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# VERSATILE 3D PRINTED PROSTHETIC ARM TO IMPROVE ACTIVITIES OF DAILY LIVING AND QUALITY OF LIFE FOR BELOW ELBOW AMPUTEE - SINGLE CASE STUDY

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***Abstract:*** This Experimental research study examined the impact of Occupational Therapy intervention focused on improving Activities of Daily Living and Quality of Life in individuals present with Below Elbow Amputation. Individuals present with Below Elbow Amputation at Sri Ramachandra Hospital including outpatient and inpatient services center were invited to participate in this study. An individual was selected for this study and the patients who met the inclusion criteria were recruited for this study, And the patient was asked to complete a UEFS questionnaire and OPUS-Health Related Quality of Life Index (HR-QOL). After a 2 week period of Occupational Therapy intervention, the study patients who completed Versatile 3D Printed Prosthetic Arm Intervention were again asked to complete the OPUS-Health Related Quality of Life Index (HR-QOL). With the results interpreted, the patient statistically shows significant improvements in Activities of Daily Living and Quality of Life. This study shows that Occupational Therapy approaches to Activities of Daily Living and Quality of Life is effective in treating individuals with Below Elbow Amputation. Occupational Therapy focuses on treating symptoms that specifically limit daily functioning and participation.

## I. INTRODUCTION

### 1.1 Below Elbow Amputation

Amputation has become one of the problems of today's society, whether it be lifestyle related or due to accident or disease. There is a large number of people who have one or both amputated lower limbs and this situation tends to increase worldwide. It is estimated that 85% of the amputations that occur in the national scenario affect the lower limbs, and in 2011, the percentage recorded was about 94% among the amputations performed by the *Sistema Único de Saúde*. People with amputation need to adapt to the loss and changes in the pace of life in interpersonal, social and professional interactions. The perception of quality of life for patients with amputation is more associated with pain, adaptation to the prosthesis and psychosocial well-being than with clinical or demographic variables such as age, gender, level or cause of amputation.

Hand-transplantation and improvements in the field of prostheses opened new frontiers in restoring hand function in below-elbow amputees. Both concepts aim at restoring reliable hand function, however, the indications, advantages and limitations for each treatment must be carefully considered depending on level and extent of amputation [1]. Hands are instrumental for our survival and welfare. We use our hands when we work, recreate, and communicate. A handshake, a touch, a sign, or signal has significant social and communicative meanings. Hands play a major role in defining the skill level of our activities and our level of social expression and integration [2].

The loss of an upper limb severely affects the ability of the amputees to carry out activities of daily living (ADLs), leading to a significant impact on their well-being. An effective replacement of the lost functions by a prosthetic limb therefore has the potential to improve the quality of lives of those living with limb loss [3].

### 1.2 3D Printed Prosthetic Arm

In the last 15 years, the market for prosthetic arms and hands has shifted toward systems with greater degrees of actuation. There has also been a progressive use of emerging technologies to overcome hardware design challenges. Moreover, the proliferation of rapid prototyping has resulted in applications in the prosthetic market. Even though there are concerns on robustness and wide-user acceptance, the affordable and customizable solution offered by rapid prototyping, combined with the possibility for easy maintenance and repair, is very attractive for prosthesis design [4]. The Cyborg Beast prosthetic hand and the proposed distance-fitting procedure represent a possible low-cost alternative for children in developing countries and those with little or no access to health care providers. Our prosthetic device may have a significant potential to positively impact quality of life and daily usage [5].

### 1.3 Occupational Therapy For Below Elbow Amputation

ADL training is initiated as early as possible in the acute phase of rehabilitation, to facilitate a return to independence in basic daily tasks. Performing self-feeding, hygiene and toileting with universal cuffs, splints, and devices secured to the residual limb allows the patient to regain some control over their environment [6].

## II. OBJECTIVES

- To Determine the use of the 3D Printed Prosthetic Arm (Trésdesis Mery)
- Find out the Improvements in Activities of Daily Living and Quality of Life

## III. REVIEW OF LITERATURE

**Steven A. Ovadia et al (2015)** studied about The elbow and wrist disarticulation procedures that are useful in preserving length when the alternative would be amputation proximal to the joint. Furthermore, in preserving the joint, these procedures offer additional benefits. Elbow disarticulation maintains a patient's ability to rotate the humerus. This motion can provide an additional means of control to a prosthetic device. Additionally, the preservation of the humeral condyles provides a good foundation onto which prosthetic devices can be fitted [7].

