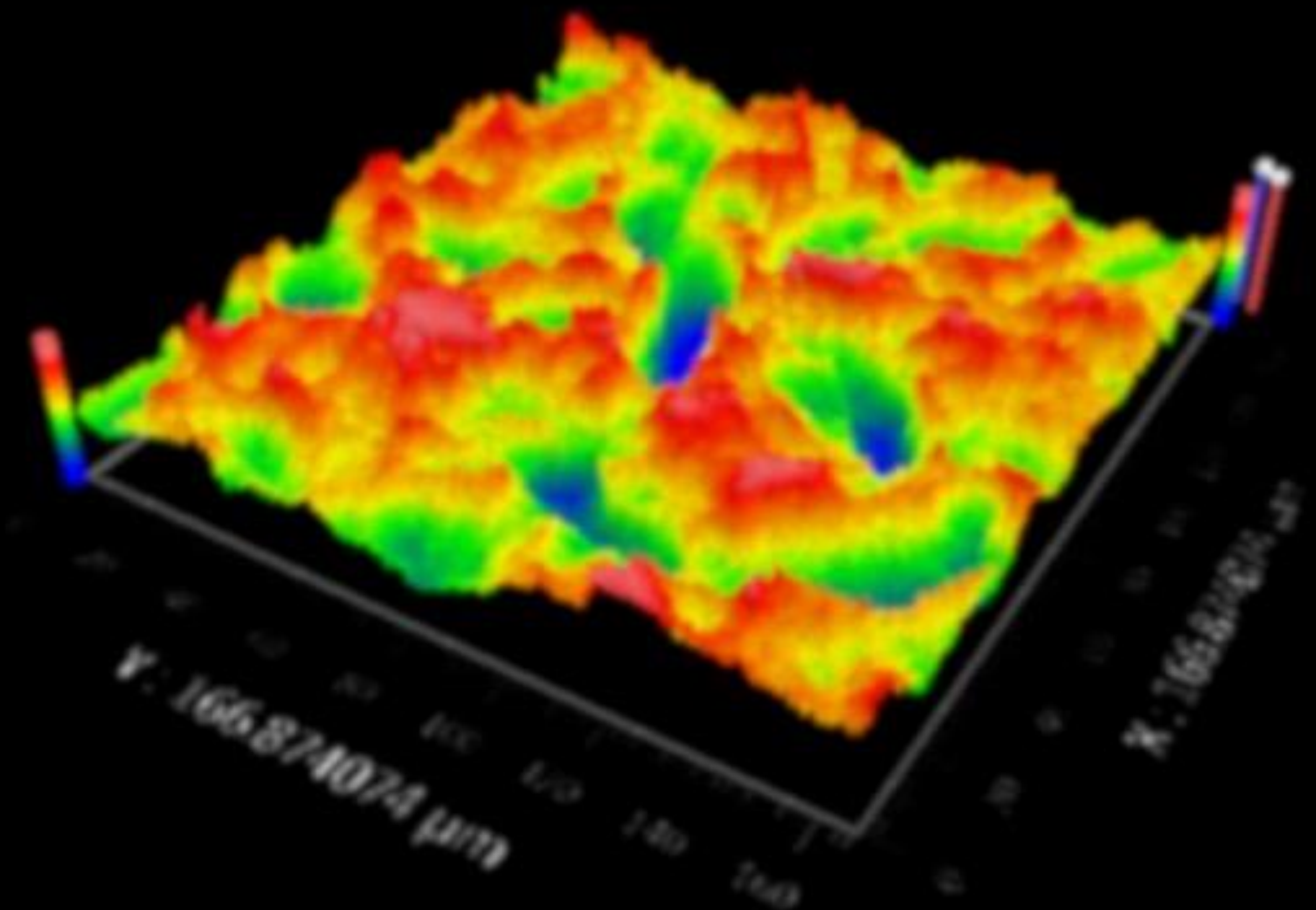
MSCs express more mRNAs for α1 and α2 integrin subunits on #9.

Olivares-Navarrete et al. Ann Biomed Eng. 2014 Dec;42(12):2551-61. doi: 10.1007/s10439-014-1108-3. Epub 2014 Sep 17.

