MultiCare™, Advanced Mechanical and Biological Properties of Nanocrystalline Hydroxyapatite Coating: Dental Implants, A Case Study

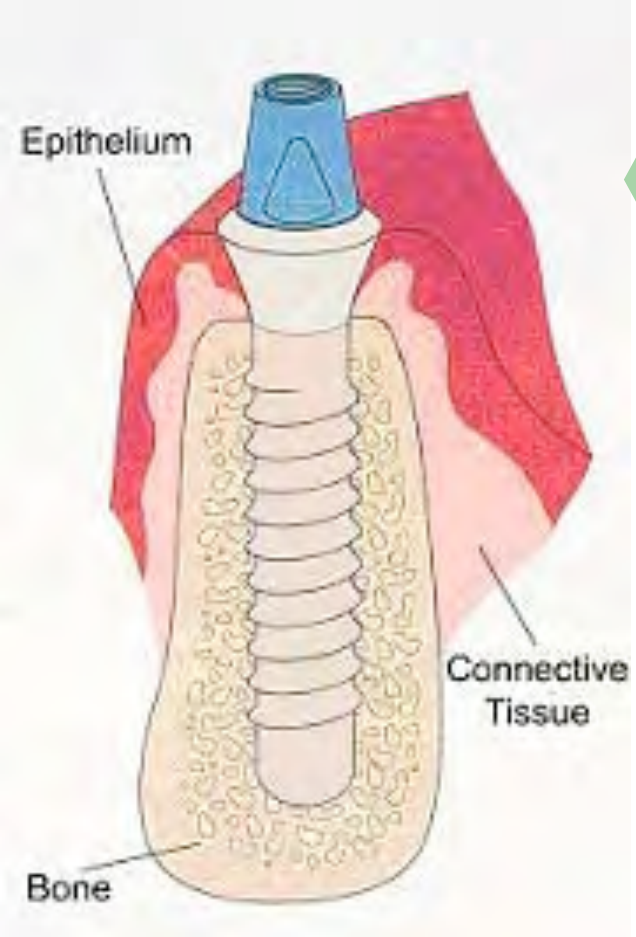
Wenping Jiang (Chief Engineer) and Ajay P. Malshe (CTO)

NanoMech LLC, Fayetteville, AR 72701

(Patents pending)

NanoMech, LLC
535 W. Research Blvd., Suite 135
M/S 100
Fayetteville, AR 72701
Ph. (479) 527-6826 Fax (479) 571-8814

The Need for Better and Smaller Implants



A typical dental implant with the local interfacing to host tissues: bone (osteoblasts), epithelium (epithelial cells) and connective tissue (fibroblasts)

Smaller implants, less invasive, suitable for risky sites with poor bone density

However, higher requirements for the surface of smaller (mini) implants, especially osseointegration

Hydroxyapatite and Osseointegration

Hydroxyapatite [HA, $Ca_{10}(PO_4)_6(OH)_2$]

Chemically similar to bone mineral

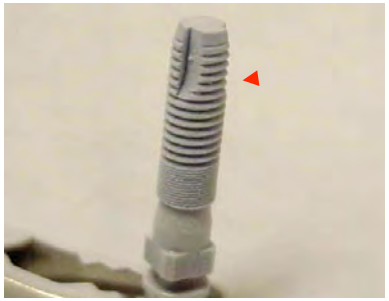
Bioactive for producing direct-bonding osteogenesis

But

Brittle and susceptible to crack growth

Therefore

Used as a coating material for load-bearing metallic implants to promote tissue-implant integration



Dental Implant

HA coated

Hip Implants

Why Nanostructured HA Desirable?

