

**21<sup>ST</sup>**   
WORLD  
**STERILIZATION**  
CONGRESS



*THREE-DIMENSIONAL PRINTED MEDICAL  
DEVICES: REGULATORY PERSPECTIVE ON  
MANUFACTURING AND STERILIZATION BY  
HEALTHCARE FACILITIES.*

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CICG, GENEVA, SWITZERLAND

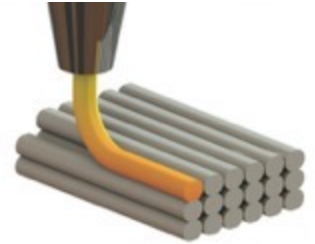


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- Possibility of manufacturing MDs in 3D
- Health Care Facilities (HCF) surgeons' requests:
  - **What are the demands, advantages and possibilities?**
- Is it possible? And how?
  - **Update on regulations**
  - **Update on sterilization**
    - **Literature review**
- What can we do concretely?

Additive manufacturing:  
successive superimpositions of thin layers of material



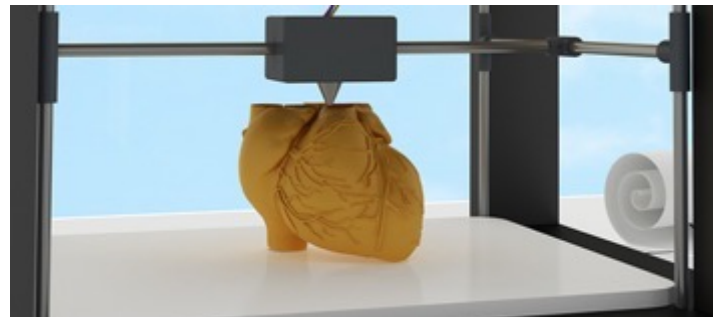
modeling

image  
cutting

layer by layer  
printing

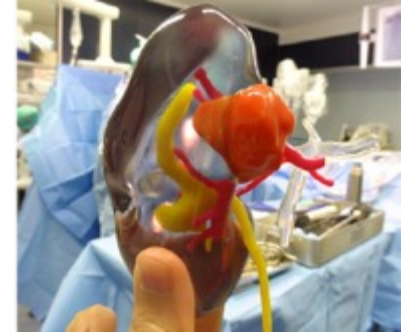
+/- finishes

- **Different printing technologies** available on the market:
  - **Fused Deposition Modeling (FDM)**
  - **Stereolithography Apparatus (SLA):** liquid solidified by a UV laser
  - **PolyJet and Multijet:** deposition of resin microdroplets polymerized by UV laser
  - **Selective Laser Sintering (SLS):** selective laser sintering, powder consolidated by UV laser



## Anatomical models

- **Training** of surgeons and students
- Improves **communication** with patients
- **Shaping** of implants (titanium plates or grids)
  - standard equipment → custom-made equipment at a lower cost



## Customized cutting guides

- **Securing** the surgeon's actions
- **Reduced** operation time



## Customized implants or prostheses

- **Reduced costs** and shorter intervention times
- **Improved patient outcomes**



# What potential advantages?

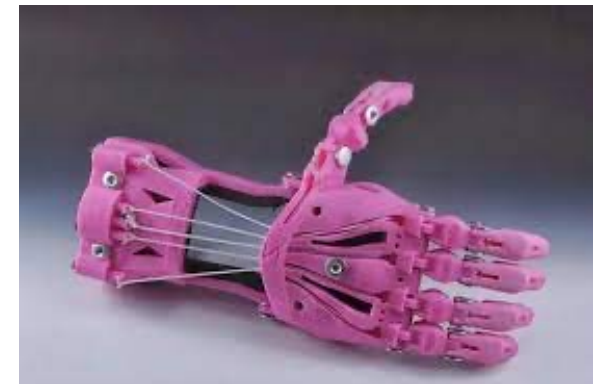
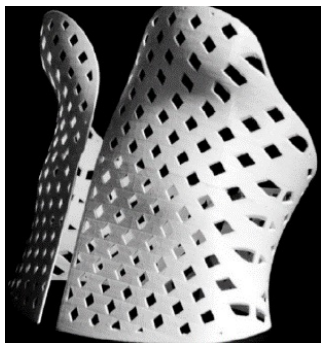
Quick to  
produce

