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BRIGHT

Erasmus+ strategic partnership for Higher Education

BOOSTING THE SCIENTIFIC EXCELLENCE AND INNOVATION CAPACITY OF 3D PRINTING METHODS IN PANDEMIC PERIOD

O4 - BRIGHT CAD e-learning webinar

Project Title	**Boosting the scientific excellence and innovation capacity of 3D printing methods in pandemic period 2020-1-RO01-KA226-HE-095517**
Output	**O4 - BRIGHT e-learning webinars on the use of 3D printing technologies in development, testing and producing of medical parts in pandemic period – CAD e-learning webinar description**
Date of Delivery	**30 November 2022**
Authors	**Filip Górski, Magdalena Żukowska, Mate Babic**
Version	**FINAL VERSION**

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1 Introduction

This is a documentation regarding the webinar #1 of the BRIGHT project, focused on computer aided design (CAD) of selected medical products. It presents methodology of creation of 3 specific product cases:

1. individualized wrist ortosis, using the AutoMedPrint system (https://automedprint.put.poznan.pl)
2. individualized pre-operative model of a tongue with cancer tumor
3. personal face protection shield

Complete design processes are shown, including 3D scanning, medical image processing and work in various CAD systems and digital tools to obtain designs ready for 3D printing.

The webinar was realized in the scope of BRIGHT project in year 2022 and is a direct result of IO4 - BRIGHT e-learning webinars related to the use of 3D printing technologies in the process of development, producing and testing of medical parts that can support hospitals in pandemic period.

The webinar is available on the BRIGHT project website by accessing the following link: https://bright-project.eu/?p=342

Webinar can be accessed directly also from YouTube, by accessing the following link: https://www.youtube.com/watch?v=FHLqj7sNMiM

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2 BRIGHT e-learning webinar #1 - CAD

2.1 Main concepts and scheme of work

The BRIGHT e-learning webinar on CAD is the first in the series of freely available educational videos, in which lecturers, scientists and practitioners from BRIGHT consortium present various aspects related to 3D printed medical parts, based on selected practical cases. The webinar presents various techniques of data gathering and processing in order to obtain digital models of selected medical parts, ready for further work. Place of this webinar in the whole series is marked in Figure 1.

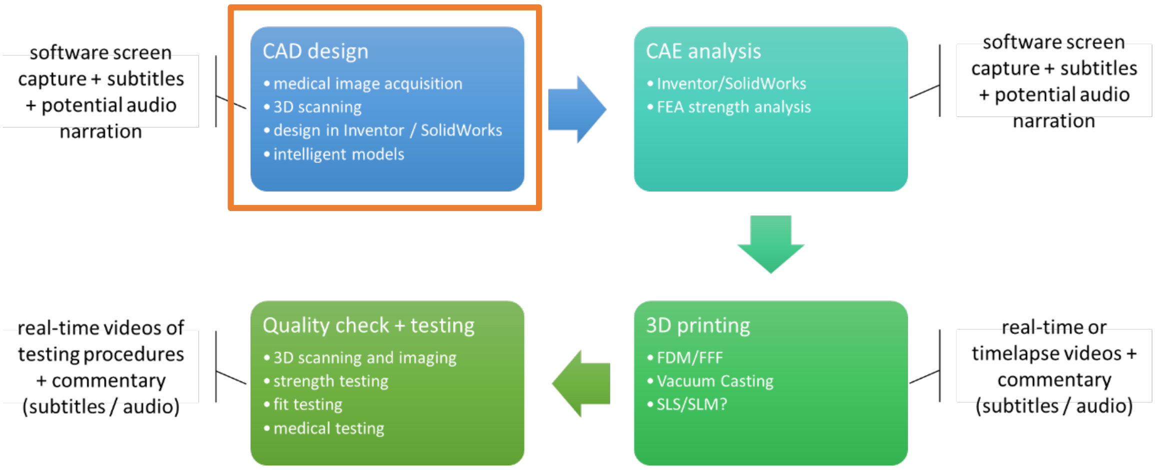

Figure 1. Place of CAD webinar among other webinars

The CAD webinar, as its name suggests, is focused on the design part. Its main purpose is first and foremost to introduce the viewers to the cases – different medical products manufactured with use of 3D printing – and to present detailed, various ways of designing various types of products. The presented techniques are cutting edge and innovative – some automation techniques are used, as well as smart, not obvious ways of data processing. The whole webinar takes approx. 1 hour and 10 minutes, but it is noteworthy that many processes have been sped up several times, in order to make it more interesting to the viewer. The webinar is available here: https://www.youtube.com/watch?v=FHLqj7sNMiM

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The webinar was taken for preparation by the team of Poznan University of Technology, generally most experienced in design of medical products of all partners in the consortium. Every part of the webinar, except modelling in case 3, was realized by team of PUT, in PUT laboratories. The general scenario with marked responsibilities is presented in table 1.

Table 1. General scenario and responsibilities for the webinar #1 – CAD

No.	Step (partial video)	Who?
1	Intro, review of cases	PUT
2	Case 1 – 3D scanning of patient	PUT
3	Case 1 – CAD design	PUT
4	Case 2 – DICOM processing	PUT
5	Case 2 – mesh processing	PUT
6	Case 2 – mold CAD design	PUT
7	Case 3 – CAD modelling	BM Plast
8	Outro	PUT

2.2 Case studies

3.2.1. Case 1 – Wrist Hand Orthosis

The first case study is an orthosis used for wrist joint stabilization in time after an injury such as fracture or for patients with conditions that require stabilization (rheumatoid arthritis, muscle atrophy and many others). The orthosis is openwork (with several possible shapes), to enable skin access in both comfort and hygienic reasons (Figure 2). It is 3D printed using FDM technology, with one of the basic FDM technology materials: PLA, ABS, PET-G and PA-12 (nylon).

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Figure 2. Wrist hand orthosis – different examples

The orthosis is customized on the basis of a non-contact measurement of geometry of patient's hand and forearm (or mirror image of the other limb, when the actual limb is damaged and e.g. wrapped in plaster cast). The measurement is done by optical 3D scanning, usually at the workplace developed as a part of the AutoMedPrint system, developed at Poznan University of Technology. After measurement, data is processed from raw scans to reconstructed, smooth limb model (Figure 3). Out of this model, sets of points are extracted to feed the intelligent CAD model.