**Stefan Salminger et al (2019)** researched about prosthetic hand function in below-elbow amputees using four different objective measurements closely related to activities of daily living. Seventeen patients who underwent prosthetic fitting after unilateral below-elbow amputation were enrolled in this study. Global upper extremity function was evaluated using the Action Research Arm Test, Southampton Hand Assessment Procedure, the Clothespin-Relocation Test, and the Box and Block Test, which monitor hand and extremity function (1)

**Saiful et al (2018)** conducted a study to investigate whether a functional prosthetic hand can cost up to £10,000 which limits its access to many amputees. With advancement of technology, one of the possibilities to overcome this issue lies in the use of 3D-printing. A 3D-printer can reduce the production cost significantly, to less than £400, for models that can achieve basic functionalities. There have been several developments of 3D-printed prosthetic hands and arms, and some of them have been made open source. This paper presents a work in progress of implementing a 3D-printed prosthetic hand based on an open source model, describes some of the important issues and challenges faced, and carries out a tasks-based control analysis for some activities of daily living; namely those that depend on power, tip, lateral, and spherical grasps [8].

## IV. METHODOLOGY

A single case study was conducted during 2021 at Sri Ramachandra Hospital Outpatient Department, Occupational Therapy unit. Patients who met the inclusion criteria were allotted into intervention by convenience sampling 1 subject were recruited for this study. Baseline assessment was done using a case record Performa which includes the demographic data and chief complaints. The patient participated in a 2 week intervention program. The outcome measures were The Upper Extremity Functional Scale (UEFS), OPUS-Health Related Quality of Life Index (HR-QOL), The OPUS-Satisfaction with Devices and Services (CSDS).

### 4.1Procedure

- The patient's Upper extremity hand Function will now be assessed using The Upper Extremity Functional Scale (UEFS).
- The pretest and posttest will be done using OPUS-Health Related Quality of Life Index (HR-QOL).

The OPUS-Satisfaction with Devices and Services (CSDS) will also be given and scored by the patient to capture their satisfactory score on using the Versatile 3D Printed Prosthetic Arm and Occupational Therapy Services.

### 4.2 Intervention Protocol

| Sessions | Intervention | Duration |
|---|---|---|
| | **Week 1** | |
| **Session 1** | • Orientation to Versatile 3D Printed Prosthetic Arm and Body powered Prosthesis<br>• Patient education and preparation for prosthetic use | 60 mins |
| **Session 2** | Cutting Food<br><br>It is easiest to cut food by holding the fork in the hook, with the hook fingers grasping the flat surface of the fork handle and the upper handle of the fork resting on the dorsal surface of the thumb of the hook. The knife is held by the sound hand. | 60 mins |
| **Session 3** | Using tools<br><br>The head of a large bolt may be secured in the hook terminal device while the wrench is held in the sound hand to tighten or loosen the bolt. Again, the amputee may need to be reminded that the prosthesis and terminal device are merely "functional assists" to aid in stabilization. | 60 mins |
| | **Week 2** | |

| | | |
|---|---|---|
| **Session 4** | Dressing<br><br>Dressing activities such as fastening trousers are accomplished by the terminal device holding the waistband or belt loop while the sound hand tucks in the shirt and fastens the waist hook, snap, or button. | 60 mins |

**4.3 Hypothesis**

**Alternative Hypothesis**

Provided Versatile 3D Printed Prosthetic Arm successfully helps improve ADLs and quality of life in both recreational activities and at work.

**Null Hypothesis**

Provided Versatile 3D Printed Prosthetic Arm fails to improve the ADLs or quality of life in both recreational activities and at work.