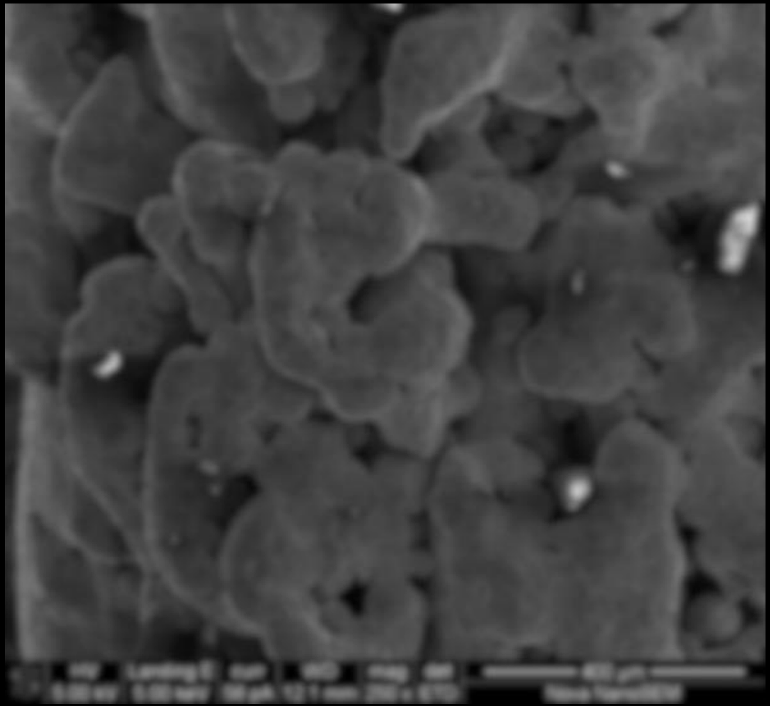
Conclusion

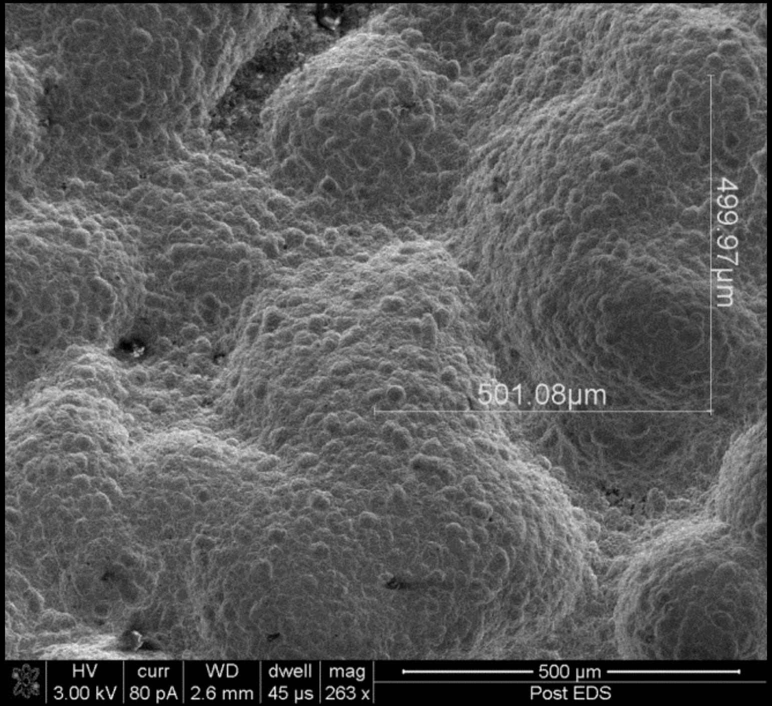
- Microstructured surfaces can vary greatly
  - #9 outperformed other samples
  - Best cellular response because the micro topography mimics an osteoclastic resorption pit
  - This *specific surface* also induced highest expression of a2 and b1 integrin mRNA due to nano-scale features (10^{-9})
- Small differences in topography will result in different cellular responses (Not all titanium implants are the same)