Economic



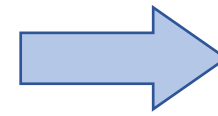
Customization

Innovation



# What possibilities?

	External manufacturing = Industrial	In-house production = Health Care Facility (HCF)
Lead time	-	+
Cost	-	+
Complexity of the medical device (MD)	+	-
Manufacturing quality	+	-
Choice of materials	+	-
Customization	-	+
Research and Development of innovative MD	+	+
Staff / skills	+	-
Infrastructure	+	-
Quality Management System / Regulations	+	-



Reverse balance if high demand



## Mandatory regulatory qualification

### MD

Cutting guides, splints,  
prostheses, implants

Software (image acquisition,  
preparation before printing)

Materials used in the production  
of MDs

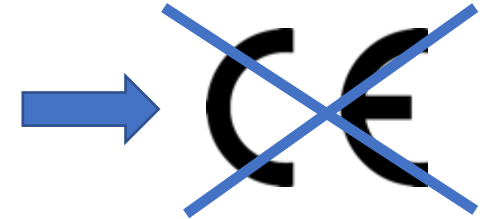
### NON MD

Prototypes

Anatomical models

## Custom MD :

applies to any MD obtained by 3D printing from the anatomical data of a given patient



## If the HCF becomes a manufacturer :

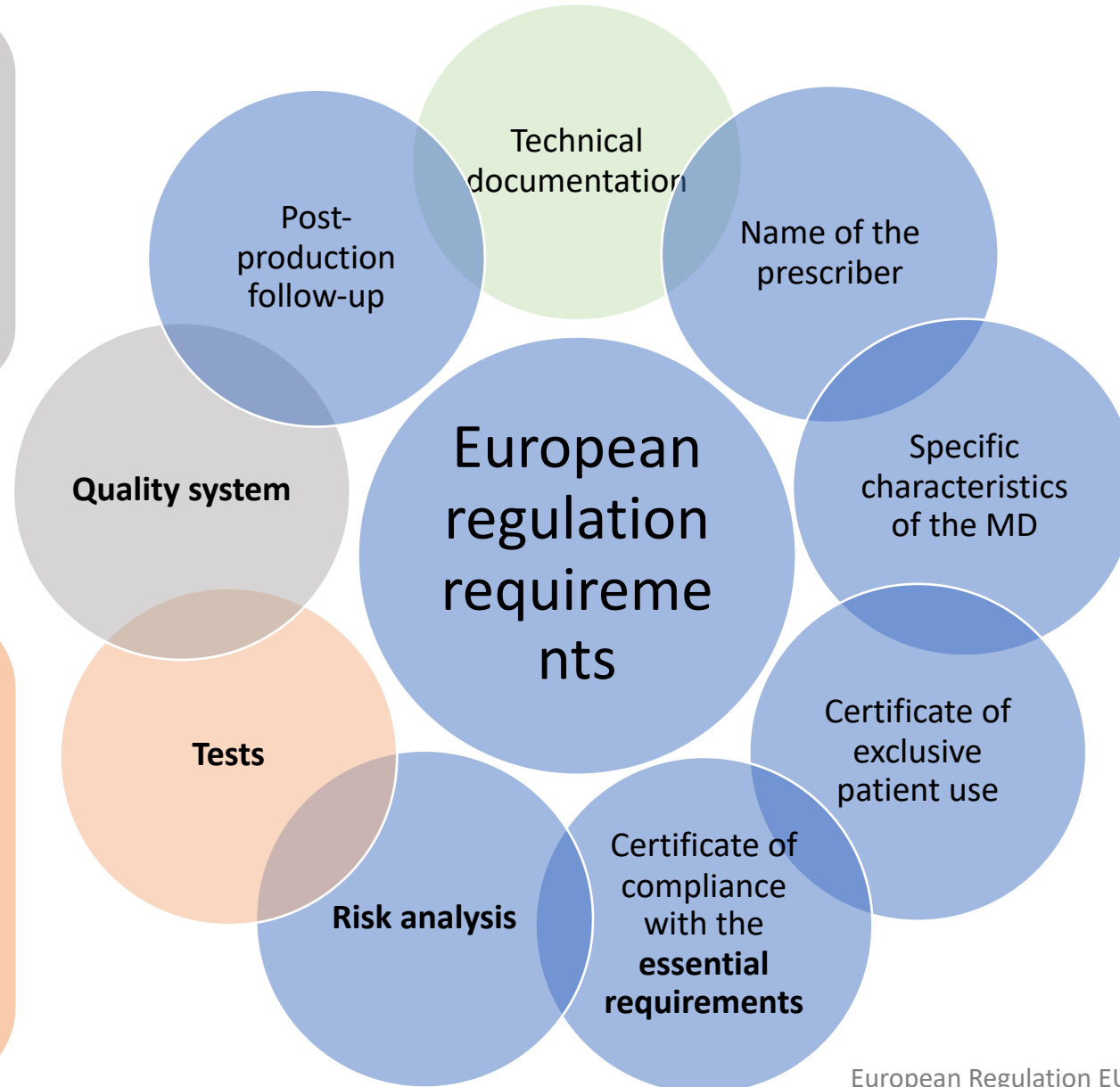
→ Compliance with EU Regulation 2017-745





