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Design and Implementation of a Low-Cost and Functional Prosthetic Hand Using 3D Printing Technology for a Member of the Association of Physical Disabilities Indonesia

Triwiyanto, Sari Luthfiyah, Levana Forra Wakidi and Bedjo Utomo
Department of Medical Electronics Technology, Health Polytechnic Minister of Health of Surabaya,

Corresponding author: Sari Luthfiyah (e-mail: sariluth@poltekkesdepkes-sby.ac.id)

ABSTRACT Many people with physical disabilities, especially transradial amputees, face difficulties in performing daily activities and have low self-esteem due to the lack of affordable and functional prosthetic hands. The aim of this community service program is to apply 3D printing technology in making prosthetic hands for the members of the Indonesian Physical Disability Association (PPDFI) branch in Surabaya. The method consists of four steps: (1) measuring the physical parameters of the amputees, such as the circumference and length of the residual limb, (2) designing and printing the prosthetic hand using 3D software and printer, (3) testing the mechanical and functional performance of the prosthetic hand, such as the ability to open and close, and (4) providing counseling and mentoring to the amputees to restore their confidence and evaluate their usage. Result: The result of this program is the availability of a low-cost and open-source prosthetic hand for the transradial amputees, which can help them to perform basic activities such as driving, holding a phone, and grabbing a bottle. The prosthetic hand can also be customized according to the needs and preferences of the amputees, such as the color or design. Conclusion: The conclusion of this program is that 3D printing technology can be used to create a functional and affordable prosthetic hand for the transradial amputees, which can improve their quality of life and self-esteem. The program also provides education and guidance to the amputees and the community about the benefits and risks of using prosthetic hands.

INDEX TERMS Community service, amputee, prosthetic hand, 3D printing

I. INTRODUCTION

Situation Analysis According to the Data and Information Center (Infodatin), the percentage of the population in East Java aged over 10 years who experienced disabilities in 2015 was as high as 9.40%. This figure is higher than the average percentage of the entire Indonesian population (8.56%)[1] [2]. Based on Infodatin, this indicates that the disability population in East Java is quite high, followed by the number of disabled individuals who are unemployed, amounting to 26.7% within the productive age range of 18-54 years (85.8%) [3]. One of the efforts to increase productivity among individuals with physical disabilities is by providing assistive devices that can restore mobility functions, one of which is the use of prosthetic hands for individuals with hand amputation disabilities. In other words, the situation in East Java presents a significant challenge. The high percentage of disabled individuals, particularly those who are unemployed, underscores the need for effective interventions. Providing assistive devices, such as prosthetic hands, is one such intervention that can help restore mobility and improve the quality of life for these individuals. By doing so, we can help them regain their independence and contribute to society, thereby addressing the issue of unemployment among the disabled population. The community service program partner is a member of the Indonesian Physical Disability Association (PPDFI) Surabaya Branch. One of the members suffers from a physical disability that was present at birth, leaving only 12 cm below the elbow joint. This condition is referred to as a transradial amputee, which means the loss of a part below the elbow joint [4][5][6]. Although the individual is still of productive age (36 years), this condition has resulted in an inability to work and a decrease in self-confidence when socializing in the community. The individual has made several attempts to have a prosthetic hand made, even if only for cosmetic purposes and not for functional movement. However, the challenge faced by the individual is the relatively high cost of making a prosthetic hand for the middle to lower class

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community, with prices ranging from 15 million to 20 million (for cosmetic prosthetic hands) [7] [8] [9]. Based on their purpose, there are two types of prosthetic hands developed in the world: for cosmetic purposes and for functional purposes [10][11][12]. In Indonesia, most prosthetic hands are still intended for cosmetic purposes, which means they are only complementary and cannot function like a hand. Several services for making cosmetic prosthetic hands have been found in big cities with relatively high manufacturing costs. The drawback of prosthetic hands with cosmetic functions is that they cannot be used for daily needs, such as holding and gripping an object (FIGURE 1).

