ADDITIVE MANUFACTURING IN IMPLANT DENTISTRY

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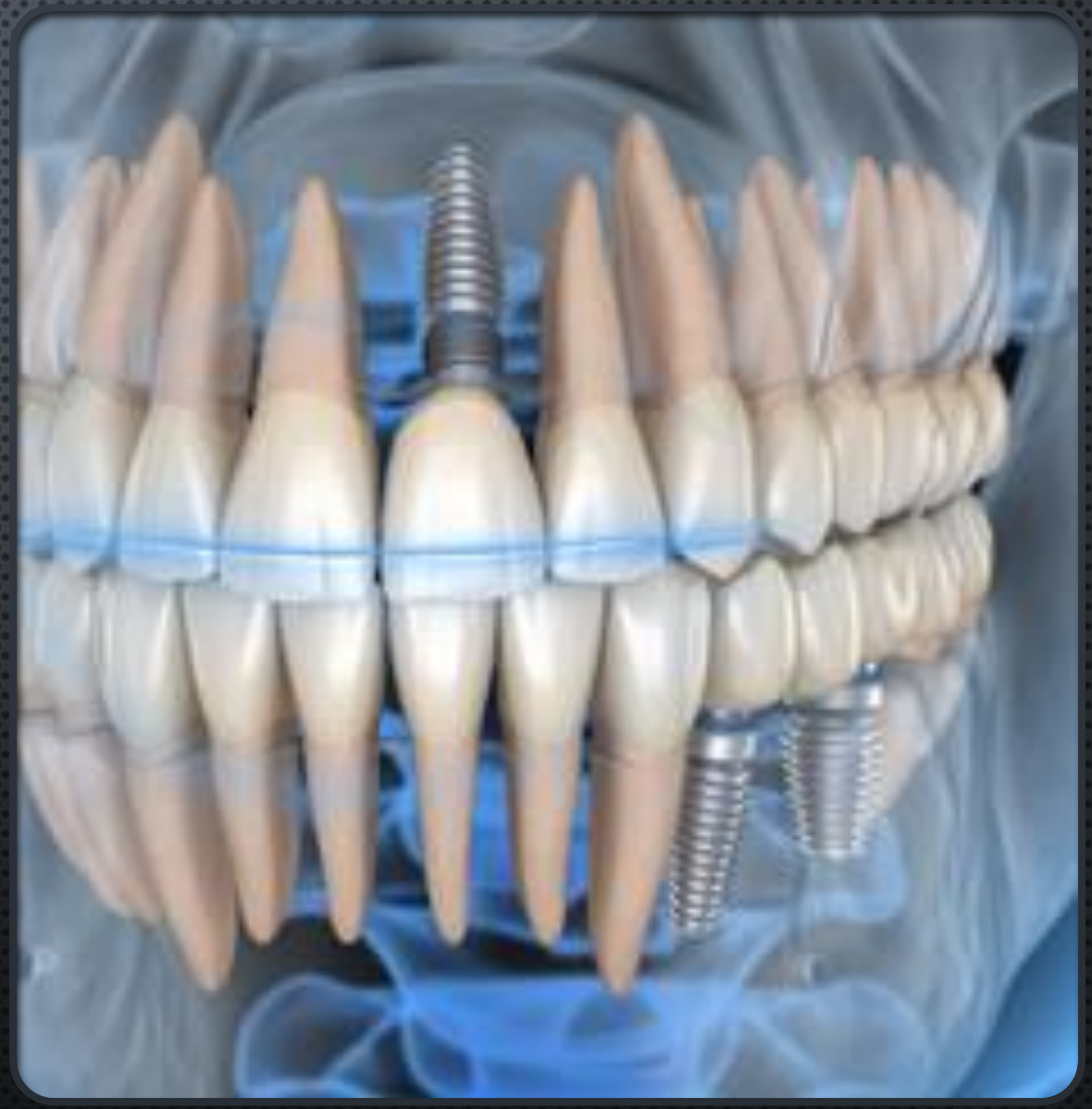
ADDITIVE MANUFACTURING IN MEDICINE AND IN DENTISTRY