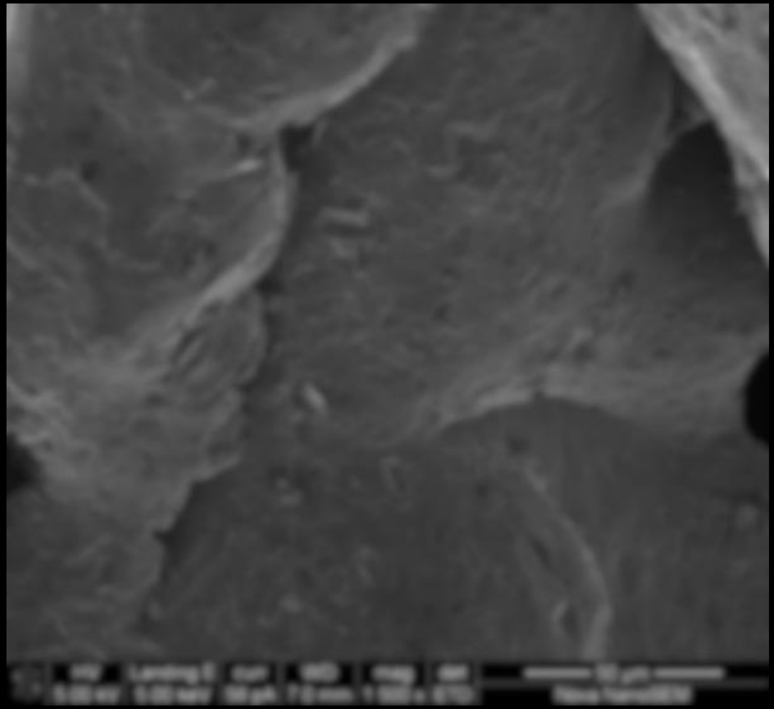

Y : 166.874074 µm

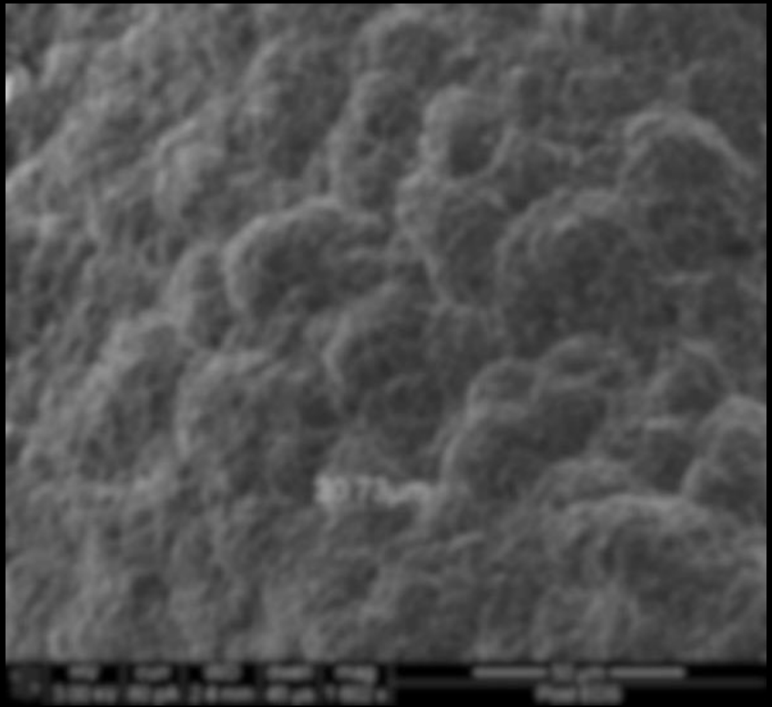
250x



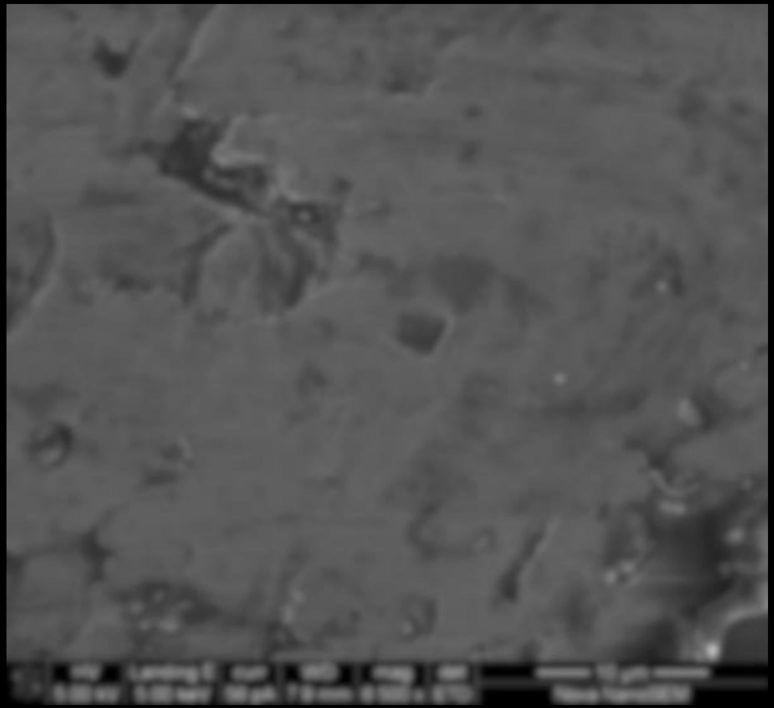

499.97µm
501.08µm
HV
3.00 kV
curr
80 pA
WD
2.6 mm
dwell
45 µs
mag
263 x
500 µm
Post EDS

