International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-2, Issue-4, April 2014

Exoskeleton Design for Upper Limb Rehabilitation of Post-Trauma Patients

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***Abstract*— Rehabilitation is a medical field linked with biomedical engineering that combines engineering techniques with medical science to provide utmost treatment for the patients to regain their strength and activity. Technology has improved in a colossal manner that it has its hand in every field such that it helped medical field to attain high standards with sophisticated equipment's influencing new level of health care. Even though technological improvement paves a way for safer life structure, it also leads to unexpected destructions that define technology as possibly a double sided sword. Accidents are inevitable and it has become a part and parcel of our lives and hence people who are exposed to accidents and destructions again turn towards the medical technology for their remedy, recovery and health care. This paper proposes the design and development of an exoskeleton for post trauma upper limb rehabilitation. This exoskeleton can be used as a rehabilitation and supportive tool for the physiotherapist to treat hand fracture. Designing of the exoskeleton is based on the dynamics of human arm. A high torque DC motor and its driver module are attached to the mechanical structure to drive the exoskeleton in both upward and downward direction. ATmega16 microcontroller is used to control the motor actuation based on the direction given by the user.**

***Index Terms*— Rehabilitation, exoskeleton, recovery, trauma.**

I. INTRODUCTION

Trauma is common among athletes, any sort of people as anyone can become a basic to chronic sufferer from a fracture. People usually think a trauma is not a serious condition, such that fracture is defined as a broken bone and in such cases it requires emergency attention altogether. Usually x-rays will be taken to determine and understand the fracture, as some people might be able to continue their work and do walking without knowing the fact of having a fracture. A stress fracture can be detected only by bone scan as it is difficult to be detected by an x-ray. Post trauma rehabilitation involves both the surgical procedures and non-surgical intervention as per the need of the hour.

People who are affected by stress fractures are mainly due to poor conditioning or over training of the body. The healing period of a mild stress fracture usually spans around 4 to 8 weeks. The fractured limb will be allowed to set for rest and healing by putting it to a brace or stationary casts. People can move around using crutches that aids in locomotion. Inflammation and pain can be reduced using ice while anti-inflammatory drugs were also available to relieve pain.

Manuscript received April 19, 2014.

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As a part of advanced technology bone stimulators can also be used to improve the rate of bone healing. Surgery is considered as the solution for severe fracture cases performed. As the acute stage passes by rehabilitation process will involve stretching of muscle and joints as well as strengthening exercises [7].

II. ORGANIZATION OF THE WORK

Radius distal fractures were among one sixth of all fractures of the body which are mostly treated in emergency care departments of healthcare centers. It is common and can be seen in people of all ages from different modes [5]. The wrist region of the human arm and also the hand are very vulnerable to trauma as they are represented as the primary tools for human activities such as defense and body expression. The disruption in bone continuity will impose a downtime for bone calcification that may last around six to eight weeks. Wrist fracture will cause pain and certainly an acute loss of physical function which results with a direct impact on functions in social and emotional ways. About 1% to 20% of patients with distal forearm fracture are experiencing debilitating consequence of dystrophy, which is commonly known as complex regional pain syndrome.

