

**PRECISION** 

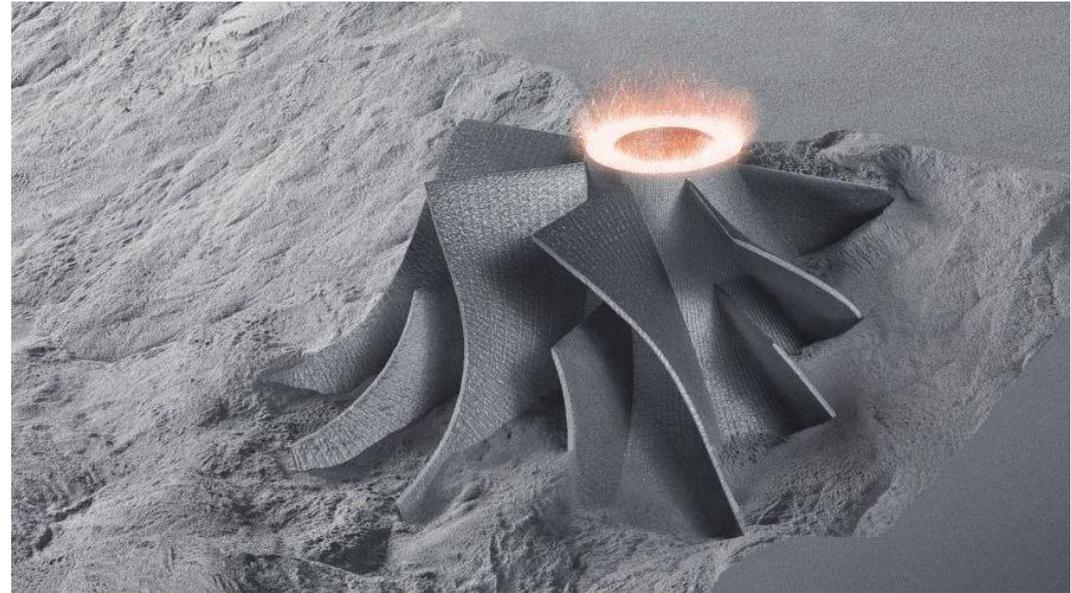
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## L'impression 3D au cœur du domaine médical

Par Laurent Lacombe  
Vice-président, fabrication additive

# L'impression 3D, quelques définitions.

- Impression 3D ?
- Fabrication additive ?



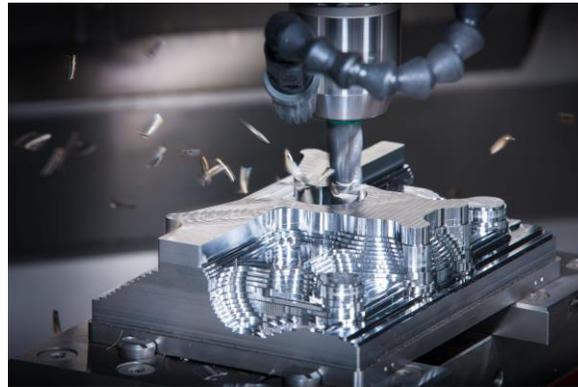
1

Procédé de fabrication : transformation d'une matière brute en objet



# Depuis longtemps l'homme...

## Usine



3

## Plie



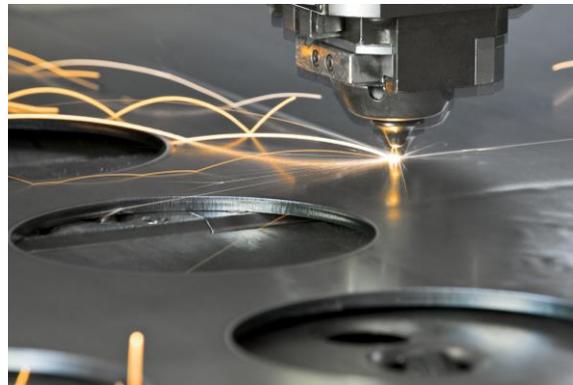
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## Forge



2

## Découpe



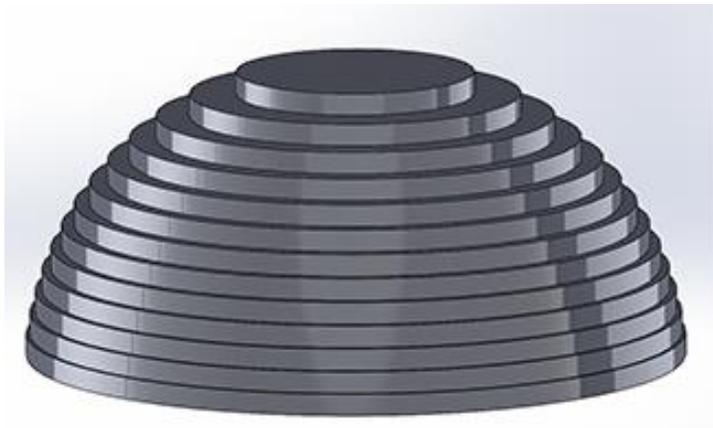
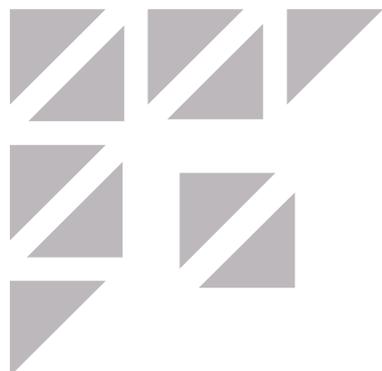
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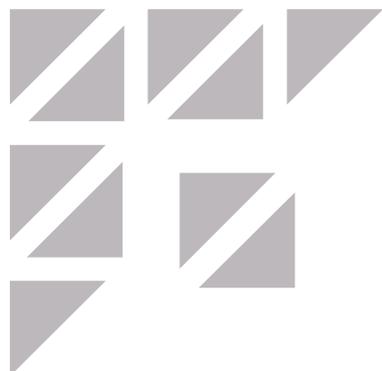


# L'impression 3D, un procédé novateur

- Procédé de fabrication par lequel la matière est ajoutée successivement couche par couche