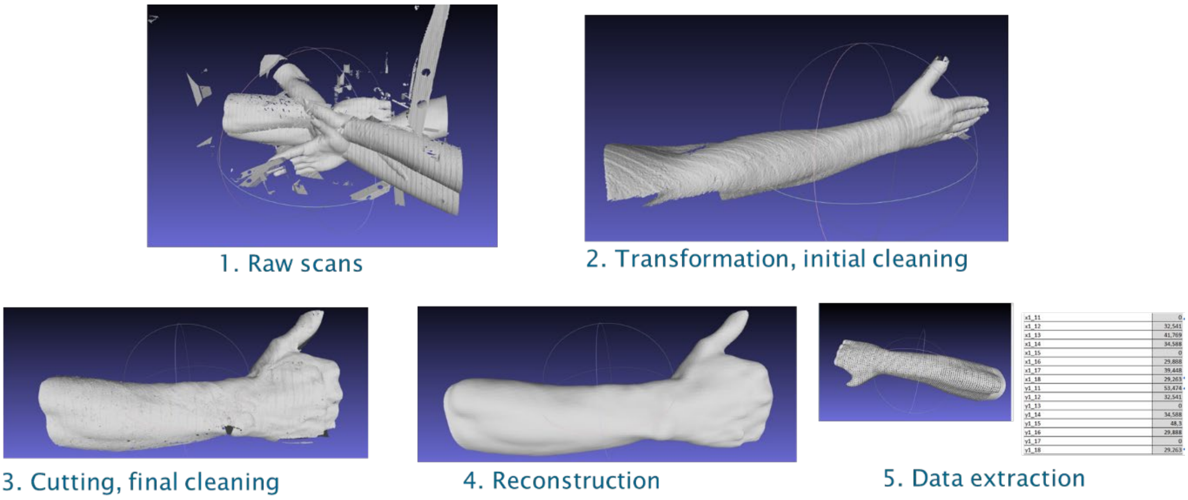

Figure 3. Data processing of 3D scans for the wrist hand orthosis model (AutoMedPrint system materials)

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The product was originally designed in the Autodesk Inventor CAD system (Figure 4), as an intelligent model – its design can be changed freely by supplying it with various data from 3D scanning, leading to automated re-design. The model and its know-how is a part of AutoMedPrint system developed at Poznan University of Technology (automedprint.put.poznan.pl), which was awarded as the Polish Product of the Future of year 2022.

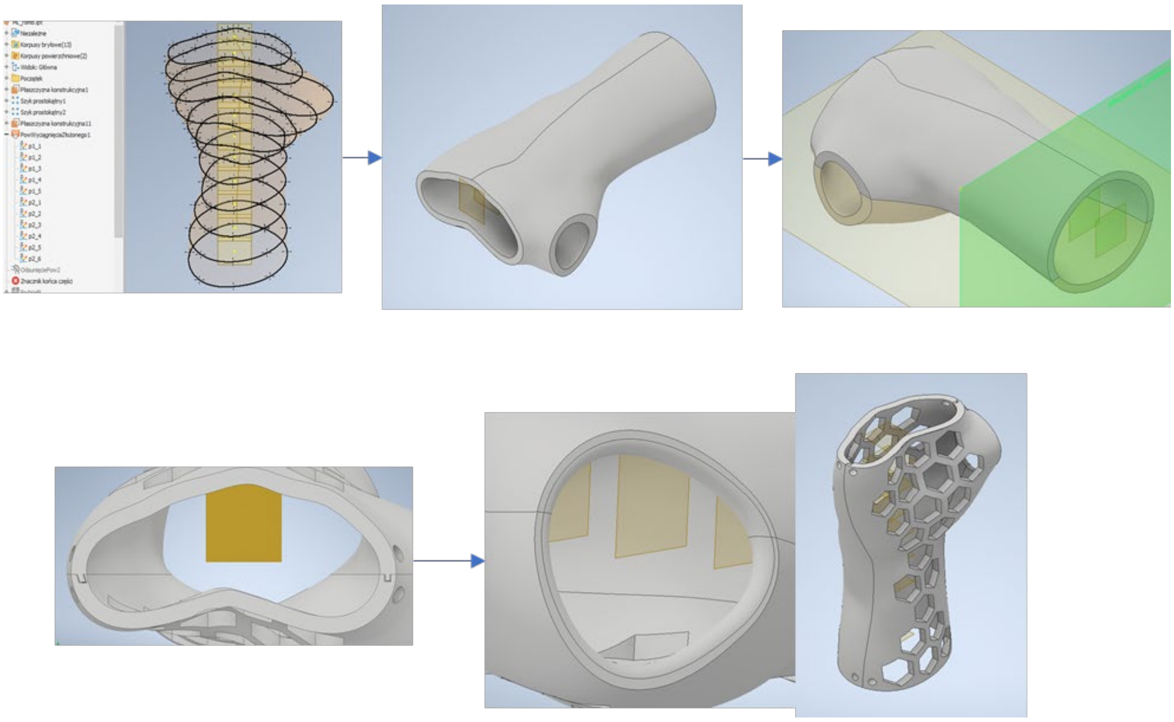

Figure 4. Design of orthosis in Inventor (AutoMedPrint system materials)

For the webinar, an actual case has been selected – a patient with current wrist injury was invited specially for realization of the webinars. The patient was a 26-year old man, with an injury to his right wrist, caused by bite of a dog resulting in some bone crush (Figure 5). A full process was undergone and recorded for him, finished with obtaining a complete functional orthosis.

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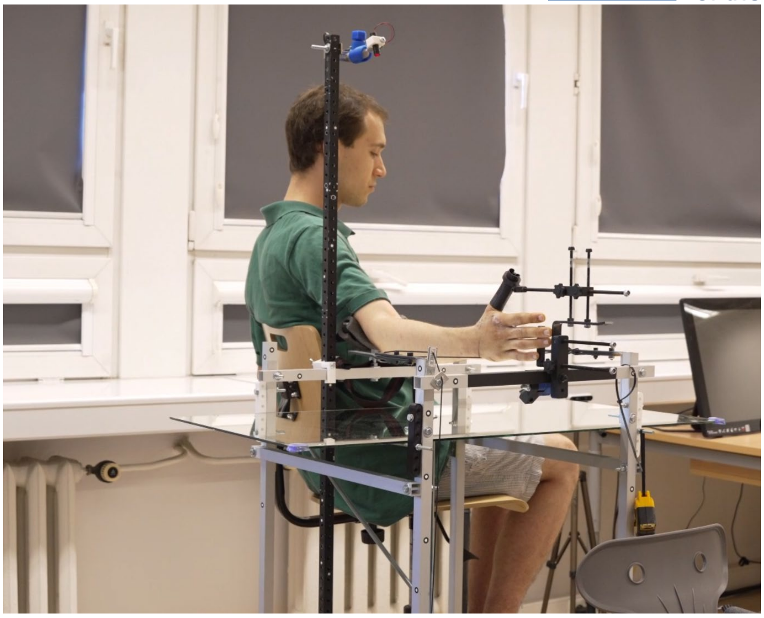