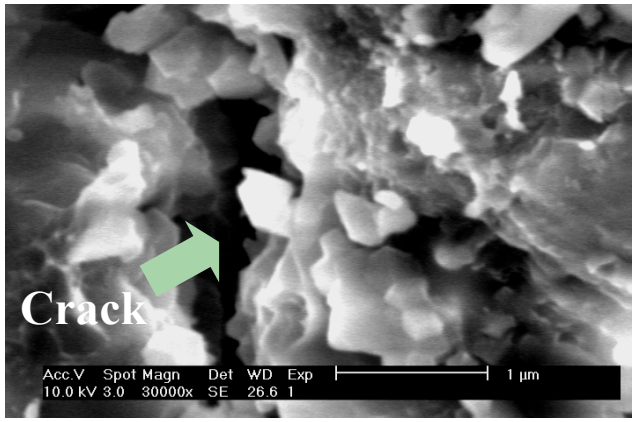
- Significant improvement in mechanical properties such as compressive strength while maintaining, at least, the same bending strength , compared to submicron and/or microsized HA (Zhang *et al*, 2002)
- Increased functions of osteoblasts (bone-forming cells) (Webster *et al*, 2000)
- Increased in vivo bone regeneration compared to microsized HA (Liu et al. 2007)

<u>Challenges</u>:

Control agglomeration and size growth during fabrication

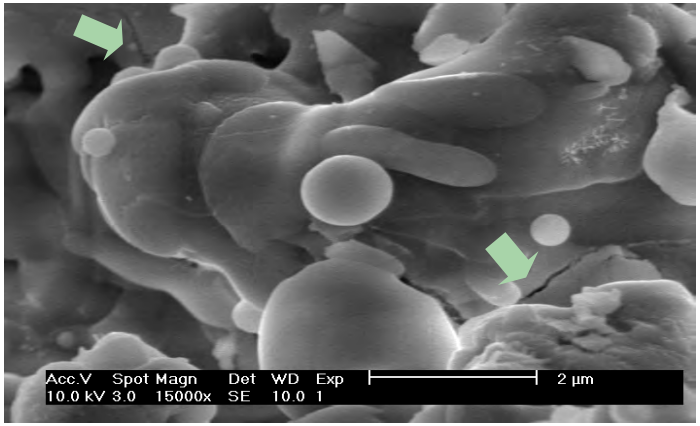
Review:
Current Deposition Methods for HA

Electrophretic deposition (EPD), dip coating, sol-gel deposition, pulsed laser deposition, RF magnetron sputter deposition, and plasma spraying. Plasma spraying is the most widely used method in current implant industry.



