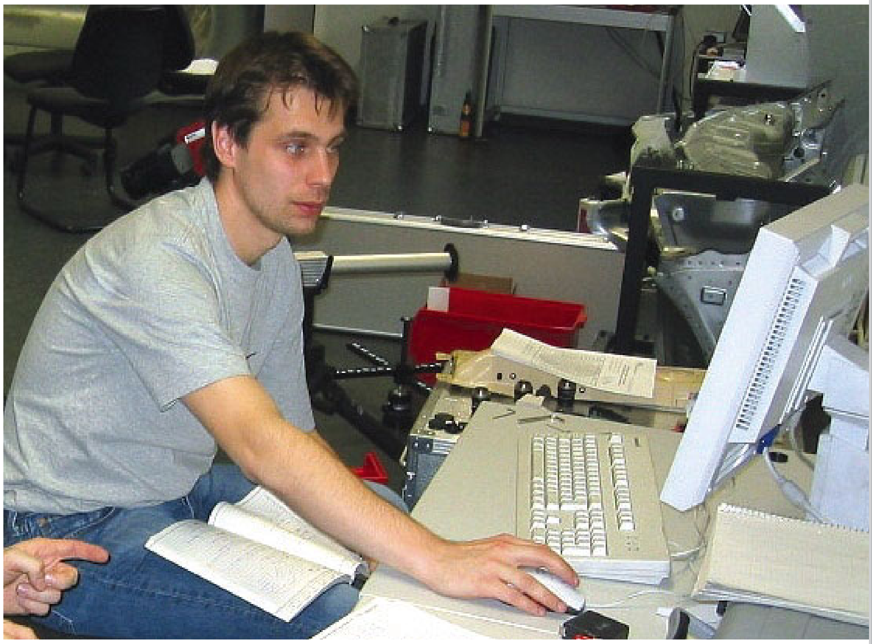
# Use of Rapid-prototyping Technology in Rehabilitation of a Patient with Facial Deformity or Partial finger or Hand Amputation

*T. Maver, H. Burger, N. Ihan Hren, L. Botolin, J. Weingartner and K. Celec,*

**Abstract:** We have been manufacturing and applying epitheses at the University Rehabilitation Institute of the Republic of Slovenia since 1993. Epitheses are aesthetic prostheses replacing individual body parts. Our experience demonstrates that patients wish to replace the lost part of their body with a prosthesis – an epithesis that is a mirror image of the relevant healthy part of the body. Six years ago, we linked up with other institutions, companies and the University of Ljubljana to search for new, more advanced technological possibilities to bring the form of epitheses closer to the form of a healthy hand or part of a face. Healthy and impaired parts of the body were scanned. A digital virtual model was made using a computer program. 3D-printing technology, DMLS (Direct Metal Laser Sintering) and SLS (Select Laser Sintering) technology were used to build up a first model or mould for manufacturing a silicone epithesis. Through this development project, we have developed high-resolution digitising of body parts and technology to produce a prototype model and mould allowing fine recognition of skin details. The time required for design and manufacture is now shorter. By using CAD-CAM high-resolution technology, the highest-quality prosthetic design can be achieved, even when the prosthetist lacks artistic skills.

**T. Maver, University Rehabilitation Institute Republic of Slovenia, Centre for Orthotics and Prosthetics, Ljubljana, Slovenia**

**Nataša Ihan Hren, University Medical Centre, Department of Maxillofacial and Oral Surgery, Ljubljana, Slovenia**



**Luka Botolin, TECOS Slovenian Tool and Die Development Centre, Celje and Ljubljana, Slovenia**

# The University Rehabilitation Institute, Republic of Slovenia

*Robert Cugelj*

The University Rehabilitation Institute, Republic of Slovenia is the main national health institution offering comprehensive rehabilitation services to people with disabilities in motor functions and of work abilities. The institute carries out rehabilitation programmes and is responsible for the balanced development of all health and other professional branches related to the issue of rehabilitation at the national level. The Institute treats around 15,000 patients a year, including over 1,900 treated in hospital wards with a total capacity of 200 beds. Operating within the institute are several specialised and subspecialised clinics for screening, rehabilitation diagnostics and therapy of patients with severe impairments and disorders of the locomotor system and resulting disabilities. Approximately 90% of the patients come from the Republic of Slovenia and the remainder from abroad. The expert staff of the institute has included excellent teachers in medical, technical and social fields throughout the 50 years of its development.

From the perspective of organisation, the activities of the institute can be grouped as follows:

- ◊ Clinical hospital for physical medicine and rehabilitation;
- ◊ Centre for vocational rehabilitation;
- ◊ Centre for prosthetics and orthotics;
- ◊ Outpatient rehabilitation services;
- ◊ Rehabilitation engineering;
- ◊ Pharmacy.

The healthcare activities are aimed at providing inpatient and outpatient care for the patients of the institute. Modern patient care at the institute tends towards outpatient diagnostics. The therapeutic services of the institute are working towards shorter hospitalisation and outpatient treatment.