# L'origine

**Stereolithography,**  
Chuck hull,  
3D Systems,  
États-Unis,  
1984



**FDM,**  
S. Scott Crump,  
Stratasys,  
États-Unis,  
1986



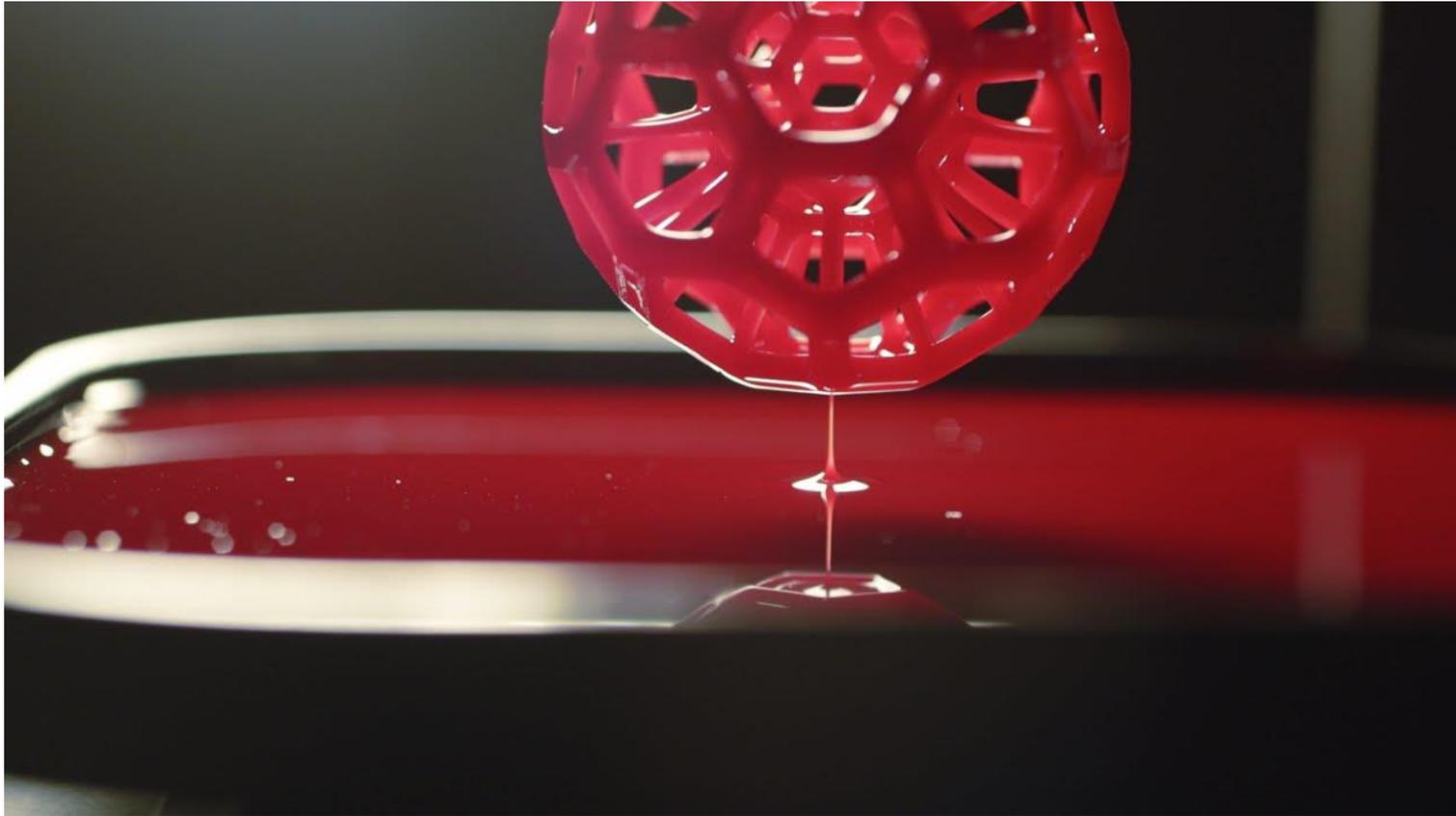
**SLS,**  
Carl Deckard,  
DTM Corp,  
États-Unis,  
1986



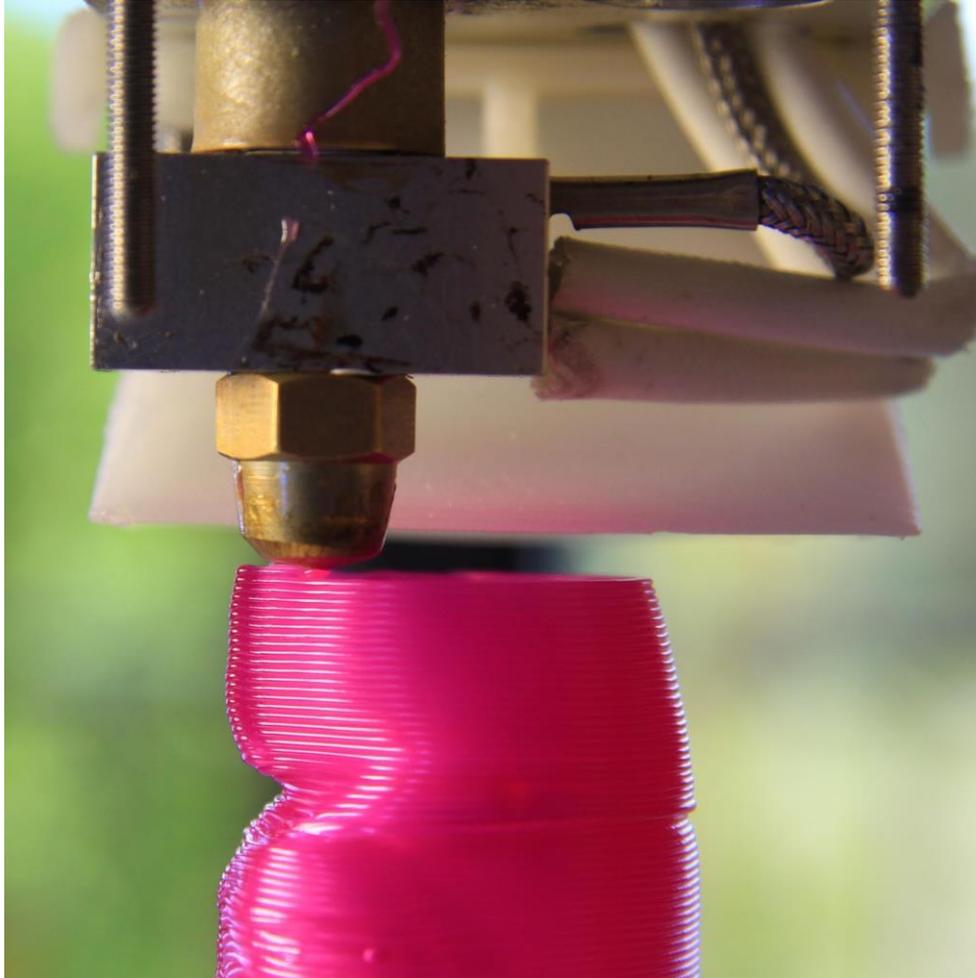
**DMLS,**  
Hans J. Langer,  
EOS,  
Allemagne,  
1989