**V.DATA ANALYSIS**

**Table 1**: Upper Extremity Functional Index Score

| UPPER EXTREMITY FUNCTIONAL TASK | |
|---|---|
| **Responses** | **TOTAL SCORE** |
| **EXTREME DIFFICULTY** | 0 |
| **QUITE A BIT OF DIFFICULTY** | 1 |
| **MODERATE DIFFICULTY** | 6 |
| **A LITTLE BIT OF DIFFICULTY** | 24 |
| **NO DIFFICULTY** | 20 |

The pre-intervention assessment results of Upper Extremity Functional Index (UEFS) Test indicated that Patient had difficulty on the Activities mentioned on the table above from (Extreme Difficulty to No Difficulty).

**Table 2**: Pre and Post intervention OPUS: HEALTH RELATED QUALITY OF LIFE INDEX)

| OPUS HEALTH RELATED QUALITY OF LIFE INDEX | RAW SCORE | RASCH MEASURE |
|---|---|---|
| **OPUS HEALTH QUALITY OF LIFE** (PRE-INTERVENTION TEST SCORE) | 66 | 57.1 |
| **OPUS HEALTH QUALITY OF LIFE** (POST-INTERVENTION TEST SCORE) | 79 | 65.18 |

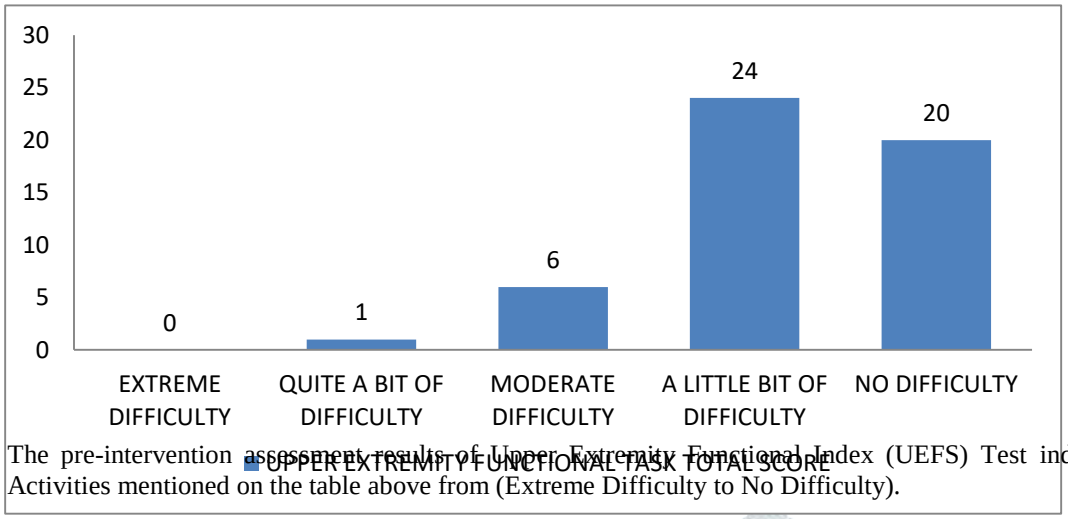
The pre-intervention and Post Intervention assessment results of **OPUS HEALTH RELATED QUALITY OF LIFE INDEX** Test indicated that Patient's Quality of Life has improved

(**Table 3**: OPUS: Satisfaction with Device and Service Results)

| OPUS: SATISFACTION WITH DEVICE AND SERVICES | | |
|---|---|---|
| S.NO | **OPINION** | **RESPONSES** |
| **1** | STRONGLY AGREE | 12 |
| **2** | AGREE | 6 |
| **3** | NEITHER AGREE NOR DISAGREE | 2 |
| **4** | DISAGREE | 0 |
| **5** | STRONGLY DISAGREE | 0 |
| **6** | DON'T KNOW/NOT APPLICABLE | 0 |

The results of **OPUS: SATISFACTION WITH DEVICE AND SERVICES** Test indicated that Patient Strongly agrees that they have satisfaction with the Device and Services.

**Figure 1:** UPPER EXTREMITY FUNCTION INDEX Total Score)




The pre-intervention assessment results of Upper Extremity Functional Index (UEFS) Test indicated that Patient had difficulty on the Activities mentioned on the table above from (Extreme Difficulty to No Difficulty).

