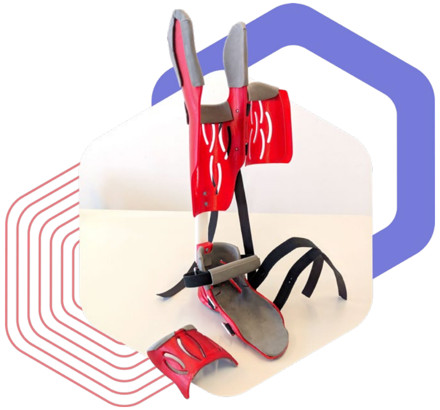
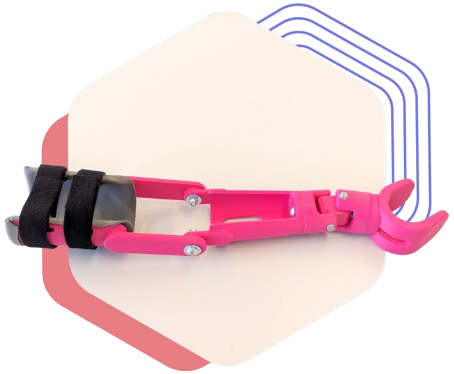
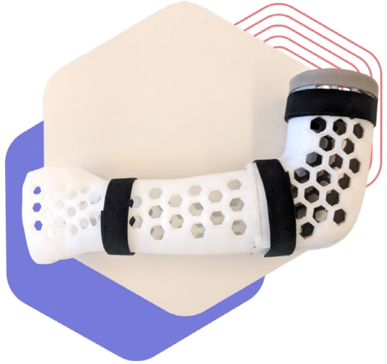
Automated CAD design and rapid prototyping of anatomically adjusted orthoses and prostheses







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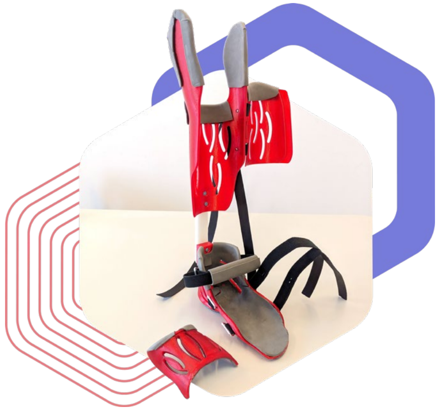
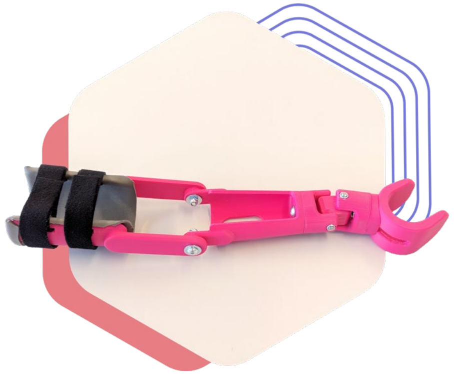
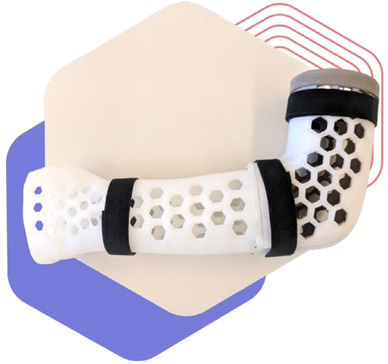






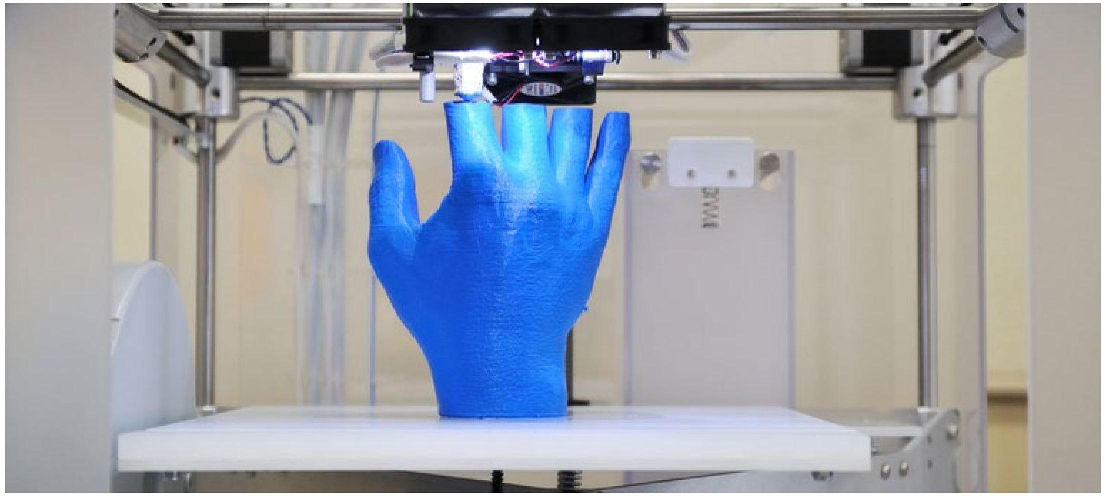
PLAN OF THE PRESENTATION

1. Introduction
2. AutoMedPrint system
3. Case study – ankle foot orthosis
4. Case study – bicycle prosthesis
5. Conclusions

