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Below Elbow Prosthetic: A Path to Independent Era

Sushmi Mazumdar
Department of Biomedical Engineering, North Eastern Hill University,Shillong

Angana Saikia
Department of Biomedical Engineering, North Eastern Hill University,Shillong

Nitin Sahai
Department of Biomedical Engineering, North Eastern Hill University,Shillong

Sudip Paul
Department of Biomedical Engineering, North Eastern Hill University,Shillong

***Abstract*—This article is intended to give a general overview of the prosthetic hand or below elbow. It describes about the existing technology, materials used and fabrication of the prosthesis. This article illustrates the development in research and the upcoming fields. It tells us that no disabled can stay a step behind than a normal being. They are no less than the normal people. The field of upper limb prosthetics has become increasingly specialized. At the same time, most practitioners see few individuals with upper limb deficiency-typically one upper limb client per year compared with about 30 clients experiencing lower limb deficiencies. Within this relatively small number of upper limb deficiencies, practitioners rarely encounter what could be considered ‘‘common’’ mobility issues associated with lower limb prosthetics.In consideration of Dillingham et al’s findings, only 1908 of the approximately 18,496 annual upper limb deficiency cases involve styloid level disarticulations to shoulder and interscapulothoracic levels. The other 16,588 individuals per year present with amputations distalto the wrist, which are much more difficult for a rehabilitation team to assess and treat. Perhaps this information gives knowledge to the amputees or disabled to lead an independent and normal life.**

***Index terms* -Prosthetic, Fabrications, EMG, Below Elbow, Robotics.**

I. INTRODUCTION

Prosthesis is a device which aids the disabled to lead a normal life. It replaces function and appearance of missing body part of the disabled. It compensates the loss of physical functions. They may lose their body part through congenital, tumor (cut, tear, burn, and freeze), disease or trauma.

Prosthesis can be of many types based on the patient’s loss. Craniofacial prosthesis, dental prosthesis, somato prosthesis and limb prosthesis.Limb prosthesis can be of two types: Upper limb prosthesis and Lower limb prosthesis. Upper limb prosthesis are further divided into Above Elbow (AE) and Below Elbow (BE) prosthesis. Variety of upper extremity prosthesis includes partial hand, trans-radial, elbow disarticulation, above the elbow, shoulder disarticulation.

Figure 1: Upper Limb Below Elbow Amputee

A. *STATISTICS*

Table:1

Distribution of disable by types of disability, sex, literacy status and residence,scheduled castes- 2011 (source of information:- http://censusindia.gov.in)

Types of disability	Sex	Literate			Illiterate		
		T	R	U	T	R	U
In movement	Persons	5,47,619	4,11,937	1,35,682	4,62,675	3,86,491	76,184
In movement	Male	3,97,151	3,02,146	95,005	2,34,853	1,97,066	37,787
In movement	Female	1,50,468	1,09,791	40,677	2,27,822	1,89,425	38,397

Table: 2

Distribution of disabled by type of disability, sex, literacy status and residence – 2011(source of information:-http://censusindia.gov.in)

Types of disability	Sex	Literate			Illiterate		
		T	R	U	T	R	U
In movement	Persons	32,72,514	22,66,321	10,06,193	21,64,312	17,69,420	3,94,892
In movement	Male	23,25,572	16,49,745	6,75,827	10,44,929	8,53,784	1,91,145
In movement	Female	9,46,942	6,16,576	3,30,366	11,19,383	9,15,636	2,03,747

Table:3

Distribution of disabled by types of disability, sex, literacy status and residence, scheduled tribes-2011(source of information:- http://censusindia.gov.in)

Types of disability	Sex	Literate			Illiterate		
		T	R	U	T	R	U
In movement	Persons	2,17,620	1,94,047	23,573	2,62,278	2,46,975	15,303
In movement	Male	1,55,224	1,39,079	16,145	1,23,770	1,16,362	7,408
In movement	Female	62,396	54,968	7,428	1,38,508	1,30,613	7,895