**Figure 2:** Pre Intervention OPUS: Health Quality of Life Index Results

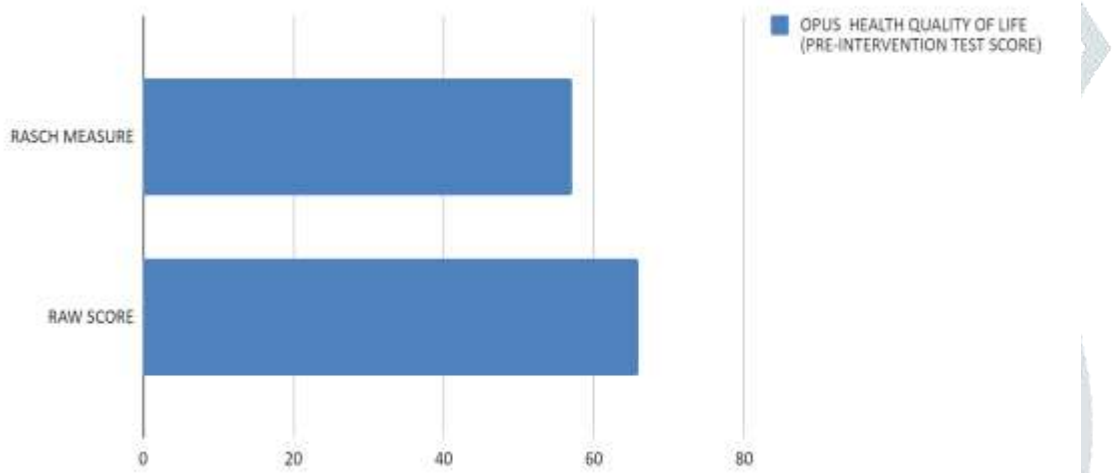
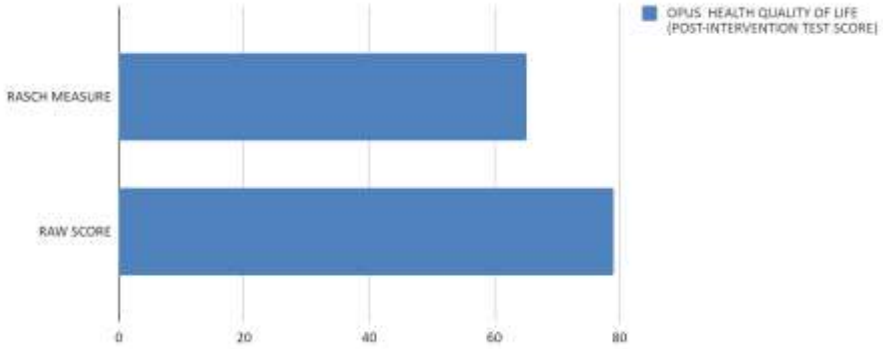
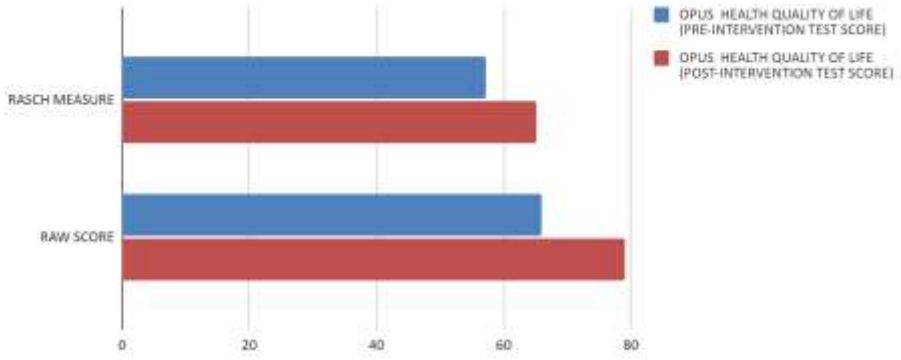