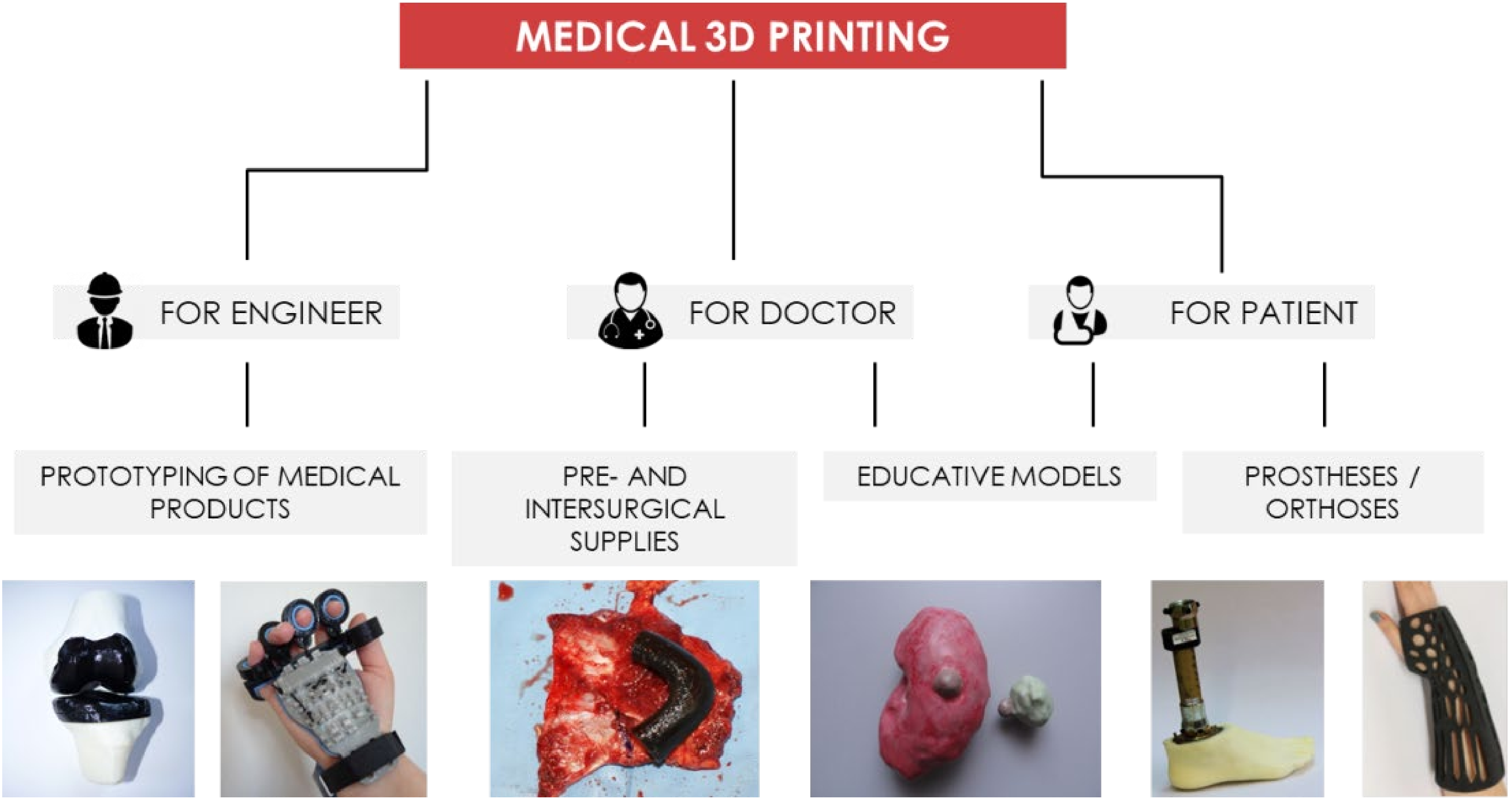
INTRODUCTION

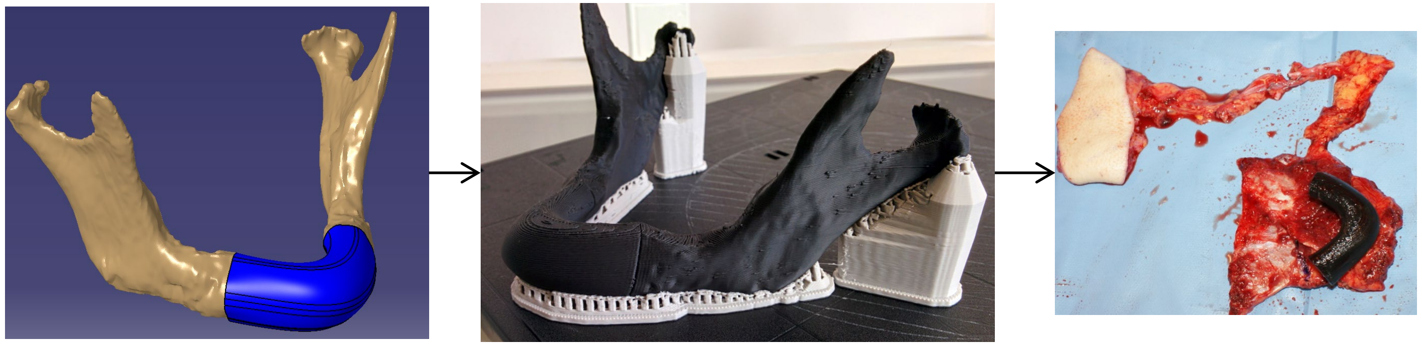
INTRODUCTION

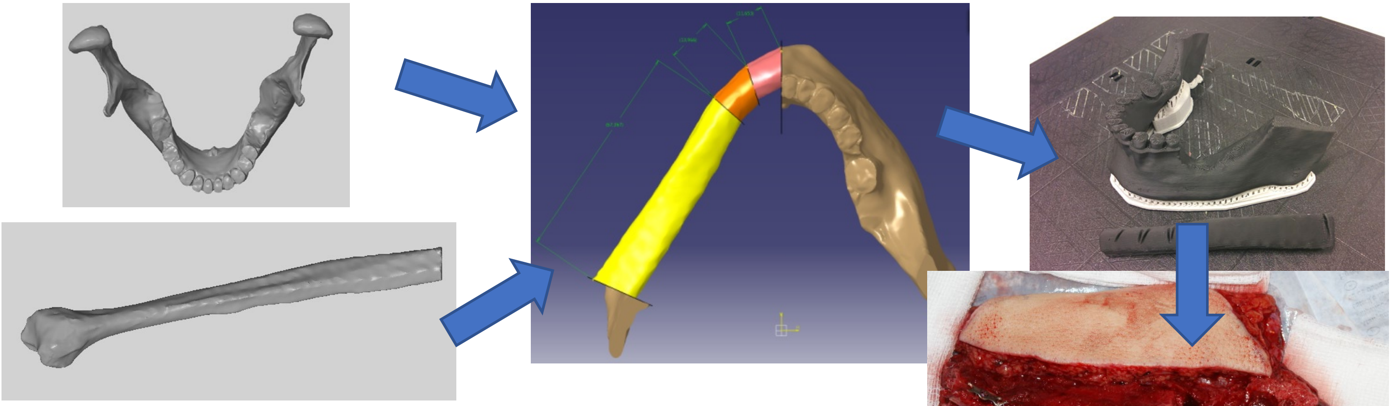
- CAD + 3D printing + medicine = brave new world, ocean of new, not yet fully utilized possibilities
- Medicine = working for the people
- EMERALD – education in 3D printing of biomimetic devices