The institute as a healthcare institution at the tertiary level carries out scientific research in the fields of medicine, rehabilitation engineering, as well as in the psychosocial field and in the field of employment. It has about 50 employees who are registered as researchers or associate researchers at the Slovenian Research Agency. Scientific research is carried out within individual organisational units and within the research department, which offers professional, technical and logistical help to other departments in the preparation and implementation of research and dissemination of its results.

# I. INTRODUCTION

We have been manufacturing and applying epitheses at the University Rehabilitation Institute Republic of Slovenia since 1993, using silicone technology (Figure 1,2). Currently, this technology is based on manual shaping, through which we strive to restore the patient's aesthetic appearance (Figure 3,4).

**Figure 1**

**Figure 2**

Our experience demonstrates that patients wish to replace the lost part of their body with a prosthesis that is a mirror image of the relevant healthy part of the body.

**Figure 3**

**Figure 4**

Four years ago, we linked up with other institutions and the University of Ljubljana to search for new, more advanced technological possibilities to bring the form of epitheses closer to the form of a healthy hand or part of a face.

To this end, we started development of an appropriate high-resolution CAD-CAM system.

# II. TECHNOLOGY

The development project covers three areas:

- ◊ a scanning system;
- ◊ positive model-construction technology; and
- ◊ tool-construction technology.

Figure 6

## Scanning system

During the development phase, three laser and optical scanners were tested in the making of a digital-3D model of a hand and stump. The following scanners were tested: freescanner CAPOD CAD-CAM system, Zscanner 700 (Figure 5) and 3D-optical scanner ATOS II 400 (Figure 6).


Figure 5

First, a plaster model of the healthy part of the body was scanned (Figure 7).

Later, a plaster model of the impaired part of the body that had previously been corrected was scanned (Figure 8).

Weingartner, RTCZ Rapid Prototyping and Rapid Tooling Centre, Hrastnik, Slovenia

Helena Burger, University Rehabilitation Institute Republic of Slovenia, Centre for Orthotics and Prosthetics, Ljubljana, Slovenia

Kristjan Celec, IB-PROCADD d.o.o., Dunajska 106, Ljubljana, Slovenia

# Positive model-construction technology

Figure 10

A digital virtual model was made using a computer program (Figure 9).

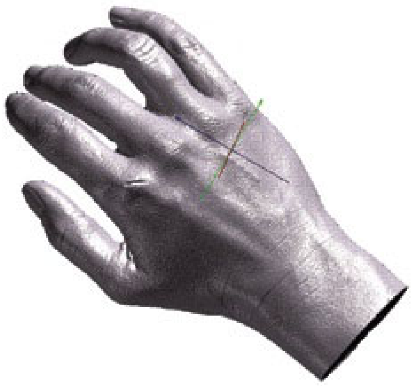


Figure 11

The healthy part of the body was treated and a mirror image of the digital model was thereby obtained (Figure 10,11,12).

