USE AND SUPPORT OF RAPID PROTOTYPING IN PRODUCING PROSTHESES AND EPITHESES

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Abstract

By introducing new technologies our intention was to find a most optimal technological possibility for improving the quality of the outlook of protheses' after a partial hand amputation (either fingers or the hand), and in manufacturing of epitheses. In the field of CAD technology we have tested some different scanners by means of which the models of fingers, palms and parts of the face were digitized. We have checked also usability of some computer programs for 3D-shapes. Various procedures of RP technology, which is to be classified among CAM technologies, have been examined with manufacturing of moulds or tools for manufacturing of an aesthetic prosthesis of a finger, the hand, and of maxilofacial protheses - epitheses. This technology provides the patients with the highest life like quality of prosthetic design.

INTRODUCTION

The development of modern technologies is being transferred from other various branches of industry into orthopaedical techniques as well as it is transferred into the field of orthotics as prosthetics.

In recent years the Computer-Aided Design - Computer-Aided Manufacturing (CAD-CAM) technology has become established. The Computer Aided Design technology made it possible to construct a product by means of a computer program. By implying the Computer Aided Manufacturing program the computer made model of the constructed product can be produced by use of a multi-axial processing machine or by using some recent laser technology procedures which are classified among RP-Rapid Prototyping Technology. The first successful trials of implying this technology in the field of medicine go back to 1992 (1). Quite soon the technology has found its way in the field of dental medicine. Coward et al. were the first to publish the results of implementing the Rapid Prototyping Technology into the field of manufacturing of maxillofacial prostheses, in the case of an auricular epithesis (2). The first publications on how this technology was implemented in the field of prosthetics dates into 2002 (3), when a part of a robotic hand and prosthetic socket for the lower limb prosthesis (4) were manufactured. Didrick (5) was the first to mention the manufacturing of an aesthetic finger prosthesis and in our Institute for Rehabilitation we have tested this technology in manufacturing of a prosthesis in case of a partial hand amputation. At present it is used also in manufacturing of epitheses.

In order to reproduce the closest match to the original fingers and hand the only way was to capture the shape of its counterpart on the healthy hand.

At the Institute for Rehabilitation the manufacturing of silicone hand prostheses was based on the shape of similar PVC cosmetic gloves or on the model of a similar hand of a third person. None of the above mentioned methods has enabled manufacturing of prostheses that would closely resemble the patient's healthy hand.

Manufacturing of epitheses takes a lot of time as manual modelling of the firstmodel is necessary to make it mirror the healthy part of the face. Accordingly, the Institute together with the partners wanted to develop a high resolution CAD-CAM technology for protheses manufacturing, where the shape is mirroring the patient's healthy part of the body.

METHODS AND SUBJECTS

Prostheses and epitheses production can be divided into the following steps:

3D Digitizing (capturing of the physical shape)
During the development phase, three laser- or optical scanners were tested while preparing a digitized 3D-model of a hand, stump and a part of the face. The following scanners were tested: the Freescanner CAPOD CAD-CAM System, the Zscanner 700, and the 3D-optical scanner ATOS II 400.

CAD Modelling (modifications on the computer model)
The 3D digital model of the healthy hand was corrected and adjusted to the digital model of the stump by means of internally developed software ATOS 6.0.0.3 and Tebis CAD. The processing and correction of the digitized model of epitheses has been performed by means of the program, called Geomagic.

Computer Aided Model or Mould Manufacturing
In the production of a master-model and tool, three technologies for fast manufacturing of first models and tools were tested: the DMLS (Direct Metal Laser Sintering), the SLS (Select Laser Sintering) and the 3D print technology.

Moulding and Finalization of Prostheses or Epitheses
In the production of prostheses after a partial amputation of the palm various colour shades of medicinal silicone were dosed into the tool. The mould was inserted into a power press so as to assure a contact between silicone and all the parts of the tool. The tool has been put onto a hot stove where silicone vulcanization was achieved by heating it to an adequate temperature. After vulcanization was completed the tool was cooled, demounted and used to finalize the prosthesis.

RESULTS 3D

Digitizing (capturing of the physical shape)

The highest quality of scanning was achieved by ATOS II 400, produced by German company GOM: it provided digital models with visible skin details.

With the Freescanner CAPOD CAD-CAM system the perception of skin details was not possible and it did not register the narrow passages between fingers and the palm. The device is considered to be suitable for digitizing of the nose only where requirements are not that high.