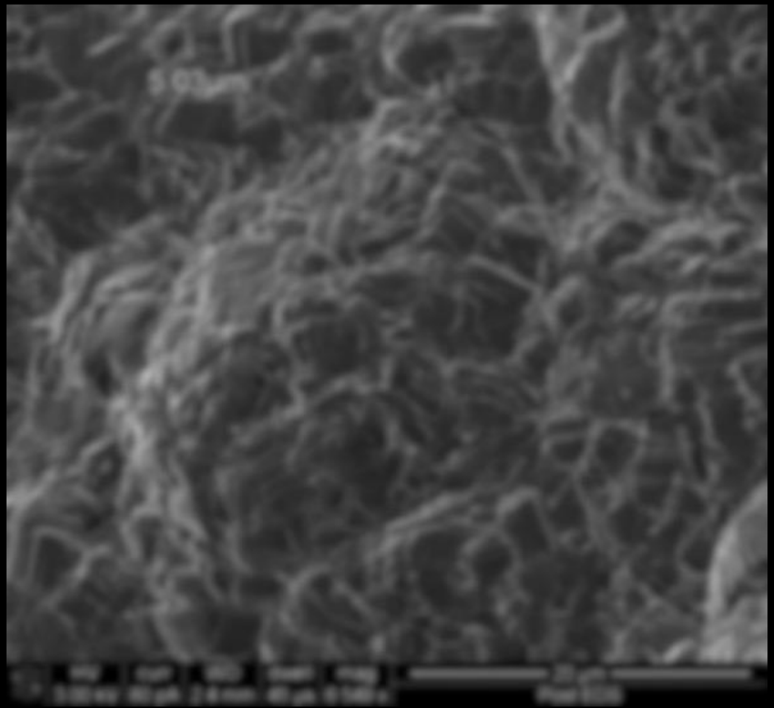
1500x





6500x





Spine

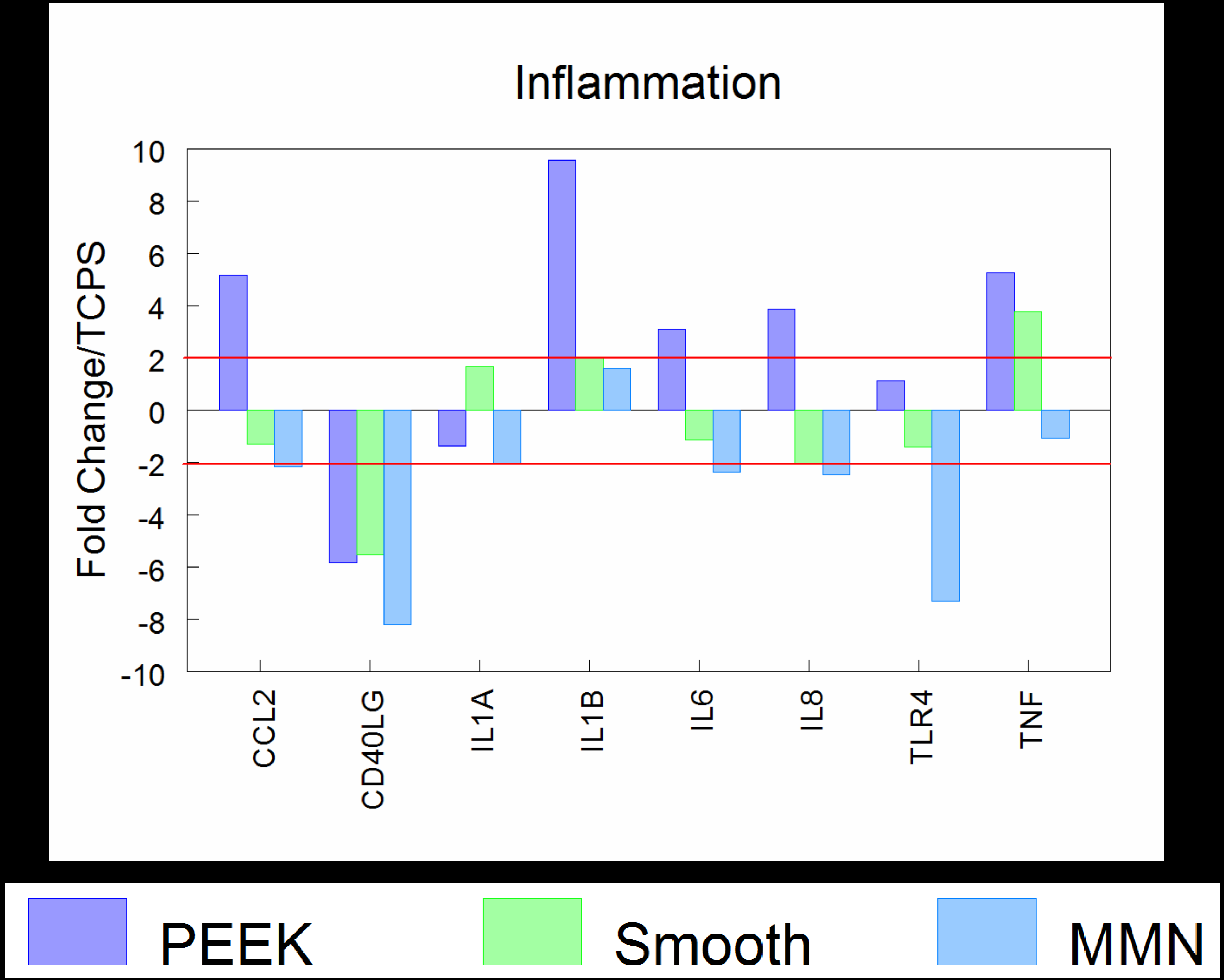
SPINE Volume 40, Number 6, pp 399-404

EPIDEMIOLOGY

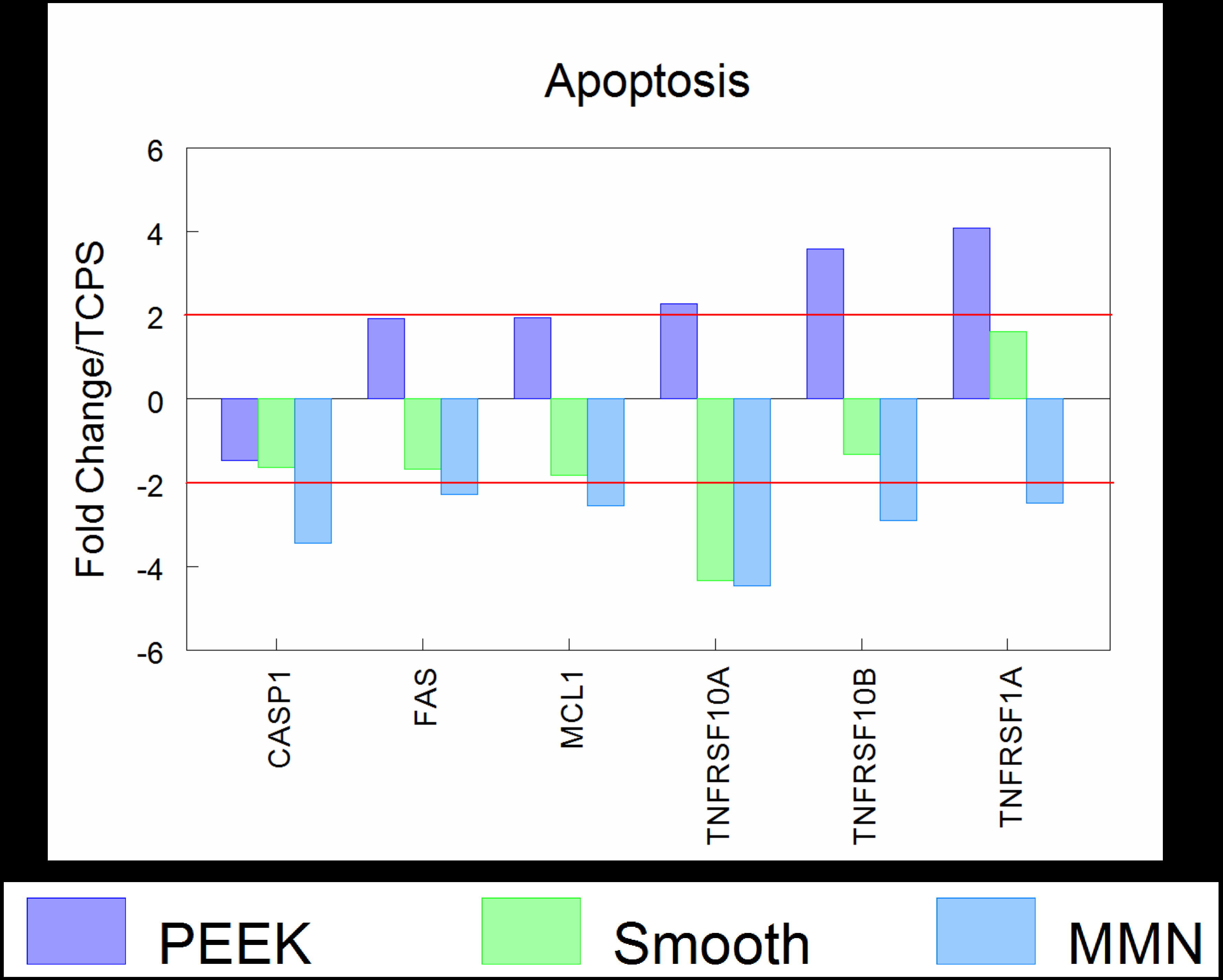
Implant Materials Generate Different Peri-implant Inflammatory Factors