Case A: plasma spayed HA, Ca/P~2.25

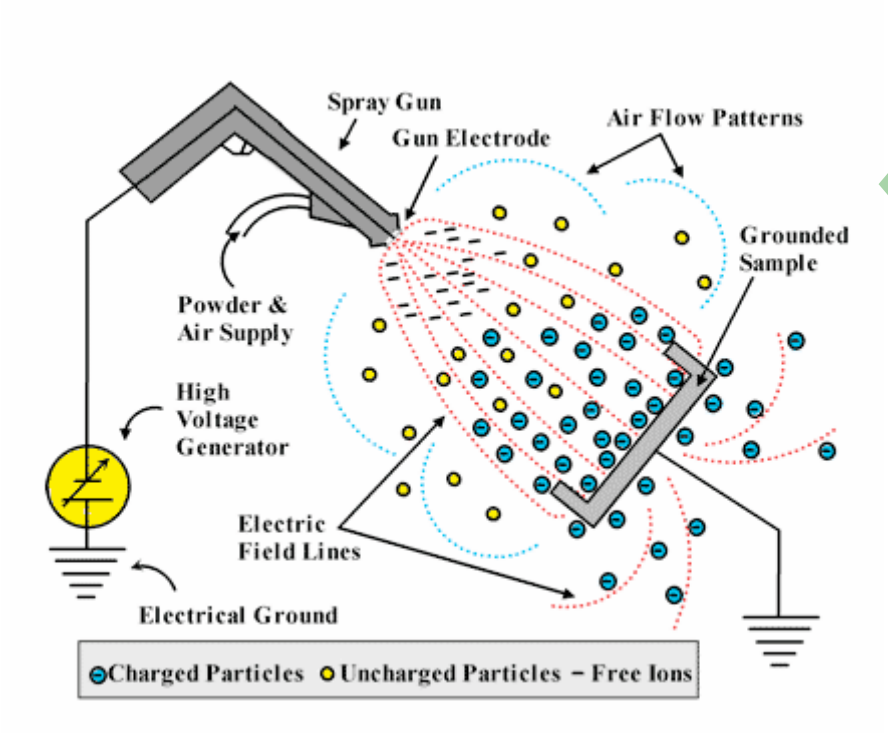
Case B: plasma spayed HA,Ca/P~1.85



The Need for Better Nano-HA Coating

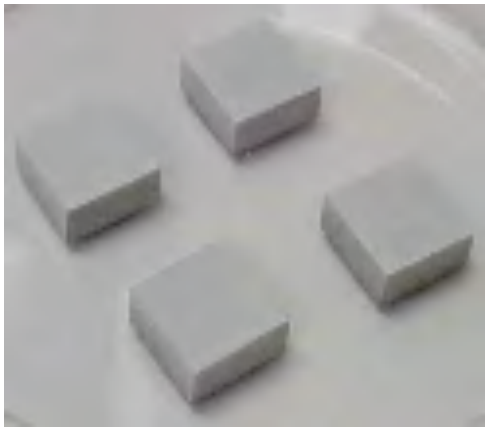
- High deposition rate with better control of deposition thickness and uniformity
- Significantly reduced agglomeration
- Conformal coating to achieve desirable edge coverage
- Compatible to simple and complex geometry
- No prolonged exposure to high temperature and pressure to prevent size growth and decomposition
- Easy to control coating chemistry, morphology, crystallinity, pore size and porosity
- Low energy consumption
- Low cost and ease of maintenance
- Good manufacturing scale-up feasibility

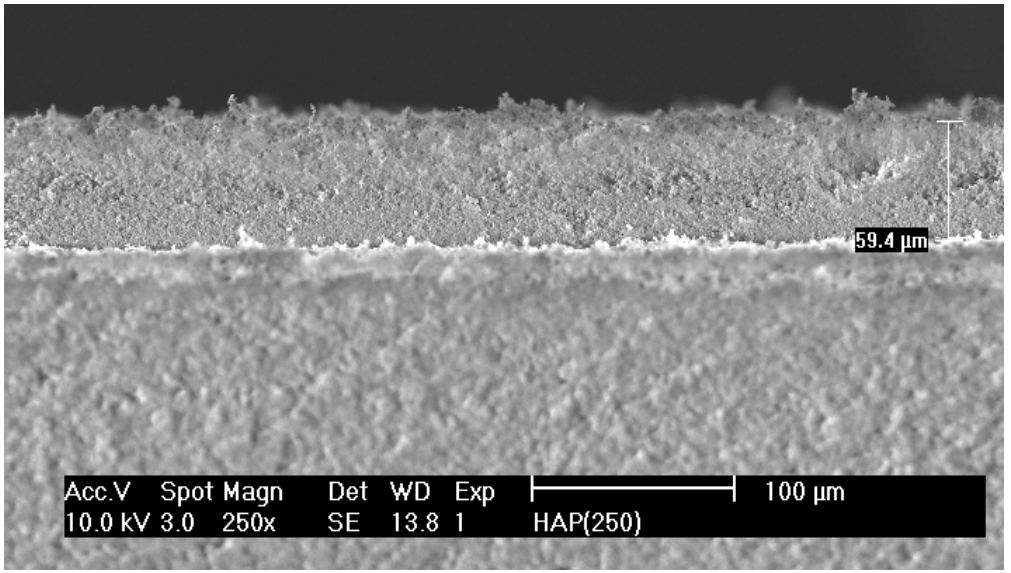
NanoSpray® Coating System



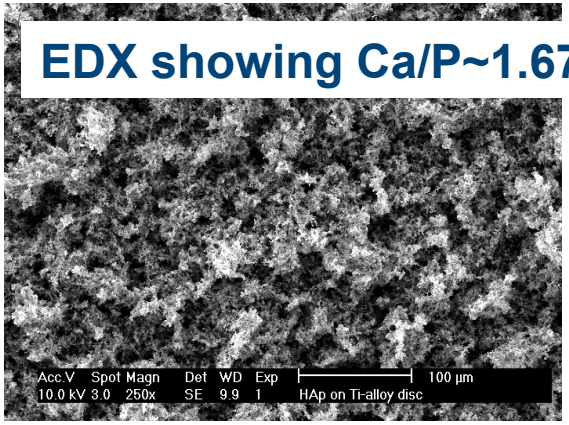
Mechanism of electrostatic spray coating (ESC) of HA nanoparticles