- **Procedures** for every part of the product's life
- NF EN ISO 13485 certification for class III IMDs

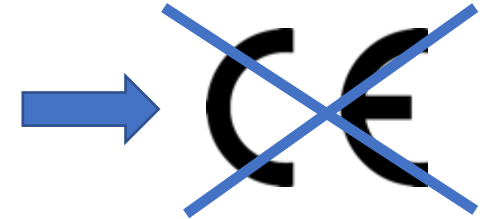
- Aging,
- Packaging
- Toxicity
- Biocompatibility
- Morphological and physicochemical characteristics of the material



- Place of manufacture
- Design
- Manufacturing
- Performance

## Custom MD :

applies to any MD obtained by 3D printing from the anatomical data of a given patient



## If the HCF becomes a manufacturer :

- Compliance with EU Regulation 2017-745
- Declaration of the activity to the relevant national authorities
- Liability for manufacturing and sterilization defects
  - Civil Liability Insurance



## Examples of identified responsibilities (Netherlands):

Step	Case selection	Image acquisition	File segmentation	Machining	Printing	Finishes
<b>Skill</b>	Benefit/risk balance; cost efficiency	Anatomy; Pathology; Technical; Radiation protection	Anatomy; Pathology; Technical	Technical	Technical	Anatomy; Technical
<b>Responsibilities</b>	Physician; Medical physicist	Radiologist; Medical physicist; Technician	Technician	Engineer; Physician	Engineer	Engineer; Physician; CSSD



## Transposition to France :

<b>Responsibilities</b>	Physician; Medical committees	Radiologist; Radio operator; Physician; Technician	Technician	Engineer; Physician	Engineer	Engineer; Physician; Pharmacist
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## Manufacturing:

- "[...] so as to eliminate or reduce as far as possible the risk of infection [...]"
- "[...] in such a way as to facilitate safe cleaning, disinfection and/or sterilization."