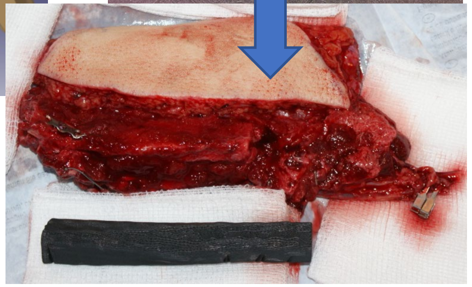


CAD+3D PRINTING IN MEDICINE





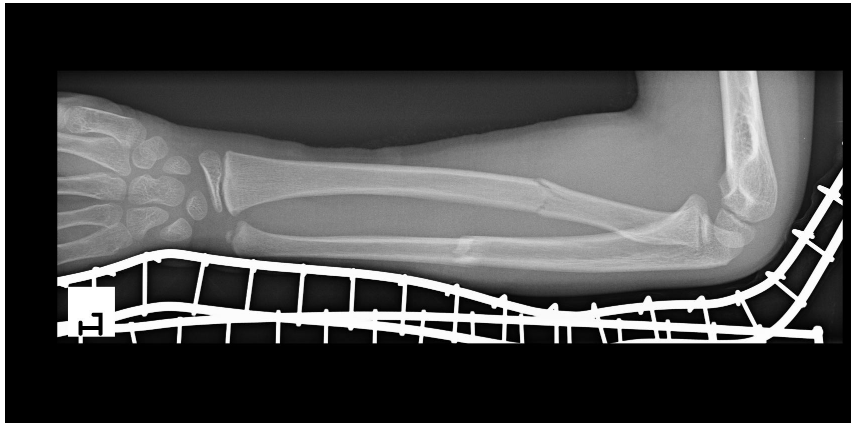




Cancer patients – life-changing reconstructive surgery

48 hours between diagnostics and surgery

Zosia and her 3D hands (some of them)



Janek and his fancy 3D printed broken arm stabilizer

3 iterations in 3 days!

IT WORKS!

- proper design helps patients and doctors
- 3D printing allows fast iterating
- we can also automate it

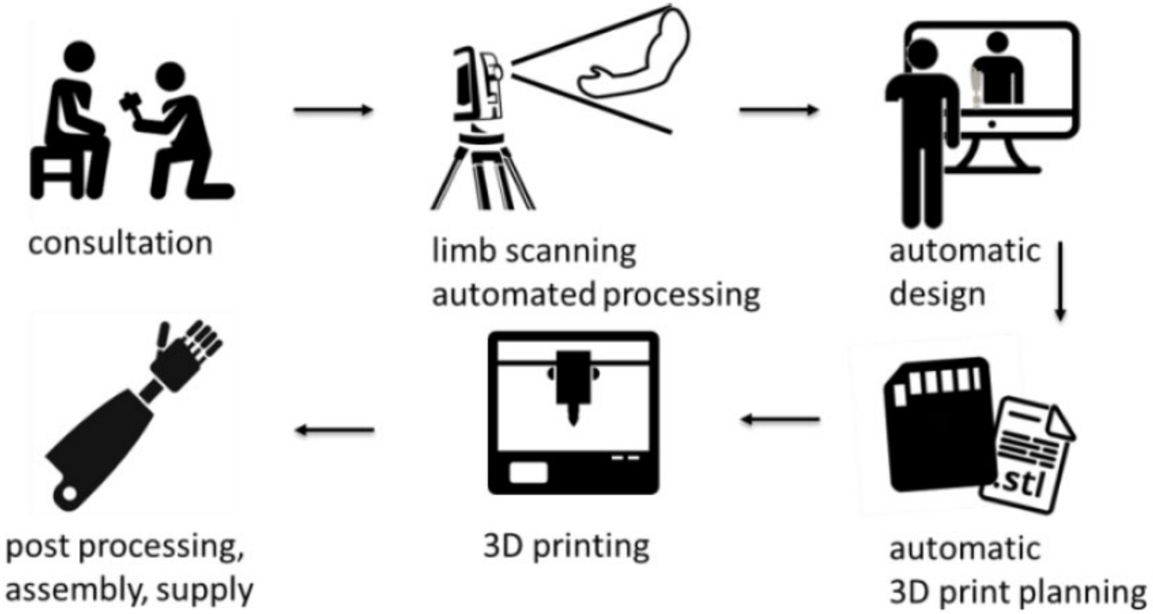
AUTOMEDPRINT SYSTEM

rapid manufacturing of anatomical orthopedic supplies

AUTOMEDPRINT – SYSTEM FOR 3D PRINTING OF ORTHOSES AND PROSTHESES

- orthoses and prostheses developed by AutoMedPrint system
- the process consists in 3D scanning, design and 3D printing

AutoMedPrint



LIDER

Narodowe Centrum Badań i Rozwoju

AUTOMEDPRINT – PRODUCT DEVELOPMENT WORKFLOW

3D scanning
- use of mechanized or manual scanning workplace
- automated processing algorithms
- automated data extraction

CAD design
- Inventor, MeshLab
- intelligent (automated) models
- solid and surface modelling

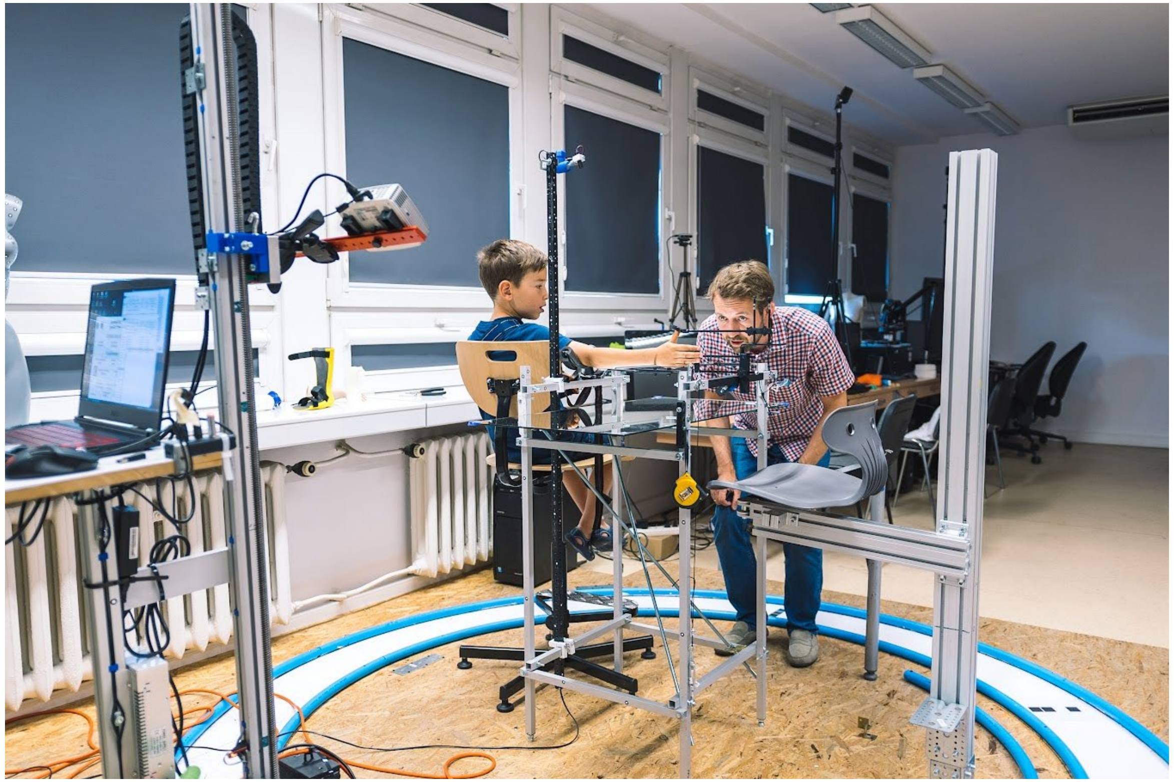
CAE analysis
- FEA strength analysis of obtained anatomical products