II. HISTORY

In the early years of B.C, Egyptians used fiber to manufacture prosthetic limbs. It was believed more for a sense of wholeness than function. The Italian unearthed a prosthetic limb made of bronze and iron with a wooden core. Then the Romans used iron hand. In 1508, German merchanary Gotz von Berlichingen had a pair of technologically advanced made after he lost his right arm in the Battle of Landshut. The hands could be manipulated by setting them with the natural hand and moved by relaxing a series of releases and springs while being suspended with leather straps. Around 1512, an Italian surgeon travelling in Asia recorded observations of a bilateral upper extremity amputee who was able to remove his hat, open his purse, and sign his name. Another story surfaced about a silver arm that was made of admiral Barbarossa, who fought the Spaniards in Bougie, Algeria, for a Turkish Sultan. In late 1500s, people started using leather, paper and glue and adjustable harness for the manufacture of prosthesis. After the civil war in nineteenth century, the lack of technology paved the way to the development and production of modern prosthesis. [1]

These advancements induced the interest of prosthetic development in modern era. Researchers are more focused on making the prosthetic hand more natural both in function and appearance. In today’s world the prosthetic hands are much lighter, made of plastic, aluminium and composite materials. The technologies in recent times include utilization of microprocessors, myoelectric, computers, hydraulics and robotics. [2]

Figure 2. Prosthetic hand during 1400s to 1800s

III MATERIALS INVOLVED

Both natural and man-made materials can be used in the manufacture of prosthetic below elbow. The manufacturer keeps in mind the properties such as biocompatible, durable, light weight and ease of fabrication. [3]. Each individual needs to be evaluated with careful consideration to their lifestyle, expectations and physical characteristics. [4]

The materials used in prosthetic below elbow are wood, leather, metal, cloth, carbon fiber. Woods are often used to provide shape and interior structural strength. It is light weight, strong, inexpensive, easy to work, and consistent in texture. Leathers are used for variety of purposes especially for suspension straps, waist belts, and socket linings. It is easy to work with, has a soft natural feel and biocompatible. Some of the materials used are:

a. Plastics:

   Plastics are used most commonly today. Nylon is a thermoplastic material which is used for sheaths, plastic laminations, bushings, suction valves, and nylon stockings to cover prostheses. It has good strength, elasticity, and low coefficient of friction. Three to eight layers of nylon are impregnated with polyester or acrylic resins during the lamination process to provide both structural strength and pleasant appearance.[3,6]

b. Acrylic resin:

   Acrylic resin is increasingly popular for laminations in prosthetics because its high strength permits a thinner, lighter-weight lamination and its thermoplastic properties allow easier adjustments of the prosthesis. Polyester resin is a thermosetting plastic which is used for laminations in prosthetics. It comes in liquid form that can be pigmented to match the skin tone of the patient.

c. Polypropylene:

   Polypropylene is an opaque white material that is relatively inexpensive, strong, durable and easy to mold. Polyethylene is a thermoplastic whose properties vary depending on density of material. These are used to produce sockets, transradial prostheses, tongue and bushings in joint mechanisms. Silicones are used in prosthetic below elbow for distal end pads in sockets, to provide a flexible rubber like end in air-cushion sockets, and for gel insets [5].

d. Plastic polymer:

   Plastic polymer laminates are widely use for the fabrication of prosthetic sockets. The advantage of plastic laminates is that the prosthetist has a great deal of control over the strength, stiffness and thickness of the finished product [6].

A. Reinforcement textile

Reinforcement textiles are the fabrics used in a laminate to provide strength. These include fiberglass, nylon, dacron, carbon and Kevlar. These materials have both advantage and disadvantages.