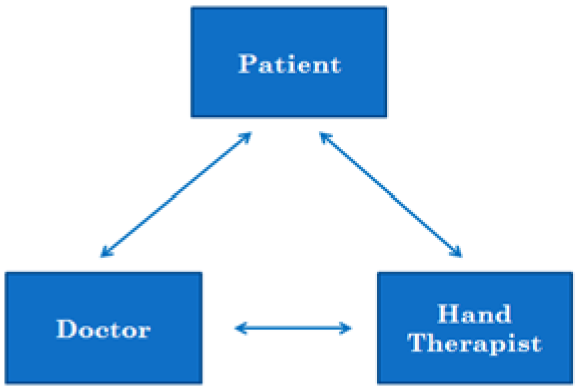

Figure 1: Ideal Tri-directional process for an efficient rehabilitation

As the day's passes by, new and more advanced efficient treatments were been approached to this type of fractures which facilitate further studies in fracture treatment that suggests the rehabilitation of a patient in specialized therapy and service is not only based on anatomical and physiological characteristics but also based on the psychological and social aspects of the patient [6]. The communication between the hand surgeon, the therapist and the patient must be directly a well-known and easily accessible hence recommends the need for a single channel communication protocol referred by Kleber et al (2009) and it forms a basis for a completely coherent and highly effective rehabilitation process. In general, rehabilitation has a direct link to the trust and faith built with in the triad group and has a significant fundamental role in the appropriated recovery from trauma, as well as the efficacy of the treatment.

III. METHODOLOGY

Rehabilitation is the process of achieving the original function or activation of one's mutilated muscles and joints. Patients who are exposed to upper limb trauma have to keep their limb stationary around three to four weeks, which may subsequently leads to stiffness of the limb muscles, cartilages and ligaments of the core area around the upper limb. The treatment process is followed by diagnosing bone growth and its solidity which would help them to be directed to a physiotherapist who will guide and instruct the patient to regenerate his capacity to do his back to normal work with his upper limb.

A. Trauma Therapy

In medical society for a simple distal radius fractures the prognosis is generally excellent. Healing time is likely to be longer for the more comminuted distal radius fractures and those that involve other injuries to the ligaments of the wrist and may require more extensive physical therapy under the guidance of physiotherapist to regain wrist function. In case of prolonged immobilization of the wrist due to treatment requirements, patients shoulder may become stiff as he will not be using upper limb joint normally. To regain both strength of the upper limb and complete range of motion in the shoulder and entire arm physical therapy is usually recommended [5].

Rehabilitation process will be advised once the surgeon feels that the injury is cured and the fracture is stable enough to begin the process of regaining the complete range of motion in patients shoulder, elbow and wrist [10]. The rehabilitation program will be planned and modified to protect the fixation of the fracture fragments if surgery has been required. Surgeon will communicate with the physical therapist and instruct him to make sure that the patient's rehabilitation program does not risk causing any damage to the fixation. The speed at which the patient progress through the program depends on the solidity of the fixation. A solid fixation allows the patient progress through the recovery program to be quick and adorable; to allow healing of the injury the progress of the patient through the rehabilitation procedure might be slowed for fixation which is not so solid.

During these procedures, it is recommended to be under the direct supervision of the therapist, since any small mistake can lead to aggravation of the injury. Hence there occurs a need to make a device that can supervise or guide the patients to do their exercise with much comfort. The exoskeleton model proposed can be attached directly to the patient's upper arm [11]. The angle of extension can be given to the microcontroller that controls the motion of the motor which is connected to the fore arm.

B. Detailed Block Diagram

The block diagram shown in figure 2 gives the detailed outline of the function carried out in the exoskeleton.

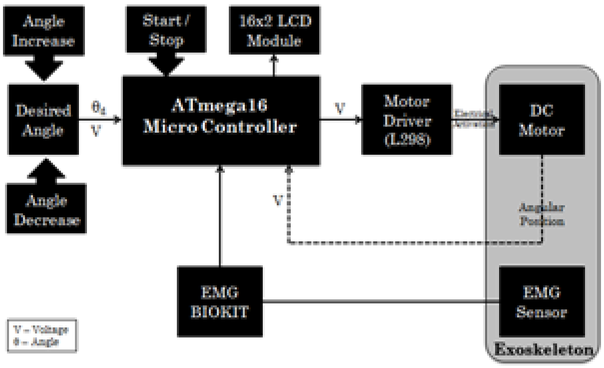

Figure 2: Functional block diagram of exoskeleton system

The angle to which the patient arm needed to be extended is considered as the desired angle and that can be given to the ATmega16 Microcontroller through two input keys that can be associated for increment and decrement of angle. L298 is the driver used to drive the motor. Two input pins and enable pin were connected between Microcontroller and the motor driver that is associated for the activation and direction control of the motor. 12V DC motor with 36kg-cm torque is connected with the motor driver L298, where control input is from ATmega16 Microcontroller. Potentiometer is fixed with a gear arrangement that can act as an angle sensor, which gives an angular feedback to the microcontroller regarding the motion of the motor.