VR/AR
- system work simulation in immersive VR
- product configuration in VR
- product visualization in AR (virtual mirror)

3D printing + assembly
- FDM/FFF
- PLA/ABS/PETG/nylon filament
- post processing
- assembling parts

Quality check + testing
- 3D scanning and imaging
- strength testing
- fit testing
- functional testing with patients

3D SCANNING



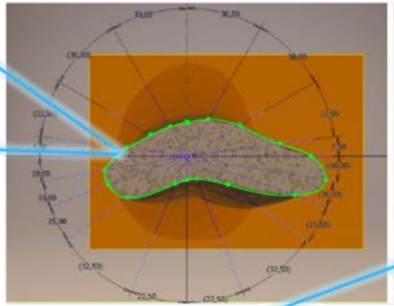
mechanized stand

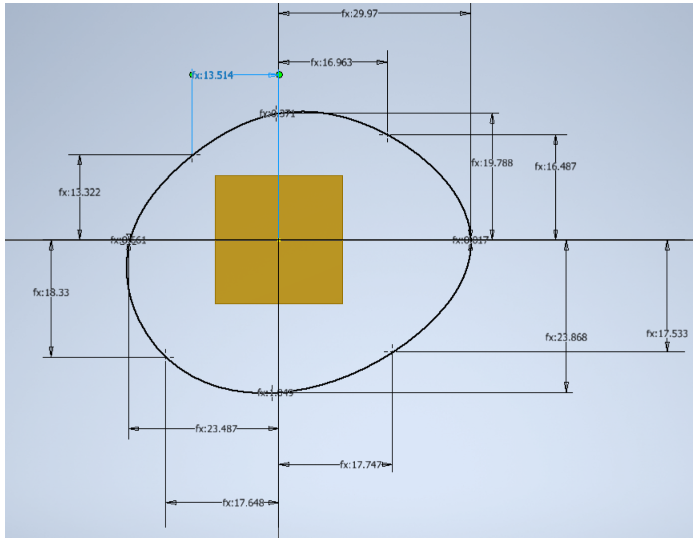
manual scanner

CAD DESIGN

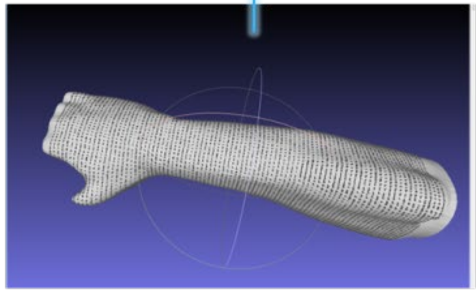
x1_11	0
x1_12	32,541
x1_13	41,769
x1_14	34,588
x1_15	0
x1_16	29,888
x1_17	39,448
x1_18	29,263
y1_11	53,474
y1_12	32,541
y1_13	0
y1_14	34,588
y1_15	48,3
y1_16	29,888
y1_17	0
y1_18	29,263