- Production of **complex 3D structures.**
- Manufacturing **accuracy**.
- **Simplified production process**: economized materials, less human resources, shorter production times.
- Used in precision medicine to achieve **personal needs**

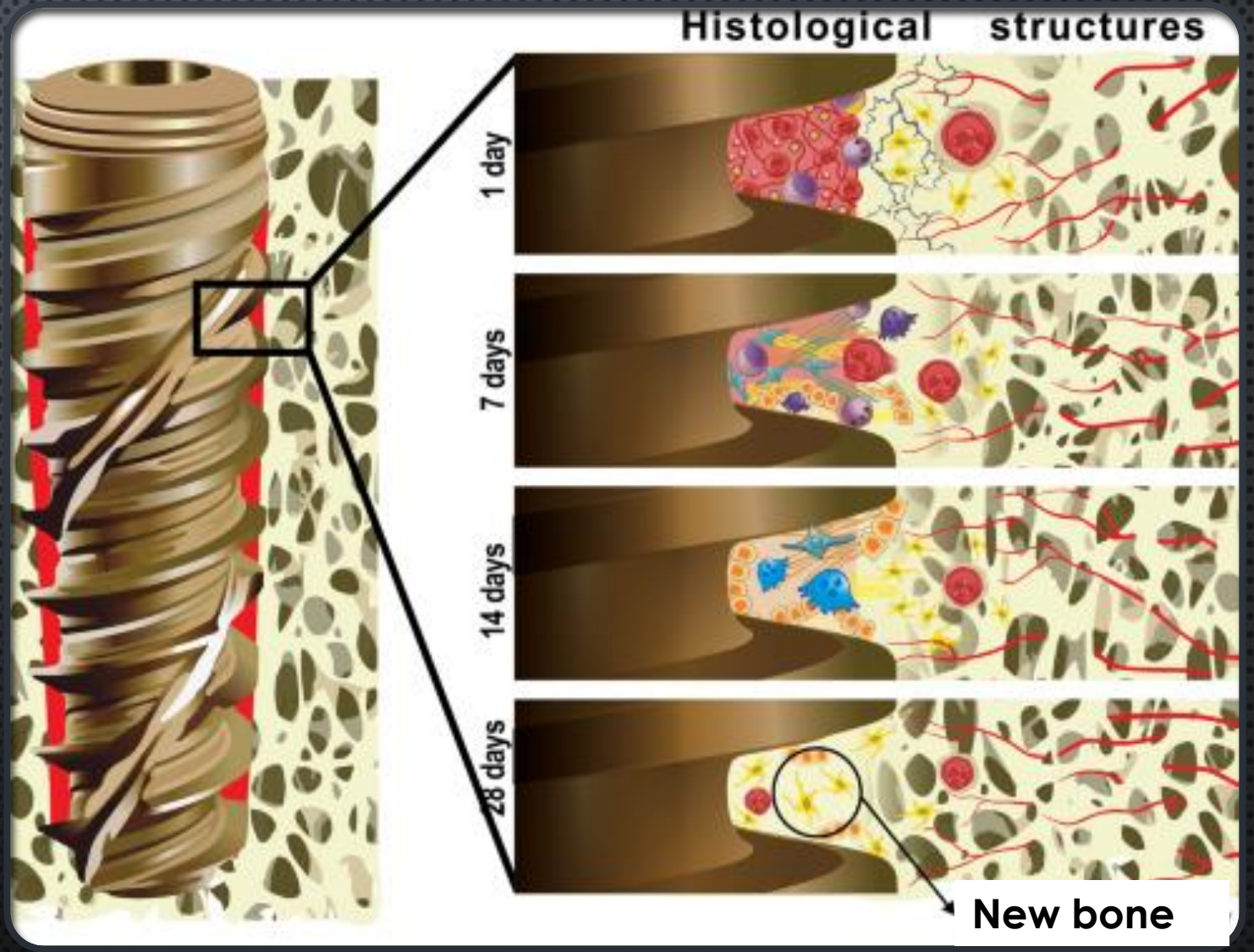
Dental Implants: The Modern Solution for Lost Teeth

- A dental implant is a prosthesis that interfaces with the jawbone to support a dental prosthesis (crown, bridge, denture)
- Made of titanium, titanium alloy or Zirconia ceramic.
- Biocompatibility is key for its success.