Figure 5. Selected case study – patient with injured hand

3.2.2. Case 2 – Tongue with cancer tumor

The second case study is an anatomical model of a tongue with cancer tumor. This type of model has a number of applications – first and foremost it is used as a pre-operative aid – for simulated surgery procedure. It is also used for mid-surgery support, to help with tissue reconstruction process (after sterilization, the model can be taken into the operating room). It can also be used for educational purposes (by students of medical universities) and for showing to the patient prior to the operation itself. The anatomical models of soft tissues can be produced either as hard models (for mid-surgery) or as soft ones (for simulated surgery before the operation), as shown in Figure 6.

Figure 6. Models of tongue with cancer tumor

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The product is customized basing on medical imaging – in the case of soft models, MRI is the most popular technique. Basic DICOM images require proper segmentation (Figure 7), then a 3D mesh is generated in STL format. It can be further processed – for hard 3D prints (using FDM, SLA, DLP or PolyJet) it can be used right away, but for soft resin, molds need to be created first and then they are printed (using FDM or PolyJet). A number of different software tools are used in the design process, starting from medical image processing software (Invesalius), through mesh processing software (GOM Inspect, MeshMixer etc.) and CAD software (Inventor).

Figures 7-9 present subsequent stages of design, starting with DICOM segmentation, through anatomical, smoothed mesh and finally – mold for casting.

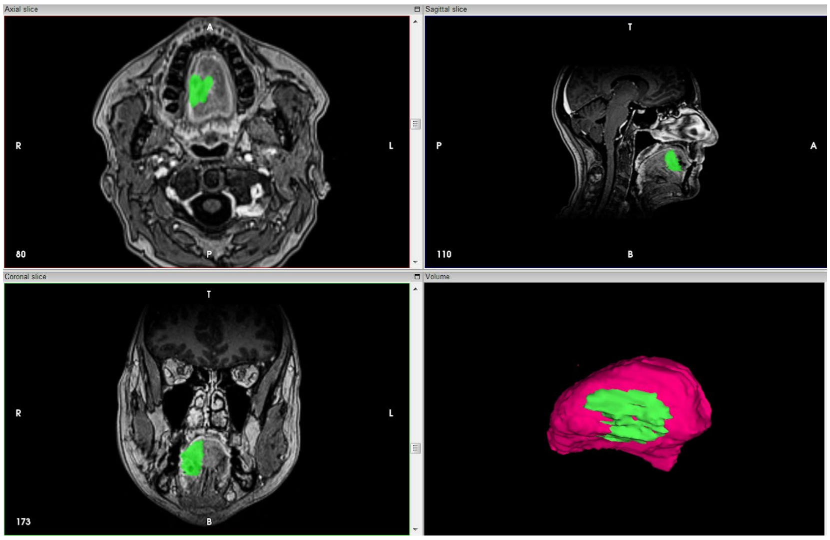

Figure 7. DICOM segmentation process

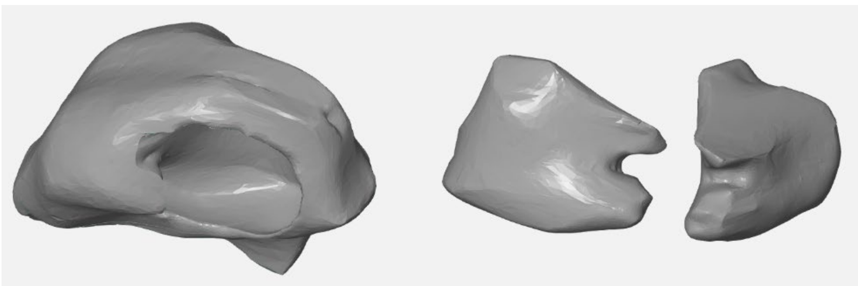

Figure 8. Design process – smoothed mesh

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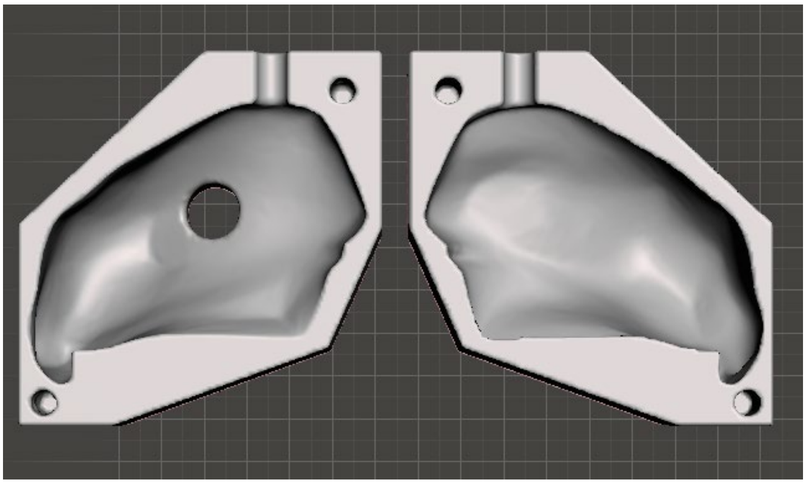

Figure 9. Casting mold of tongue

For the webinar, a clinical case of a cancer was selected in cooperation with Poznan University of Medical Sciences – it was a 53-year old woman with tongue cancer, diagnosed with use of Magnetic Resonance Imaging (MRI). By the time of webinars realization, the patient was already recovering after surgery, so it was not a current clinical case – however still relevant.

3.2.3. Case 3 – Face shield

The third case study is a 3D printable face shield, used in times of COVID pandemic as a quick-resort disposable protection device for medical personnel dealing with the infected. The 3D printed part is the head section, to which a transparent shield is attached, along with a rubber band holding the whole shield at user's head. Originally, the product was designed by the Prusa company in Czech Republic and first recommended for use by Czech Ministry of Health. It was printed with success in Poland in beginning of 2020's pandemics, during the action "print for the doctor" (orig. "*drukuj dla lekarza*"), where hundreds of shields were supplied to hospitals and other medical facilities off charge (Figure 10).