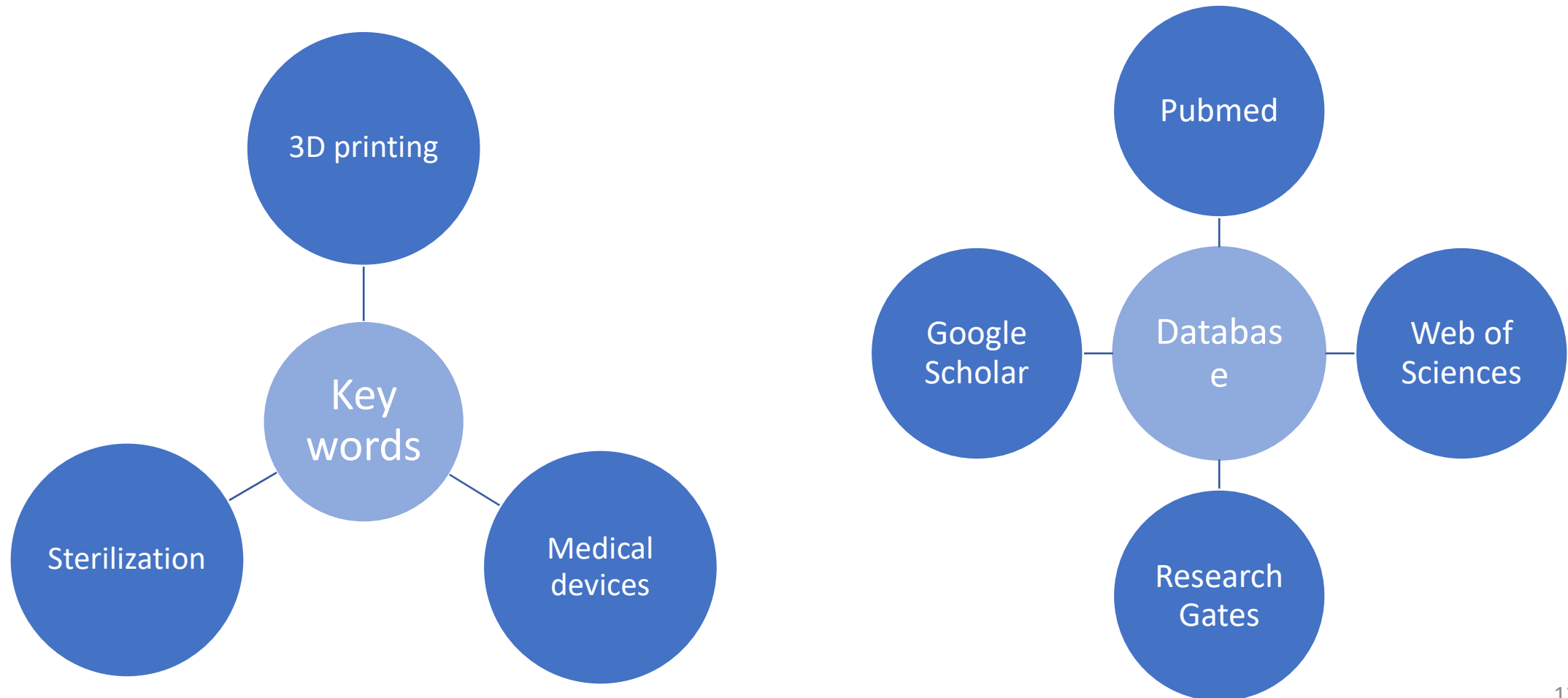
## Sterilization:

- " [...] through appropriate and validated methods."

- No detailed instructions in the European regulation
- No validated sterilization method for 3D printing



## Literature review on sterilization of 3D printed MDs



✓ 4 publications  , 9  , 5 outside Europe

✓ Possible sterilization method in HCF in France

✗ No radiosterilization  ethylene oxide



→ Issues:

Is it sterilizable? Process resistance?

➤ Deformation tests

Is it sterile? Process efficiency?