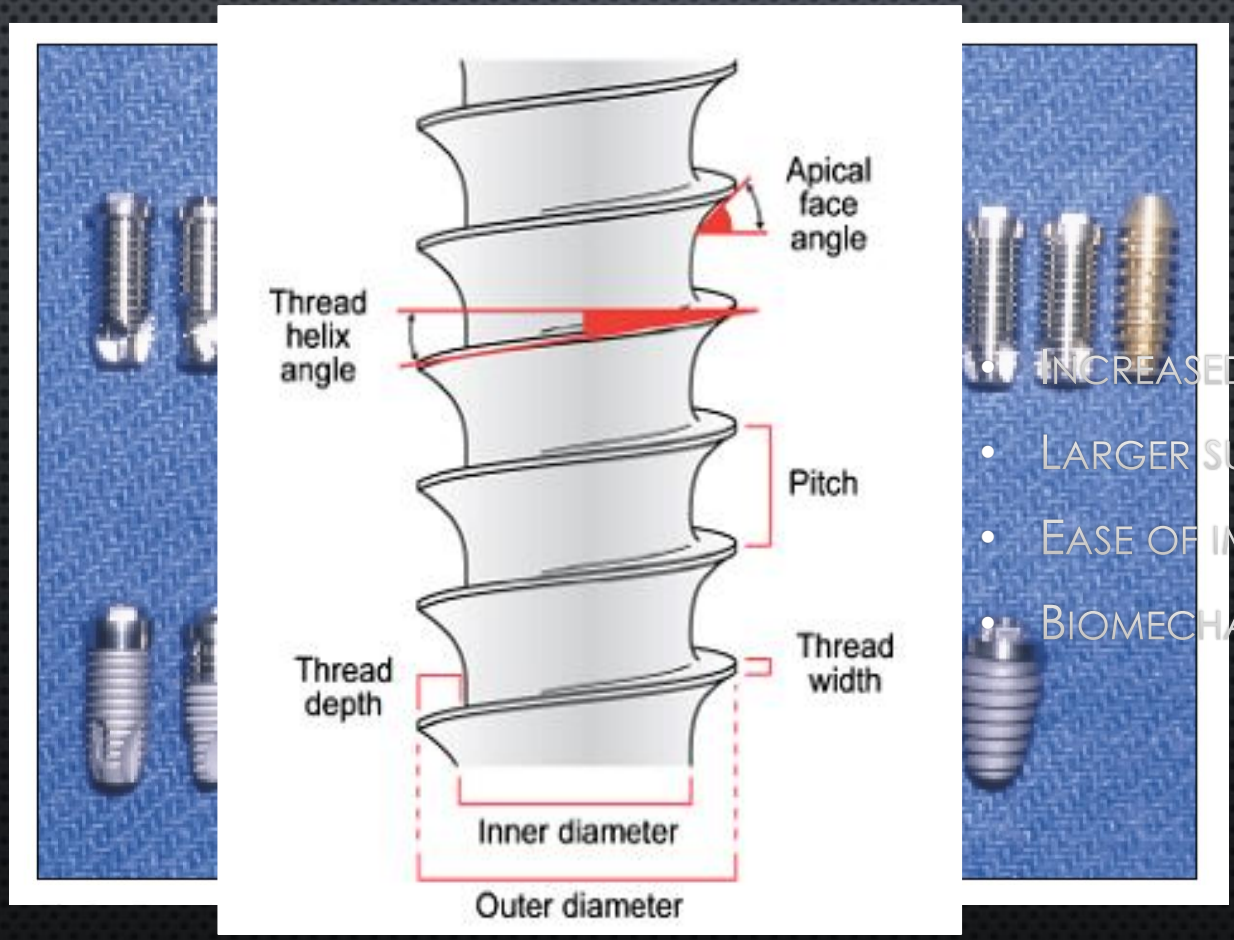
KEY FOR SUCCESS : OSSEOINTEGRATION

- THE DEFINITION OF OSSEOINTEGRATION (ALBREKTSSON 1981) "A DIRECT FUNCTIONAL AND STRUCTURAL CONNECTION BETWEEN LIVING BONE AND THE SURFACE OF A LOAD BEARING IMPLANT"
- BONE REMODELING AROUND THE IMPLANT THREADS – STABILITY !!!
- 10 YEARS SURVIVAL RATE OF OVER 95%