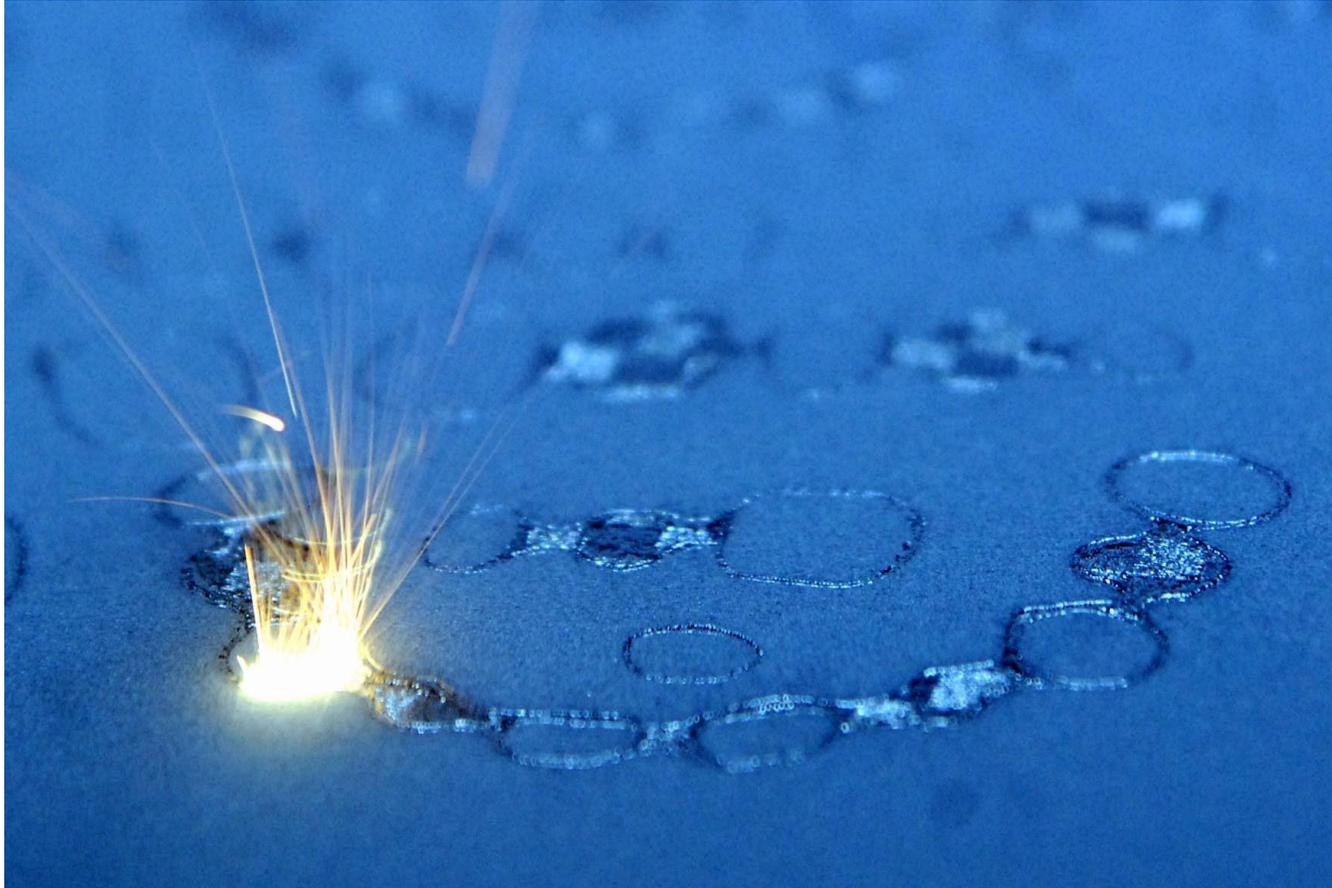
# Stereolithography



# FDM (Fused deposition modeling)



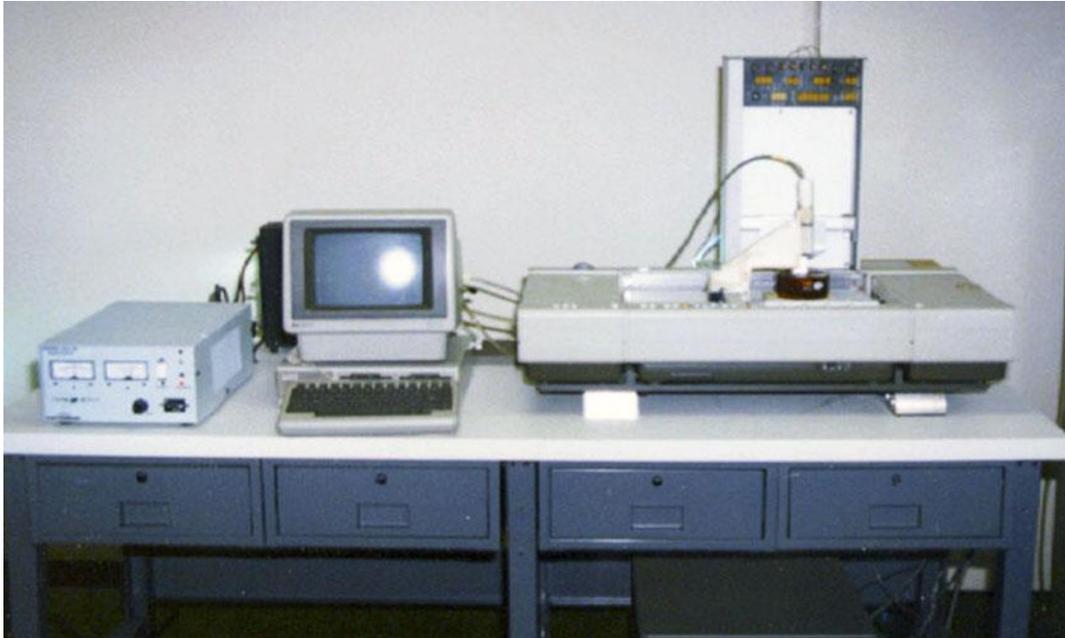
# SLS, SLM, DMLS



## Metal and Ceramic nanoparticle jetting



# L'évolution



SLA-1, 3D Systems, 1987<sup>7</sup>



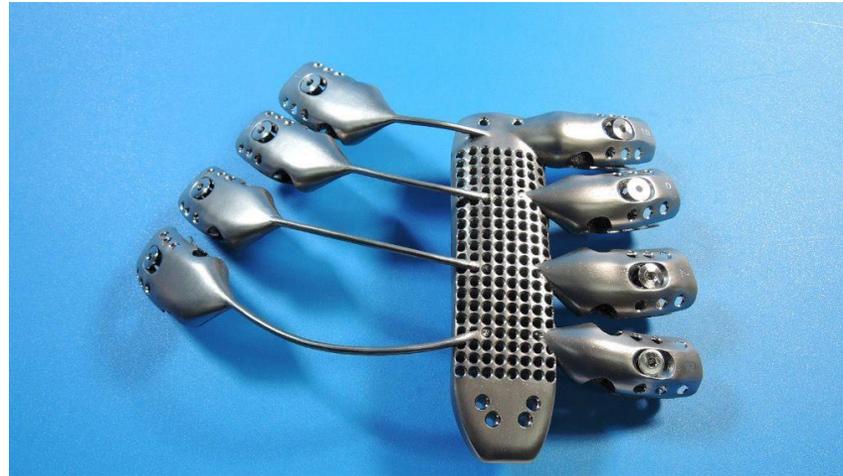
Projet 7000, 3D Systems, 2017<sup>8</sup>



# L'adoption



Buse de carburant, GE<sup>9</sup>



Implant de sternum/côtes<sup>10</sup>

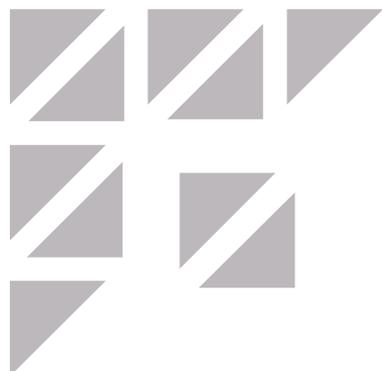


Gyroide<sup>11</sup>

# L'impression 3D en santé

Le rôle de ce nouveau procédé?





# L'impression 3D en santé

Les secteurs d'application :

