International Journal of Health Sciences and Research
Volume 14; Issue: 11; November 2024
Website: www.ijhsr.org
Case Study *ISSN: 2249-9571*

Innovative Modified Passive Functional Shoulder Prosthesis Incorporating a Double-Axis Hinge Shoulder Joint with Servo Motor for Shoulder Disarticulation Patient

Ankit Kumar Ray [1], Yashika Kumar[2]

[1] Intern, Indian Spinal Injury Centre- Institute of Rehabilitation Sciences, Vasant Kunj, New Delhi, India.
[2] Assistant professor (P&O), Indian Spinal Injury Centre- Institute of Rehabilitation Sciences, Vasant Kunj, New Delhi, India

Corresponding Author: Ankit Kumar Ray

DOI: https://doi.org/10.52403/ijhsr.20241116

ABSTRACT

BACKGROUND: Amputation is the removal of a body extremity due to the result of any trauma, medical illness, tumor or surgery. Trauma is the leading cause of amputation in upper limb, accounting for 80% of acquired amputations. The levels of amputation in upper limb are trans-phalangeal, trans-metacarpal, trans-carpal, wrist disarticulation, trans-radial, elbow disarticulation, trans-humeral, shoulder disarticulation, and forequarter amputation. Passive prosthesis is usually prescribed as the involvement of joints is more in amputation and the level of amputation is higher. A passive functional prosthesis can be socially beneficial because it can assist in promoting a psychological acceptance of the amputee's impaired image. The passive functional prosthesis does provide articulation and need sound limb to achieve desired position.
Aim: This study aimed to design and develop modified passive functional shoulder prosthesis incorporating a double-axis hinge shoulder joint with servo motor for enhanced mobility and psychological satisfaction in shoulder disarticulation patient.
Method: In this study a patient is taken with the amputation level through the shoulder to which passive functional shoulder prosthesis is prescribed. After this a modified passive functional shoulder prosthesis incorporating a double-axis hinge shoulder joint and servo motor was designed and fabricated for the patients of shoulder disarticulation and pretest data was taken using Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0) and then prosthesis is given to the patients and after this post test data was taken and data analysis was done.
Result: The modified passive functional shoulder prosthesis incorporating a double-axis hinge shoulder joint and servo motor has improved the function and psychological satisfaction of the patient with shoulder disarticulation the pre-test data was 3.7 and the post-test value comes 8.6.
Discussion and conclusion: This study showed improved result in the function and psychological satisfaction of the patient with shoulder disarticulation as the passive functional shoulder prosthesis includes the double axis hinge shoulder joint with servo motor is developed which provide two degree of freedom of movement i.e., the flexion and extension motion in sagittal plane using the servo motor which drive the power from the 12V

Li-ion battery. In this study, we evaluated the satisfaction of a patient with modified passive function shoulder prosthesis incorporating a double-axis hinge shoulder joint and servo motor and concluded that it provides the function and psychological satisfaction to the patient with shoulder disarticulation.

Keywords: Amputation, level of amputation, Shoulder disarticulation, Artificial Limb, Passive Prosthesis.

INTRODUCTION

An amputation is elimination of a body extremity as a result of any blunt trauma, medical illness and prolonged constriction or surgery [1]. Trauma is the most common cause of acquired amputations in the upper limb, affecting men between the ages of 15 and 45. Amputations are categorized according to the joint level at which they are executed that is trans-phalangeal, trans-metacarpal, trans-carpal, wrist disarticulation, trans-radial, elbow disarticulation, trans-humeral, shoulder disarticulation, and forequarter amputation.[2] The surgical separation of the entire arm from the shoulder joint is known as a shoulder disarticulation. In this surgery the humerus and the entire arm are removed from the scapula (glenoid cavity) and clavicle (collar bone). Most shoulder disarticulations are not actually disarticulations; rather, they are ultra-high transhumeral amputations with a small part of the humeral head and neck remaining to preserve cosmesis. Upper extremity amputations at the level of the shoulder disarticulation occur much less commonly than amputations at other levels.