spline curves approximating the shape of limb in a given location

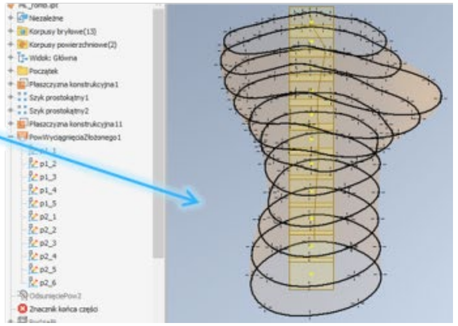


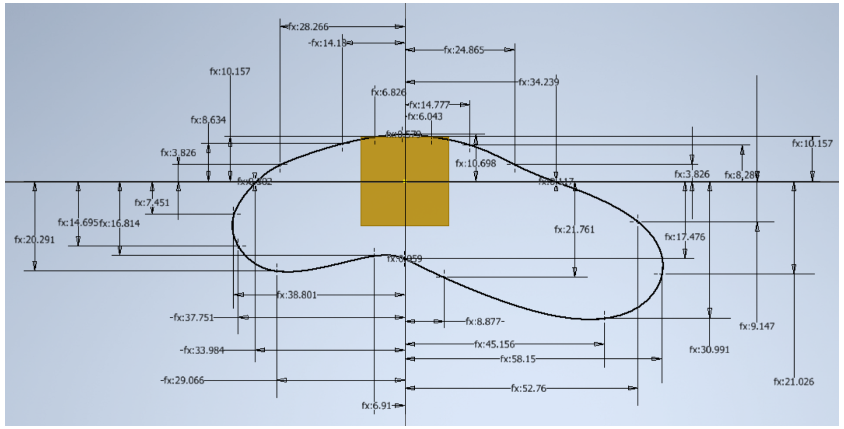


patient data extracted from the 3D scan

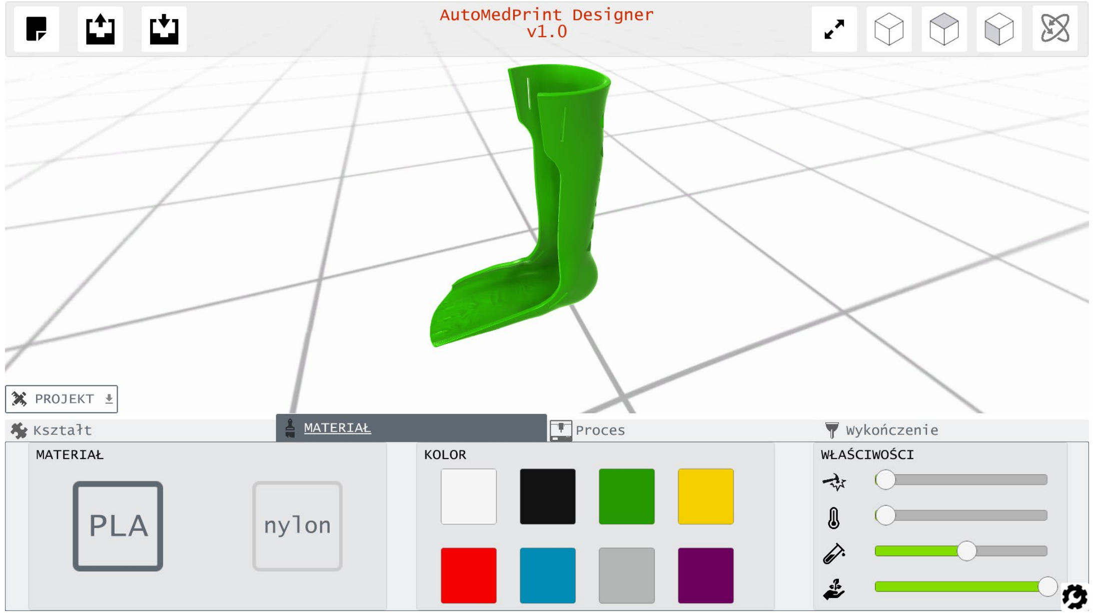


full parametric limb reconstruction using extracted data





VIRTUAL REALITY – DESIGN AID



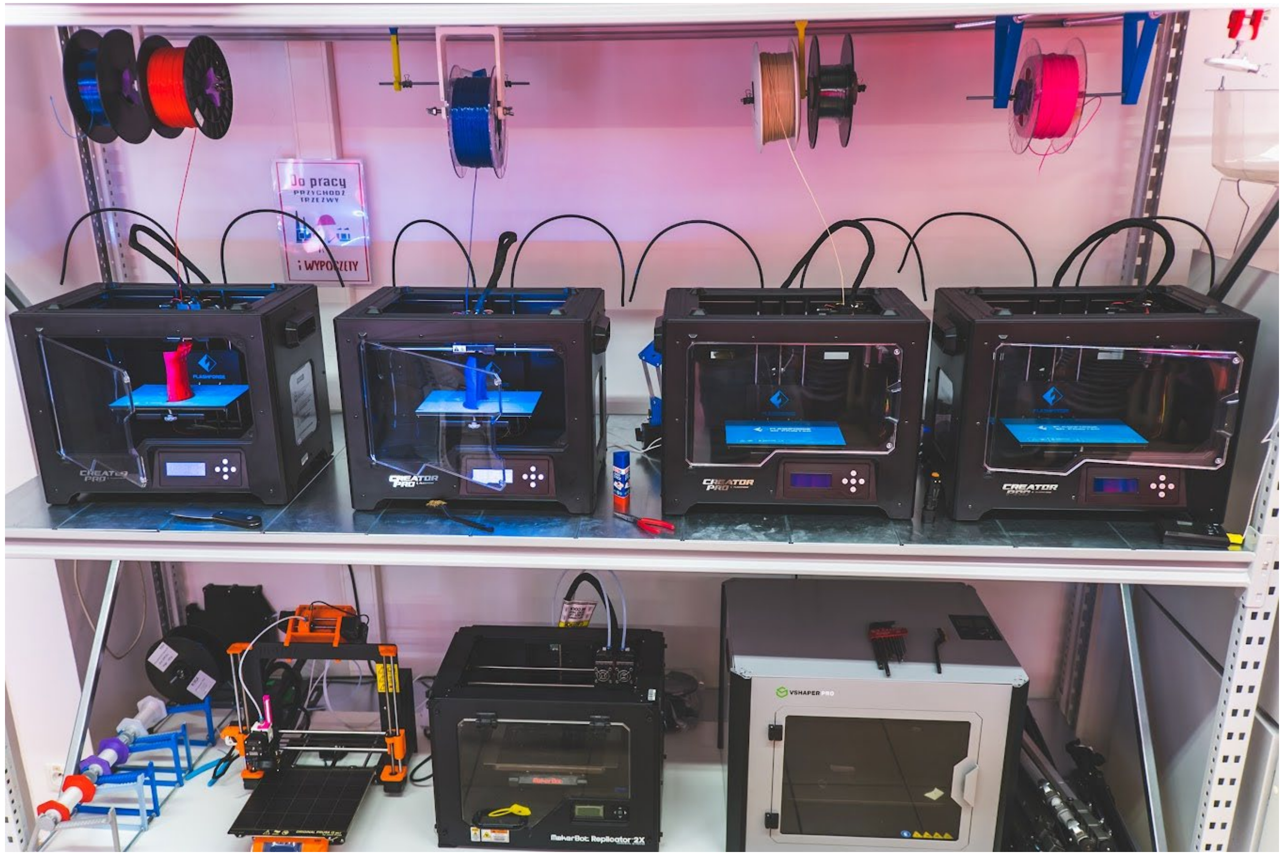
3D product configurator

immersive VR simulation

3D PRINTING

Virtual laboratory available at

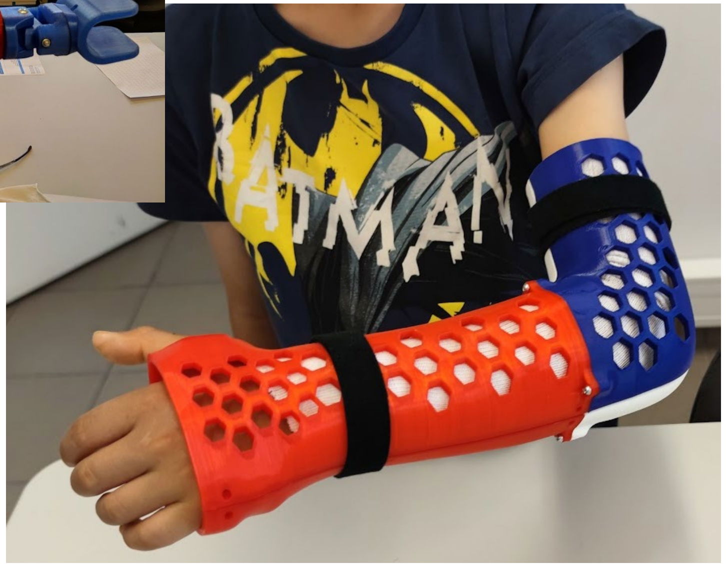
3dspot.pl/120BM



FDM printers – standard (cartesian)

FDM printers – Delta

PATIENT TESTING



AUTOMEDPRINT
POLISH PRODUCT OF THE FUTURE

- AutoMedPrint system was awarded the Polish Product of the Future award in July 2022 by Polish Ministry of Science
- the system was evaluated as a breakthrough innovation due to automation, allowing obtaining ready products (orthoses, prostheses) quickly and cheaply