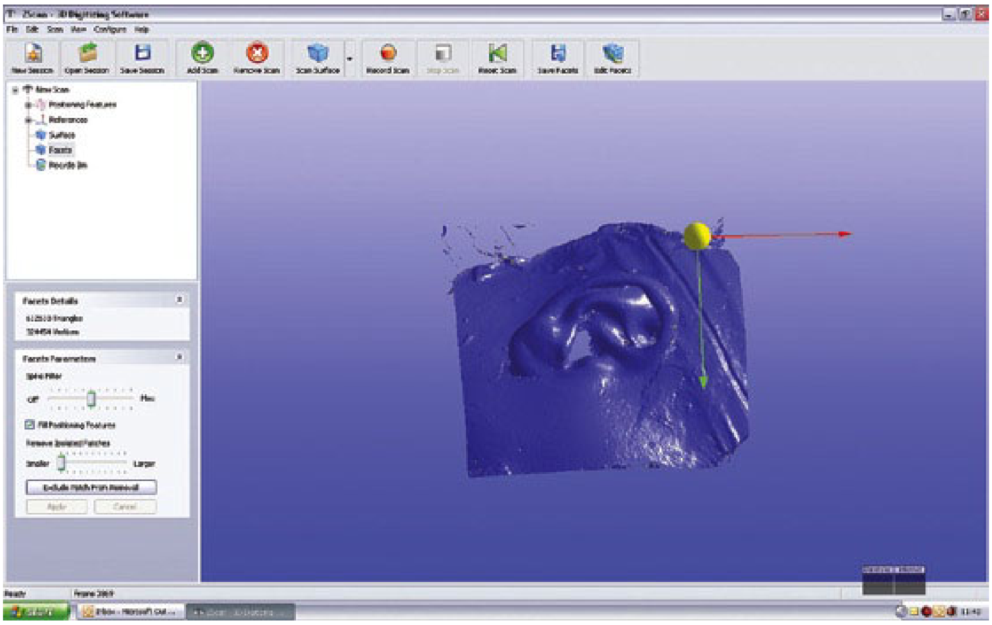


Figure 12

Figure 13

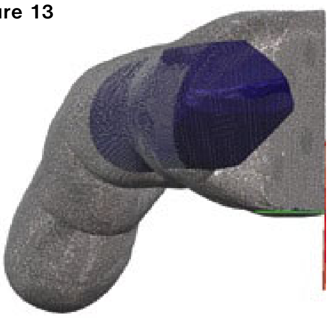


Figure 14

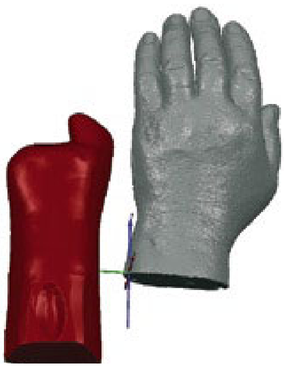


Figure 15

This virtual digital model was then gradually adjusted to the model of the impaired part of the body (Figure 13,14,15). The digital picture of the model was transferred to the STL database.

## Mould-construction technology

3D-printing technology, SLS (Select Laser Sintering) and DMLS (Direct Metal Laser Sintering) technology were used to build up a first model or mould.

Figure 16

Figure 16

3D-printing technology was used to make a prototype model of the auricular and finger epithesis (Figure 16, 17).

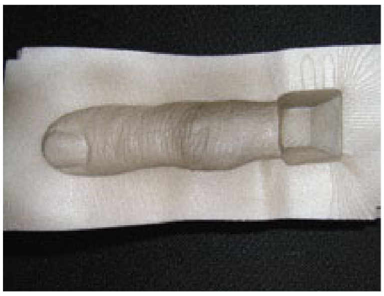


Figure 18

DMLS technology was used to make a tool for manufacturing a silicone finger epithesis (Figure 18).

At the final trial, SLS technology was used to produce a tool for manufacturing a silicone finger epithesis (Figure 19).

Figure 19

## III. RESULTS

With the assistance of experts from the companies participating in this project, we tested and identified the devices and technological procedures to enable the manufacture of epitheses.

The best results in scanning were achieved using the ATOS II photo scanner (Figure 20). When scanning directly on the body, there were some problems due to slight movements of the body. This was the reason for additionally scanning plaster models of the healthy as well as the impaired parts of the body.

Figure 20

The virtual positive model shows all skin details, including fingerprints (Figure 11). In this way, the first part of the development project was completed.

This virtual model helps to make a prototype model of an epithesis or mould in the STL database. The program allows adaptation of the digital model of the healthy part of the body to the digital model of the stump (Figure 14) or the impaired part of the face.

The highest apparency of skin details in the mould was achieved using the DMLS technology (Direct Metal Laser Sintering) with 0.04mm accuracy. In the testing of the SLS (Select Laser Sintering) technology and the print technology, the accuracy was 0.1mm. When inspecting the moulds, the most accurate surface was found to be that produced by the DMLS technology. Silicone was poured into the moulds and, after vulcanisation, the quality of the test prostheses was found to depend on the apparency of the skin prints. The highest quality for the mould surface was achieved by the DMLS technology and the lowest by the 3D-print technology, which produced a rougher surface for the prostheses test model, despite the satisfactory apparency of the skin prints. The SLS technology was selected for mould manufacturing due to its accessible cost. The apparency of skin prints achieved by the SLS was not essentially lower than that achieved by the DMLS technology.

The mould can be directly used to be filled with silicone material (Figure 21).

Figure 21

# IV. CONCLUSIONS

During the development phase, CAD-CAM technology processes were defined to enable production of silicone prostheses after partial hand amputation (Figure 22, 22a), which in their form mirror the patient's healthy hand (Figure 23).

Figure 22

Figure 22a

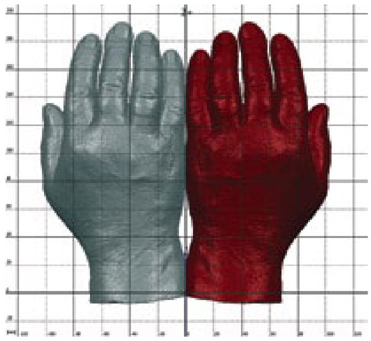


Figure 23

Most centres for manufacturing silicone hand prostheses currently use manual modelling. The quality of such prostheses depends largely on the artistic skills of the prosthetist. By using CAD-CAM high-resolution technology, the highest-quality prosthetic design can be achieved even when the prosthetist lacks artistic skills. Rapid-prototyping technology has been already used in designing and making of maxillofacial prostheses – epitheses (Figure 24, 25), as has already been treated in international expert literature.

The final appearance of the prosthesis depends greatly on its shape and colour (Figure 26, 27). Our experience in using the CAD-CAM high-resolution technology have shown that this technology enables computer-based manufacturing of prostheses, which in their form mirror the healthy hand.

Figure 24

Figure 25

Figure 26

Figure 27

The use of such technology reduces the time required for design and manufacture. However, the technological process is more expensive due to the application of highly developed technology, which means the product – the epithesis – is also more costly. We are working on reducing the number of steps in the technological process to improve speed, accuracy and cost, so our patients can be offered optimal quality at affordable prices.