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Case report: Auxiliary device for recreational use in a child with upper limb malformation, made by additive manufacture (3D printing).

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Abstract. Patients with a deficiency in any member of body have difficulties in day-to-day activities, such as practicing recreational physical activities and, in case of children, play. Therefore, the aim of this project was to create a low cost and water resistant device that would help children with disabilities of the upper limb to have greater freedom and comfort when it comes to playing. Another important point, with customization that refers to characters of movies and comics, is to promote a significant improvement in self-esteem and in the relationship with other children, especially in school environment, reducing bulling and shame episodes. For this, a prototype mechanical device was created by additive manufacture (3D printing), customized with characteristics of "Iron Man" character of Marvel®.

Keywords. *Upper limb malformation, deficiency, low cost personalized devices.*

Introduction. Individuals with malformations or disabilities, have impossibility or difficulty in performing common tasks, as dressing, eating, walking, tinkering with a computer, and doing the same physical things. To improve quality of life of these individuals, the development of new forms of treatment and orthotics for patients with motor impairments or amputations is important [1].

The past few decades have evolved as a constant, and accessibility and contribution are still widely discussed in society. Computer-aided design (CAD) software emerged as a rapid solution (RP) in 1987 and can be configured as a constructive additive process used for the activation of physical prototypes from a three-dimensional digital model. The rapid investigation was inserted in medical area (dentistry) in 1991, and the first chapters were inserted in the medical area and later evolved more effectively for uses in patients. It is possible to discover interdisciplinary work in the production of biomedical models, which involve areas such as engineering, computer and health sciences, among others [2].

In Brazil, according to Normative Resolution ANS - RN No. 338 of October 21, 2013, prosthesis can be defined as any permanent or transient material that totally or partially replaces a limb, organ or tissue of the body [3]. Prostheses are used to artificially replace a part of the body, providing independence and improving the patient's quality of life and self-esteem [4].

The use of upper limb prostheses is necessary when the person does not have the limb, whether due to congenital malformation or amputation, due to trauma, accident, illness or surgical complication [5].

The prostheses for upper limbs can be classified according to their functionality in: passive and active, latter being divided into mechanical, myoelectric and hybrid. The passive or esthetic prostheses aim at completing the missing image of the body, providing greater comfort and assisting in desensitization of the stump. This type of prosthesis is easy to handle and can be used at any level of amputation, however, they have low functionality since they do not allow the fingers to move. Active mechanical prostheses are functional, since they can be activated by patient: they enable opening and closing of the fingers, which are mechanically activated, that is, from muscle contraction and /or movements of proximal segments to stump, through cables and tie rods. This type of prosthesis requires training to use in order to better control movements. The active myoelectric type prostheses are functional and allow movements very similar to those of a human hand. The myoelectric control occurs through electrical potentials captured by electrodes on the surface of residual limb skin during muscle contraction, which are sent to a microprocessor, responsible for triggering the components that control movements of the hand, allowing independent movements, such as typing on a keyboard or tying a shoelace. This type of prosthesis presents greater functionality and complexity and, consequently, higher cost and training requirements. Finally, hybrid-type active prostheses combine mechanisms of mechanical and myoelectric prosthesis [6].

In order to better meet the users' needs as well as be feasible for most of the population, prostheses need to be lighter, cheaper and functional. However, in Brazil, the reality in today's market is not this: mechanical and myoelectric prostheses are very expensive, being accessible only to a small part of the population; in addition, most hand prostheses are still imported. A good solution to the problem related to the cost of a functional, mechanical or myoelectric prosthesis is rapid prototyping, which reduces the cost and time of production of the parts.

The first mechanical prosthesis printed in 3D resulted in creation of a virtual community, which provides files for printing various models of hand prostheses. With the emergence of community, manufacture of prostheses of upper limbs became the target of several studies, both for improvement of the models available and for creation of new ones.

In view of this scenario, for a 6-year-old male A.M.A.C volunteer, presenting a malformation in transradial position (below the elbow, between the wrist joint and elbow joint), was designed a prototype of a mechanical device, customized with Characteristics of Iron Man character of company Marvel®, made by 3D printing, for recreational use only (not a prosthesis).