Carbon fiber is used to create thin, light weight and strong prosthetic sockets but is very difficult to reshape when an adjustment is required. Fiberglass is commonly used to reinforce polyester resin laminations where mechanical attachments such as bolts and screws will fasten. The light weight prostheses are designed and are successfully used as endoskeletal BE prosthesis and exoskeletal BE prosthesis. By reducing the weight considerably compared to other available alternatives, it is more likely that the amputee will make use of the prostheses to efficiently perform various activities.[7]

IV. FABRICATION

Prosthetic limbs are typically made using following steps: [9]

- Measurement of the stump.
- Measurement of the body to determine the size required for the artificial limb.
- Fitting of a liner and creating a model.
- Formation of sheet around the model.
- Formation of permanent socket.

Factors to be considered when a new prosthesis is prescribed: [3]

- Weight bearing
- Suspension

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- Activity level
- Structure of the prosthesis
- Prosthetic components
- Expense
- Unique consideration.

A. *The manufacturing process of prosthesis*

Prosthetic limbs are not mass-produced to be sold in stores. They are first prescribed by a medical doctor, usually after consultation with the amputee, a prosthetist, and a physical therapist. The patient then visits the prosthetist and a physical therapist [7].

Steps to be followed in measuring and casting process are:[8,9]

- Accuracy and attention to details are important in the manufacture because the goal is to have a limb that comes as close as possible to being as comfortable and useful as a natural one. Before work on the fabrication of the limb is begun, the prosthetist evaluates the amputee and takes an impression or digital reading of the residual limb.
- The prosthetist then measures the lengths of relevant body segments and determines the location of bones and tendons in the remaining part of the limb. Using the impression and measurements, the prosthetist then makes a plaster cast of the stump. This is most commonly made of plaster of Paris, because it dries fast and yields a detailed impression. From the plaster cast, a positive model-an exact duplicate-of the stump is made.
- Then a sheet (thermoplastic/polymer/thermosetting) is simply laid over the top of the mold in a vacuum chamber. Then the air between the sheet and the mold is sucked out of the chamber, collapsing the sheet around the mold and forcing it into the exact shape of the mold. This sheet is now the test socket.
- Before the permanent socket is made, the prosthetist works with the patient to ensure that the test socket fits properly. The patient is also asked to explain how the fit feels. The permanent socket is then formed.

Figure 3. Prosthetic hand fabrication

There are many other ways of fabrication of prosthetic hand:

- Plaster pieces: including soft-foam pieces used as liners or padding, are made in the usual plastic forming methods.
  - Vacuum-forming
  - Injecting molding
  - Extruding

The various components are put together in a variety of ways, using bolts, adhesives, and lamination [6].

V. ADVANCEMENT IN RESEARCH

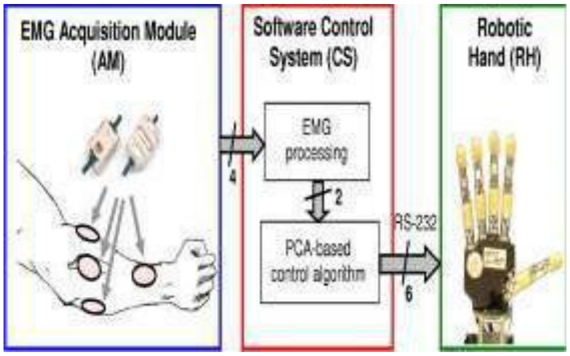

Figure 4. System overview.

The above experimental setup include the EMG acquisition module (AM, with four active electrodes placed on the user's forearm and an acquisition board) and the software control system (CS), which ran on a laptop and was interfaced with the hand (RH) via serial port. The CS acquired and decoded the four EMG signals to generate two independent input signals; these were fed into the PCA-based algorithm that generated and sent the six motor control commands to the robotic hand [11].

Scientist are getting closer and closer to approximating the function of human limbs. Microcontroller or microprocessor controlled prosthetic hand gripper have been developed that controls the movement. Arduino microcontrollers are also involved. The main advantage of this type of controlled prosthetic below elbow is closer approximation natural hand movement. Variations in speed are also possible and are taken into account by sensors and communicated to the processor which adjust the changes accordingly [12].