- **EVERY YEAR, MORE THAN 800,000 IMPLANTS ARE PLACED IN THE USA AND MORE THAN 1.8 MILLION IN THE EU.**



DESIGN PARAMETERS TO IMPROVE : OSSEOINTEGRATION

Macro-design parameters

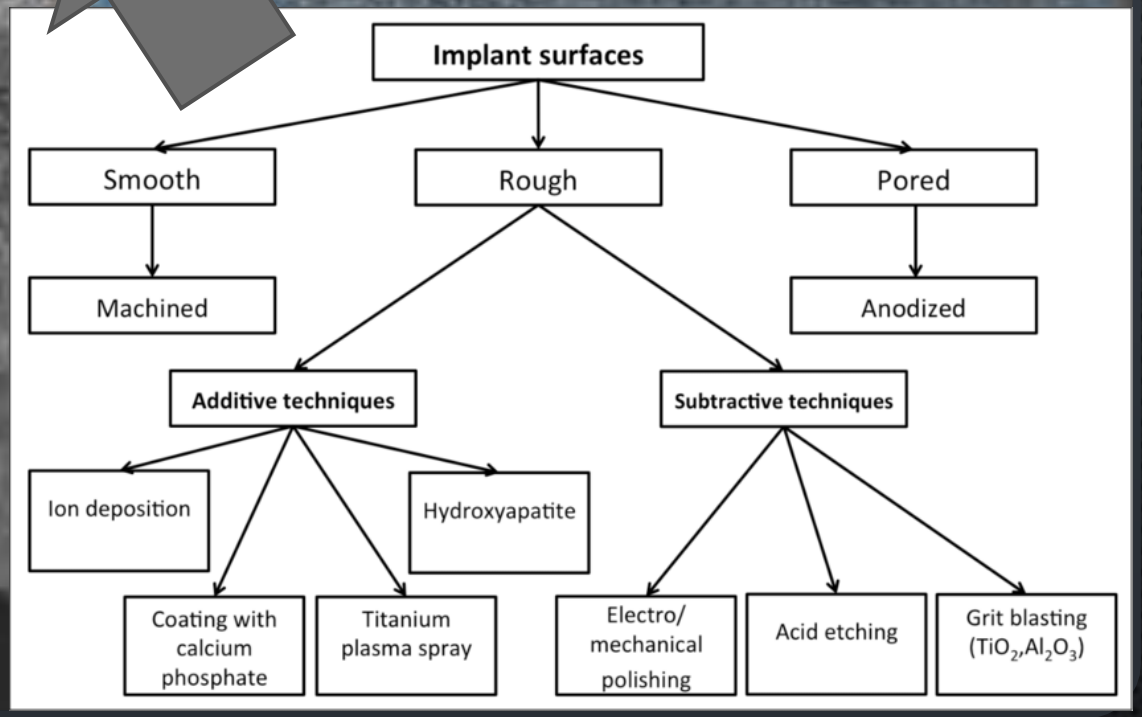


- INCREASED IMPLANT STABILITY
- LARGER SURFACE AREA
- EASE OF IMPLANT HANDLING AND INSERTION
- BIOMECHANICAL LOAD DISTRIBUTION