**Figure 3:** Post Intervention OPUS: Health Quality of Life Results)



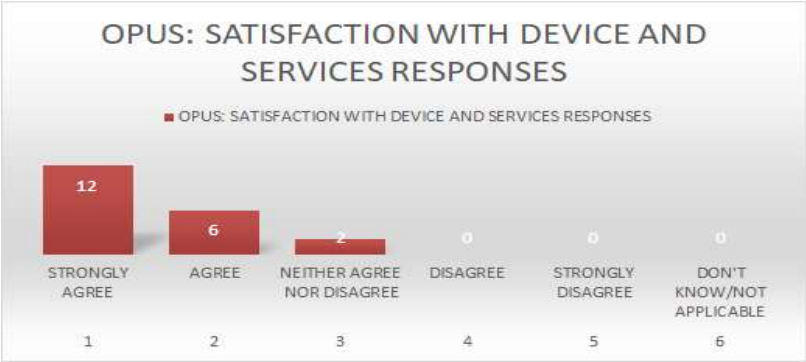

There is an improvement in the post test score from the pre test score after 2 weeks of intervention using Prosthetic Training in OPUS-Health Related Quality of Life Index (HR-QOL).

**Figure 4:** Pre and Post Intervention OPUS: Health Quality of Life Index Results)




The post-intervention assessment results of the OPUS: Health Quality of Life Index indicated that Patient had improvement in his Quality of Life and adapting to their new life.

**Figure 5**: OPUS: Satisfaction with Device and Service Result)




OPUS: Satisfaction with Device and Service Result shows positive results from the patient those they STRONGLY AGREE in most aspects

## VI. RESULTS

As this study is a single case study, analyses are best interpreted through visual analysis of graphic data. The result from OPUS: Health Quality of Life Index assessment was displayed for participant to illustrate the changes during pre intervention and post intervention phase.

OPUS: Satisfaction with Device and Services results….

## VII. DISCUSSION

### Importance of Occupational Therapy for Upper Limb Amputation

Primary care Physicians, Neurologists, Physical Therapists (pt), and Psychologists are members of a multidisciplinary program, but Occupational Therapy for Below Elbow Amputation has not been well researched or widely utilized. While other healthcare providers on a multidisciplinary Amputee treatment team can offer pharmacological treatments, psychological intervention, and physical exercises focusing on strength and mobilization, Occupational Therapists can offer a variety of different treatment approaches and Prosthetic arms for daily functioning, as well as how daily habits and routines impact health outcomes.

Occupational Therapy referral is required when a patient has problems in daily routines, or habits and/or if the patient is having difficulty participating in activities of daily life.

This Case Study describes how Occupational Therapy can be used successfully in treating Below Elbow Amputee using Prosthetic Training.

Despite limitations, the results indicate Occupational Therapy can significantly improve the daily performance of patients with Below elbow Amputee. The Goal of Occupational Therapy is to enhance independence, productivity, and safety in all activities related to personal care, employment, and leisure activities. Occupational Therapists provide Prosthesis training, energy conservation techniques.

### Importance of 3D Printed Prosthesis

The emergence of 3D printing has opened many opportunities for artificial hands for assistive purposes. Although prostheses are not anatomical avatars, careful appliance prescription and training, coordinated with the child's growth and developmental changes, can optimize the benefits the child derives from the prosthesis.

### 3D Printed Prosthetic Arm and Quality of Life

Prostheses may help with social acceptance or may be useful as tools for specialized activities, but they do appear to improve function or quality of life. This multicenter study aimed to examine the reasons for prosthesis rejection and assess the quality of life (QOL) among patients with upper limb deficiency. QOL was significantly higher in prosthesis users than in nonusers. More prosthesis users were employed compared with nonusers.

## VIII. LIMITATIONS

- This was a single-patient case study. Based on these results, it could not be generalized that Occupational Therapy can be effective in improving occupational performance of below elbow amputee populations.

- Results from this study cannot be generalized to other Below Elbow Amputee populations, or to other populations treated by multidisciplinary teams that include Occupational Therapists, because it comes under single case study.
- The results should be interpreted with the understanding that this was an experimental research study with a single sample size.

## XI. RECOMMENDATION

- Inclusion of more samples can be helpful in generalizing the treatment plan for the condition.
- Implementing the future research with added mechanisms to the 3D printed prosthetic arm.
- Implementing the future researches with different types of prosthesis.
- Future projects can be done with experimental and control groups.

## X. CONCLUSION

Occupational Therapy Versatile 3D Printed Prosthetic Arm intervention has shown better improvement in Activities of Daily Living and Quality of Life in patients with Below Elbow Amputee.

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