Production of personalized child orthosis using additive technology

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***Abstract* — This paper explains the production of a personalized child orthosis with 3D printing technology. In agreement with the doctor's specialists, an appropriate candidate was selected. The components of a child's orthosis have been modelled and adapted based on the scans from candidate acquired with 3D scanning technology. The 3D scanning process with OrtoSCAN digitizer and component modelling in Autodesk Fusion 360 are explained. Customized child orthosis components were made using two 3D printers: Prusa i3 P3Steel and Geeetech Prusa i3 Pro. Patient visit was followed by assembling of the orthosis. After final design and orthosis trial, the conclusion is that less modification on the shoulder part is needed and there is still room for further optimization of the orthosis. By using a generative design, it is possible to obtain an even more lighter customized orthosis that will satisfy the required mechanical properties and fulfill its function.**

I. Introduction

Orthoses made with technologies such as traditional plaster molding fabrication techniques are expensive, require mold as well as long lasting preparation. Because of accelerated growth in childhood, buying such orthoses is economically unprofitable. Neuromotor diseases cause weakness and deformation of the muscle tissue and frustration of children due to the inability to control the desired actions in everyday activities. A custom orthosis made on a 3D printer will help the selected child to better control the hand movements. The custom orthosis should stabilize the arms and direct them to the central position so that the candidate can handle the desired objects. 3D printing technology is suitable for creating a pediatric custom orthosis because of its relatively short production time, ease of handling and the ability to create components of various shapes that are very demanding or almost impossible to obtain by classical methods of making. Dimensions of individual orthosis components as well as possible additional adjustments can be performed without major difficulties in a very short time. 3D printing does not have much waste, making it an environmentally friendly technology. Orthosis can be designed without mold preparation using reversible engineering and modern manufacturing processes such as 3D scanning. 3D printing offers the possibility of quick and easy modification of all parts of the orthosis and adjustment in accordance with the growth and development of the child. The experience and knowledge gained in making a 3D print orthosis will serve for the help and other small patients that would be needed.

II. Research questions

The paper examines the usability of personalized aids made on the cheapest open source FDM device for 3D printing. Since the orthosis was intended for a child with neuromotor disease and weakness of the muscle tissue, it was necessary to design and make a usable aid with the lowest possible weight and sufficient strength. The possibility of reversing engineering using 3D scanning device to prepare a personalized orthosis was also tested. This kind of preparation can significantly save time of making customized aids. Another goal was to make the cheaper and simpler orthosis that meets all of the observed criteria and fulfills its function. An example of a suitable orthosis is Wilmington Robotic Exoskeleton - WREX, which was initially fixed to the patient's wheelchair. Attached WREX orthosis is not suitable for patients who do not require a wheelchair, so today different WREX orthosis variants are produced. Authors Gunn, Shank and Eppes in their article *User Evaluation of a Dynamic Arm Orthosis for People with Neuromuscular Disorders* describe the types of 3D printed WREX orthosis mounted on the wheelchair and placed on the patient back [2]. The results of the conducted research indicate significant improvements in the function and coordination of hands in everyday activities. The orthosis considered in this paper is portable and fixed on the back of the child

III. Methodology

The procedure of selecting candidates for the printed 3D pediatric customized orthosis lasted about 2 months. It was necessary to contact associations and hospitals that could contain information on a suitable patient. As a suitable candidate is planned little patient up to 7 years of age. Customized orthosis would help him perform simple activities such as self-feeding, coloring or huging. Professional advice was provided by neuropediatric specialist Zrinka Ereš Hrvaćanin and orthopedic Dr. Hrvoje Pitlovic. A 4-year-old girl who has limited control over the actions of her arms was selected as a suitable candidate. It was estimated that a customized orthosis would help her to better coordinate hands and allow better development, and therefore better quality of everyday life.

Figure 1. 3D scanning

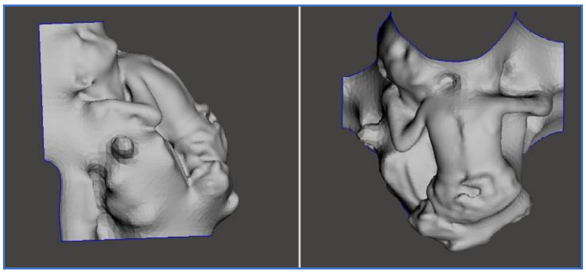

Figure 2. 3D scan

Due to the need for modeling the construction component for the orthosis tightening, the patients back are scanned. The precise customized component is called a "butterfly". The “butterfly” should be placed on the back of the patient with as minor abnormalities as possible in order to reduce the risk of irritation when wearing the orthosis. OrtoSCAN and its OrtoFLEX application were used for scanning. Additional model processing was done in Meshmixer. The OrtoSCAN device consists of a central patient stand and two pillars each containing two digitization tapes. In each digitization tape there is one projector, computer and camera that are connected to the main computer via the OrtoFLEX application.

Figure 3. Modeling the “butterfly” component based on back images in Autodesk Fusion360

Modeling of the basic parts of customized orthosis was based on the available models from the free CAD database. All other parts of the orthosis were created in Autodesk Fusion 360. To make the orthosis adaptable to each next little patient, parametric modeling was used. After the parametric modeling of the orthosis, fixing “butterfly” orthosis component to an elastic fabric waistcoat was performed. The “butterfly” beck component was first made unilaterally because the patient did not hold both hands in the same position. During the scanning the right arm and right shoulder were in the proper position so only they are considered.

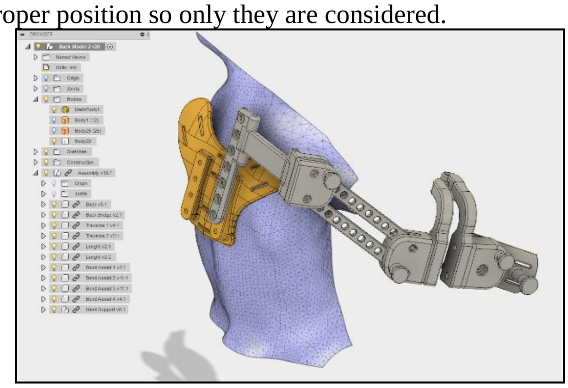

Figure 4. Digital customized orthosis

Figure 5. 3D printed customized orthosis

Customized children's orthosis is made on low-cost 3D printers Prusa i3 P3Steel and Geeetech Prusa i3 Pro B. 3D printer Prusa i3 are one of the most common low-cost printer on the market. They are mostly used as beginner 3D printers and for educational purposes. 3D printers used in this paper were part of the project "e-workshops" in Osijek and assembled by the students of elementary and high schools under supervision of the teachers.

IV. SOLUTION/DISCUSSION

The modeling of the back “butterfly” orthosis component based on the patient 3D scans images did not take much time. Approximately the time of modeling the "butterfly" component was 15 hours, considering the time needed to familiarize the tool and the program. The customized children's orthosis has been successfully developed with 3D printing technology. The printing process lasted over 80 hours and approximately 650 grams of material was consumed, taking into consideration both the test and the failed prints. 3D printing advantage is the production speed and the strength combined with the smaller mass of components. The time to assemble customized orthosis was approximately 30 minutes. The orthosis trial lasted twenty minutes. Placing the orthosis on the patient lasted less than 5 minutes, while in the rest of the time the arms were laded to different positions to test the motion limitation. There is no need for big changes and the orthosis is a suitable size for a patient. Possible improvements would be a new solution for fixing the components on the back of the patient and redesigning certain arm components to reduce the orthosis distance from the the patient's shoulders.

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