DESIGN PARAMETERS TO IMPROVE : OSSEOINTEGRATION

Micro-design-Surface topography

- SURFACE ROUGHNESS (MICRO-NANOSCALE)
- WETTABILITY (SURFACE ENERGY)
- OXIDE LAYER PROPERTIES
- POROSITY/TEXTURE



DESIGN PARAMETERS TO IMPROVE : OSSEOINTEGRATION

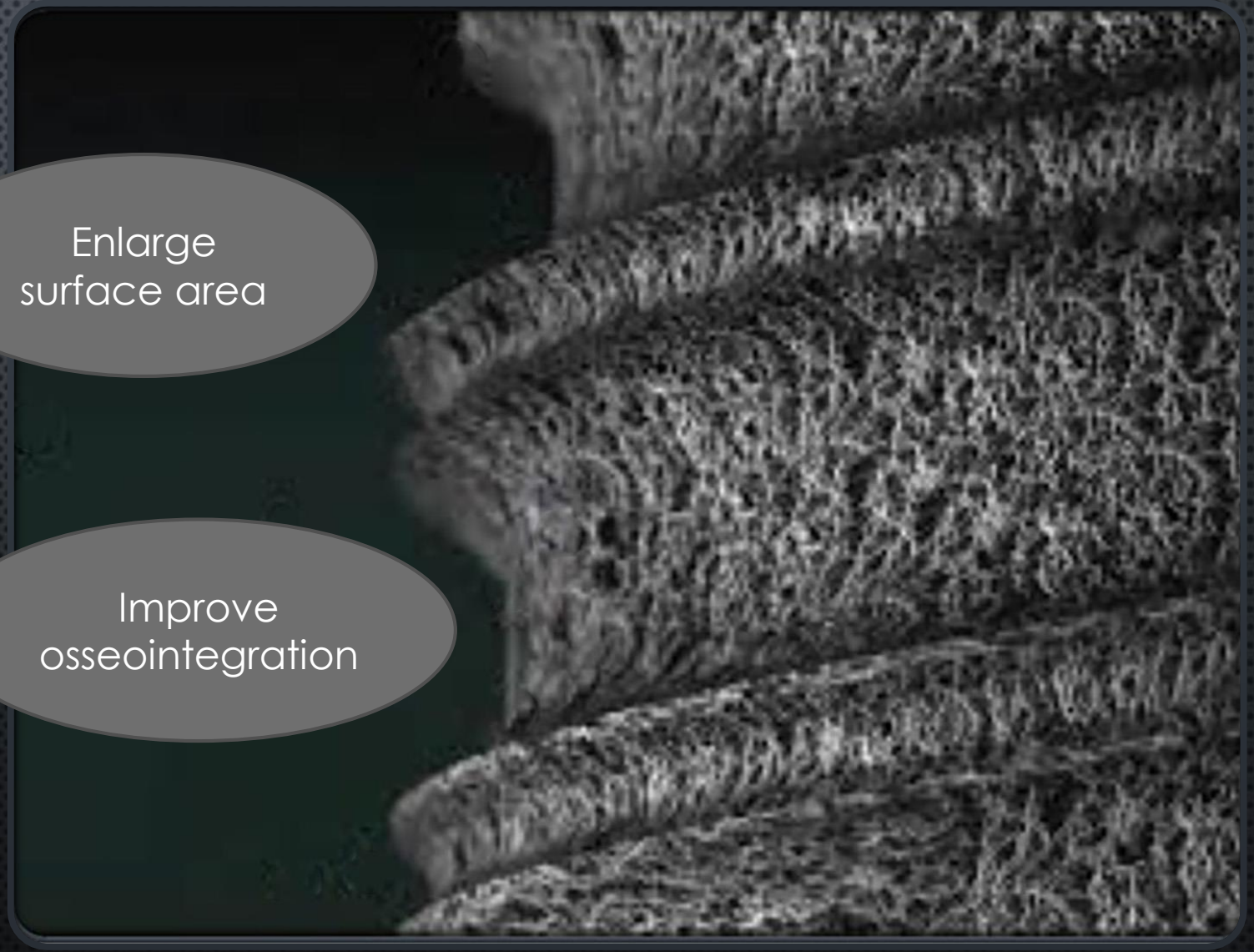
Micro-design-Surface topography

Enlarge surface area

Improve implant fixation and stability

Improve osseointegration

Improve wound healing

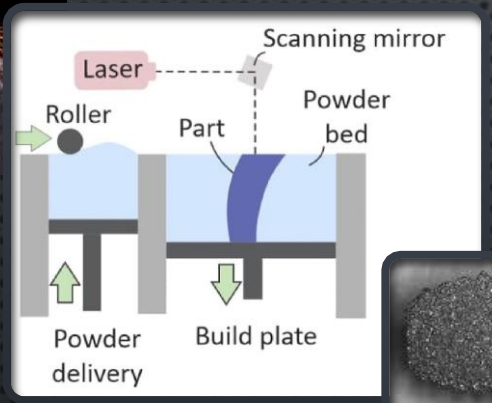