## Implantologie :

- Orthopédie
- Maxillofaciale
- Neurochirurgie
- ORL

## Modèle :

- Dentisterie
- Planification des chirurgies
- Guides de coupe

## Tissu :

- Pancréas
- Vaisseaux sanguins
- Cartilage

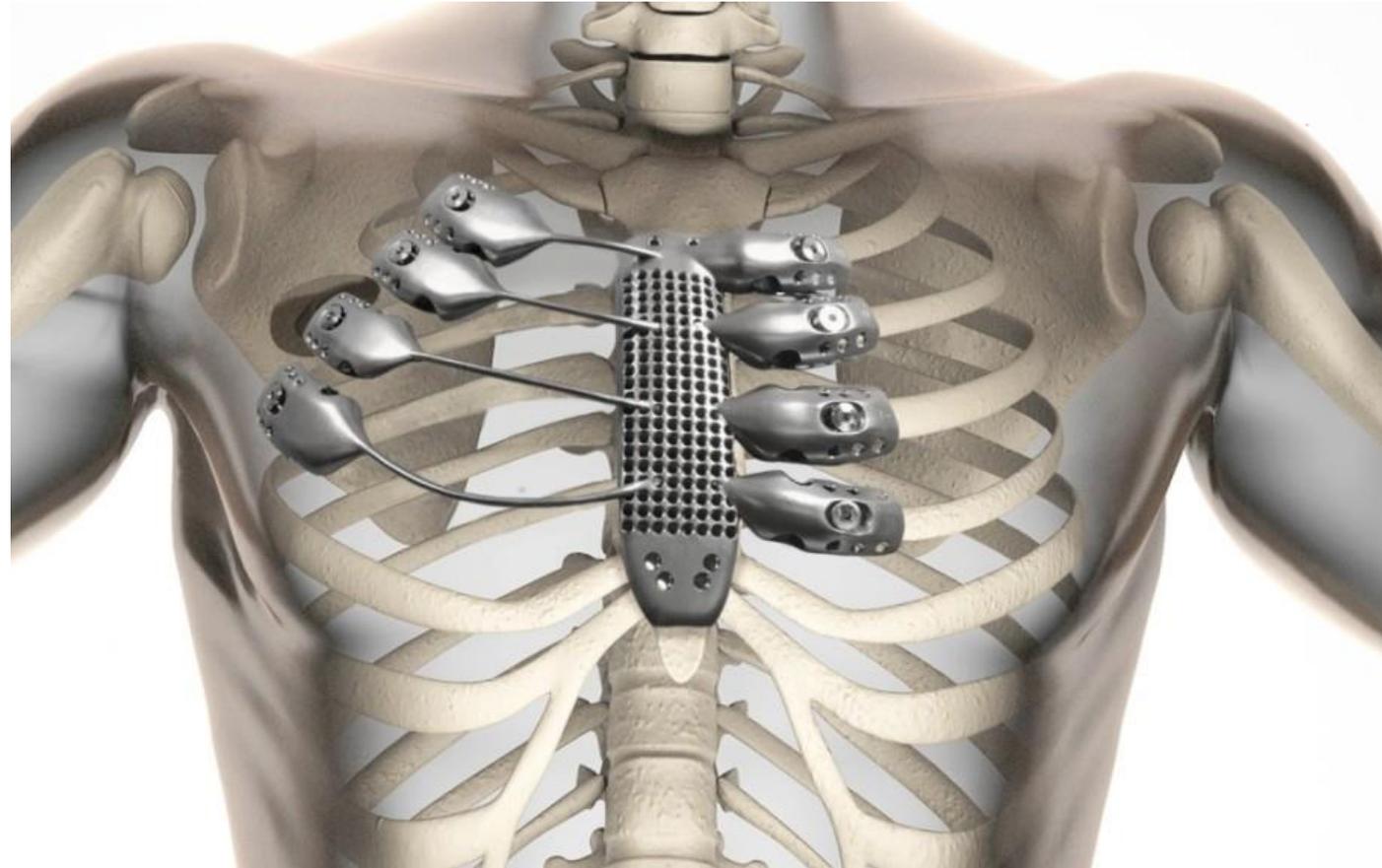


# Domaine d'application : Implantologie



Remplacement de hanche personnalisé<sup>12</sup>

# Domaine d'application : Implantologie



Implant de sternum/côtes personnalisé<sup>13</sup>

# Domaine d'application : Chirurgie maxillofaciale



Implant maxillofacial sur-mesure<sup>14</sup>

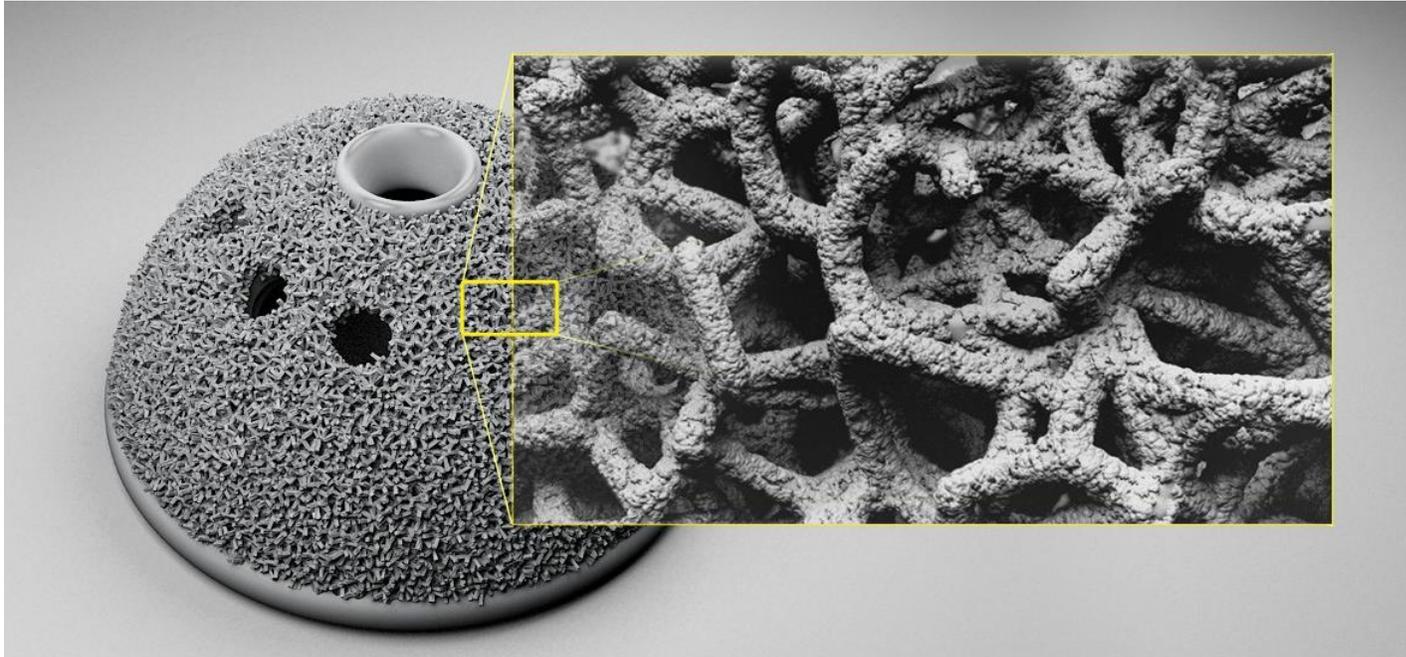
# Domaine d'application : Neurochirurgie