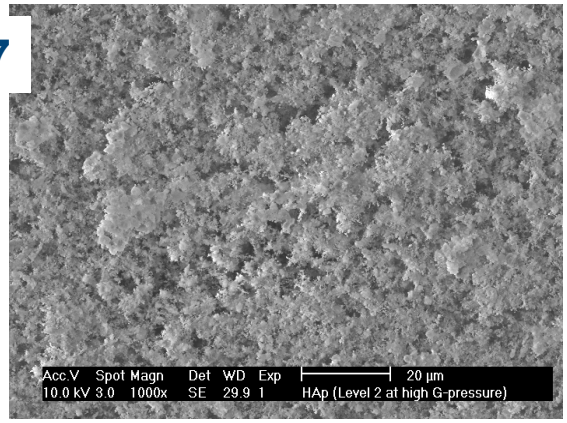
HA Coating Results

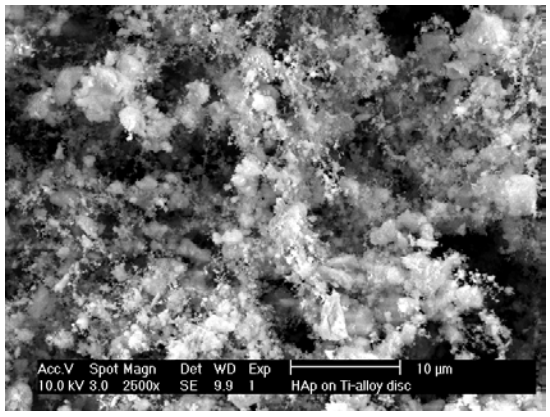




EDX showing Ca/P~1.67







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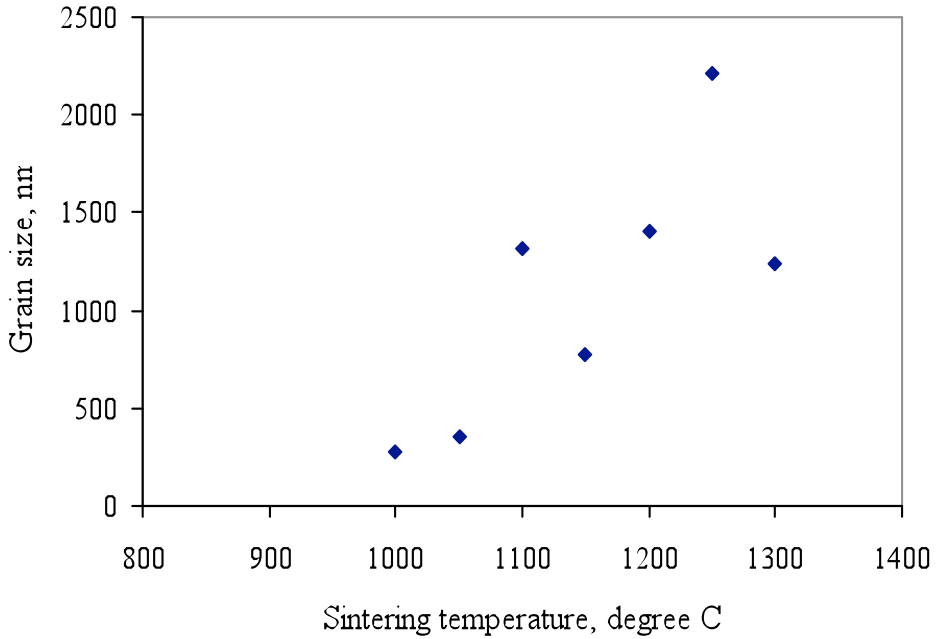
Sintering of HA coating after NanoSpray®