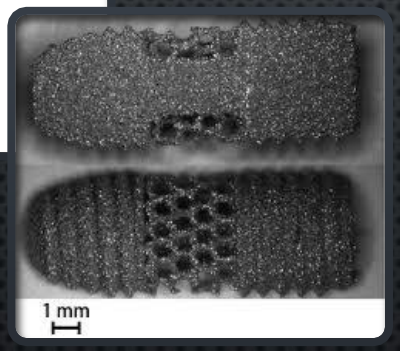
CONVENTIONAL METHODS TO MANUFACTURE A DENTAL IMPLANT

SUBTRACTIVE PROCESS: MACHINING, FORGING, AND MILLING

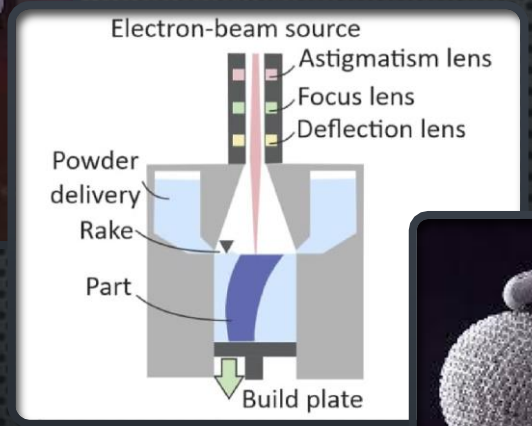
- Tool fracture and chattering
- Significant amount of material waste.
- Can introduce microcracks on the metal
- Costly and time-consuming process.

ADDITIVE METHODS TO MANUFACTURE A DENTAL IMPLANT





Laser powder bed fusion (LPBF): selective laser melting (SLM) or direct metal laser sintering (DMLS)