Implant en neurochirurgie<sup>15</sup>

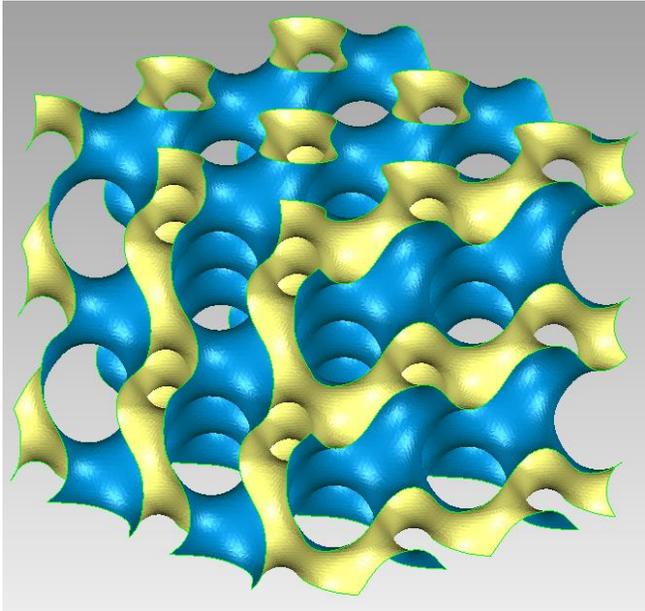


# Ingénierie de surface : les structures poreuses



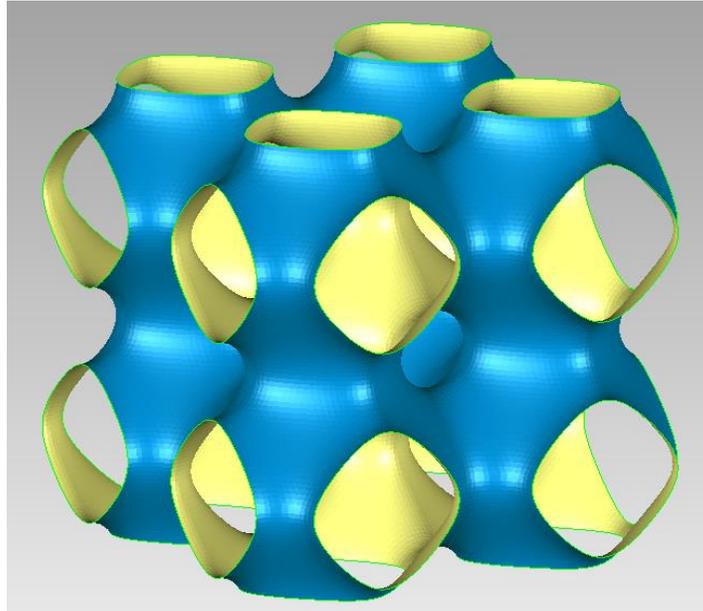
- Augmentation de l'ostéointegration
- Diminution du bone shielding
- Évite l'utilisation du ciment orthopédique

# Ingénierie de surface : les structures poreuses



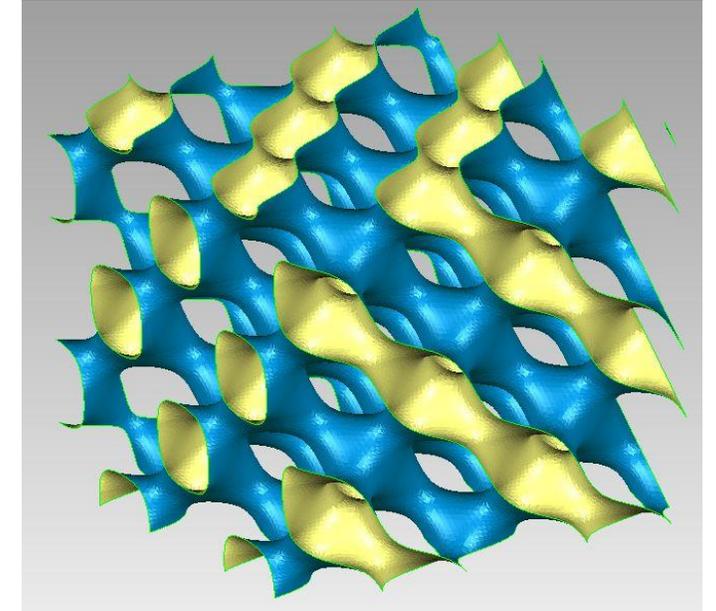
Surface Gyroide

$$F(x, y, z) = \sin(x) \cos(y) + \sin(y) \cos(z) + \sin(z) \cos(x)$$



Surface Schwarz P

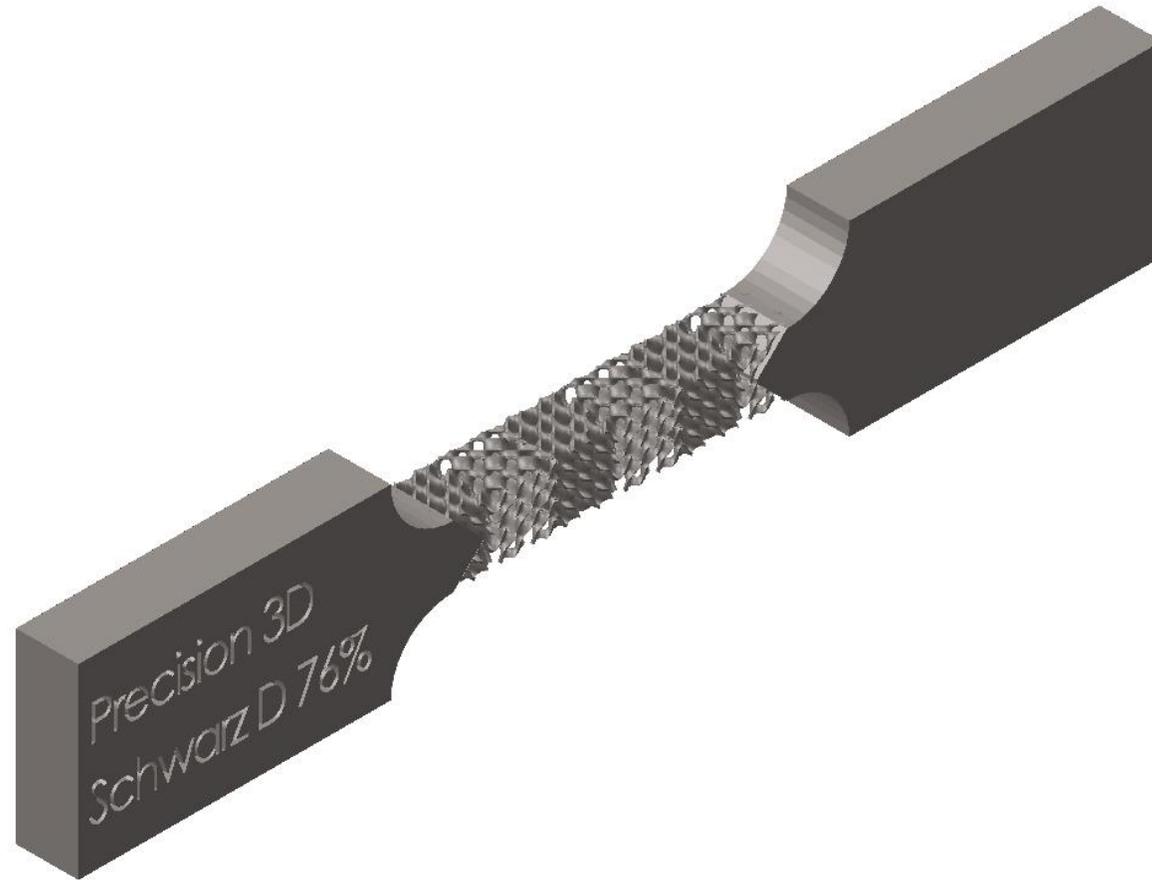
$$F(x, y, z) = \cos(x) + \cos(y) + \cos(z)$$



Surface Schwarz D

$$F(x, y, z) = \sin(x) \sin(y) \sin(z) + \sin(x) \cos(y) \cos(z) + \cos(x) \sin(y) \cos(z) + \cos(x) \cos(y) \sin(z)$$

