
Design and Development of a New and Portable Continuous Passive Motion Device for Knee Rehabilitation

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ABSTRACT: *The juncture of association of two bones is called as a joint. The most complex and largest in the human body is considered to be the knee that primarily serves as the joint that allows flexion, extension and slight side to side movement. Knee joint is crucial to many daily living activities, such as walking, running and stair climbing, sitting and standing. Therefore any injury or loss of joint function will lead to decreased quality of life. The patients are first advised to get non- surgical treatments such as exercises or physiotherapy. The knee replacement surgery is the most common alternative way, if non-surgical treatments are not effective. But an instantaneous treatment is essential immediately after a knee surgery. It includes multiple sessions of physiotherapy in which the physiotherapist flexes and extends the leg, for a greater degree of self-dependence and improved quality of life. Since the CPM treatment elevates the flow of blood and advances the rehabilitation process in a decreased period of time. The research is to study the principle, need and applications of continuous passive motion device and then design and develop a new, light, portable and cost effective CPM machine with a compatible interface. Since the CPM ceaselessly flexes and extends the knee joint without any efforts of the patient's muscles, that is why, the machine is named passive. Generally, a CPM consists of an electric motor, a liquid crystal display, an arduino board, a motor driver and the mechanical part. In this study, a new, cost effective and portable CPM machine has been designed and manufactured. Now the patient does not need someone to help or go to health centres and pass their healing course at their own houses.*

KEYWORDS: *physiotherapy, continuous passive motion, passive motion, rehabilitation, joint stiffness, knee anatomy.*

INTRODUCTION

The juncture of association of two bones is called as a joint. The association and the firmness of the joints are maintained by strand of connective tissues and the ligaments. Human beings have a plenty of joints and they use them for many different daily living activities. The most complex and largest joint in the human body is considered to be knee that primarily serves as the joint that allows flexion, extension, and distorts in a very small degree left to right. The knee casts a hinge between femur and tibia.

Since, the knee joint is pivotal for various daily living activities, therefore deduction or misplacement of joint function will largely affect the life by decreasing its quality. as we very well knows that a lot of tolerance power and time is needed in the healing process of a muscle and for its strengthening [1].

Passive motion in the knee does not require muscle activation. We contract our hamstrings to flex our knee. Similarly, we contract our quadriceps to extend our knee. The contraction of the muscles may increase the contact stresses within the knee or change the movement of the tibia comparative to the femur [3].

The concept of designing or need for a continuous passive motion device was first time given by Robert Salter in early 1980's. When a study was made on rabbit's knee joint, it was observed that if slow and continuous motion is provided to the joint under pressure then that helps in increasing the time of recovery and rehabilitation of the knee joint, as compared to prolonged articular rest [4]. Due to fatigue ability of muscles, a patient finds difficulty in movement of his/her joint constantly, so he enclosed the result that passive motion is needed for motion to be continuous. He also concluded that CPM also has an additional benefit that if the

slow movement is done, then it is practicable to apply it directly after operation or injury without causing pain to the patient. The above abstraction was made from the gate-control theory of pain by Melzack and Wall [5, 6] that with contending afferent sensory stimulation, painful stimuli would be forbidden [7]. Since, increase in recovery time and regeneration of articular cartilage is observed due to early joint movement, so the later research and development was driven primarily regarding CPM [8].