As a result of military operations in Iraq and Afghanistan, approximately 800 people had major limb amputations as of July 2008, with upper limb amputations accounting for 20% of these cases. [3]

The loss of the entire upper limb profoundly impacts the functions of the human body like range of motion. An artificial device termed prosthesis is used to replace the part of the body that has been lost as a result of damage, illness, or a congenital problem. Generally patients with shoulder disarticulation have 4 available prosthetic options to be used, each with distinct advantages and disadvantages. These include a passive non-functional prosthesis, a passive functional prosthesis, a body (cable) powered prosthesis, an externally powered prosthesis (for example, myoelectric), or a hybrid prosthesis that involves mixing body-powered and externally powered components to best meet the functional and aesthetic desires of the patient.[4]

Body powered prosthesis uses the cables and harness for the functioning of the prosthesis, whereas externally powered prosthesis rely on electric power to drive motors to operate prosthetic componentry such as multi – articulating hands, elbow and shoulder. It has been noted that these prostheses have several drawbacks, such as the need for significant strength, which is lost in higher level amputations, and the expensive cost of externally powered prostheses, which restricts user access due to their large weight and intricate structure. [5]

Passive prosthesis is usually used which non-functional prosthesis is generally made of light weight foam covered with polyvinyl chloride (PVC) or silicone and serves primarily to create the illusion of an intact limb. This can be especially important with amputation at the shoulder level to allow appropriate clothing fit and appearance. For an entirely passive prosthesis, the armhangs from a fitted shoulder cap, and the elbow is simple and non-functional but can articulate so that it can be passively positioned by the sound limb. The hand can be contoured, painted, and textured to bear a striking resemblance to the sound limb. [6]

A passive functional prosthesis can have any number of passive articulating joints that have manual lock/unlock mechanisms

that can be used to place the limb in various positions using the sound limb or even a stationary object. To replicate the natural arc of motion during stride, a shoulder unit with this feature might also be adjusted to swing freely. Passive prosthesis does provide articulation and need sound limb to achieve the required position.

Roughly 30% of amputees wear a passive prosthesis. [7] A passive functional prosthesis can be socially beneficial because it can assist in promoting a psychological acceptance of the amputee's impaired body image. Passive devices for the shoulder region are a good option for individuals requiring a lightweight device, who have recently undergone amputation and old patients. The passive prosthesis doesn't provide any articulation and need sound limb to achieve the required position. There is limited evidence of the availability of the passive prosthesis for shoulder disarticulation which is functional at the same. So, this study attempt to develop a passive functional shoulder disarticulation prosthesis by incorporating a double – axis hinge joint with a servo motor to provide function and psychological satisfaction to the patient with shoulder disarticulation.

MATERIALS & METHODS

In this study, a shoulder disarticulation patient is taken. The patient is a 69-year-old male with the amputation through shoulder. There is a small part of humeral head is intact in the joint. The cause of the amputation is trauma which was caused in 1969. Patient is prescribed passive shoulder prosthesis. The first prosthesis use by the patient in 1971 is passive non - functional prosthesis which is bulky and cosmetically not good. He faces many issues with the prosthesis like donning, doffing, weight of the prosthesis. So, an attempt is made to fabricate a passive functional shoulder joint which is double axis hinge joint providing abduction/adduction movement using sound limb and flexion/extension movement by using a servo motor which drive the power from a 12V Lithium ion rechargeable battery.