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Figure 10. 3D Printed assembled face shields for a hospital

The shield is printable of any material – PLA and PET-G are recommended as being known for proper behavior in contact with user's skin. ABS and other materials could also be used, provided that there is no direct skin contact or sterilization is performed before and also after use. 3D printing of the head part takes approx. 20-40 minutes, depending on the material and printer used. Apart from the 3D printed main part, the product also contains the shield (cut out of rigid foil), protective foam and rubber band for head mounting (Figure 11).

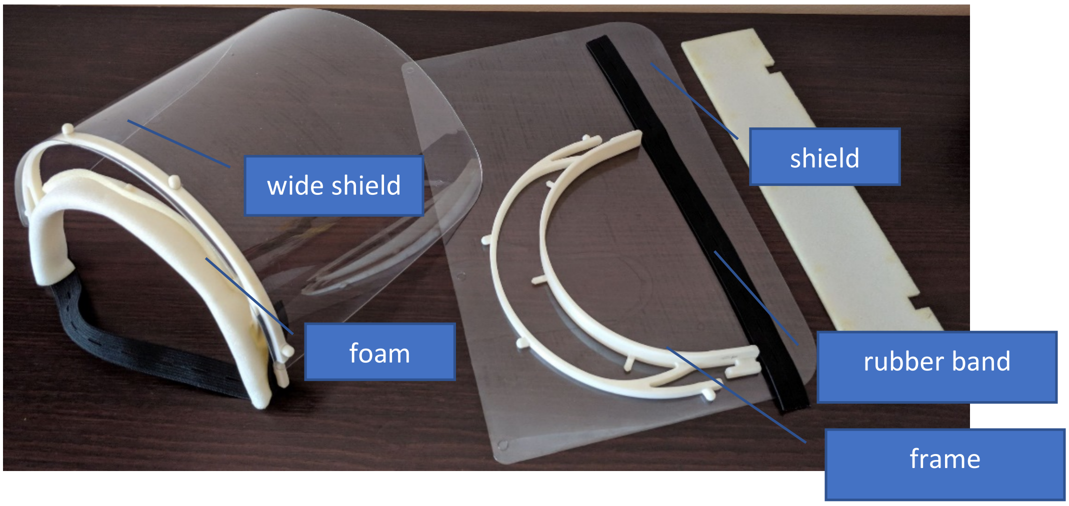

Figure 11. Structure of the shield.

The design of the shield can be prepared in any software – originally, it was Autodesk Inventor CAD system, where the models were prepared by PUT team (Figure 12). Final stage of development of that product in Inventor is shown in Figure 13. Figure 14 shows work realized in the Rhinoceros software, as done in the case of the webinar.

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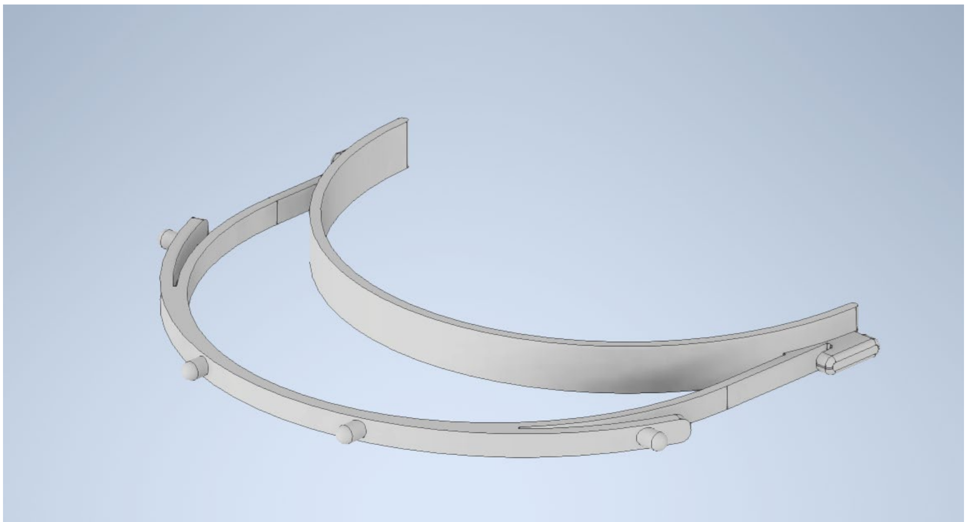

Figure 12. Face shield model, basic (Prusa) version, designed in Autodesk Inventor