This project aimed to recover and aid part of the movements of the volunteer's left arm, mainly for use during recreational activities and games. Another important point addressed is the improvement in self-esteem and decrease of cases of bulling and episodes of shame or excessive shyness compared to colleagues in school environment.

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Materials and methods. This Project was based into another design named "SUPERHERO ENABLE 3D PRINTED PROSTHESIS", created by Christian Silva and Wilmer Garcia; it's licensed under the Creative Commons - Attribution - Non-Commercial - No Derivatives license. These parts drawings were obtained from the open source online community, Thinkverse. Christian Silva is a mechatronics engineer who works with a Bogotá, Colombia-based group of volunteers who help local children and adults receive free or low cost prosthetic devices. And Wilmer Garcia is an Art Studend from the National University of Colombia.
From the three-dimensional model it was possible to print the parts for mounting the device. The phalanges of the fingers were perforated longitudinally so that it was possible to embed helical springs. The part of the spring in the proximal phalanx was anchored in the centerpiece of the hand. This modification in the design allowed the fingers not to be printed on flexible materials, and can make the entire device with a single material. For the production of the pieces, the technology of additive manufacture was used by 3D printing by deposition of molten material, utilizing filaments of PLA material. Measurements of the patient's stump were obtained through the preparation of a model in gypsum, made from an alginate mold.

Results and discussion. The stump molding was performed in a satisfactory manner and allowed to obtain the volunteer's measurements, adaptation of the design and fittings of the upper arm and the forearm. The mold and some CAD designed pieces can be seen in Fig. 1:

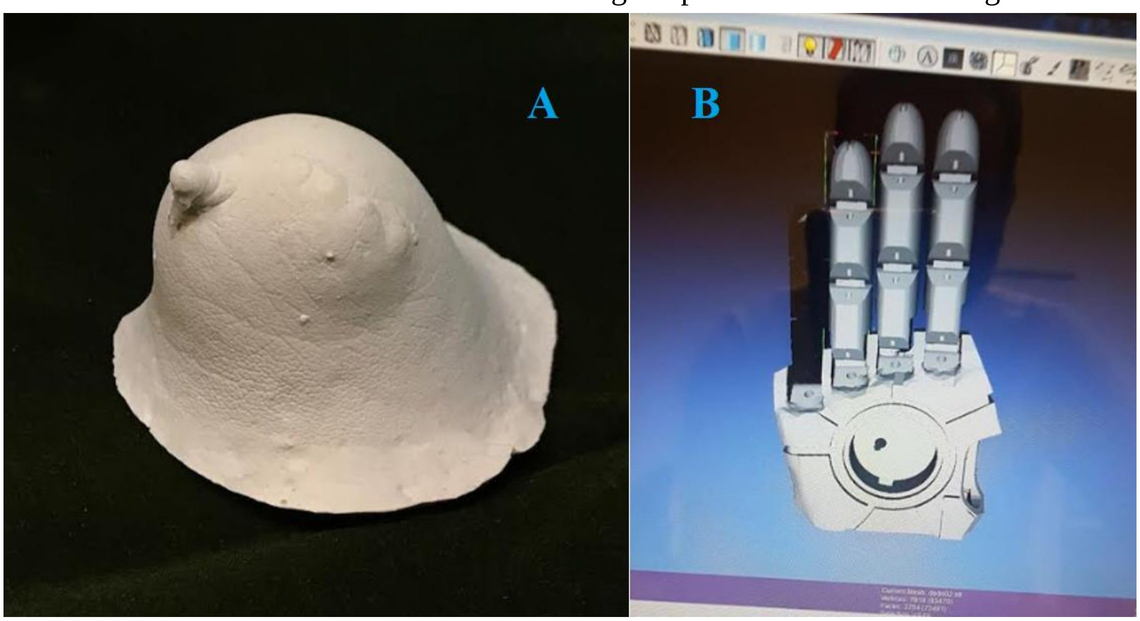

Figure 1. A- stump mold; B- CAD designed pieces.