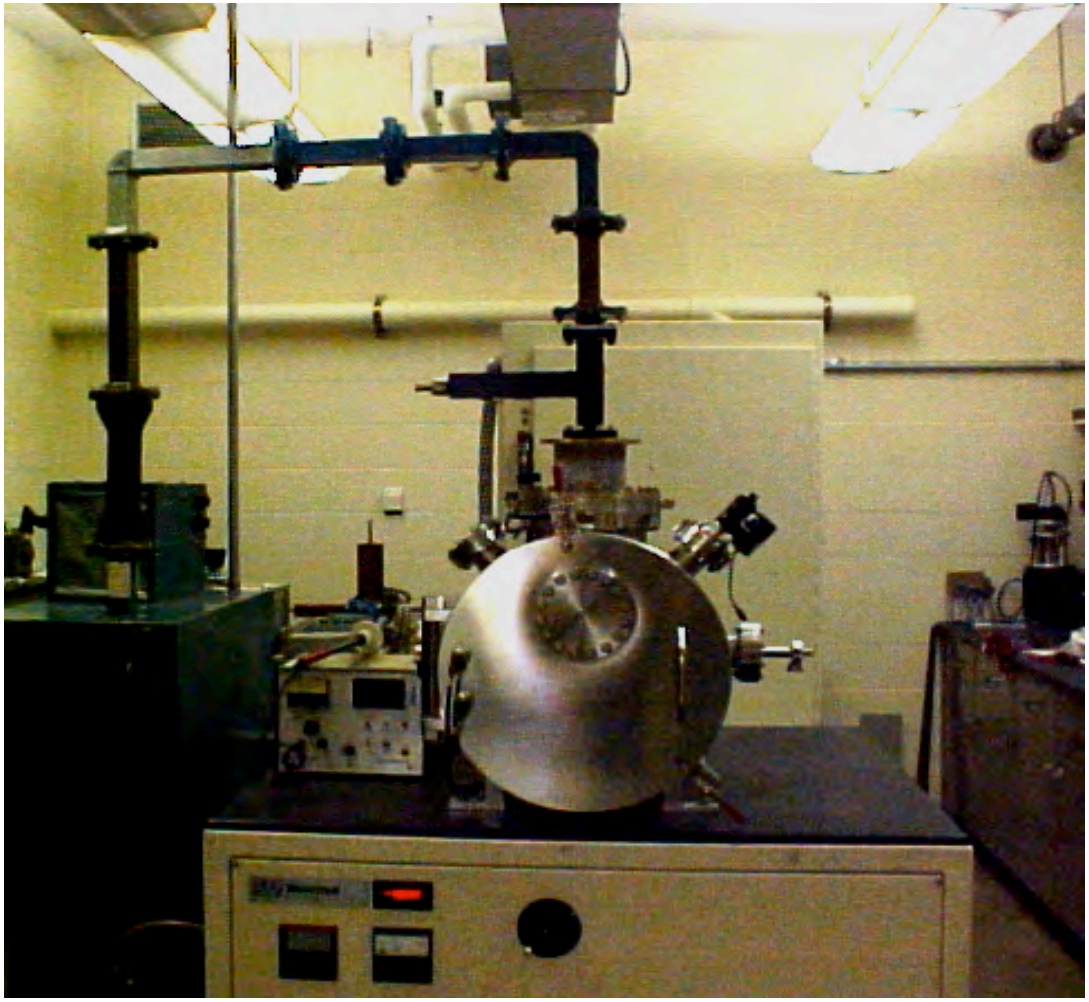
Requirements

- Desired chemistry: Ca/P~1.67;
- Controlled size growth: less than 250 nm;
- Good adhesion.

Correlation between HA grain growth and sintering temperature (Kash *et al*., 2001)