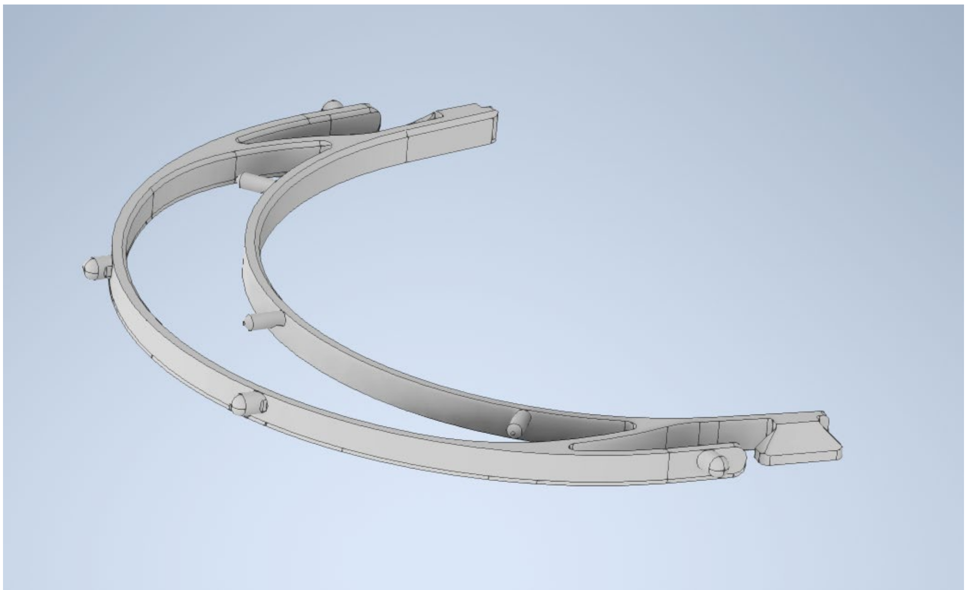

Figure 13. Face shield final model (version 11), designed in Inventor

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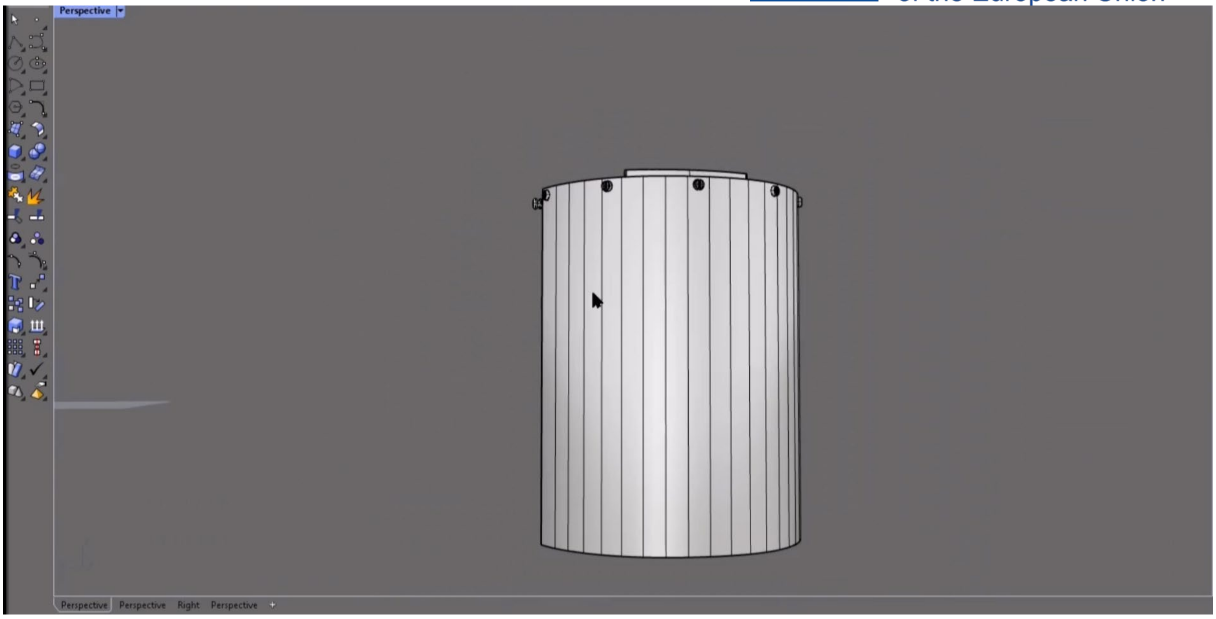

Figure 14. Face shield drawn in Rhinoceros

2.3 Input data and used software

The following input data was used for design of all cases in the webinar:

1) 3D scan of patient's injured limb – STL mesh (case 1)
2) basic model of wrist hand orthosis from the AutoMedPrint system (case 1)
3) DICOM data and diagnosis of the patient (case 2)
4) basic Prusa model of the face shield, approved by Czech Ministry of Health (case 3)

The following software was used:

1) AutoMedPrint system software (custom made by PUT) – Figure 15
2) MeshLab – open source
3) Autodesk Inventor – free for students
4) InVesalius (Figure 16) – open source
5) MeshMixer (Figure 17) – free
6) Blender – free
7) Rhinoceros (Figure 18)

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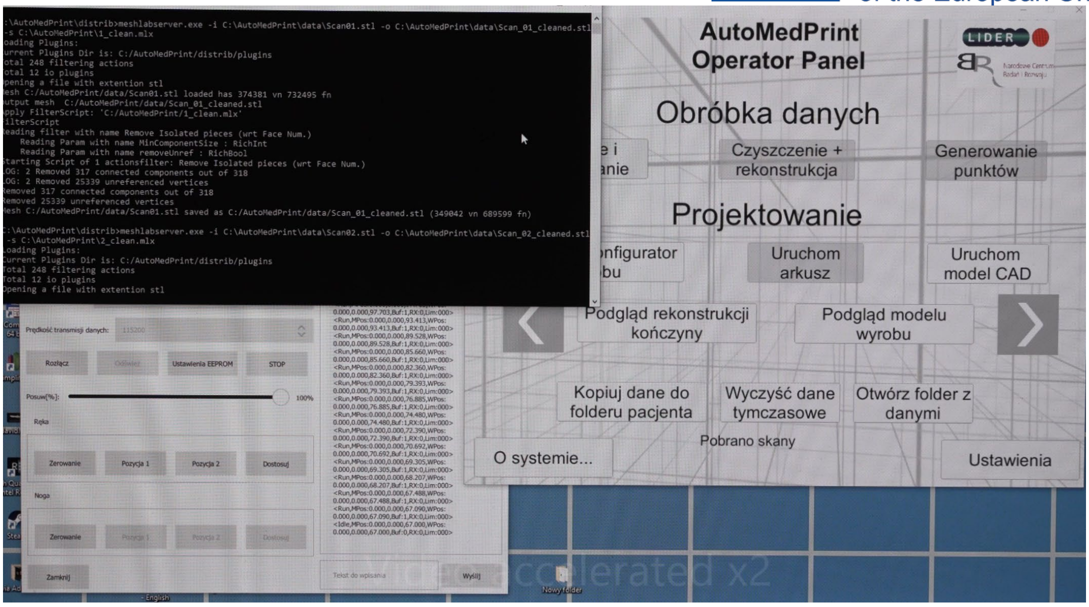

Figure 15. AutoMedPrint system software used for mesh processing and orthosis generation