IV. DESIGN OF MECHANICAL STRUCTURE

The model of the exoskeleton is shown in Figure 3. The upper arm and forearm straps are fabricated using aluminium material which has the low density profile and resistance towards corrosion due to passivation phenomenon.

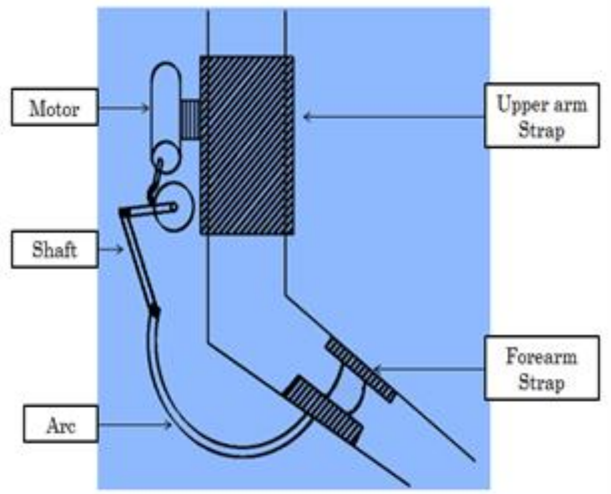

Figure 3: Exoskeleton Model

The casting design of lower and upper cuff of the exoskeleton shown in Figure 4 and 5 were designed using Solid Works with measurements noted [3]. Figure 6 and 7 gives the front and isometric view of the shaft respectively which is used to drive the arm by the motor. The shaft along with the arc delivers the motor movement to the forearm cuff [9].

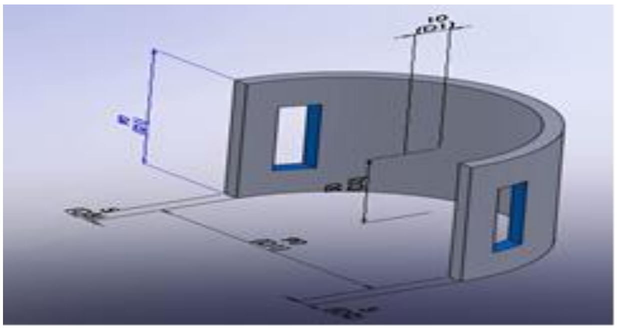

Figure 4: Design of Lower Cuff

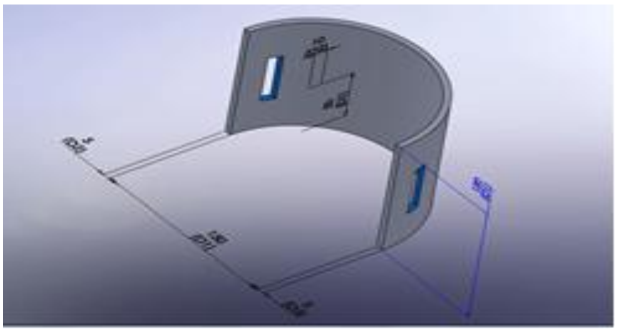

Figure 5: Design of Upper Cuff

Slight modifications have been made to the model to facilitate grounding of exoskeleton in order to distribute the weight to the ground. As the exoskeleton is a study model, several adjustments can be made on the slider that has been placed to study the human arm movement and exoskeleton efficiency.