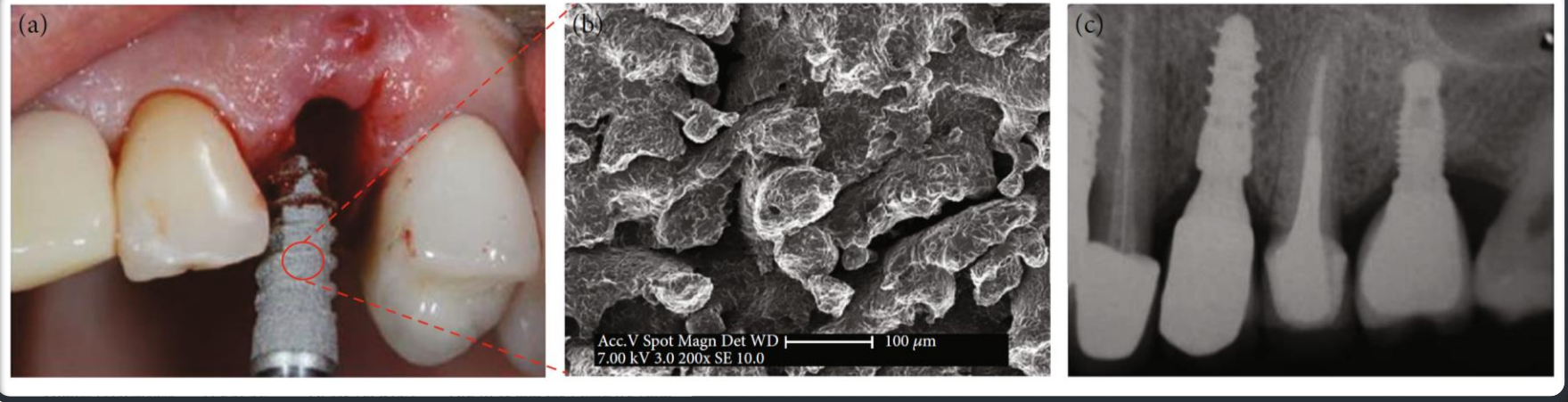
The electron beam powder bed fusion (EPBF) /electron beam melting (EBM)

CLINICAL USE OF ADDITIVE MANUFACTURED DENTAL IMPLANTS

Table 3: Application

Author	Application	Cases	Specification	Scann				
Tunchel et al. [121]	Dental implant	82	Tixos^R (Leader Implants, Italy) 3.3 mm/ 3.75 mm/4.5 mm	CBC				
Mangano et al. [145]	Immediate dental implant	15	Root analogue	CBC (CS9300,				
Figliuzzi et al. [146]	Immediate dental implant in the anterior maxilla	1	Root analogue	CBC (CS9300,				
Mangano et al. [147]	Immediate loading of four unsplinted implants	62	Tixos^R (Leader Implants, Italy) 2.7 mm/3.2 mm	CBCT (CS9300, USA)	Belgium)	alloy	M270, Germany)	for 4 years) Biological complications (6%), prosthetic complications (12.9%)
Mangano et al. [120]	Implant templates	20	Tooth-supported	CBCT (CS9300, USA)	Nauta (DWS, Vicenza)	Resin	SLA (XFAB2000, DWS, Vicenza)	96.4% of the templates were steady and suitable for clinical use
Derksen et al. [148]	Implant templates	66	Tooth-supported	CBCT (Morita, Japan)	coDiagnostiX (Dental Wings, Canada)	Biomaterial (MED 610)	3D printing (Eden 260V, Stratasys, USA)	The mean angular deviation was 2.72° The mean deviations at the implant's entry point and apex were 0.75 mm and 1.06 mm, respectively
Xu et al. [149]	Implant drills in allogenic tooth transplantation	1	Not mentioned	CBCT	Not mentioned	Metal powder	DLMS	The donor tooth fitted well in the recipient's alveolar bone The inflammatory and replacement resorption was stable after 4 months
Mena-Álvarez et al. [150]	Autotransplantation templates	1	Tooth-supported	CBCT (White Fox, France)	Not mentioned	Not mentioned	3D printing (Explora 3D lab, Spain)	2-year follow-up: accurate placement of the donor tooth in the recipient site with good physiological clinical and radiologic results

Note: cases: the number of patients enrolled in the research; DIB: distance between the implant shoulder and the first visible bone-implant contact; CBCT: cone-beam computed tomography; Ti-6Al-4V: titanium-6 aluminium-4 vanadium; SLA: stereolithography; DLMS: direct laser metal sintering; DLMF: direct laser metal formation.