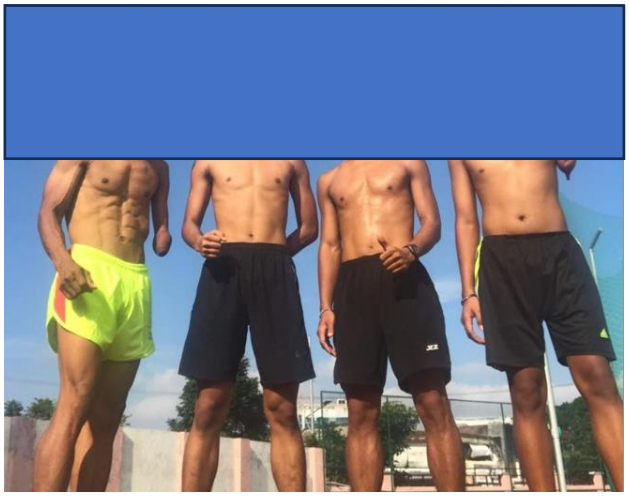

FIGURE 1. Photo of several members of the Indonesian Physical Disability Association (PPDFI) Surabaya Branch

Several large companies have developed functional prosthetic hands that can be moved using electromyography signals, which are signals generated by muscles during contraction. Several large companies, including Ottobock and Stepper, have made prosthetic devices that can be moved using bioelectric signals (EMG), but the prices offered by these companies are very expensive, starting from the range of 250,000,000 to 750,000,000 [13]. Meanwhile, 3D printing technology has developed rapidly, making it very possible to develop cheap prosthetic hands. The application of this technology has been realized in community service activities in 2021 for residents who have undergone amputation due to work accidents in the form of mechanical prosthetic hands that are moved by the elbow angle (FIGURE 2).

Based on the situation analysis, it is very possible to implement functional prosthetic hands for partners who have undergone transradial amputation by utilizing materials that can be purchased and made independently using 3D printing technology. The great desire of the physically disabled community to get cheap prosthetic hands is very large, therefore the proposer proposes a community partnership program with the title: "APPLICATION OF 3D PRINTING TECHNOLOGY IN THE MANUFACTURE OF PROSTHETIC HANDS ON MEMBERS OF THE INDONESIAN PHYSICAL DISABILITY ASSOCIATION (PPDFI) SURABAYA BRANCH"

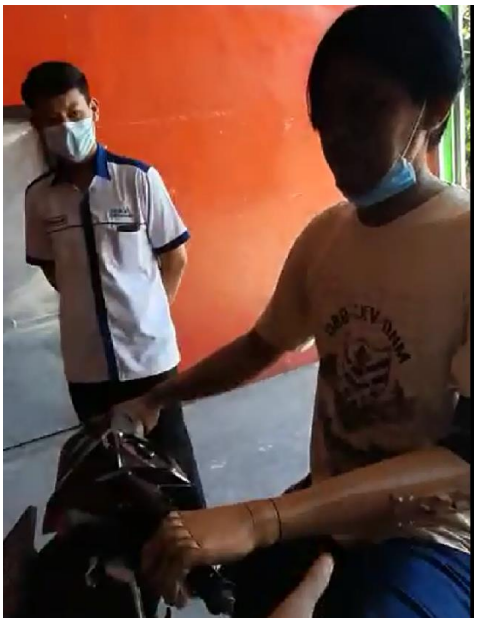

FIGURE 2. One of the implementations of 3D printing technology in the manufacture of prosthetic hands that has been carried out in Sidoarjo [7].

Problem Formulation Based on observations and direct discussions with partners, several problems were identified:

a. The partner has undergone a transradial amputation, which is an amputation starting from the left wrist, making it impossible to perform activities using both hands, such as driving a motor vehicle and some jobs that require coordination with two hands.
b. The partner comes from a lower-middle-class family and is therefore unable to afford a prosthetic hand device because the available prosthetic hands are priced out of reach for the lower class community.
c. The partner experiences a decrease in self-confidence when socializing with the local community due to the loss of part of the hand.

In other words, the partner faces significant challenges due to the physical limitations and socio-economic constraints. The inability to perform tasks that require the use of both hands has limited their ability to engage in certain activities, including driving and certain types of work. Furthermore, the high cost of prosthetic hands has made it difficult for them to afford this potentially life-changing device. Lastly, the loss of part of the hand has had a psychological impact, leading to decreased self-confidence, particularly when interacting with others in the community. These issues highlight the need for affordable, functional prosthetic solutions that can help individuals like the partner regain their independence and confidence.

Proposed solutions based on the problems faced by the partner, through the community service program with the

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"Community Partnership Program (PKM)" scheme, through Science and Technology for the Community, the proposer offers several solutions as shown in FIGURE 3.