Microwave Sintering



Microwave Processing system

Frequency-2.45GHz

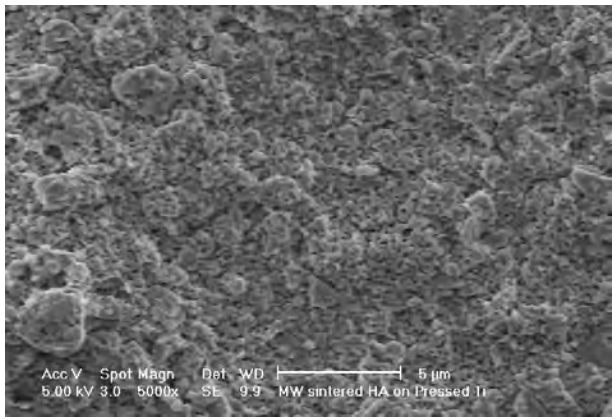
Power-6 kW

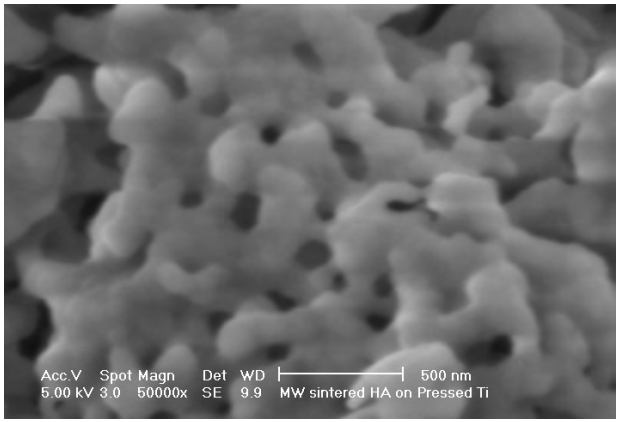
Maximum Temperature-1800^{o}C

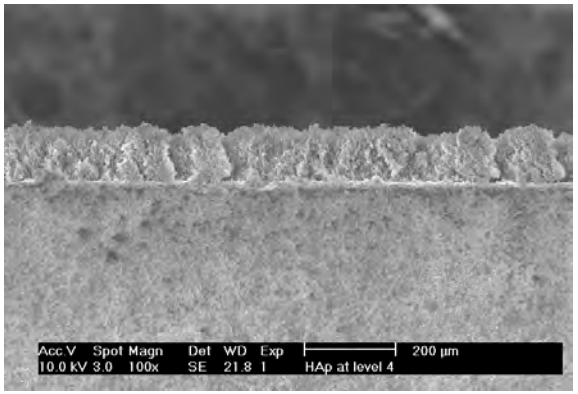
Vacuum-10^{-5} Torr

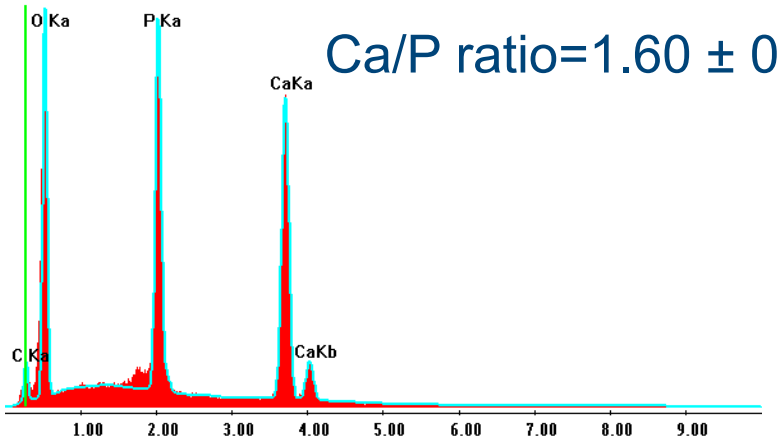
Sample size: $100 \times 250 mm^2$