The prototyping of the 35 pieces was performed and the assembly includes the use of helicoidal springs inside of phalanges and nylon threads on ventral part of the fingers. This scheme allows the tension of nylon foci with adduction movement of the elbow joint, that is, when folding the arm hand closes, and when stretching the arm the fingers return to initial position, recovery by the coils, causing the hand open. The mechanism of opening and closing of fingers was considered efficient and easy to adapt by the volunteer. Fig. 2 shows the parts after prototyping and Fig. 3 shows the assembly of the device.

Figure 2. Prototype pieces.

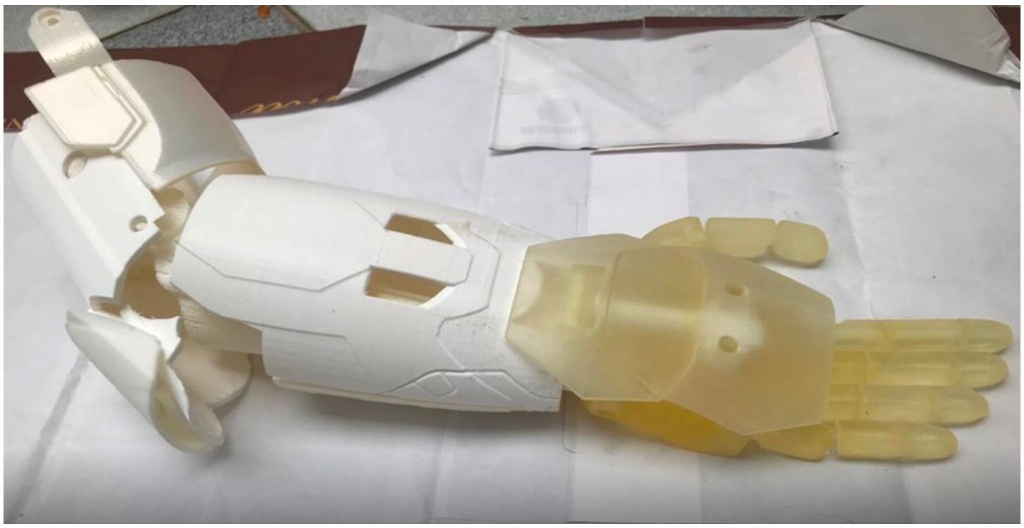

Figure 3. Device's initial assembly.

After assembly for initial operation verification, the parts were painted with inert acrylic paint to avoid possible allergies, and the inside of the parts that would come in contact with arm were covered with EVA for comfort during use. The closure of the parts in the stump is realized with Velcro, to allow ideal coupling and to guarantee the comfort during the use. The Velcro closures can be seen in Fig.4, marked in blue. In Fig. 4 it's possible to see also the light system in hand, main feature of Marvel's® "Iron Man" character.

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Figure 4. Device's closure system and Marvel's® "Iron Man" character.

The user reported that he considered the device light and comfortable, in addition to considering customization a very relevant point that brings an increase of self-esteem, especially in school environment. The final assembly and use by the volunteer at school can be seen in Fig.5:

Figure 5. Volunteer wearing the device at school.

Conclusion. The developed device was considered satisfactory and met the expectations of researchers and volunteer. The device is easy to operate and allows simple movements to hold and move objects, improving the quality of life, especially in recreational activities. The volunteer and his legal guardians report a significant improvement in self-esteem and relationships in the school environment. In this way, confirming the psychological benefit in a way even superior to the physical benefits, brought by the incorporation of the comic's characterization of device. The reduction of costs and popularization of this class of recreational devices can be considered an important point to be developed in future projects, mainly in the current Brazilian's economic scenario.

Acknowledgments. We thank Professor Aron José Pazin de Andrade and staff, for support.

Disclosure. The authors report no conflicts of interest in this work. The project was developed with equipment and resources of the authors themselves, on a voluntary basis, and without the involvement of research institutions USP and UFABC. The undeveloped device was donated to the AMAC with support and participation of legal guardians and subsequent follow-up of the physiotherapy team that attends it.

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