'Myoelectric' hands have movable fingers that grip and gesture naturally, and move in various ways in response to tiny muscular movements in the residual limb. Prosthesis of this type utilizes the residual neuromuscular system of the human body to control the functions of an electric powered prosthetic hand, wrist or elbow [13]. EMG from selected extrinsicmuscles could be used to control physiologically appropriate DOFs in a multi-digithand prosthesis. EMG from specific muscles can be collected using intramuscular techniques, such as chronically implanted myoelectric sensors (IMES) or by needle or fine-wire electrodes inserted into targeted muscles for acute recordings [16].

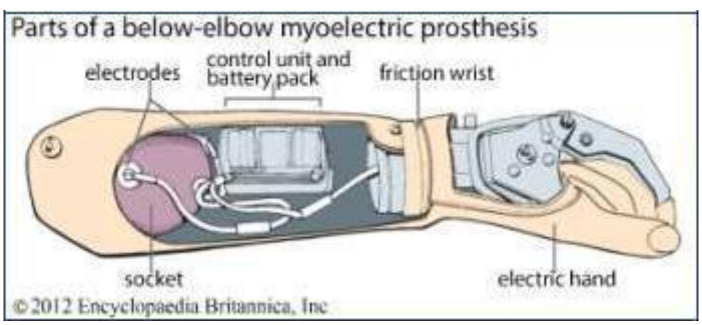

Figure 5. Myoelectric Prosthesis

Robotic prosthetic hands have a long way to go in the prosthetic field. It integrates components like biosensors, mechanical sensors, controllers and actuators to complete its task along with the computer technology. It can bring multiple DOFs into action and allow the hand to better match the natural hand [14]. Robotics have improved in their ability to take signals from the human brain and translate those signals into motion.

Figure 6. Prosthetic arm

A cybernetic hand is connected by a neural interface to a human and thus makes it possible to exploit sensory motor mechanism for controlling hand actions. This allows human amputees dexterous sensory motor control via a neural interface that provides efferent commands to control the hand and sensory feedback from artificial sensors [15].

VI. Conclusion

Current advances in robotics, neuroscience, and microelectronics are bringing the visions of science fiction closer to reality every year. But there are certain population of people who are unable to afford and lacks behind. People who are in poverty line miss the auspicious opportunity to lead a normal life. Therefore researchers are more focused on bringing the prosthetic hand to more cost-effective, biocompatible and comfortable using the technologies and existing materials. So that all the disabled or amputees can make their life independent and lead a better life.

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Authors' Profile

Sushmi Mazumdar: She is currentl working as Project Assistant in the Department of Biomedical Engineering, NEHU, Shillong. She worked as a trainee in Biomedical Department of Vijaya Hospital Chennai. She have completed her B-Tech degree in Biomedical from Sathyabama University, Chennai, India in 2014.

Angana Saikia: She is currently working as Junior Research Fellow in the Department of Biomedical Engineering, NEHU,Shillong. Previously she was working as a faculty in Electronics in Institute of Engineering And Management, Assam for a period of one year from August 2011 to July 2012. She completed her B.E in Applied Electronics and Instrumentation from Guwahati University, Assam, India in 2011 and her M-tech in Bioelectronics from Tezpur Central University, Assam, India in 2014.

Nitin Sahai: He is currently working as assistant professor in the Department of Biomedical Engineering, NEHU, Shillong. Previously he worked as an assistant professor of lovely professional university , Jalandhar , India. He cmpleted his B-tech degree in Biotechnology from Uttar Pradesh Technical Universuty in 2007 and M-tech degree in Biomedical Engineering from Motilal Nehru National Institute of Technology , Allahabad, India in 2010.

SudipPaul:He is currently working as Assistant Professor in the Department of Biomedical Engineering, NEHU, Shillong. He completed his B-tech degree in Biomedical Engineering from West Bengal University of Technology , India in 2007 and M-tech degree in Biomedical Engineering from Banaras Hindu UniversityIndia in 2009. He is pursuing Phd from IIT(BHU).