➤ Sterility test

Printing technology		FDM				
Materials		ABS and by-products	PC and by-products	PLA	PPSF	Ultem
H2O2 plasma gas		(1,2,3,4)	(1,6)	(6)	(1)	(1)
Autoclave	121°C, 20 min	(1)	(1)		(1)	(1)
	125°C, 20 min	(5)	(5)			
	134°C, 4 min	(1)	(1)		(1)	(1)
	134°C, 45 min			(7)		

No deformation
  Variable
  deformation

**FDM = Fused Deposition Modeling**

**ABS = Acrylonitrile Butadiene Styrene**

**PC = Polycarbonate**

**PLA = Acide Polylactique**

**PPSF = Polysulfone**

**Ultem = Polyétherimide**

**=> Thermoplastics**



Printing technology		SLA		Polyjet	SLS	
Materials		PMMA	Dental resins	MED610	Polyamide 12	Visijet resin
H2O2 plasma gas		(8)		(14)		
Autoclave	121°C, 20 min	(8)	(9,10)	(9,14)		(16)
	134°C, 4 min	(8)	(11,12)			
	134°C, 10 min			(14)		
	134°C, 18 min		(13)		(15)	

**SLA = Stereolithography Apparatus**


**SLS = Selective Laser Sintering**

**PMMA = Poly-methyl-methacrylate**

=> thermoplastic polymer

**MED610 = Composite plastic**

**Polyamide 12 = Plastic copolymer**

 No deformation

 Deformation

Printing technology		FDM					SLA
		ABS and by-products	PC and by-products	PPSF	Ultem	PLA	Dental resin
H2O2 plasma gas		(1,2)	(1)	(1)	(1)	(17)	
Autoclave	121°C, 20 min	(1)	(1)	(1)	(1)		
	134°C, 4 min	(1)	(1)	(1)	(1)		
	134°C, 12 min					(18)	
	134°C, 18 min						(5)
	134°C, 35 min		Sterile				Non-sterile