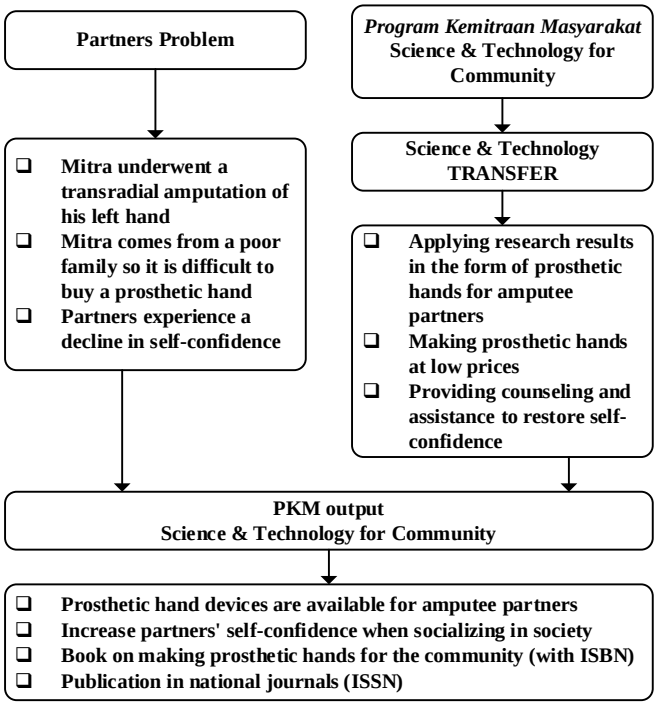

FIGURE 3. Solutions offered in solving partner problems

The journey towards overcoming physical disabilities and regaining self-confidence is a challenging one. However, with the right approach and technological advancements, it is possible to make significant strides. The solutions is proposed to address the challenges faced by a transradial amputee partner, focusing on education, design and creation of a functional prosthetic hand, affordability, and ongoing support. Firstly, education forms the foundation of this journey. It is crucial to provide comprehensive knowledge about prosthetic hands, including the materials used, the technology behind their manufacturing, and potential risks. This knowledge empowers the partner, enabling them to make informed decisions and understand the functionality and limitations of their prosthetic hand. It also helps to dispel any fears or misconceptions they may have, thereby fostering a positive attitude towards their new reality. Secondly, the design and creation of a functional prosthetic hand tailored to the partner's needs are paramount. The prosthetic hand should not only serve as a physical replacement but also enable the partner to perform basic daily tasks such as driving, holding a mobile phone, and handling a drink bottle. This functionality is vital as it enhances the partner's independence and improves their quality of life. The design process involves careful consideration of the partner's residual limb, lifestyle, and personal preferences, ensuring that the prosthetic hand is comfortable, practical, and aesthetically pleasing. Thirdly, affordability is a significant factor. Prosthetic devices can be prohibitively expensive, putting them out of reach for many individuals. Therefore, providing an affordable prosthetic hand made from locally available materials is a game-changer. The use of 3D printing technology and developed electronic technology makes this possible. 3D printing allows for cost-effective production and customization, while electronic technology enables the prosthetic hand to mimic natural hand movements. This combination of affordability and advanced technology makes prosthetic hands accessible to a wider population. Lastly, ongoing support and evaluation are essential. The journey does not end with the fitting of the prosthetic hand. It is a continuous process that requires regular follow-ups and adjustments to ensure the prosthetic hand continues to meet the partner's needs. Moreover, psychological support is necessary to help the partner regain their self-confidence. Using a prosthetic hand can be a significant adjustment, and having someone to guide them through this process can make a world of difference. In conclusion, the proposed solutions offer a holistic approach to addressing the challenges faced by the partner. By focusing on education, design and creation of a functional prosthetic hand, affordability, and ongoing support, it is possible to significantly improve the partner's quality of life and self-confidence. This approach underscores the power of technology and human resilience in overcoming physical disabilities. In other words, the proposed solutions aim to address the partner's challenges through a combination of education, design and manufacturing of a functional prosthetic hand, affordability, and ongoing support. The goal is not only to provide a physical solution but also to help the partner regain self-confidence and improve their quality of life. The use of locally available materials and 3D printing technology ensures that the solution is both affordable and accessible. Furthermore, the ongoing support and evaluation ensure that the prosthetic hand meets the partner's needs and can be adjusted as necessary.