HA Coating after Microwave Sintering



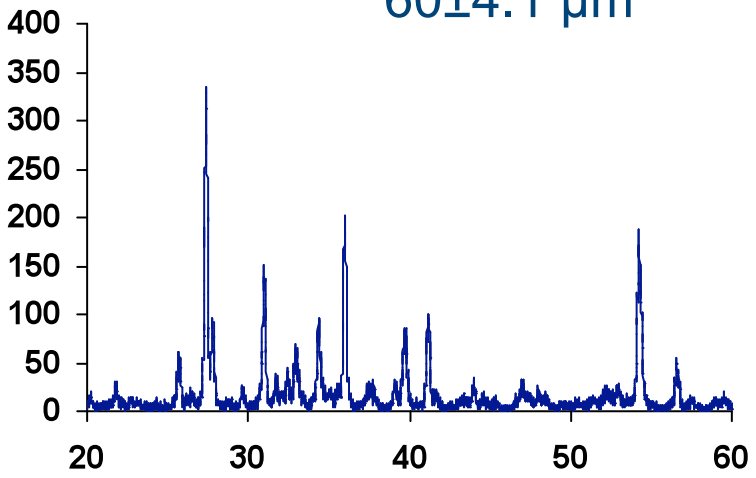






Ca/P ratio=1.60 ± 0.06

60±4.1 µm



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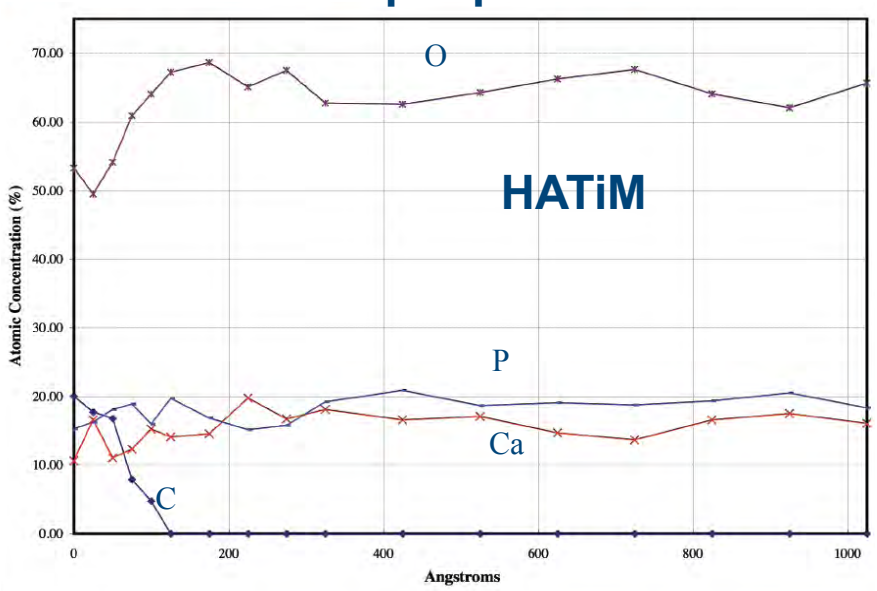
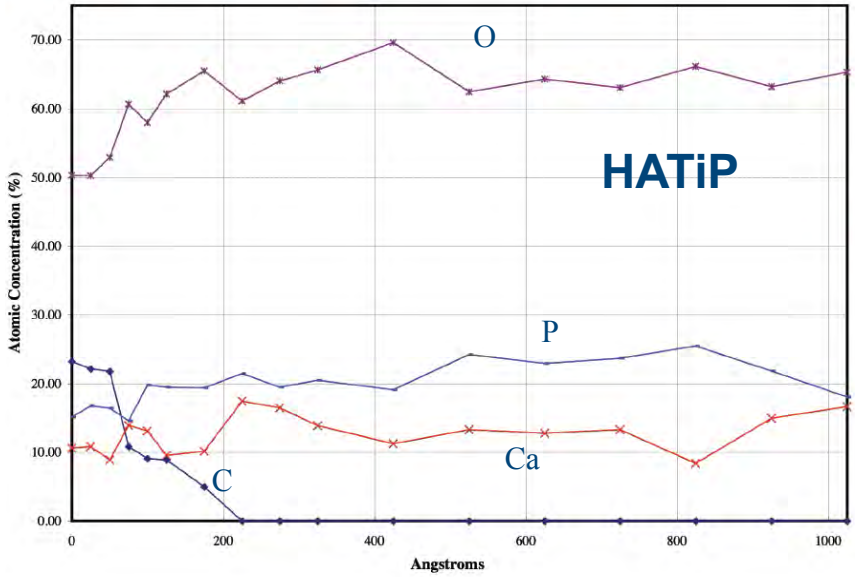
XPS Results

Samples (at.%)	Ti	Ca	P	O
TiP	90.56	-	-	9.44
HATiP	-	31.68	22.58	45.75
HATiM	-	32.20	21.78	46.01