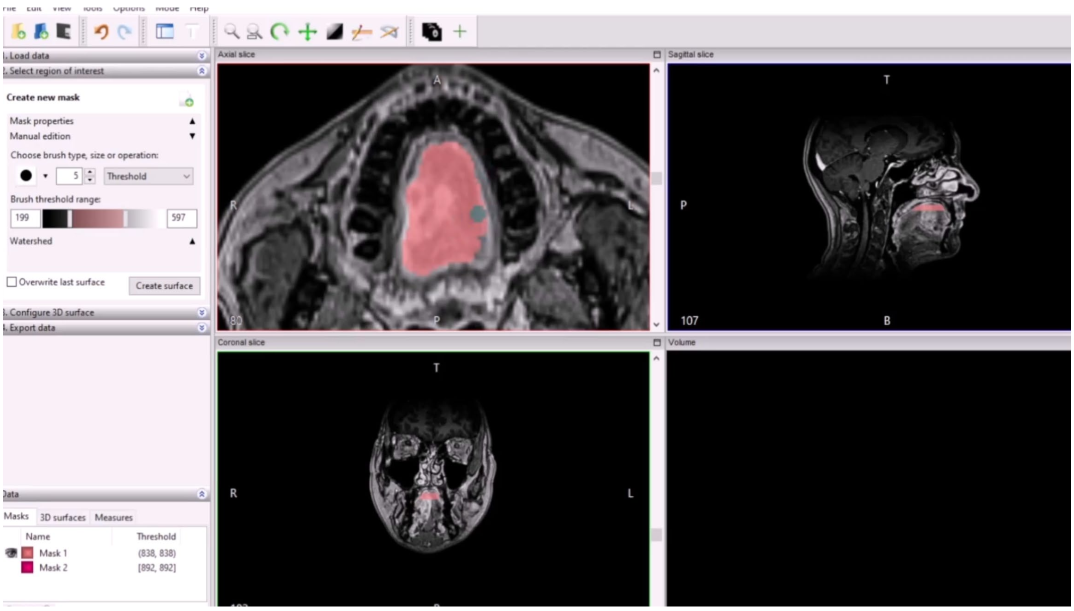

Figure 16. InVesalius – DICOM processing

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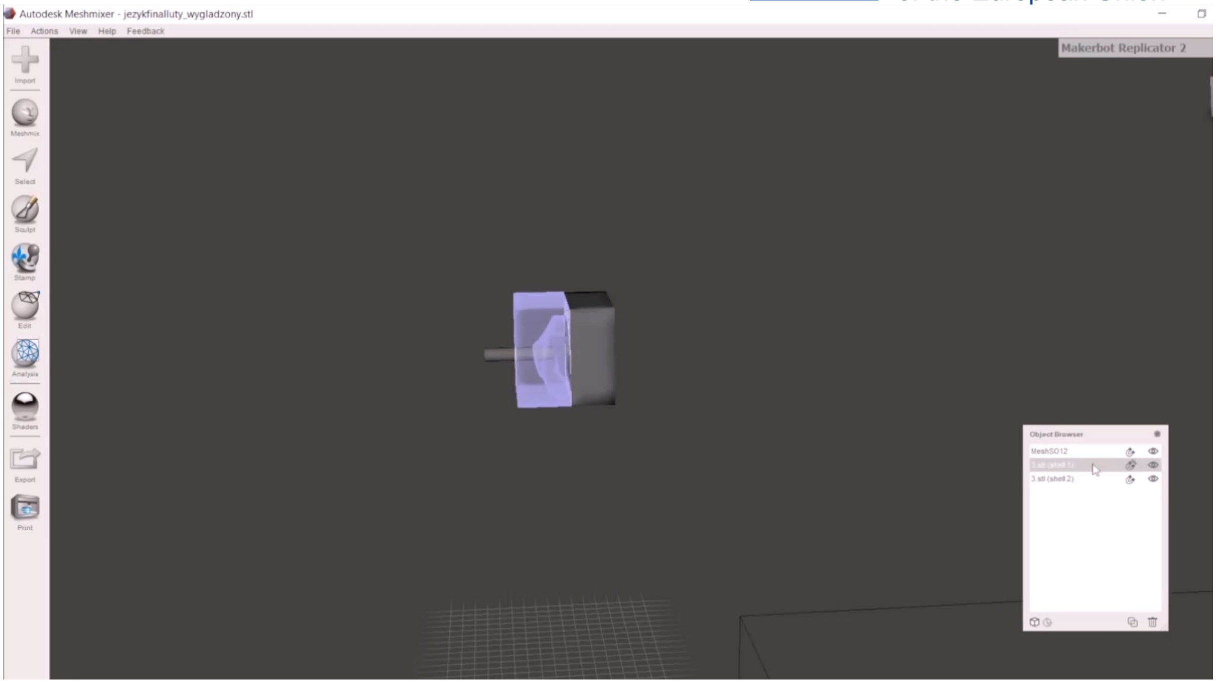

Figure 17. MeshMixer – mold design

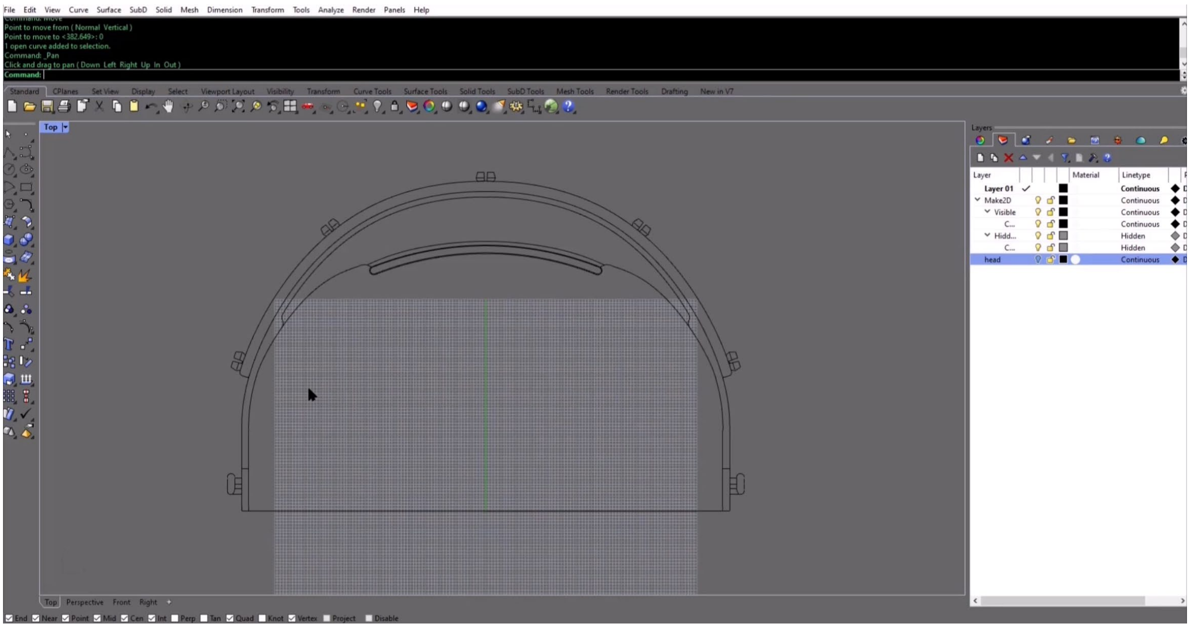

Figure 18. Rhinoceros – curves drawing

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2.4 Course of the webinar

The webinar starts with the intro credits, in which logos of all partners, EU, BRIGHT project and other important information are used, as presented in Figure 19.

Figure 19. Graphics used in intro credits of the webinar.