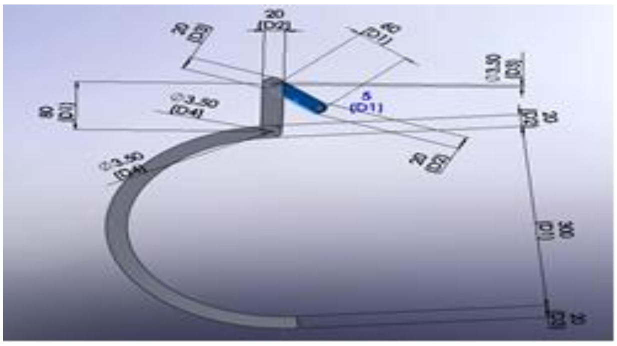

Figure 6: Front View of Shaft with Arc

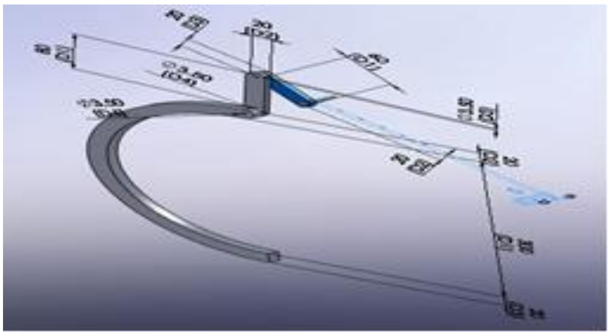

Figure 7: Isometric View of Shaft with Arc

V. Development of Exoskeleton

The developed exoskeleton model is shown in figure 8. It can be activated to drive a human arm using a high torque DC motor and electronic part shown in figure 9.

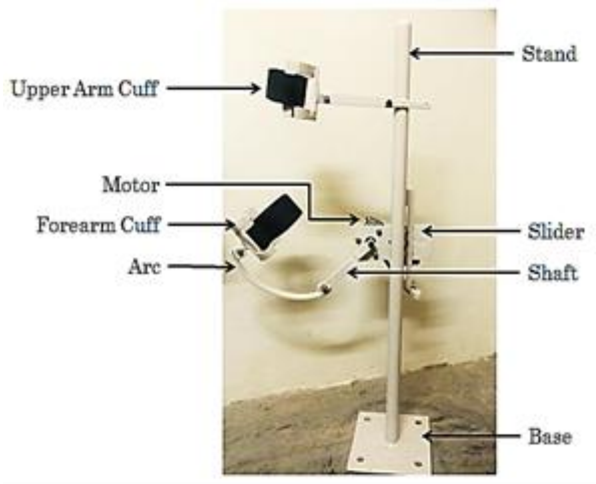

Figure 8: Mechanical Part of the Developed Exoskeleton

Cuffs, arc and shaft were fabricated with aluminium material while the base and slider were fabricated with stainless steel to hold the structure. Necessary arrangement can be made to vary the height and length of the forearm cuff by using a slider attached to the base stand.

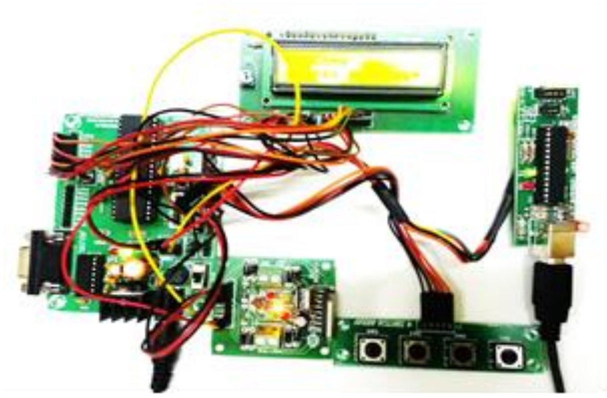

Figure 9: Electronic Part of the Developed Exoskeleton

Electronic part consists of ATmega16 microcontroller kit, L298 Motor driver circuit, LCD display. 5V supply is needed for microcontroller kit and 12V supply is needed for DC motor driver to run the motor.