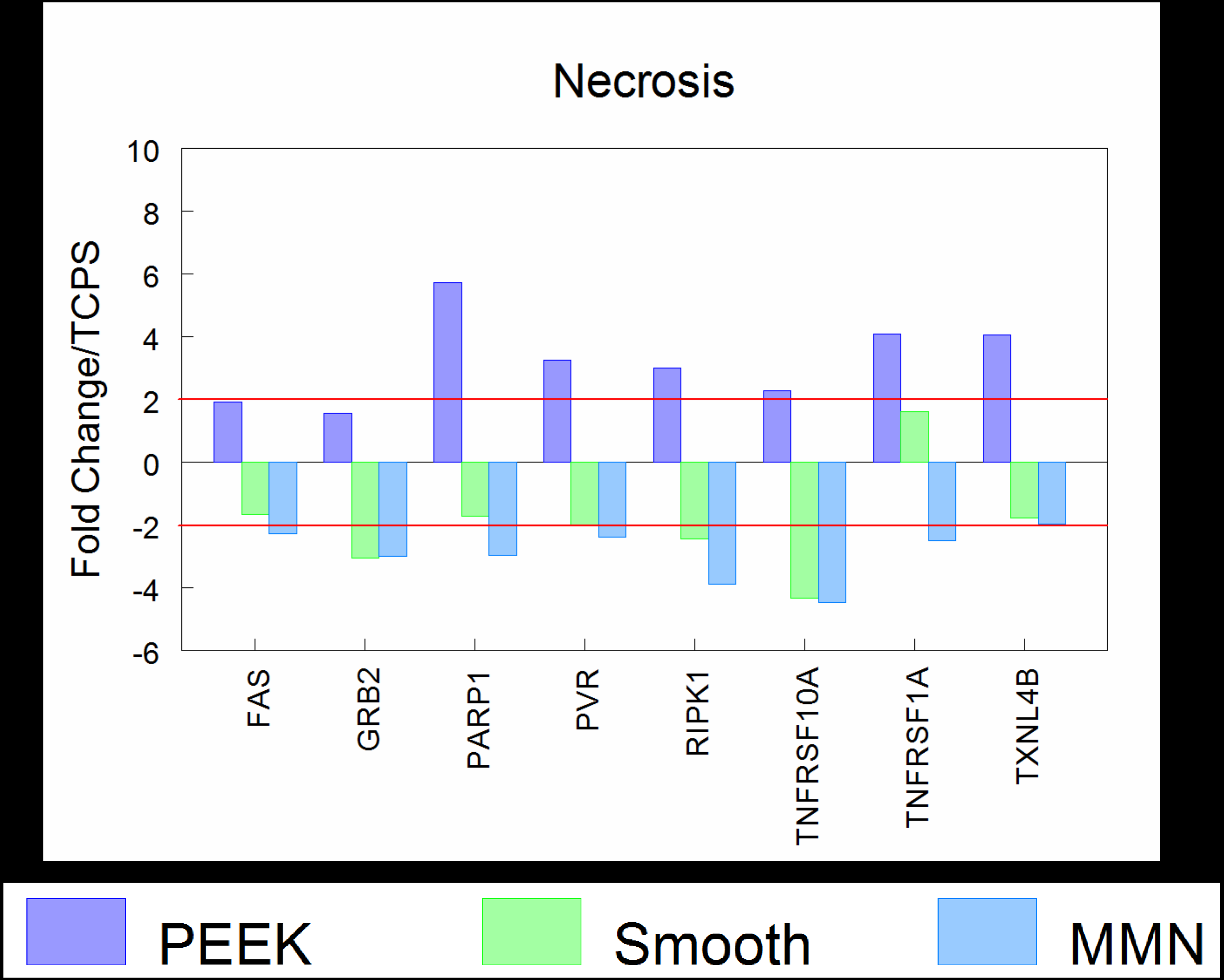
Poly-ether-ether-ketone Promotes Fibrosis and Microtextured Titanium Promotes Osteogenic Factors

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*¶



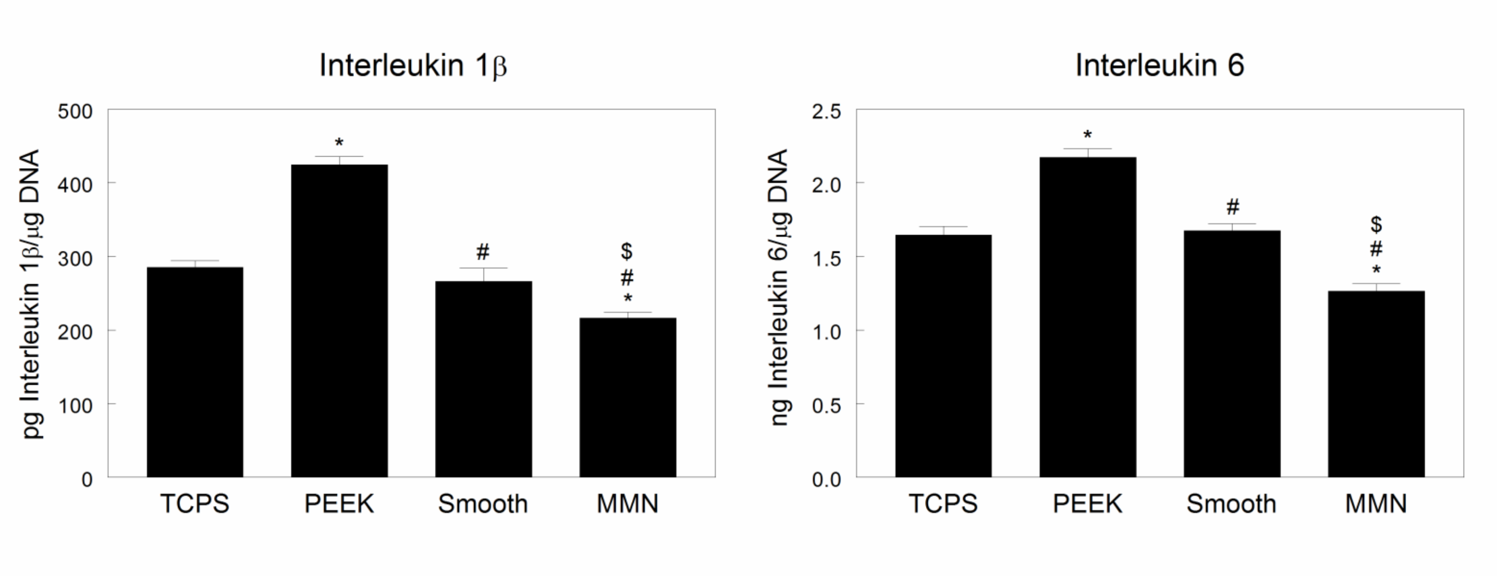
Inflammation
Fold Change/TCPS
10
8
6
4
2
0
-2
-4
-6
-8
-10
CCL2
CD40LG
IL1A
IL1B
IL6
IL8
TLR4
TNF
PEEK
Smooth
MMN