After the credits, the introduction is realized. It is done by representatives of PUT team, who are also engaged in the other activities in this and subsequent webinars. The cases are also introduced and shortly described – all according to scenario written beforehand (Figure 20).

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Figure 20. Webinar #1 – intro by PUT team

The next two stages of webinar present different phases of designing the first case – wrist hand orthosis. First phase is 3D scanning of patient's limb and data processing. For that part, AutoMedPrint system was used (see more at https://automedprint.put.poznan.pl). Complete set of actions is presented (Figure 21). Then, Autodesk Inventor model of the orthosis is shown. In general, the design is automated and the user rarely has to interact with the CAD system (in the AutoMedPrint system the model re-creates itself when obtaining dataset of another patient, extracted from a 3D scan). Here, for increased educational value, all the stages of design were shown by manual interaction with the CAD system (Figure 22).

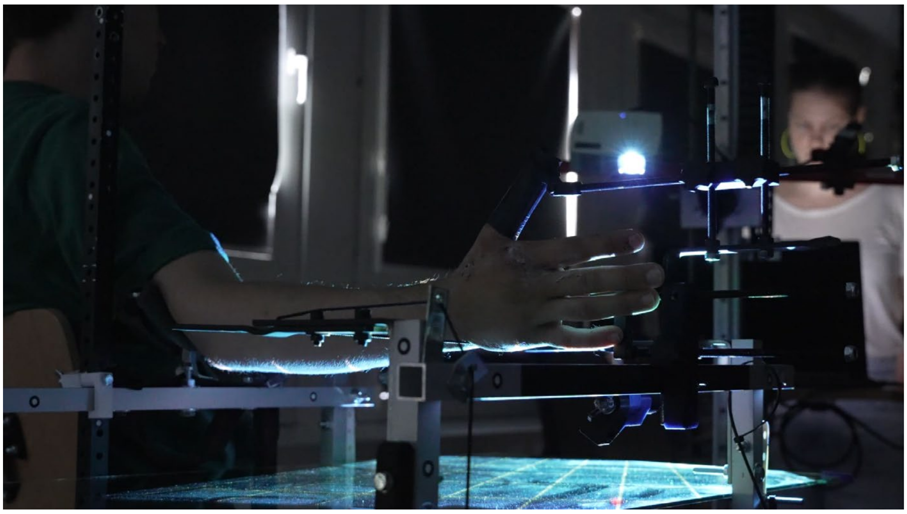

Figure 21. Webinar #1, case study 1 – patient scanning

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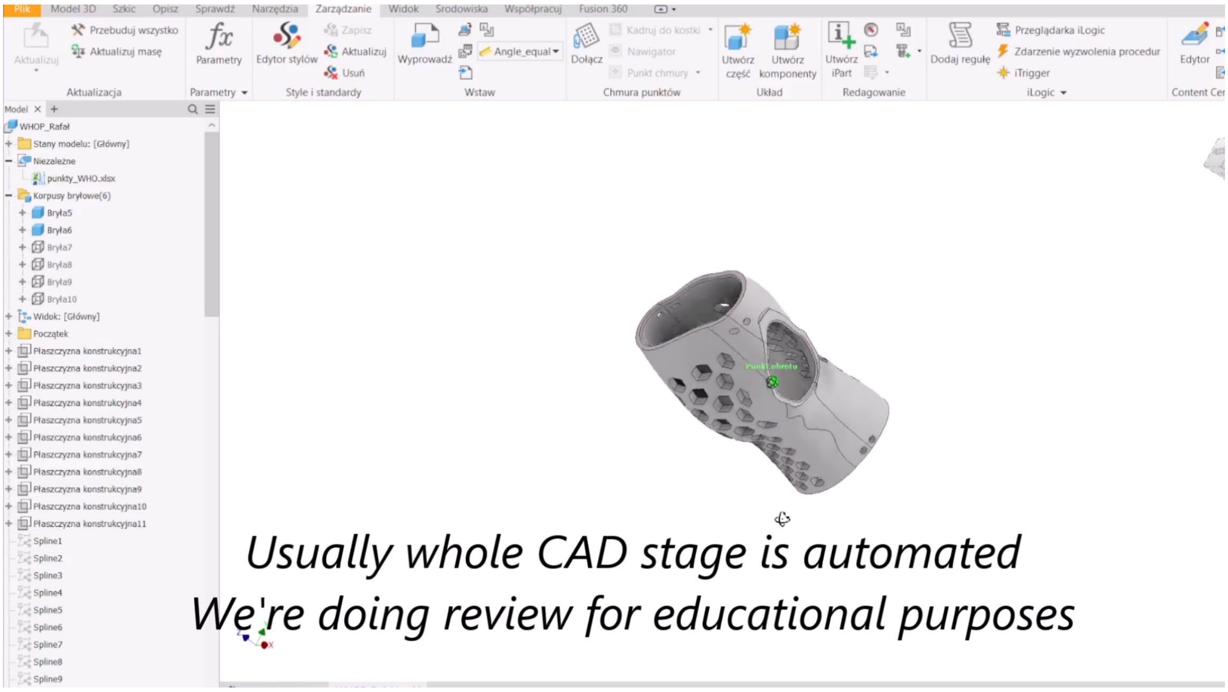

Figure 22. Webinar #1, case study 1 – product design

The 4-6 sections of the webinar are various stages of design of anatomical model of tongue with tumor. Here, mostly freeware / open source software was used. The DICOM processing and segmentation in InVesalius software is shown in Figure 16. Result of this process – performed on raw set of medical images straight from the MRI system, with aid of professional radiologist – is a triangular mesh in the STL format. The next stage is realized in GOM Inspect software – it is repairing and smoothing of the mesh (Figure 23). After the mesh is ready, it can be used for direct printing using hard materials (for pre-operative purposes). For soft resin casting in vacuum, mold must be prepared. This is done using a combination of free software – Blender and MeshMixer (Figure 24). Full procedure is shown in the webinar.