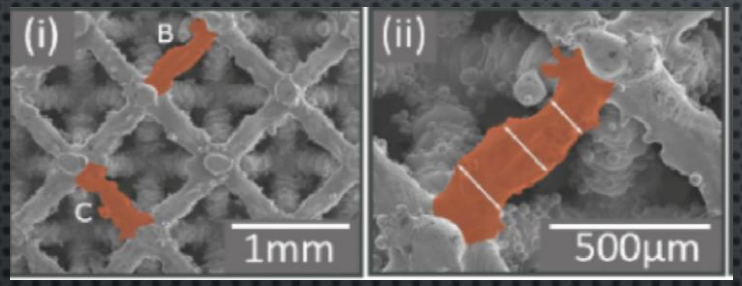


- Survival rate of 94% (3y follow up)
- Can be personalized
- Surface roughness >15μm (high)
- Mechanical performance scarce
- Long term biologic reliability missing

STRUCTURAL DEFECTS IN METALLIC ADDITIVELY MANUFACTURED IMPLANTS

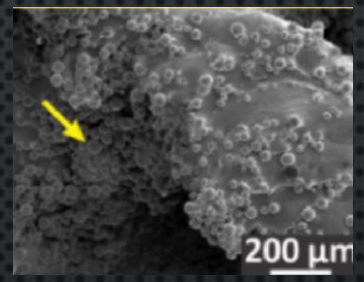
Geometric type

Dimensional inaccuracy: Due to shrinkage and residual stresses



- WAVINESS
- THICKNESS VARIATION
- Varying cross section shape
- Over or under size part

Surface roughness: Due to exposure amount to laser/electron beam and heat dissipation



- UNMOLTEN POWDER
- HIGH SURFACE ROUGHNESS
- LARGE DISPERSIION OF SURFACE ROUGHNESS
- FORMATION OF SPHERICAL BEADS

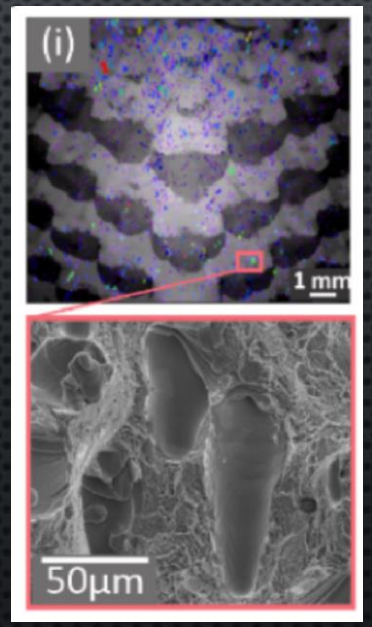
Poor surface quality and structural integrity can diminish the mechanical performance of the metallic structures

STRUCTURAL DEFECTS IN METALLIC ADDITIVELY MANUFACTURED IMPLANTS

Microstructural type

Porosity: Due to melting speed (Insufficient melting and gas entrapment

- INTERNAL VOIDS
- CLOSED POROSITIES
- INCOMPLETE FUSION DEFECT
- KEYHOLE DEFECTS



Material property imperfection: Due to process parameters and building orientation

- VARIATION IN MICROSTRUCTURE AND CRYSTALLINE PROPERTIES
- ANISOTROPY
- GRADIENT IN MECHANICAL PROPERTIES ALONG THE STRUCTURE
- RESIDUAL STRESSES

Poor surface quality and structural integrity can diminish the mechanical performance of the metallic structures

Conclusions and Future Perspectives

- Additive Manufacturing (AM) techniques have revolutionized the design and processing of implantable biomaterials both in medicine and in dentistry
- AM has opened new opportunities towards personalized medicine with costume made implants.
- Using AM has enabled fabricating complex 3D parts with high-precision
- **With that many obstacles in adopting AM for the industries still needs to be addressed:**
- Unify and optimize the processing parameters in order to prevent geometric and microstructural defects
- post-processing treatments need to be eliminated to prevent costs and reduce processing time
- the AM process hinders industrial mass production of metal implants and solutions for production rate is of high demand
- **Mechanical and biological reliability issues still need to be evaluated**
- **THANK YOU!**