Polski Produkt Przyszłości

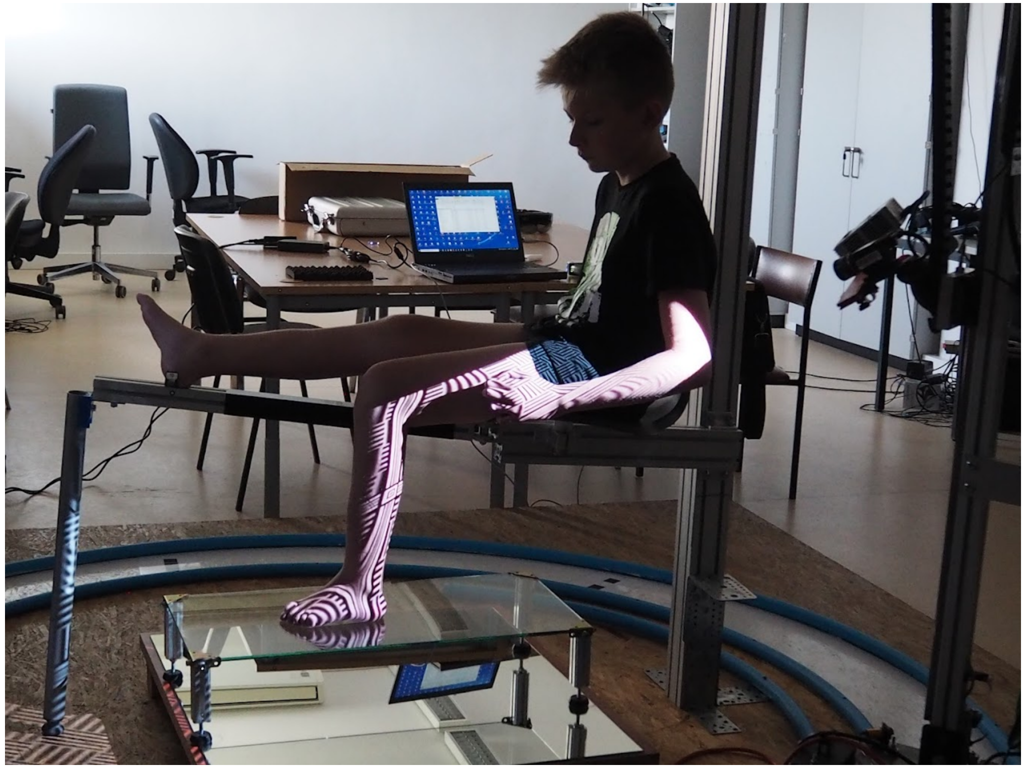
AutoMedPrint

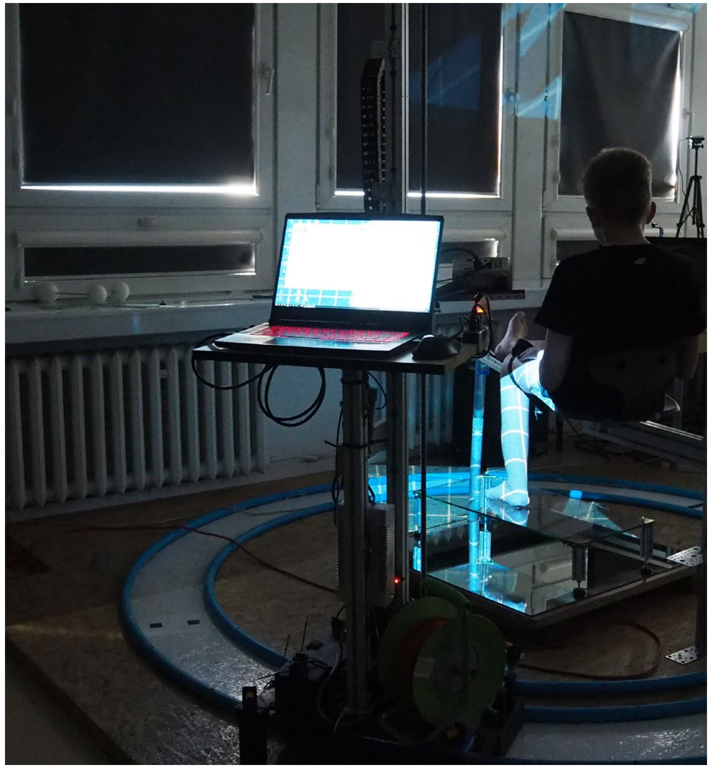
CASE #1
INDIVIDUALIZED ANKLE FOOT ORTHOSIS

THE CONCEPT AND THE NEED

- Miłosz – 13-year old with spina bifida
- most patients with this condition are unable to walk
- Miłosz can walk in specialized, very expensive orthoses
- the orthoses cannot be used in water
- special orthoses needed for swimming and pool use!

3D SCANNING

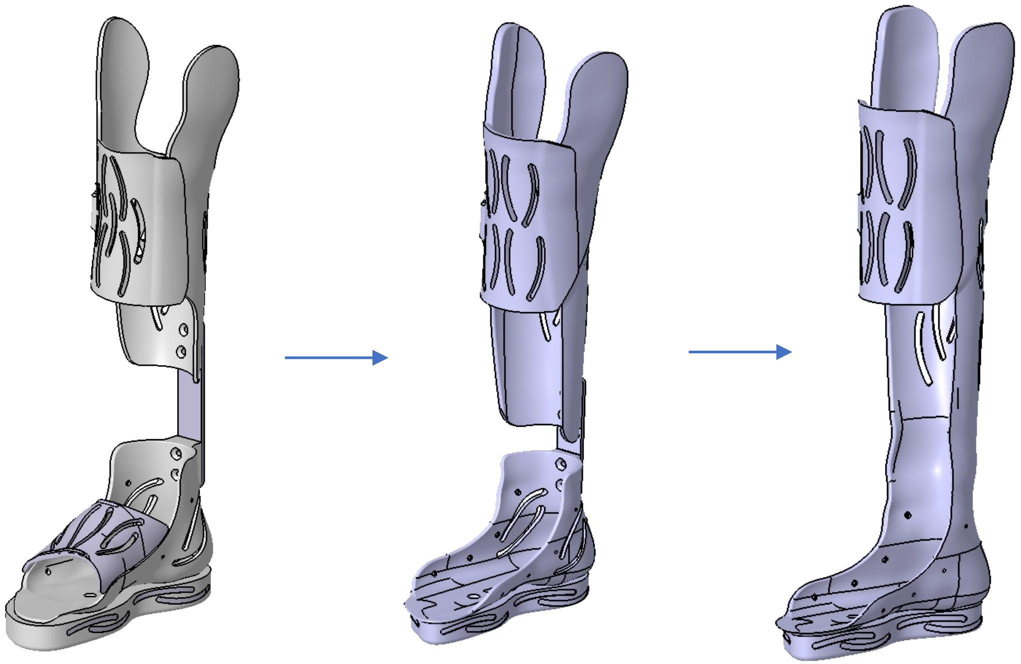




- David SLS-3 + mechanized stand
- EinScan Pro for additional scanning
- automated algorithm for scan joining and processing (MeshLab)

DESIGN

3-layered hybrid model
wireframe + surface + solid



shape change – 3 basic iterations with sub-iterations (total 6 versions for both legs)

MANUFACTURING

- FDM technology,
- PET-G - delta-type machine (height), TEVO Little Monster
- PA12 (nylon) – Zortrax M300 machine
- weight: ~800g right leg, ~680g left leg – PETG, ~570g right leg, ~430g left leg - nylon
- time: ~1500 minutes per leg – PETG, ~3500 minutes per leg - nylon