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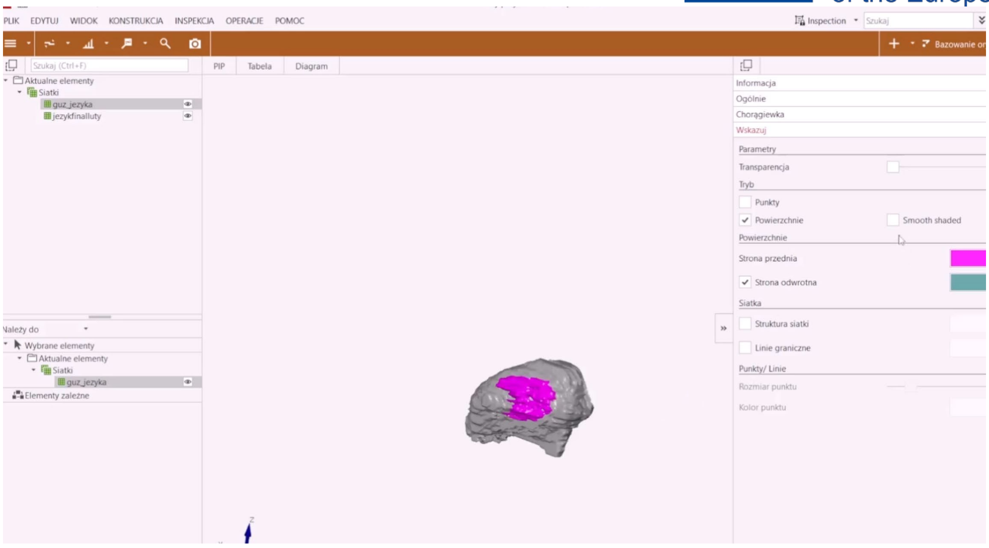

Figure 23. Webinar #1, case study 2 – mesh processing

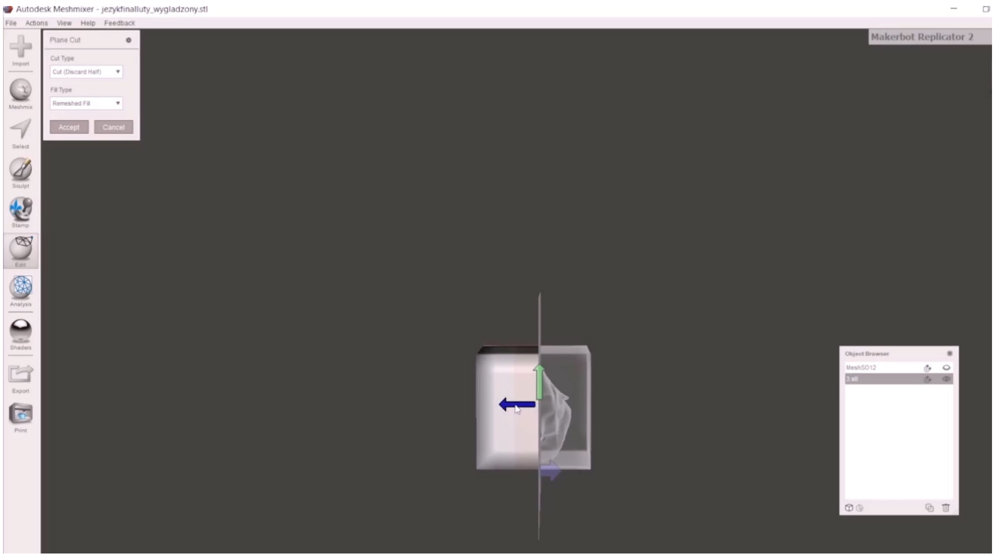

Figure 24. Webinar #1, case study 2 – mold design

Design of the third product is realized in a different manner. To diversify the used software and increase the educational effect, regular CAD software and solid modelling (such as Inventor or SolidWorks) was not used in this case. Here, Rhinoceros software was used with features of surface modelling. Full process was covered, starting from the scratch. The modelling is presented in Figure 25, while final effect – in Figure 26. This process concludes this webinar.

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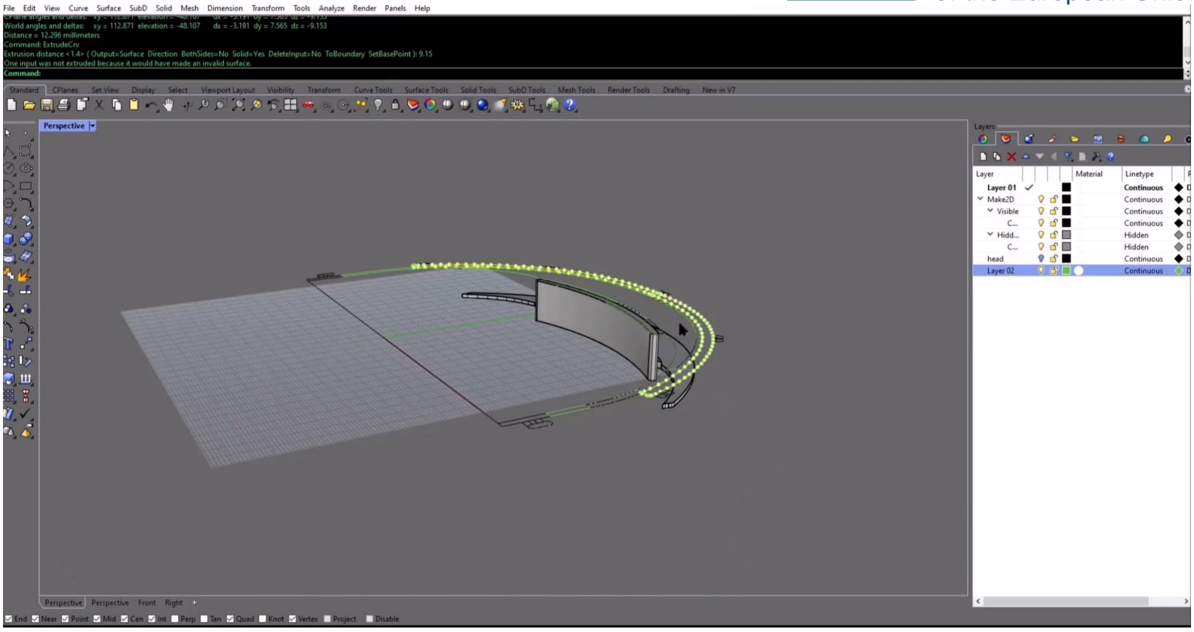

Figure 25. Webinar #1, case study 3 – 3D design

Figure 26. Webinar #1, case study 3 – final result

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3 Summary

In this document, first webinar of BRIGHT project was briefly described. Motivations, concepts, work plan and distribution were presented, as well as selected case studies. Used software and input data were specified. Course of the webinar was also presented. All the screens come from the webinar itself, or the models that were created specifically for it. The webinar is also a documentation of design phase of 3 out of 5 case studies realized in the BRIGHT project. The webinar is of great educational value for students wanting to learn how modern digital design of medical 3D printable products is realized.

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