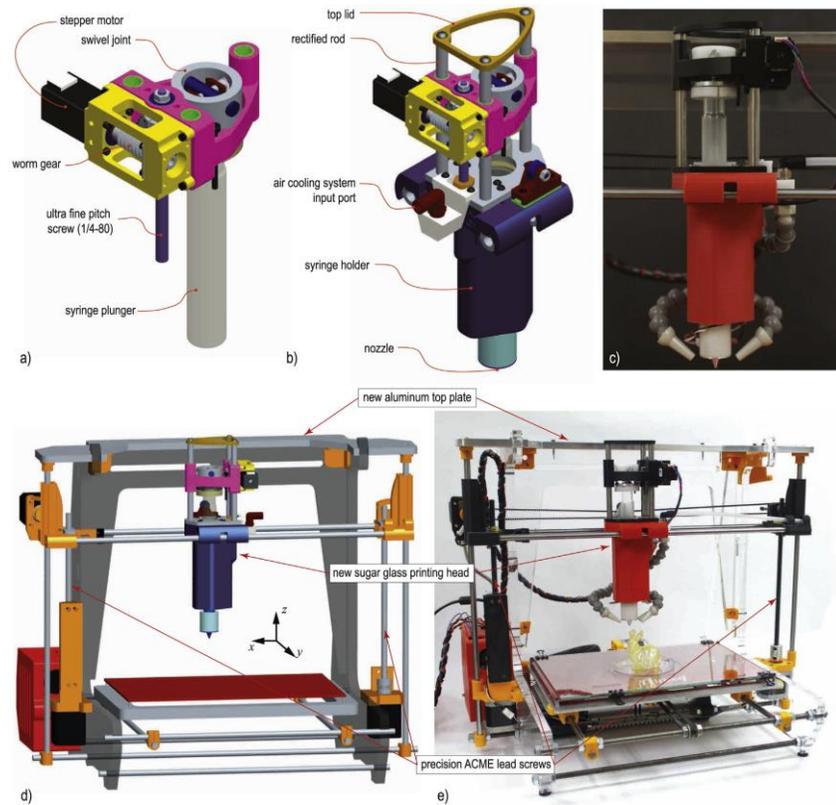
# Ingénierie de surface : les structures poreuses



ASTM E8 SUBSIZE



# Domaine d'application : Reconstruction d'organe

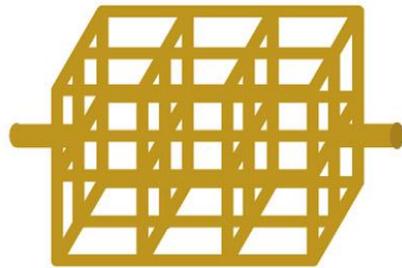


Imprimante à filament de sucre<sup>16</sup>

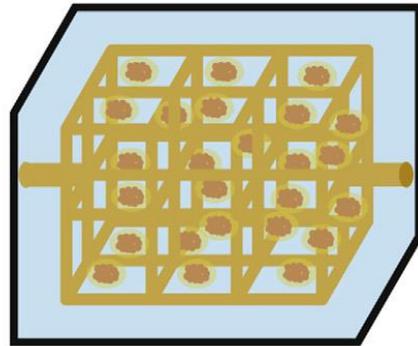


Modèle en sucre<sup>16</sup>

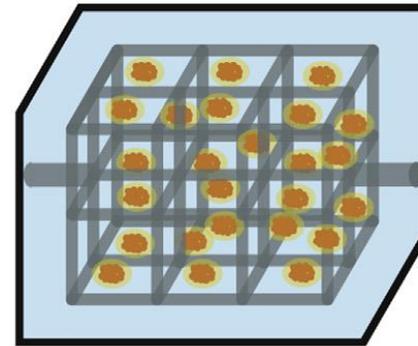
# Domaine d'application : Reconstruction d'organe



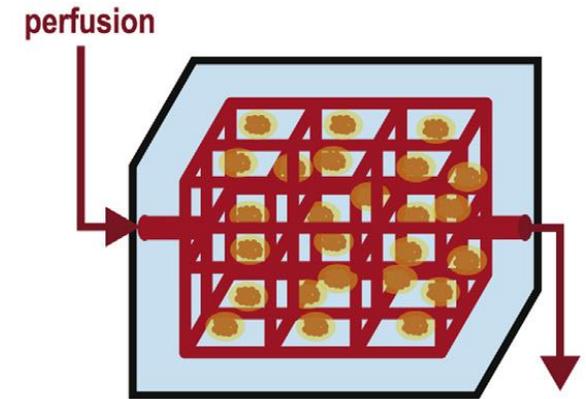
1. Print a temporary 3D structure made out of sugar glass.



2. Add cells dispersed in a hydrogel matrix.



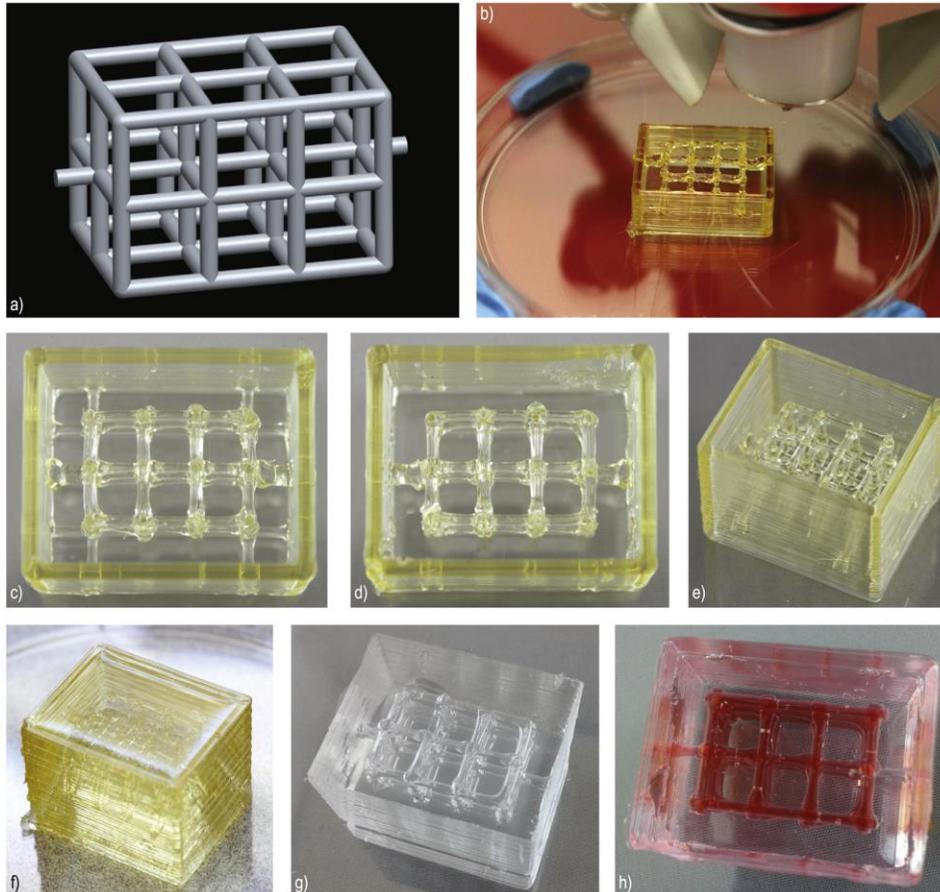
3. Gel the matrix and dissolve the temporary sugar glass structure.



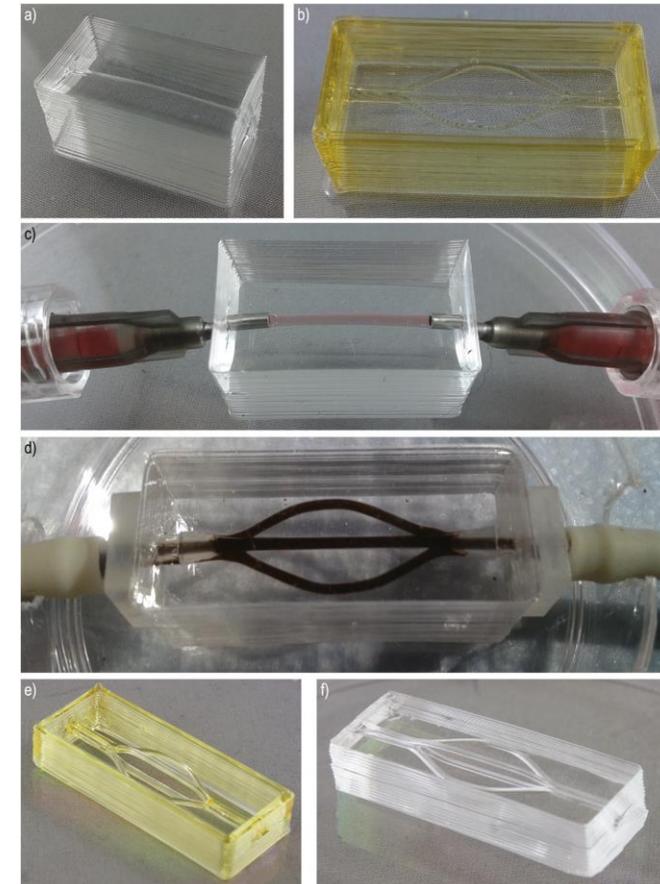
4. Begin perfusion in the newly created channels.