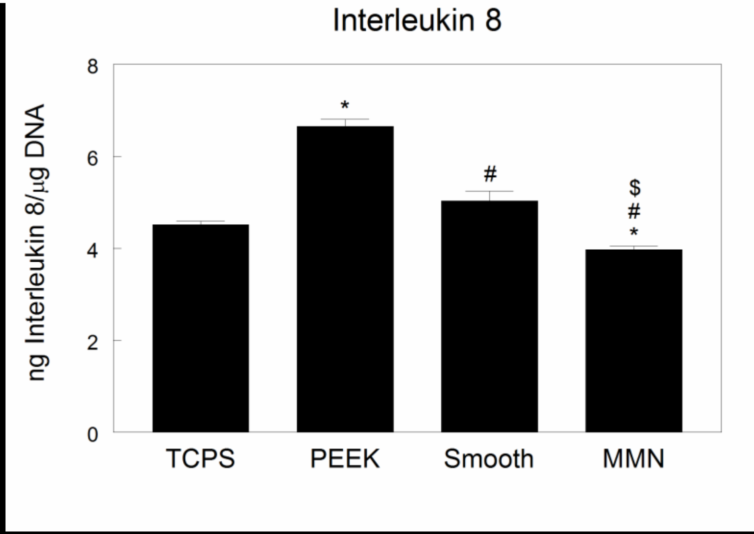

Apoptosis
Fold Change/TCPS
6
4
2
0
-2
-4
-6
CASP1
FAS
MCL1
TNFRSF10A
TNFRSF10B
TNFRSF1A
PEEK
Smooth
MMN



Necrosis
Fold Change/TCPS
10
8
6
4
2
0
-2
-4
-6
FAS
GRB2
PARP1
PVR
RIPK1
TNFRSF10A
TNFRSF1A
TXNL4B
PEEK
Smooth
MMN