II. METHOD

Time and place the Community Partnership Program (PKM) activities are scheduled to take place from May to October 2023. The location of the activities is at the Indonesian Physical Disability Association (PPDFI) Surabaya Branch, with the secretariat located in Dukuh Kupang Barat, Surabaya. Implementation method the community service program, titled "Application of 3D Printing Technology in the Manufacture of Prosthetic Hands for Members of the Indonesian Physical Disability Association (PPDFI) Surabaya Branch," is designed to address the challenges faced by the partner. In other words, the program is strategically planned and executed over a period of six months at a location that is accessible to the partner. The implementation method is carefully designed to ensure the successful application of 3D printing technology in the creation of prosthetic hands. This method takes into account various factors such as the partner's needs, available resources, and the timeline of the program. The ultimate goal is to provide a practical and affordable solution to the partner's challenges, thereby improving their quality of life and self-confidence. The

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steps of the planned activities in providing solutions to the partner are outlined in the steps shown in Figure 31. After conducting observations and discussions, the following steps are taken:

1. PREPARATION: To design a prosthetic hand, several physical parameters on the partner need to be measured, such as the diameter of the hand circumference, the length of the amputated part, weight, and height. In addition to physical parameters, we also conduct medical measurements, such as blood pressure, heart health, and diabetes.
2. IMPLEMENTATION: a. Once the physical parameters are obtained, the next step is to design the prosthetic hand using a 3D application program. The main tools and materials needed are filament made from PLA material and a tool used to print the prosthetic hand, namely using a three-dimensional printing machine (3D printing). The process of printing the prosthetic hand is done in parts, namely fingers, palms, back of the hand, and socket. After the printing process per part, the assembly process of each part into one unit (prosthetic hand) is continued. b. After the prosthetic hand is produced and has been assembled, the next step is to conduct mechanical and functional testing to perform basic movements. The basic movements that can be performed include: opening and closing. Next is the installation of the prosthetic hand on the partner.
3. EVALUATION: To see the functionality of the prosthetic device, monitoring and evaluation are needed after installation on the partner. Regular monitoring is carried out every two weeks, and monthly, which includes durability, ergonomics, and clinical impact on the partner's body.
4. OUTPUT: After the implementation process of the PKM, the next step is to publish the results and evaluations in the form of publications to books or journals.

In other words, the process of providing solutions to the partner involves a series of well-planned steps, starting from preparation, implementation, evaluation, to output. Each step is crucial and contributes to the overall success of the project. The use of 3D printing technology in the design and creation of the prosthetic hand, coupled with regular monitoring and evaluation, ensures the development of a functional, comfortable, and affordable prosthetic hand that meets the partner's needs. The final step involves sharing the findings and evaluations through publications, thereby contributing to the body of knowledge in this field.

III. RESULT

Outcomes The outcomes of the Community Partnership Program (PKM) titled "Application of 3D Printing Technology in the Manufacture of Prosthetic Hands for Members of the Indonesian Physical Disability Association (PPDFI) Surabaya Branch" are as follows:

1. The availability of prosthetic hands for members of the PPDFI Surabaya branch, which can assist partners who have undergone transradial amputation on the hand to carry out activities related to hand movements more effectively and can enhance self-confidence.
2. The results of this activity will be published in a National Journal with an ISSN, namely Frontiers in Community Service and Empowerment, which is a national journal with the publisher FORITIKES.
3. The results of this activity can be made into a Copyright for a prosthetic hand using open-source 3D printing technology.

In other words, the program aims to provide tangible and impactful outcomes that not only improve the quality of life for the members of the PPDFI Surabaya branch but also contribute to the body of knowledge in this field. The creation of prosthetic hands using 3D printing technology not only enhances the mobility of the members but also boosts their self-confidence. Furthermore, the publication of the results in a national journal ensures that the findings and insights gained from this program are shared with a wider audience, thereby fostering further research and development in this area. Lastly, the creation of a Copyright for the prosthetic hand underscores the innovative use of open-source 3D printing technology in addressing physical disabilities [14].