**FDM = Fused Deposition Modeling**

**SLA = Stereolithography Apparatus**

**ABS = Acrylonitrile Butadiene Styrene**

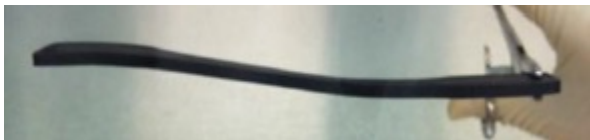
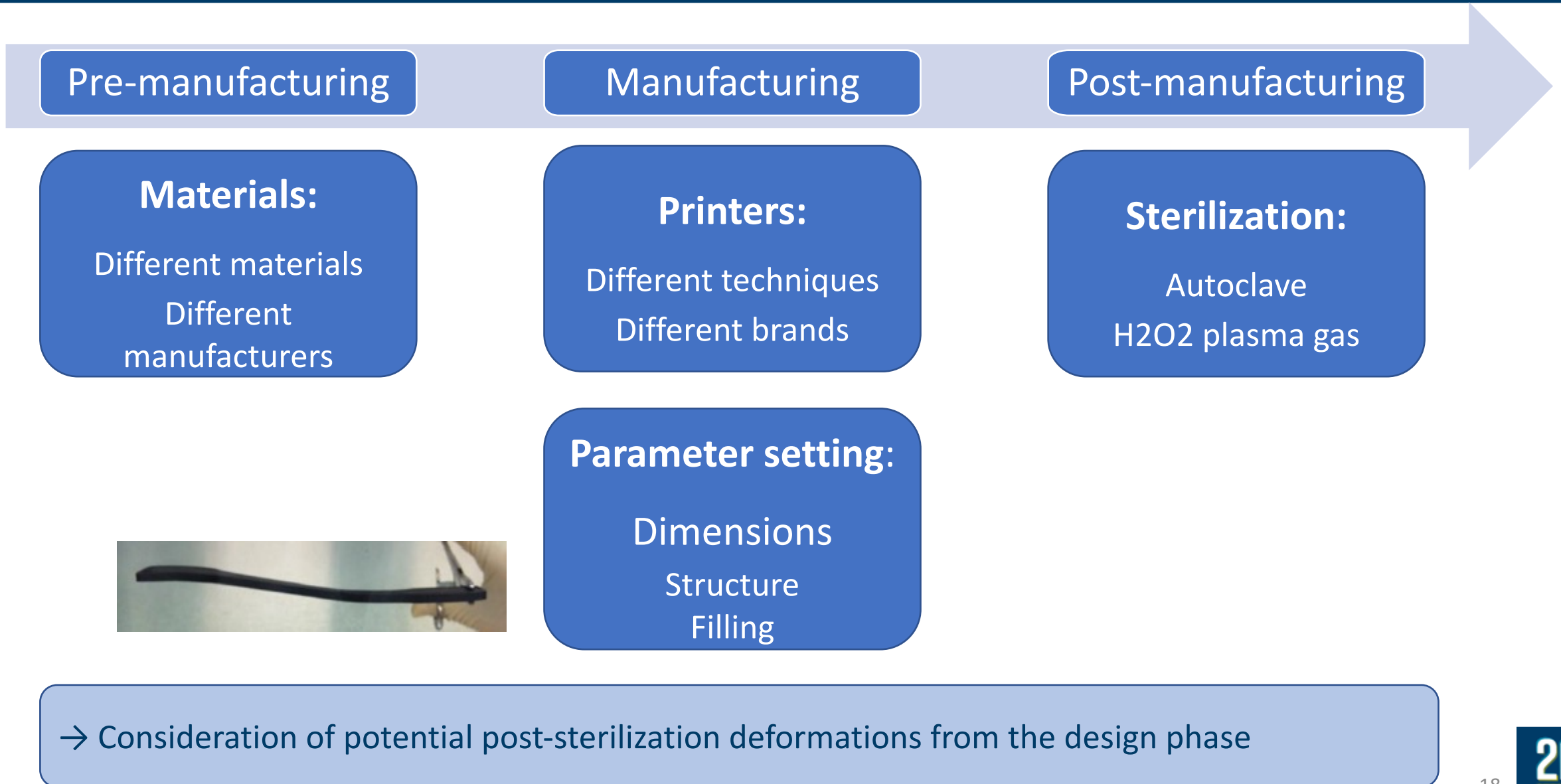
**PC = Polycarbonate**

**PPSF = Polysulfone**

**Ultem = Polyétherimide**

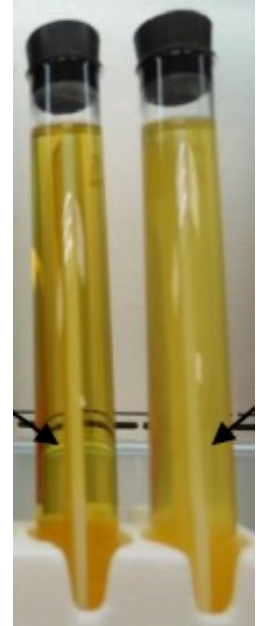
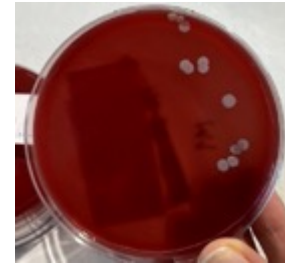
**PLA = Acide Polylactique**

**=> Thermoplastics**



## Tests performed:

- Different shapes, +/- complex
- Different fillings
- Different culture media (liquid and solid)
- Different seeding or no seeding at all



## To find out more:

- Difference in bioburden depending if manufacturing in CAZ or not
- Test on at least 20% of units or minimum 4 units (*European Pharmacopoeia*)
- Inoculation with *Bacillus stearothermophilus* (*gold standard*)