The Zscanner 700 proved to be precise enough to enable scanning of ear models. In finger- or hand scanning it did not register all the skin details.

CAD Modelling (modifications, made on the computer model)

ATOS program enables model mirroring, adjusting of the stump and the mirroring model of the healthy hand, as well as ajdusting the models into the coordinate system. The program Tebis CAD was used with some more pretentious modelling, as for instance widening or broadening of pixel points net in a digitized model, for controlling the difference in volumes of the two models, providing the control of thickness, change of flexion in finger joints, and correction of skin details. With correction and mirroring of the model in an auricular or orbital epithesis the Geomagic computer program was implemented: it enabled model mirroring, adjusting the model as to its volume, providing defect corrections on the model, etc.

Computer Aided Model or Mould Manufacturing

The highest level of appearance of skin details in the hand prostheses tool was achieved by the DMLS technology (Direct Metal Laser Sintering) with 0.04 mm accuracy. In the testing of the SLS (Select Laser Sintering) technology and the print technology, the accuracy was 0.1 mm. After the tools check the most accurate surface was found to be the one produced by the DMLS technology. Silicone was poured into the tools and after the vulcanization the quality of test prostheses was found to depend on the appearance of skin prints. The highest quality of the tool surface was achieved by the DMLS technology and the lowest by the 3D print technology. The latter produced a rougher surface of the prostheses test model despite the satisfactory appearance of the skin prints. The appearance of skin prints achieved by the SLS was not essentially lower than the one achieved by the DMLS technology. The SLS technology was selected for tool manufacturing of the hand prostheses due to its accessible costs.

Moulding and Finalization of the Prostheses or Epitheses

The procedure of finalization of the prostheses has been performed in accordance with the established technological ways.

DISCUSSION

The final appearance of a prosthesis depends greatly on its shape. In most centres for manufacturing silicone hand prostheses the procedures of manual modelling (6, 7) are used nowadays. The quality of such prostheses depends on the prosthetist's artistic skills. By using the CAD-CAM high resolution technology, the highest-quality prosthetic design can be achieved even when a prosthetist lacks artistic skills. The same procedure is mentioned by Didrick (5), by whom this technology has been applied in the procedure of manufacturing of finger prostheses. There was not possible to make a comparison of experience other authors had made in the field of implying the CAD-CAM technology in prostheses manufacturing after partial amputation of the hand since in the medicine articles' base it was not possible to find any evidence on the use of this technology with colleagues abroad.

Due to existing licence contracts or partnership enterprises eventual comparisons between individual computer programs have not been performed.

DMLS technology may offer the greatest precision yet due to the heavy weight of the tool and the high price it is less suitable.

As to its quality and price the print technology proved to be the most favorable solution in manufacturing a prototype of auricular or orbital epitheses. The material which this technology is based on is quite brittle. Accordingly, it may enable grinding but it cannot achieve the necessary tenacity which is inavoidable for the manufacturing of the tool.

During the development phase, the CAD-CAM technology processes were defined to enable the production of silicone prostheses after partial hand amputations, which in their form mirror the patient's healthy hand.

As to manufacturing of epitheses it has been stated that the technological procedure is an adequate one and qualitative enough to ensure manufacturing of an epithesis prototype, improving the similarity of the model with the healthy part of the face, and saving the time of forming; however, we implemented the procedure only for the manufacturing of the prototype and not for the tool itself.

Some more experiences in implementing this new technology could be evidented in some expert articles on epitheses manufacturing.

Already in 1997 the preliminary report on use of CAD-CAM technology for manufacturing of face prostheses has been published by Chen LH et al. (8) Further it was Sykes who confirmed the advantages of this technology since he used it in epitheses shaping and -manufacturing (9).

Some further authors (10-14) tended to publish their experiences on epitheses manufacturing by implying the CAD-CAM or Rapid Prototyping technology, respectively. All authors report of benefit of the said technology which is said to be precise and time-saving for the prosthetics.

CONCLUSION

Our experiences in using the CAD-CAM high resolution technology have shown that such technology enables computer-based manufacturing of a prosthesis which in its form mirrors the healthy hand. This technology provides the patients with the highest quality of lifelike prosthetic design.

New technology customizes the final product to such measures that it significantly contributes to successful post-traumatic rehabilitation of a patient from personal, psychological, aesthetical and practical aspects. The results were very promising and eventually proved that the approach, with further improvements, will provide final products with better quality, providing a ground for better and faster rehabilitation of patients.

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