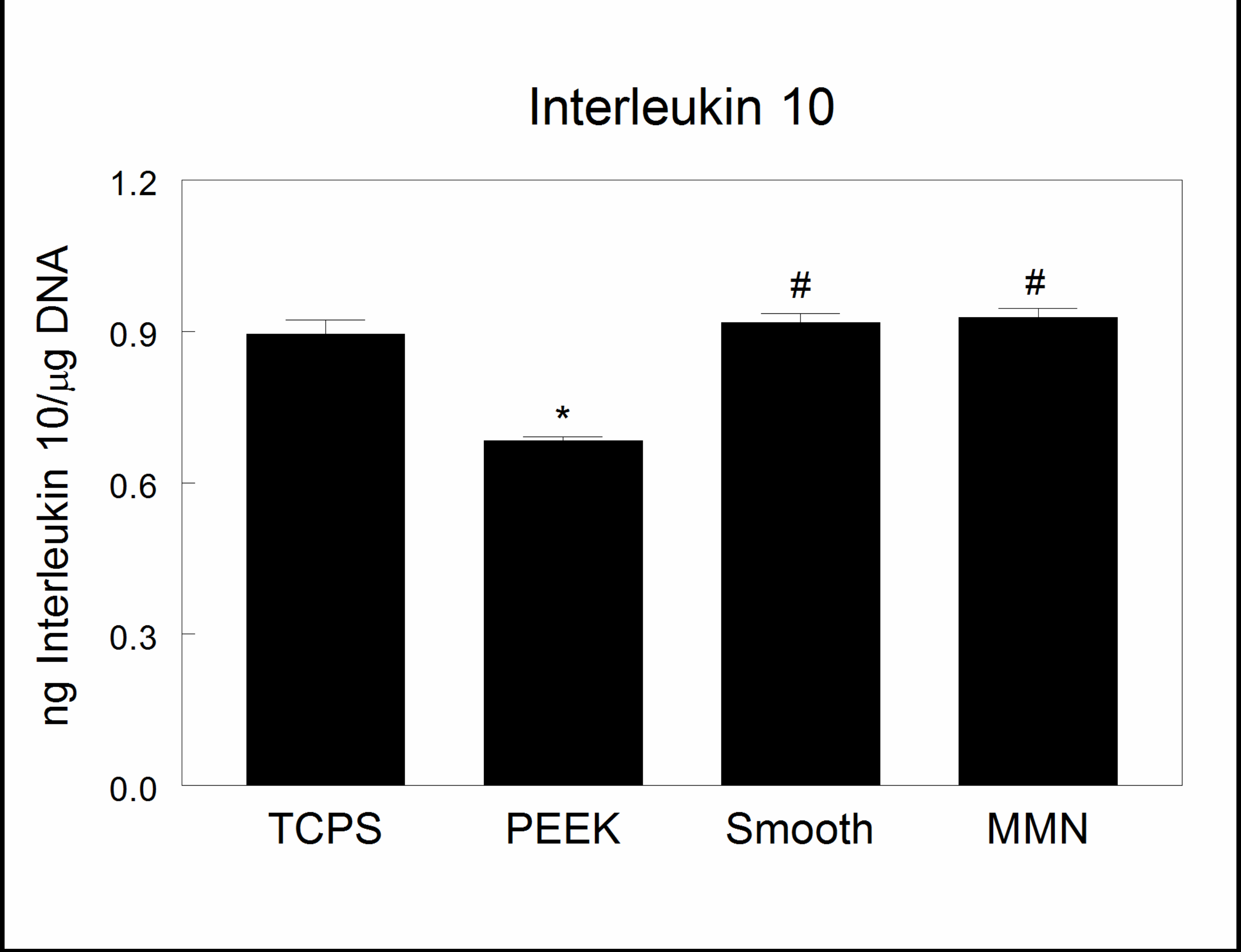
Pro-inflammatory Interleukins





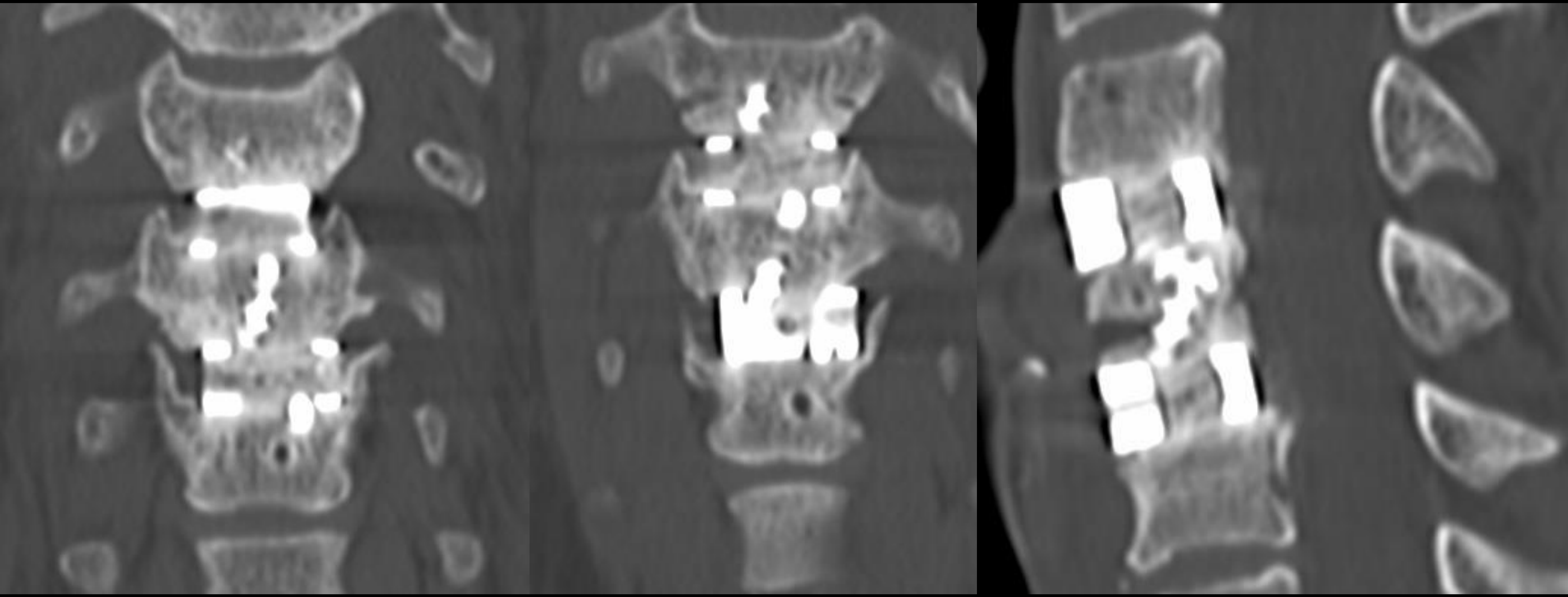
* vs TCPS
# vs PEEK
$ vs Smooth

Anti-inflammatory Interleukin

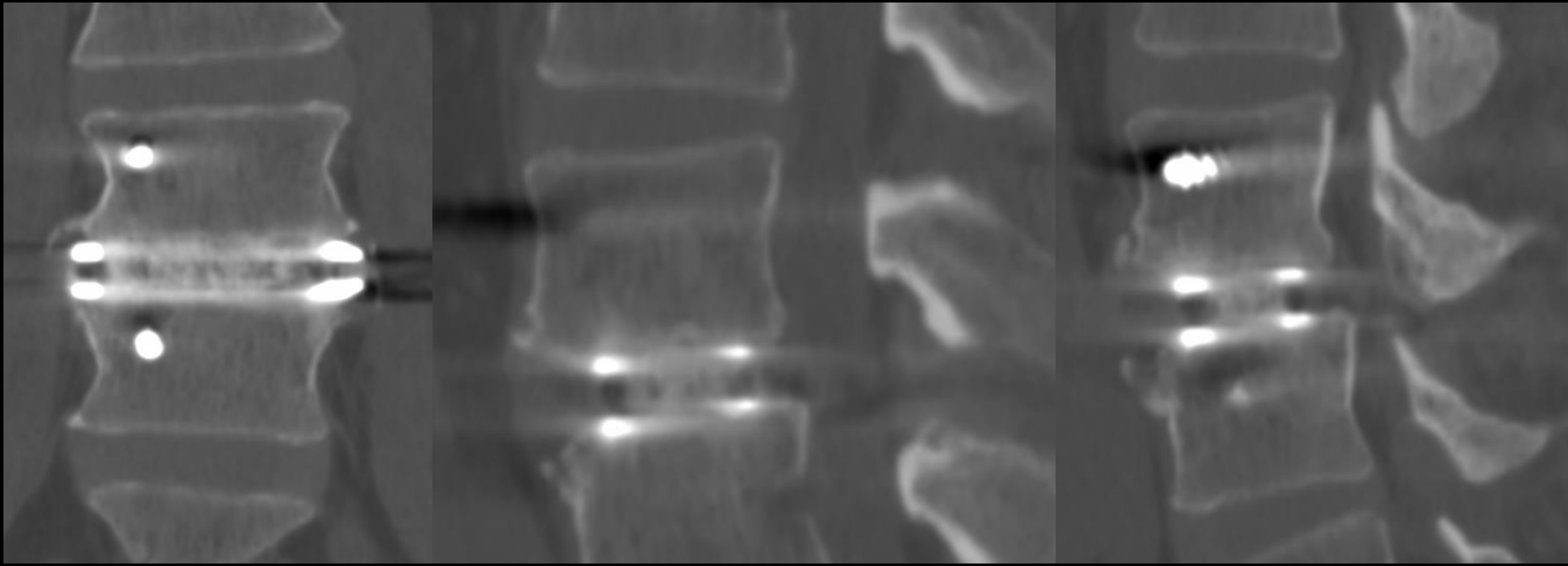


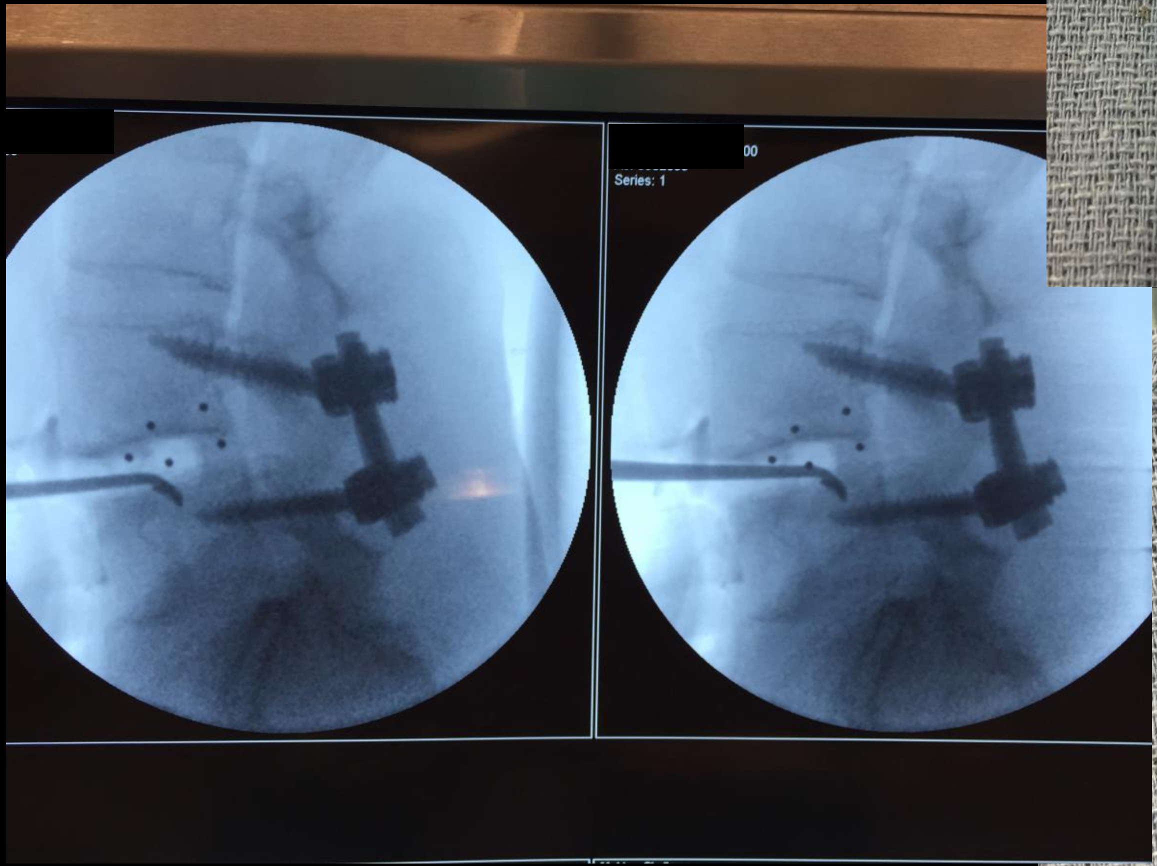
* vs TCPS
# vs PEEK
$ vs Smooth

Pt FS 3 months



Pt MT 3 Months Postop




Series: 1

TISSUE SENT: A. Implant
B. End plate fibrosis scar tissue

CLINICAL HISTORY: Radiculitis, lumbago, post-laminectomy

FINAL PATHOLOGICAL DIAGNOSIS:

A. HARDWARE, SPINE, REMOVAL:
- ORTHOPEDIC HARDWARE IDENTIFIED (GROSS ONLY).

B. SOFT TISSUE, SPINE, EXCISION:
- CARTILAGE AND FIBROUS TISSUE WITH FOREIGN BODY GIANT CELL REACTION AND GRANULATION TISSUE.

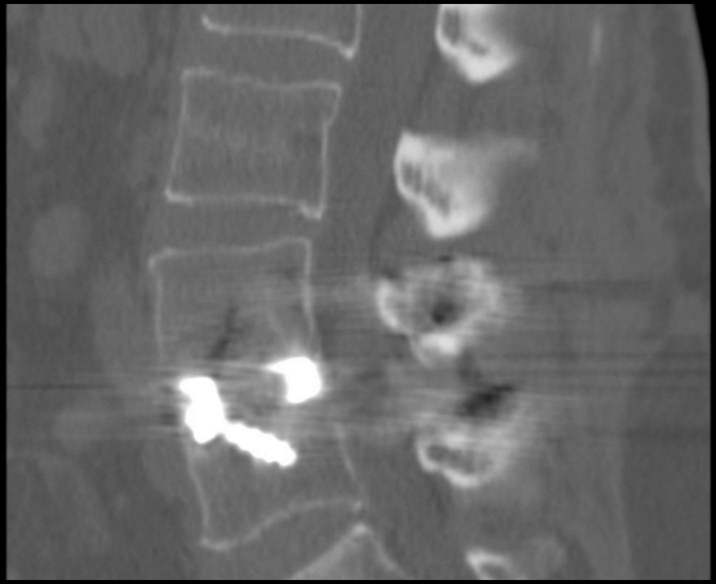
Primary Pathologist – Jennifer R. Rushton, M.D.

GROSS DESCRIPTION:
A. Received in formalin labeled “previous surgery implant” is a 2.5 x 1.3 x 0.9 cm white tan synthetic spacer with saw toothed edges. The device is partially inscribed as 23 mm – 4 degrees. The specimen is received with scant attached purple-tan tissue. No tissue is submitted for microscopic examination. The specimen is for gross identification purposes only.

B. Received in formalin labeled “end plate fibrosis – scar tissue” is a 2.5 x 1.3 x 0.4 cm irregularly shaped fragment of purple to light tan fibrous tissue. Sections reveal a rubbery to focally calcified purple-tan cut surfaces. No distinct lesions are identified. The specimen is entirely submitted as B1, post fixation and brief decalcification. (DDV; sgh; 1030 hrs; 08/16/15)

MICROSCOPIC DESCRIPTION:
A. (Gross only).

B. Microscopic examination performed. Results reflected in final diagnosis. (JRR; lc; 8/17/15)



	Back Pain	Right Leg Pain	Left Leg Pain	ODI
Preop	6	1	6	38%
2 wk f/u	6	1	4	N/A
6 wk f/u	3	0	3	N/A
3 mo f/u	3	0	1	26%
6 mo f/u	3	0	2	18%


FLORIDA


William A. Shands Hospital
at the University of Florida