POST PROCESSING, ASSEMBLY

- manual grinding and polishing
- EVA foam used for internal filling
- velcro straps, rivets, nuts and bolts – for assembly

PROTOTYPING, TESTING



- V1 – fitting problems, unstable, some components unnecessary

- V2 PETG – failed during walk
- V2 nylon – failed after some time

-V3 - successful

FINAL VERSION

CONCLUSIONS

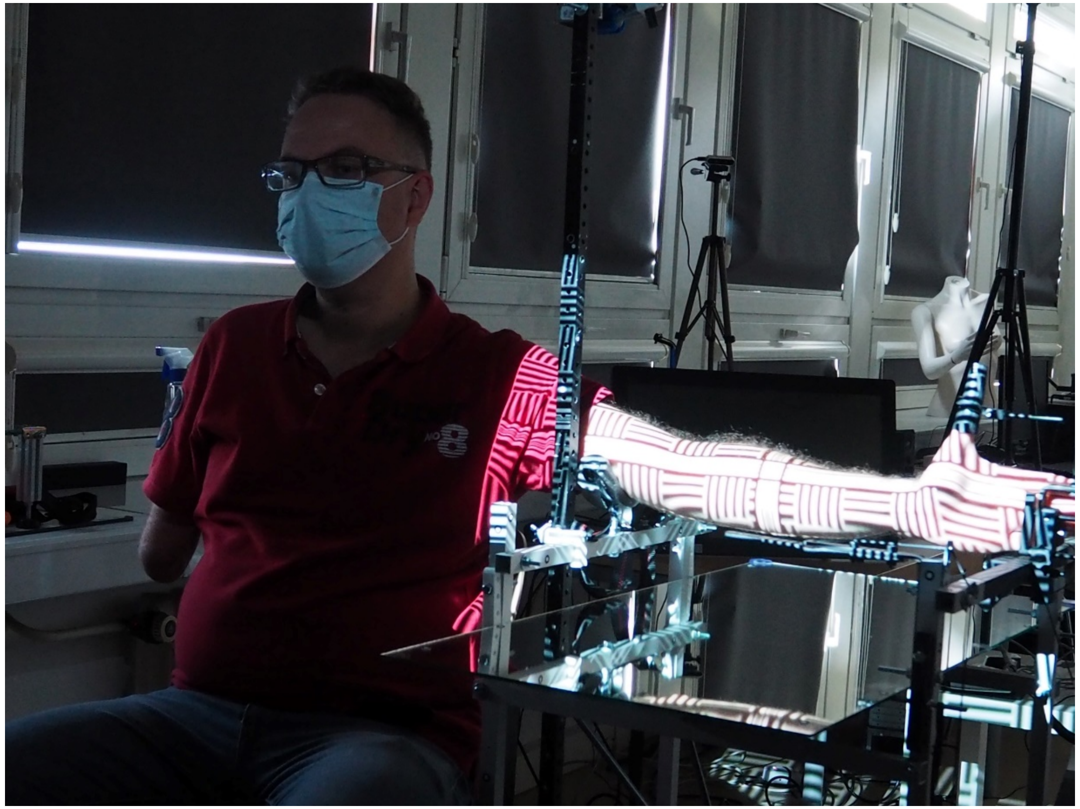
- it is possible to create useful orthoses for a very difficult case by a fraction of a price of commercial equipment!
- design iteration can take time (3 months)
- leg orthoses are difficult for standard FDM (strength!)
- easier for smaller children, difficult for teenagers and adults
- without 3D printing – only manual, very expensive work

CASE #2
INDIVIDUALIZED BICYCLE PROSTHESIS

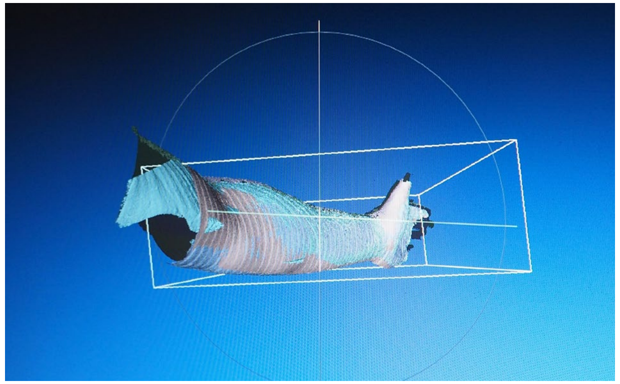
THE CONCEPT AND THE NEED

- Maciej, 40 years old, passionate cyclist
- born with no right forearm
- tested dozens of prostheses in his lifetime, not a single one allowed for comfortable and safe bicycle riding