Construction du réseau vasculaire<sup>16</sup>

# Domaine d'application : Reconstruction d'organe



Réseau vasculaire<sup>16</sup>



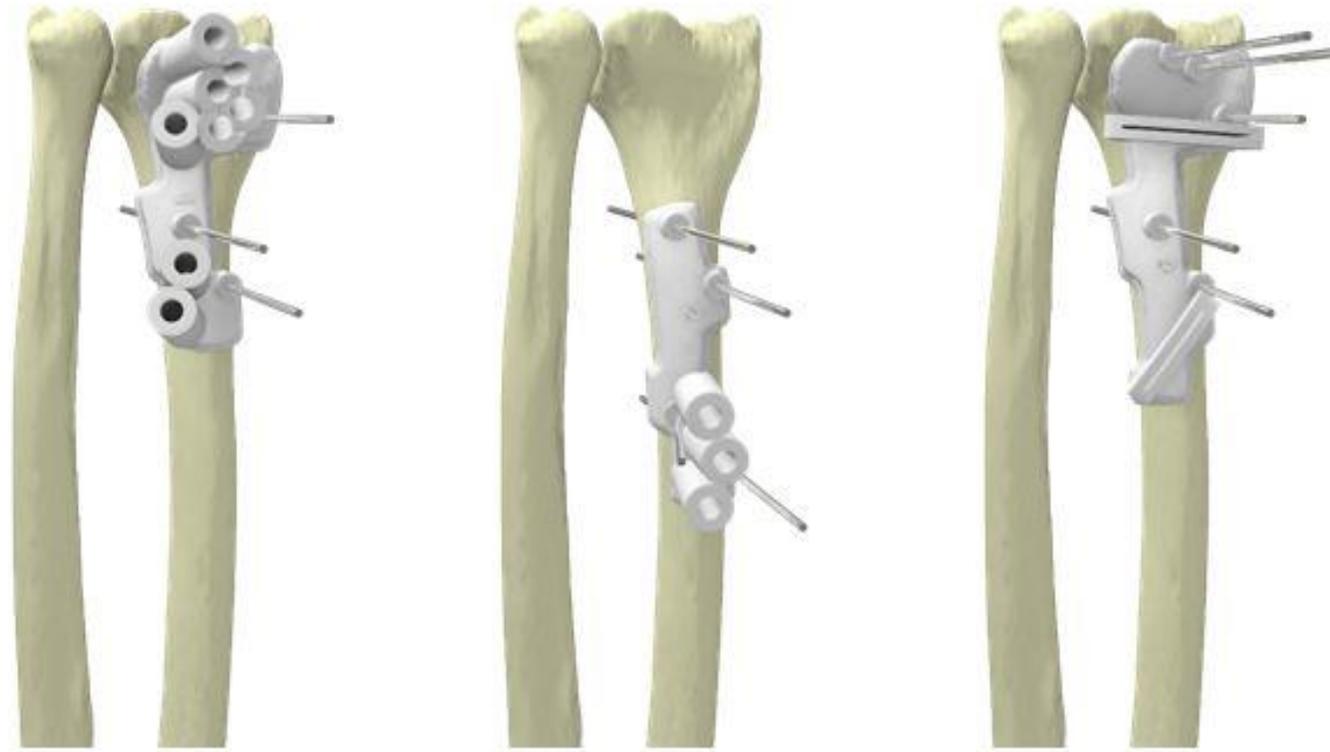
Réseau vasculaire<sup>16</sup>

# Domaine d'application : Planification des chirurgies

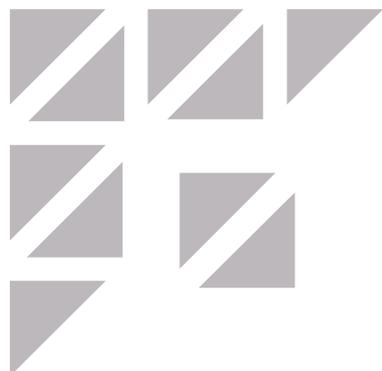


Modèle d'os en plastique pour la planification des chirurgies<sup>17</sup>

# Domaine d'application : Outils chirurgicaux

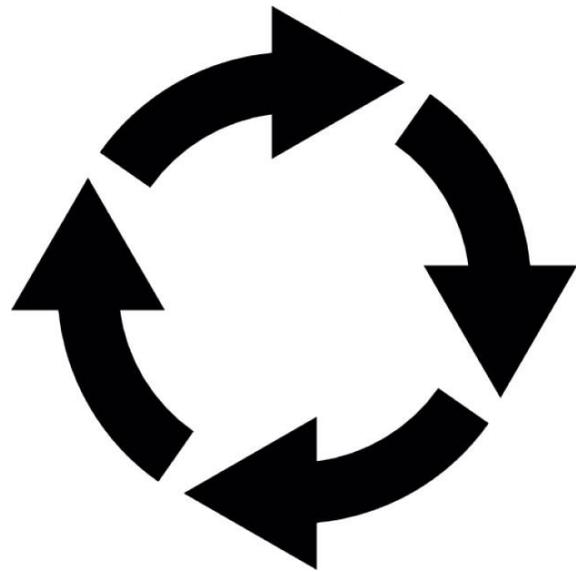


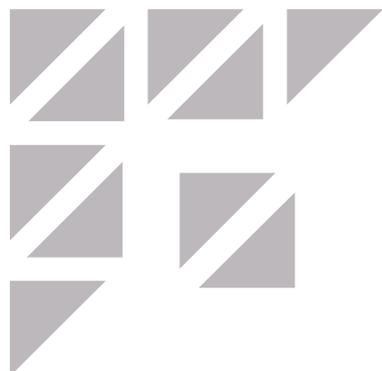
Guides de coupe chirurgicaux<sup>18</sup>



# Perspectives d'avenir et défis

- Intégration de l'impression 3D

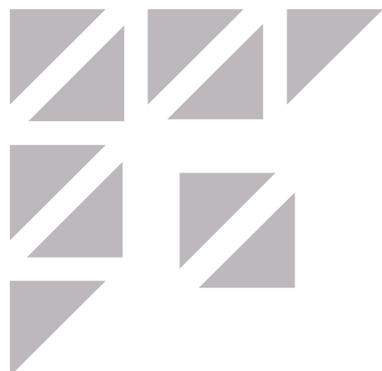




# Perspectives d'avenir et défis

- Affaires réglementaire





# Perspectives d'avenir et défis

FDA IMPACT ON U.S.  
**MEDICAL**  
**TECHNOLOGY**  
**INNOVATION**

A Survey of Over 200 Medical Technology Companies

PREPARED BY **Josh Makower, MD** Consulting Professor of Medicine, Stanford University;  
CEO, ExploraMed Development, LLC; Venture Partner, NEA • **Abed Meer** MD-MBA  
Candidate, Stanford University • **Lyn Denend** Research Associate, Stanford University

WITH SUPPORT FROM Medical Device Manufacturers Association (MDMA) • National  
Venture Capital Association (NVCA) • And multiple State medical industry organizations

INDEPENDENT DATA ANALYSIS AND VERIFICATION BY PricewaterhouseCoopers LLP

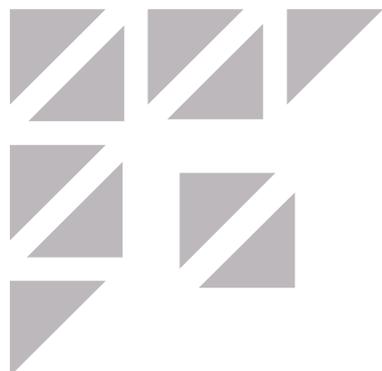


# Perspectives d'avenir et défis



Unpredictable, inefficient, and expensive regulatory processes are jeopardizing America's leadership position in medtech innovation.