VI. Conclusion and Future Scope

The exoskeleton model has been developed, that adopts microcontroller assisted mechanism to help patients rehabilitate their upper arm movement and 120 degree arm flexibility. Besides, it can also be used for stroke patients to activate their muscle function. The model is fabricated in a way to adjust the height and length of the forearm cuff, which can be handful in the study of patient's convenience, arm movement and flexibility. Programming is done in ATmega16 microcontroller to drive the motor using motor driver module.

Patient interface has to be studied, and EMG (Electromyography) signal has to be implemented to the exoskeleton as a stress feedback. Angular position can also be given as a feedback using shaft encoder. Microcontroller can be configured as PI controller to improve the reliability and efficiency of the exoskeleton operation. Exoskeleton can be made compact and portable by using high torque, low weight motor.

ACKNOWLEDGMENT

We gratefully acknowledge the funding provided from Karunya University under "Seed Money for Students Project 2013-2014". We thank the EIE family of Karunya University, for supporting us in doing this work.

REFERENCES

[1] Ying Mao, Sunil Kumar Agrawal "Design of Cable-Driven Arm Exoskeleton (CAREX) for Neural Rehabilitation" IEEE Transactions on Robotics 28, 2012, pp. 922-931.

[2] Tommaso Lenzi, Nicola Vitiello, Stefano Marco Maria De Rossi, Stefano Roccella, Fabrizio Vecchi, Maria Chiara Carrozza "NEUROExos: a Variable Impedance Powered Elbow Exoskeleton" IEEE International Conference on Robotics and Automation, 2011, pp. 1419-1426.

[3] Ying Mao and Sunil K. Agrawal "A Cable Driven Upper Arm Exoskeleton for Upper Extremity Rehabilitation" IEEE International Conference on Robotics and Automation, 2011, pp. 4163-4168.

[4] Elizabeth A. Brackbill, Ying Mao, Sunil K. Agrawal, Madhu Annapragada, Venkatesh N. Dubey "Dynamics and Control of a 4-DOF Wearable Cable-Driven Upper Arm Exoskeleton" 2009 IEEE International Conference on Robotics and Automation, 2009, pp. 2300-2305.

[5] Kazuo Kiguchi, Mohammad Habibur Rahman, Makoto Sasaki, Kenbu Teramoto "Development of a 3-DOF Mobile Exoskeleton Robot for Human Upper-Limb Motion Assist" Journal of Robotics and Autonomous Systems 56 Elsevier, 2008, pp. 678–691.

[6] Kleber O. Andrade, Gisele G. Ito, Ricardo C. Joaquim, Bruno Jardim, Adriano A., G.Siqueira, GLauco A. P. Caurin and Marcelo Becker "A Robotic System for Rehabilitation of Distal Radius Fracture Using Games" Brazilian Symposium on Games and Digital Entertainment, IEEE, 2010, pp. 25-32.

[7] Y. Mao and S. Agrawal "A cable driven upper arm exoskeleton for upper extremity rehabilitation" in Proceedings IEEE International Conference Robotic Automation, 2010, pp. 4163–4168.

[8] G. Yang, H. L. Ho, W. Chen, W. Lin, S. H. Yeo, and M. Kurbanhusen "A haptic device wearable on a human arm" in Proceedings IEEE International Conference Robotic Automation Mechatronics, 2004, pp. 243–247.

[9] C. Carignan, M. Liszka, and S. Roderick "Design of an arm exoskeleton with scapula motion for shoulder rehabilitation" in Proceedings International Conference Advanced Robotics, 2005, pp. 524–531.

[10] J. C. Perry, J. Rosen, and S. Burns "Upper-limb powered exoskeleton design" IEEE/ASME Transactions on Mechatronics 12, 2007, pp. 408–417.

[11] S. Oh and S. Agrawal "Cable suspended planar robots with redundant cables: Controllers with positive tensions" IEEE Transactions on Robotics 21, 2005, pp. 457–465.

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