Elemental depth profiles



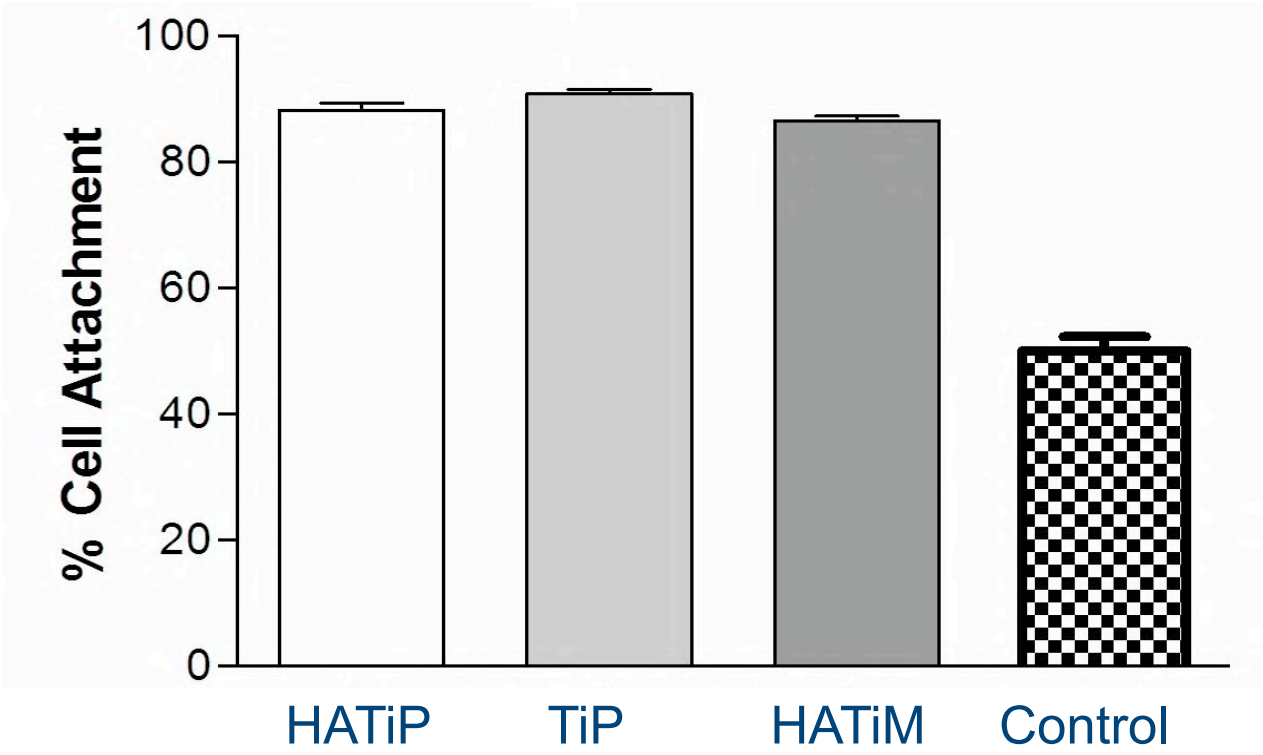


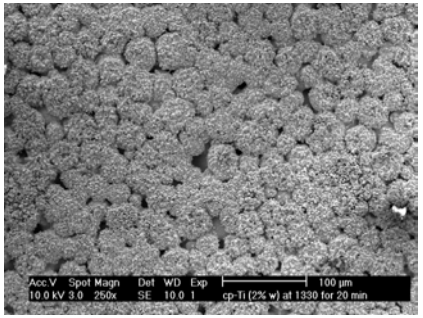
Adhesion Strength: Microscratch Tests

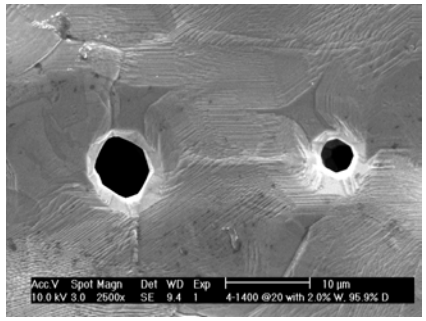
Nano-HA coating on TiP Critical Load (N)	11.38±1.87
Nano-HA coating on TiM Critical Load (N)	9.02±0.62

ASTM C1624

Attachment of Human Palatal Mesenchymal cells







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Dr Clark Stanford, Univ of Iowa

Summary of the Developed HA Coating

Unique nano-scale surface features:

•Large effective surface areas enhance cell attachment and growth

•Nano-scale roughness promotes implant-tissue integration

•Nano-to-micron pores provide more anchor sites for inducing cell activities

Coating chemistry:

• Biomimetic to natural tissues

• Promotes cell attachment

• Reduces dissolution in body fluids due to high crystallinity

Coating mechanical properties:

• Improved adhesion strength to prevent delamination