- Many issues:
  - Appointing a Quality and Regulatory Management Officer
  - Setting up an infrastructure for manufacturing
  - Setting up models for sterilization
- Need to control the **entire process** and perform **tests**:

## Manufacturing

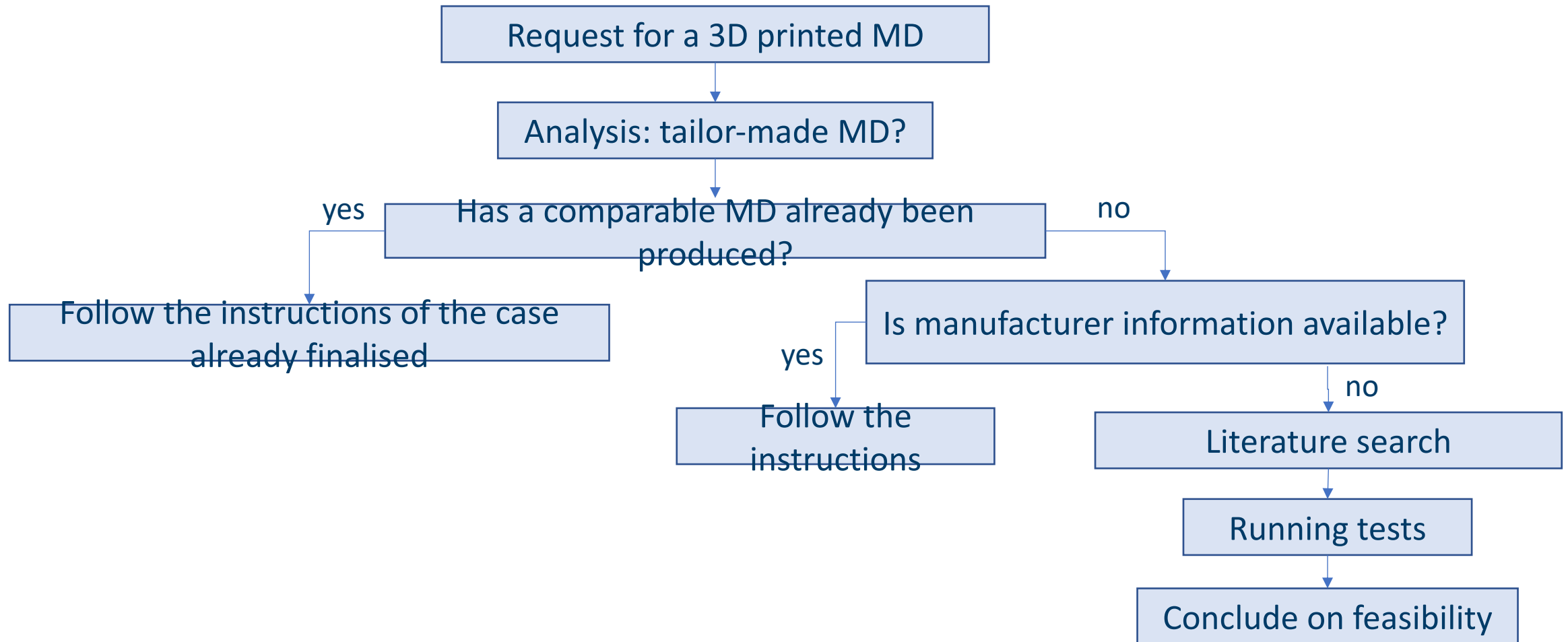
- Centralization
- CAZ

## Pre-disinfection / Washing

- Resistance to detergents ?
  - Thermal disinfection in a washer-disinfector ?
  - Ultrasounds?
- Efficiency of this wash cycle?

## Sterilization

- Choice of packaging
- Autoclave or plasma gas?
- Sterility tests
- Deformation tests



- Regular control tests for the same MD model
- Confirm tests for all new MD models

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**Thank you for your attention**

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