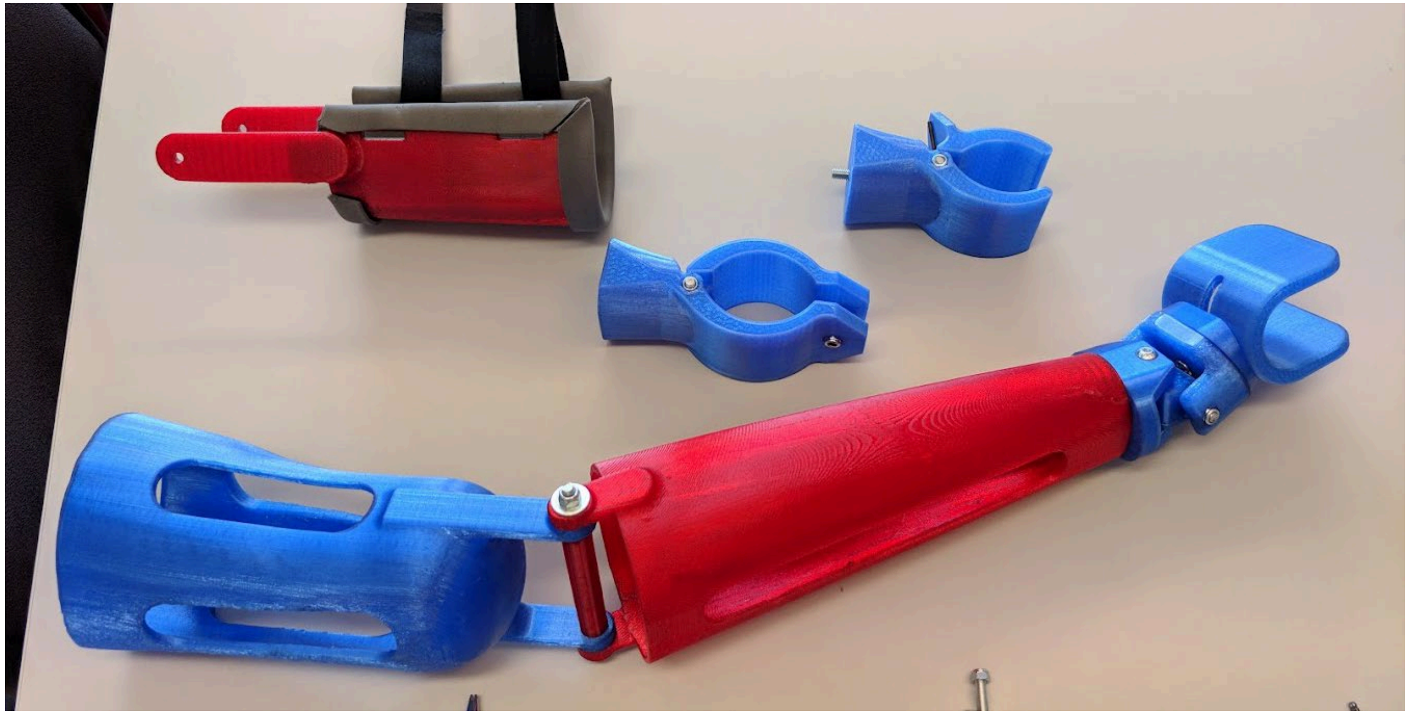
3D SCANNING AND DESIGN



- 3d scanning using AutoMedPrint system (David SLS-3 scanner)
- design based on bicycle prosthetics for children
- modular construction of the prosthesis, with interchangeable parts



MANUFACTURING

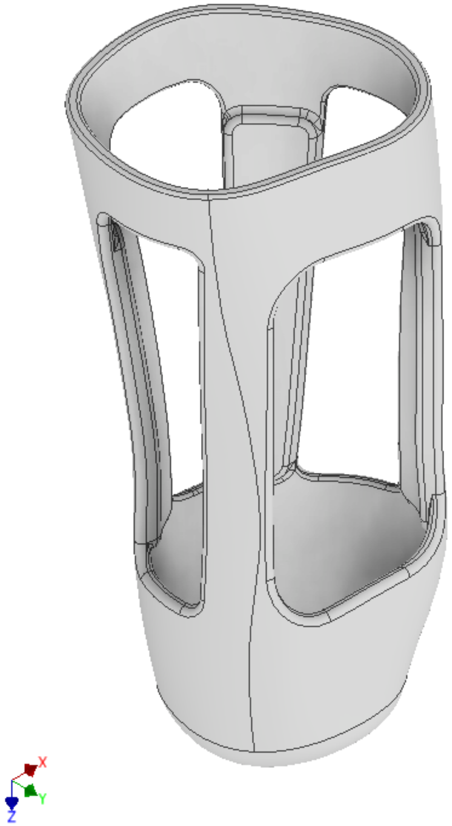


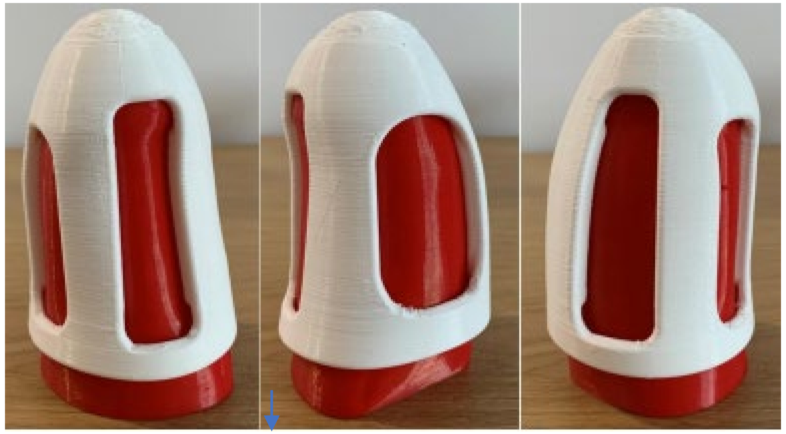
- regular FDM 3D printing – FlashForge Creator Pro, Creality machines
- PLA/PETG/nylon used
- final version: PLA, with emphasis on strength

PROTOTYPING, TESTING – BASIC PROSTHESIS

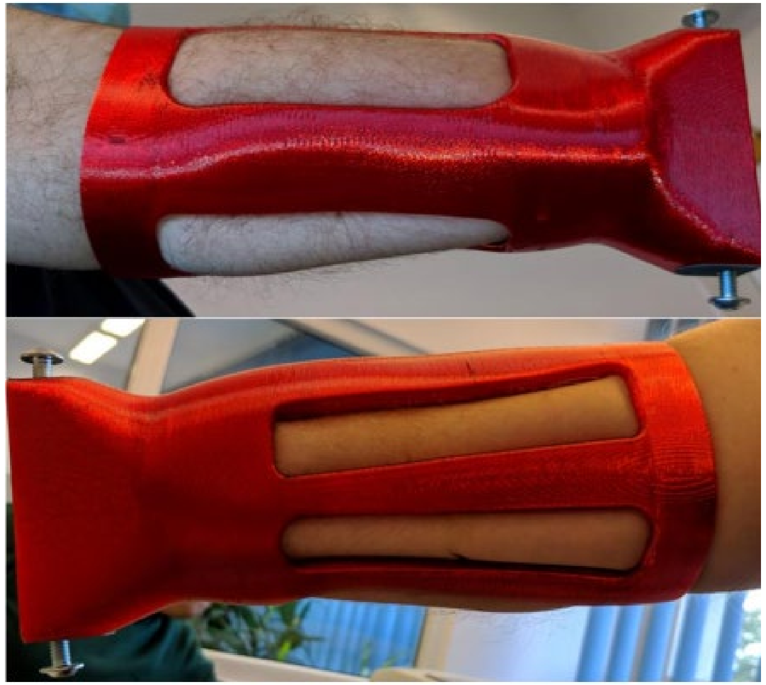
- 3 versions of the end effector
- 3 versions of socket
- 2 material versions

PROTOTYPING, TESTING – NEW PROSTHETIC SOCKET





- experimental compressive-release socket (CRS)
- testing – 1) digital 2) phantom 3) patient



FINAL VERSION

CONCLUSIONS

- potential of 3D printing in prosthetics is probably not used very efficiently
- needs of adult patients are very different than children patients
- functional, specialized prosthesis can be 3D printed for a fraction of a cost of a traditional, expensive one
- design changes can be introduced anytime, as many times as feedback is gathered from patients
- 3D printed prostheses and orthoses could be converted into mechatronic devices by adding sensors and actuators, helping in therapeutic or daily activities

EMERALD PROJECT

- EMERALD: focus on teaching bio-mechatronics – how to create 3D printed anatomically shaped orthoses and prostheses with mechatronic components
- 4 case studies – in work
- 8 teaching modules (e-books) – available in September
- 8 toolkits – in work
- virtual platform – in work

Thank you for your attention!

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