# Perspectives d'avenir et défis

1                   **Technical Considerations for**  
2                   **Additive Manufactured Devices**

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3  
4  
5                   **Draft Guidance for Industry and**  
6                   **Food and Drug Administration Staff**

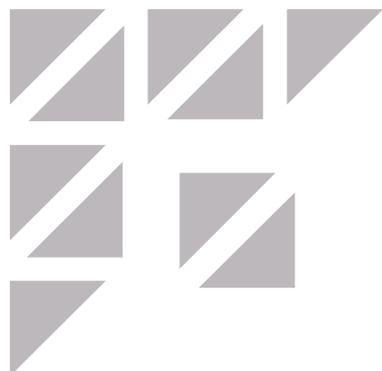
7  
8                   *DRAFT GUIDANCE*

9  
10                  **This guidance document is being distributed for comment purposes only.**

11  
12                                  **Document issued on May 10, 2016.**

13  
14                  You should submit comments and suggestions regarding this draft document within 60 days of  
15                  publication in the *Federal Register* of the notice announcing the availability of the draft  
16                  guidance. Submit electronic comments to <http://www.regulations.gov>. Submit written  
17                  comments to the Division of Dockets Management (HFA-305) Food and Drug





# Références

<sup>1</sup><http://3dtoday.ru/upload/main/692/69208305ddfd4d8bfed90c377ea7ac78.jpg>

<sup>2</sup><https://mfgtalkradio.com/s1-e18/>

<sup>3</sup>[http://www.precisionmetalgroupp.com/wp-content/uploads/2016/09/iMachining3D\\_Live\\_cutting2.jpg](http://www.precisionmetalgroupp.com/wp-content/uploads/2016/09/iMachining3D_Live_cutting2.jpg)

<sup>4</sup><http://tongengineering.com/wp-content/uploads/2015/12/Close-Laser-Cutting.jpg>

<sup>5</sup>[http://www.smartclima.com/wp-content/uploads/2014/11/sheet\\_metal-bending-process.jpg](http://www.smartclima.com/wp-content/uploads/2014/11/sheet_metal-bending-process.jpg)

<sup>6</sup>[http://www.istockphoto.com/ca/photo/sliced-multi-grain-bread-gm528318087-53553338?esource=SEO\\_GIS\\_CDN\\_Redirect](http://www.istockphoto.com/ca/photo/sliced-multi-grain-bread-gm528318087-53553338?esource=SEO_GIS_CDN_Redirect)

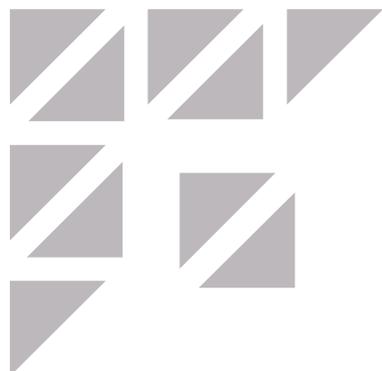
<sup>7</sup><https://www.sculpteo.com/blog/wp-content/uploads/2016/12/History-3DP-blog.jpg>

<sup>8</sup>[https://fr.3dsystems.com/sites/default/files/styles/image\\_general\\_full\\_size/public/2017-02/Projet7000-Angle-940px\\_hero\\_0.png?itok=6SGcVjc\\_](https://fr.3dsystems.com/sites/default/files/styles/image_general_full_size/public/2017-02/Projet7000-Angle-940px_hero_0.png?itok=6SGcVjc_)

<sup>9</sup>[https://3dprint.com/wp-content/uploads/2016/04/3dp\\_geplant\\_fuel\\_nozzle-e1459756191474.jpg](https://3dprint.com/wp-content/uploads/2016/04/3dp_geplant_fuel_nozzle-e1459756191474.jpg)

<sup>10</sup>[http://media.npr.org/assets/img/2015/09/15/sternumimplant\\_wide-7779ce45ec0d0076c96a1c2d703a607b53bc3617-s900-c85.jpg](http://media.npr.org/assets/img/2015/09/15/sternumimplant_wide-7779ce45ec0d0076c96a1c2d703a607b53bc3617-s900-c85.jpg)





# Références

<sup>11</sup>[https://www.sciencenewsforstudents.org/sites/student.societyforscience.org/files/main/articles/cool\\_jobs\\_math\\_gyroid\\_grossman\\_01.jpg](https://www.sciencenewsforstudents.org/sites/student.societyforscience.org/files/main/articles/cool_jobs_math_gyroid_grossman_01.jpg)

<sup>12</sup>[http://www.prototypetoday.com/media/k2/galleries/4730/EOS\\_Medical\\_Alphaform\\_Instrument\\_aria\\_HipImplant\\_Download1.jpg](http://www.prototypetoday.com/media/k2/galleries/4730/EOS_Medical_Alphaform_Instrument_aria_HipImplant_Download1.jpg)

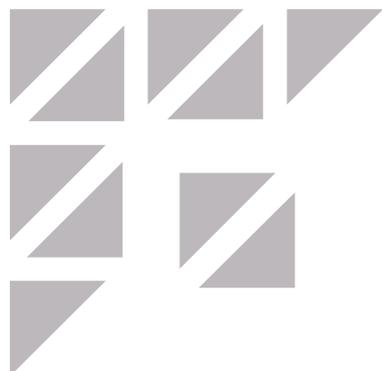
<sup>13</sup>[https://www.geek.com/wp-content/uploads/2015/09/titanium-sternum\\_ribs-625x350.jpg](https://www.geek.com/wp-content/uploads/2015/09/titanium-sternum_ribs-625x350.jpg)

<sup>14</sup>[https://static.dezeen.com/uploads/2015/10/Custom-fit-3D-printed-medical-implant-bone-reconstruction-Sebastiaan-Deviaene\\_dezeen\\_04\\_468.jpg](https://static.dezeen.com/uploads/2015/10/Custom-fit-3D-printed-medical-implant-bone-reconstruction-Sebastiaan-Deviaene_dezeen_04_468.jpg)

<sup>15</sup><https://www.3dprintingbusiness.directory/news/wp-content/uploads/2017/04/1-craniomaxillofacial-skull-implant-640x559.jpg>

<sup>16</sup>André Bégin-Drolet, Marc-André Dussault, Stephanie A. Fernandez, Jeanne Larose-Dutil, Richard L. Leask, Corinne A. Hoesli, Jean Ruel, 2016, Design of a 3D printer head for additive manufacturing of sugar glass for tissue engineering applications





# Références

<sup>17</sup><http://www.prodways.com/en/wp-content/uploads/sites/2/2016/10/3D-printing-medical-3D-printed-surgical-guide.jpg>

<sup>18</sup><http://3dprintingindustry.com/wp-content/uploads/2015/07/materialise-lima-kneww.jpg>