For amputee patients, measuring parameters on the circumference of the lower and upper biceps, the circumference of the forearm (top and bottom), and the length of the palm can assist in determining the appropriate size for the prosthetic model. The measurement of the upper and lower biceps circumference is carried out to determine the size of the upper prosthetic arm. The measurement of the forearm (top and bottom) circumference is done to determine the size of the lower prosthetic arm. The measurement of the length of the palm is carried out to determine the size of the prosthetic hand. The measurement of the upper and lower biceps circumference is done using a measuring tape. The tape is placed around the upper or lower arm at a certain point, and then the measurement result is read. The measurement of the forearm (top and bottom) circumference is also done using a measuring tape. The tape is placed around the lower arm at a certain point, and then the measurement result is read. The measurement of the length of the palm is done using a caliper. The caliper is placed on top of the palm at a certain point, and then the measurement result is read.

All measurements must be carried out by trained and experienced medical personnel in taking patient body measurements. The measurement results must be recorded correctly and accurately to ensure that the prosthetic made matches the patient's body size. In other words, the process of creating a prosthetic involves a series of precise measurements to ensure a perfect fit. These measurements, taken by trained medical personnel, are crucial in designing a prosthetic that not only fits the patient's residual limb but also mimics the natural movement of the limb. This meticulous process underscores the importance of accuracy and precision in prosthetic design,

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ultimately contributing to the comfort and functionality of the prosthetic (FIGURE 4).

(a) (b)

FIGURE 4. Measurement of several physical parameters on participants with hand amputations due to work accidents (a) top view, (b) front view.

3D printing is a technology used to create three-dimensional models of an object. In this case, 3D printing is used to create a prosthetic hand based on measurements taken from the respondent [15][16]. The 3D machine used is the Creality Cr 10, and the filament material used is PLA type [17]. PLA (Polylactic Acid) is a material commonly used in 3D printing. This material is made from natural ingredients such as corn and potato starch, making it more environmentally friendly compared to other 3D printing materials. In addition, PLA is easy to print and has a smooth surface [18].

The 3D printed result for the prosthetic hand can be customized to fit the respondent's body size. Measurements are taken on the circumference of the lower and upper biceps, the circumference of the forearm (top and bottom), and the length of the palm. These measurements assist in determining the appropriate size for the prosthesis. The measurement of the upper and lower biceps circumference is carried out to determine the size of the upper prosthetic arm. The measurement of the forearm (top and bottom) circumference is done to determine the size of the lower prosthetic arm. The measurement of the length of the palm is carried out to determine the size of the prosthetic hand [19].

All measurements must be carried out by trained and experienced medical personnel in taking patient body measurements. The measurement results must be recorded correctly and accurately to ensure that the prosthetic made matches the patient's body size. Once the measurements are completed, the measurement data is input into the 3D printing software. This software will produce a three-dimensional model of the prosthetic hand based on the measurement data. The three-dimensional model is then printed using the 3D Creality Cr 10 machine using PLA filament material [20]. This machine has the capability to print objects with quite large dimensions, making it suitable for printing prosthetic hands. After the printing process is completed, the 3D printed result needs to be further processed to be used as a prosthetic hand. This process includes cleaning the mold, installing electronic components (if needed), and adjusting to fit the respondent's body size. The 3D printed result for the prosthetic hand can assist the respondent in carrying out daily activities such as gripping items or holding writing tools. In addition, the 3D printed result can also be customized to the respondent's needs such as a specific color or design.

IV. CONCLUSION

In conclusion, the primary objective of this Community Partnership Program (PKM), as indicated by its title, is to apply 3D printing technology in the creation of prosthetic hands for individuals who have undergone transradial amputation, as a means to enhance their quality of life. The outcomes of this program demonstrate that patients can utilize the prosthetic hand to assist in carrying out daily activities. During the PKM activities, the prosthetic hand was tested on an amputee patient, specifically for the action of gripping a mineral water bottle. Observations indicate that the patient requires regular practice to effectively use the prosthetic hand. In the future, several developments can be undertaken, particularly in terms of control and the size of the prosthetic hand, so that patients can experience a prosthetic hand that functions like a normal hand.
It is important to note a few recommendations for future endeavors. Firstly, the physical parameters of the patient's hand (upper arm circumference, wrist circumference, and forearm length) are crucial as they significantly determine the outcome of the 3D printer mold. Secondly, setting the infill parameters on the 3D printing mold is vital in determining the weight of the prosthetic hand, ensuring that the patient is not overly burdened by it. Lastly, the PKM team at Poltekkes Kemenkes Surabaya can conduct activities with the same theme on a broader scope through associations or unions of people with disabilities at the regional, national, and even international levels. This will further the reach and impact of such beneficial programs.

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