FLOW OF THE STUDY

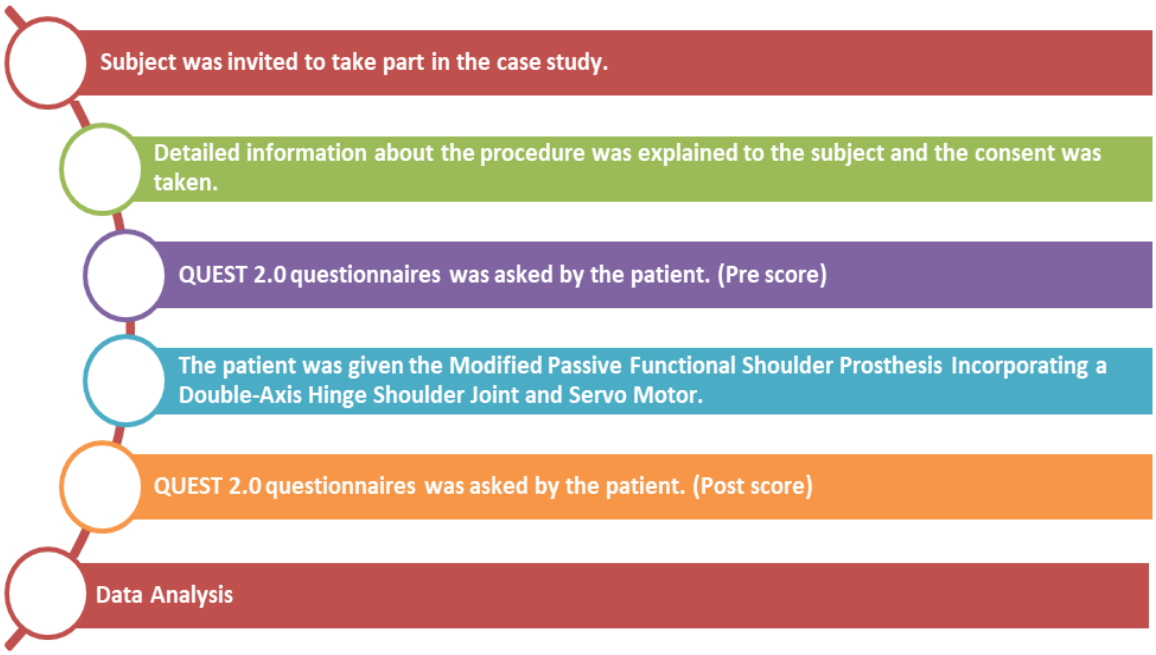


FIG 1: **MODIFIED DOUBLE AXIS HINGE SHOULDER JOINT WITH SERVO MOTOR**

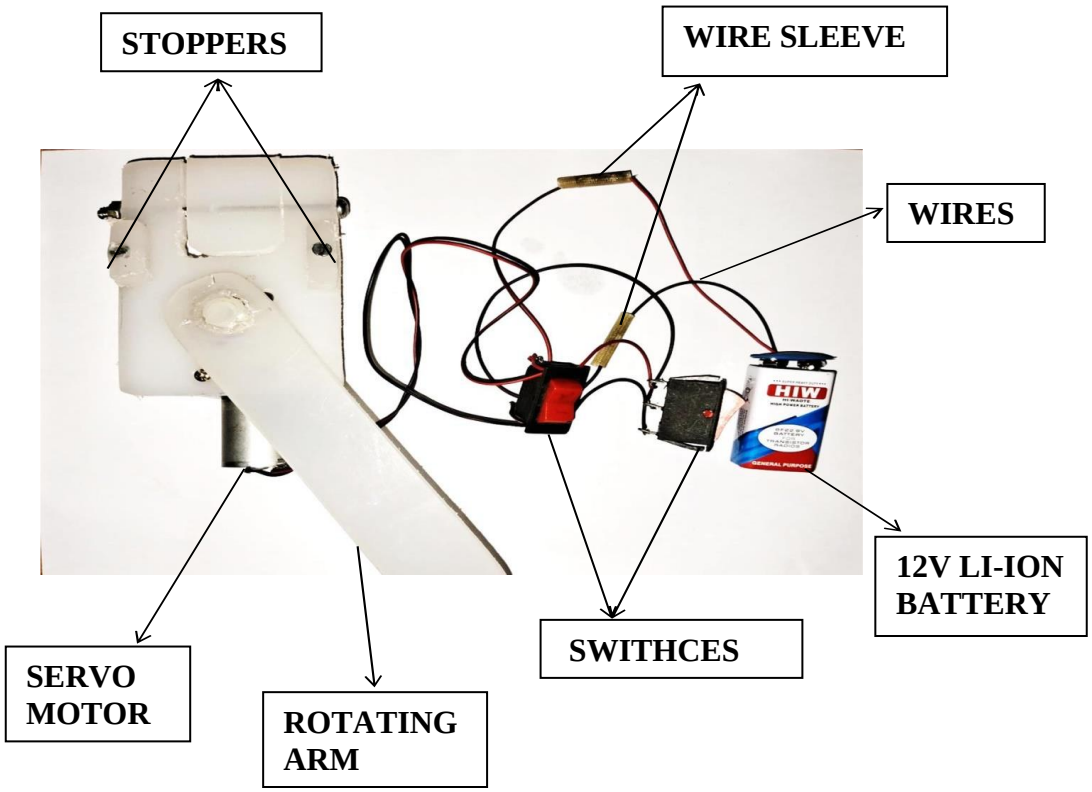


FIG 2: COMPLETE PROSTHESIS

FIG 3: PROSTHESIS DONN BY PATIENT

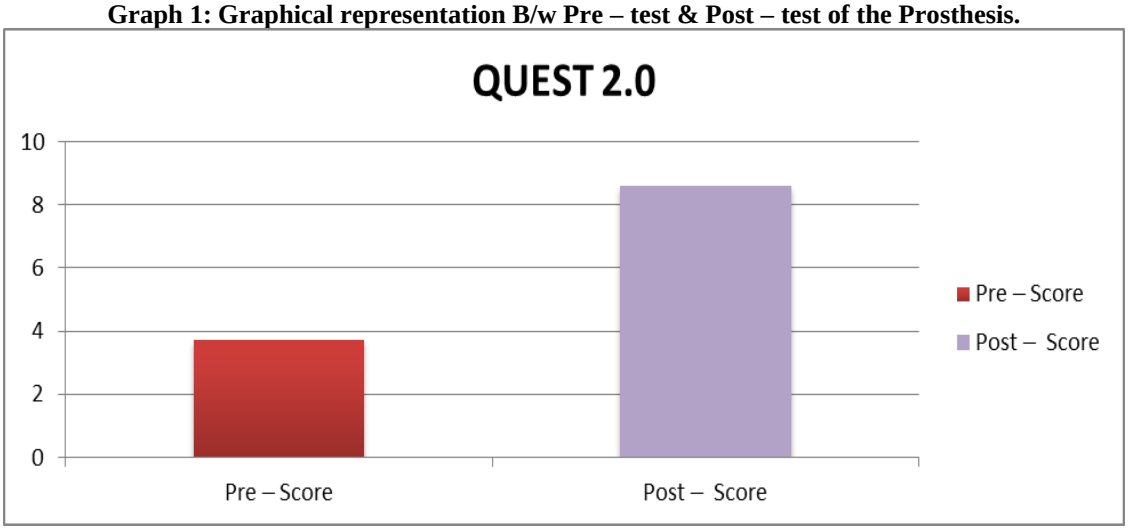
RESULT

A cost effective modified passive functional prosthesis with double axis hinge shoulder joint and servo motor for the shoulder disarticulation patient was developed effectively and has improves psychological satisfaction and enhanced mobility. The pre – test score was 3.7 which is towards More or Less satisfied and post – test score was 8.6 which is towards totally satisfied.

TABLE 1: AVERAGE SCORE OF PRE – TEST AND POST – TEST OF PROSTHESIS.

Total	Pre – Score	Post – Score
QUEST 2.0	3.7	8.6

Graph 1: Graphical representation B/w Pre – test & Post – test of the Prosthesis.



DISCUSSION

Function of the upper limb is far more complex than that of the lower limb and often involves an open kinetic chain of movement to perform an array of activities such as self-care, interaction with the environment, interaction with others, self-expression, and other fine and gross motor activities. Shoulder disarticulation results in the loss of the entire upper limb due to the trauma. Unlike the other forms of amputation, such as those at the forearm or wrist level, shoulder disarticulation entails the removal of entire arm, including the humerus bone, at the point where it articulates with the scapula and clavicle. The prosthetic options for higher level amputees, such as shoulder disarticulation, are limited and costly. Despite technological advances of electric powered prostheses, lighter passive prostheses are preferred option for who have recently undergone amputation and old patients.

The objective of this study is the development of passive functional shoulder prosthesis which includes the double – axis hinge joint with servo motor and evaluates the efficacy of the passive prosthesis with double – axis hinge joint with servo motor on satisfaction of the patient.

Thomas Bertels et al (2012), Biomechanical influences of shoulder disarticulation prosthesis during standing and level walking; in this study they observe the impact of a functional arm prosthesis on body posture and gait of shoulder disarticulation patients and found that an arm prosthesis does not only offer functional and cosmetic benefits. The results confirm that unilateral shoulder disarticulation patients benefit from functional arm prosthesis with a free swinging shoulder joint in terms of optimized posture and gait dynamics.[8] Susumu Kimizuka et al (2020), Development of a Shoulder Disarticulation Prosthesis System Intuitively controlled With the Trunk Surface Electromyogram, in this study; they developed intuitively operational powered shoulder disarticulation prosthesis with four degrees of freedom using surface electromyogram control. Moreover, they identified the most suitable place to measure the EMG used to control the shoulder disarticulation prosthesis from the trunk by multipoint measurement.

They conducted evaluation experiments of the proposed myoelectric shoulder disarticulation prosthesis using myoelectric at a suitable place. As a result, they identified two proper EMG measurement points from the body trunk being as chest and back and demonstrated by the evaluation experiment that all subjects, including actual bilateral shoulder disarticulation amputee, could manipulate the proposed shoulder disarticulation prosthesis.[9] Laura A. Miller (2011) et al,

Control of a Six Degree of Freedom Prosthetic Arm After Targeted Muscle Reinnervation Surgery; in this study they evaluate the control of a complex prosthesis for a shoulder disarticulation-level amputee with targeted muscle reinnervation. This study provides an exciting demonstration of the multiple DOF control that is possible by combining targeted muscle reinnervation electromyographic control signals, residual limb electromyographic control signals, and conventional shoulder switches and force sensing resistors. With this new device the subject was able to easily control 2 DOF simultaneously in many different combinations. [10] Jorge M Zuniga (2016) et al, the development of a low-cost three-dimensional printed shoulder, arm, and hand prostheses for children; The aim of this study was to describe inexpensive three-dimensional printed mechanical shoulder prosthesis to assist a pre-selected subject in performing bi-manual activities. Based on observations and feedback, the researchers concluded that potential limitations of the design were low grip strength and low durability of the prosthetic device. The use of 3D printing technology for the design of upper limb prostheses remains in early-stage development. [11]

In this study a passive functional prosthesis with double axis hinge shoulder joint with servo motor is developed which provide two degree of freedom of movement i.e., the flexion and extension motion in sagittal plane using the servo motor which drive the power from the 12V Li-ion battery and adduction motion using the sound limb. Thus, the finding support the fact that prosthesis does not only offer functional and cosmetic benefits and socially acceptable used to control the shoulder disarticulation prosthesis from the trunk by multipoint measurement.

CONCLUSION

In this study, we developed passive functional shoulder disarticulation prosthesis by incorporating a double– axis hinge shoulder joint with servo motor. With the use of battery, servo motor and switches patient were able to control the flexion and extension movement without spending much energy and able to lock the shoulder joint at various angle as per the patient needed. For the abduction movement patient has to use the sound limb to control the prosthesis. The study shows that double axis hinge joint with servo motor provide function and psychological satisfaction to the patient with shoulder disarticulation and also this study is an attempt to develop the device for higher level shoulder amputation.

Declaration by Authors

Acknowledgement: None
Source of Funding: None
Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Smith DG. General principles of amputation surgery. In: Smith DG, Michael JW, Bowker JH, eds. Atlas of amputations and limb deficiencies: surgical, prosthetic, and rehabilitation principles. 3rd ed. Rosemont (IL): American Academy of Orthopaedic Surgeons; 2004. p. 21–30.
2. Maduri P, Akhondi H. Upper Limb Amputation. [Updated 2023 Aug 8]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK540962/
3. Sandra L. Hubbard Winkler. Upper limb amputation and prosthetics epidemiology, evidence, and outcomes.
4. Department of Veteran Affairs, Department of Defense. VA/ DoD Evidence-Based Clinical Practice Guideline for the Management of Upper Extremity Amputation Rehabilitation. Washington D.C.; 2014.
5. Imbinto I, Peccia C, Controzzi M, et al. Treatment of the partial hand amputation: an engineering perspective. IEEE Rev Biomed Eng. 2016; 9:32–48
6. Douglas Murphy, Chapter 18 fundamental of amputation care and proshetics
7. Maat B, Smit G, Plettenburg D, Breedveld P. Passive prosthetic hands and tools: a

literature review. Prosthet Orthot Int. 2017;42(1):66–74.1
8. Thomas Bertels et al, Biomechanical influences of shoulder disarticulation prosthesis duringstanding and level walking, Prosthetics and Orthotics International 36(2) 165–172.
9. Kimizuka S, Tanaka Y, Togo S, Jiang Y and Yokoi H (2020), Development of a Shoulder Disarticulation Prosthesis System Intuitively Controlled With the Trunk Surface Electromyogram. Front. Neurorobot. 14:542033. doi: 10.3389/fnbot.2020.542033.
10. Laura A. Miller et al, Control of a Six Degree of Freedom Prosthetic Arm after Targeted Muscle Reinnervation Surgery; in this study they evaluate the control of a complex prosthesis for a shoulder disarticulation-level amputee with targeted muscle reinnervation Arch Phys Med Rehabil. 2008 November; 89(11): 2057–2065.
11. Jorge M Zuniga et al, The development of a low-cost three-dimensional printed shoulder, arm, and hand prostheses for children, Prosthetics and Orthotics International 2017, Vol. 41(2) 205–209.

How to cite this article: Ankit Kumar Ray, Yashika Kumar. Innovative modified passive functional shoulder prosthesis incorporating a double-axis hinge shoulder joint with servo motor for shoulder disarticulation patient. *Int J Health Sci Res.* 2024; 14(11):159-165. DOI: *https://doi.org/10.52403/ijhsr.20241116*

******