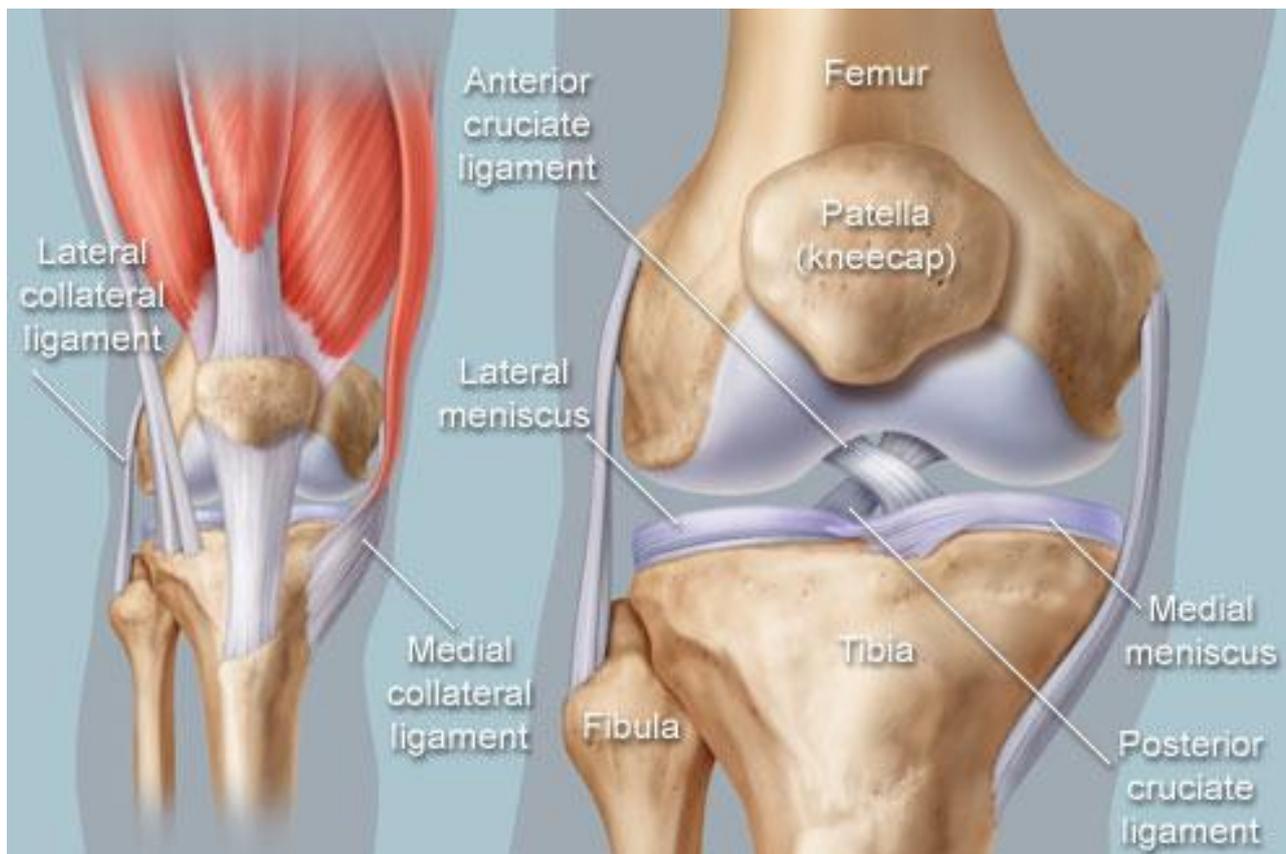


Figure 1: The knee joint anatomy [2]

Physiotherapy also referred to as physical therapy, includes evaluation, diagnosis, and treatment of a wide range of diseases, disorders and disabilities using physical means. Physical therapy is a branch of medical science where physical measures such as heat, light, ultrasound, water, electricity and exercises are used in the diagnosis and treatment of orthopaedic afflictions. Any kind of medication in this procedure is evaded [9].

Rehabilitation is a new way of diagnosis schemed to smoothen the course of retrieval from injury, illness or disease to as normal a condition as possible. The application of science and technology to enhance the quality of life of handicap individuals is known as rehabilitation engineering. If due to an injury, a stroke, an infection, tumour, surgery or any kind of progressive disorder harms a person and limits its ability to function normally then the person should be provided rehabilitation services [10].

Due to an injury to a joint leads to joint stiffness which evolves as following four stages: bleeding, edema, granulation and fibrosis. Because of proceeding researches it has been found that if CPM is used correctly throughout the initial phases of joint stiffness, then it will result in preventing the formation of edema by pumping it and the blood away from the affected area. It is observed that if correct and complete movement is provided to the affected area immediately after surgery and uninterrupted up to the point that swelling stops to develop then it will effectively prevent joint stiffness and hence improves joint flexibility and promotes well-being [11].

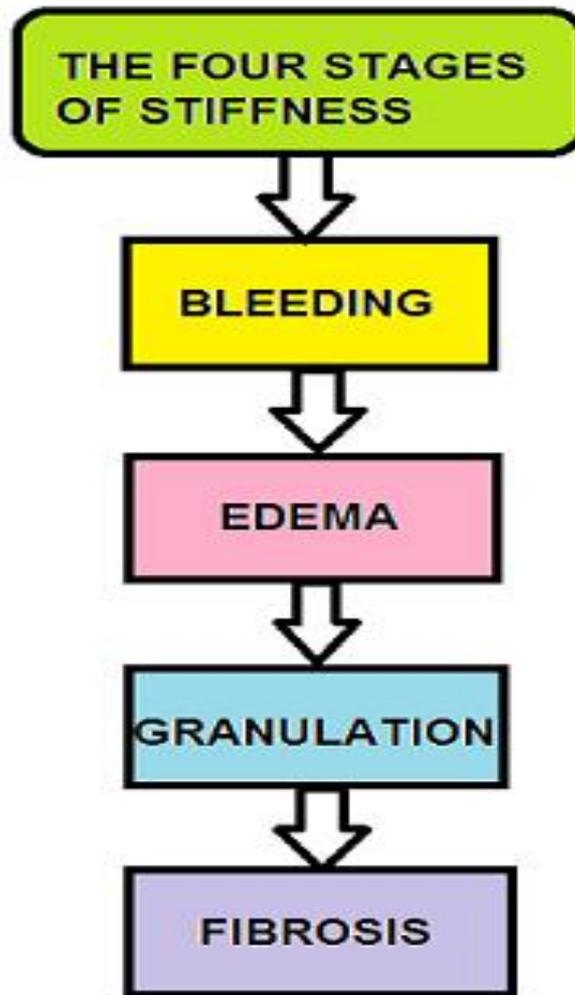


Figure 2: Pathophysiology of joint stiffness [11]

So CPM is increasing being used at home because it is self-manageable treatment and has become a part of usual care program.

As stated above, the acknowledged issues the main aim of this research is design and development of a new, light, portable and cost effective CPM machine with a user friendly interface for both the user and operator. The software, mechanical hardware and electrical hardware operate the device based on the user input parameters.

METHODOLOGY

As reported according to the above mentioned study, it is found that the basic principle on which the CPM is founded is that joint movement is required for the preservation of articular cartilage. So a CPM was developed which is needed to prevent cartilage degeneration consociated with immobilization, minimizes scar tissue formation, decrease swelling and pain, maintain and increase ROM, improves circulation and so on. Certain applications of CPM are in anterior cruciate ligament reconstruction, total knee replacement, total shoulder and ankle replacement, rotator cuff repair, sub acromial decompression, cartilage repair, intra-articular fractures etc.

The steps followed in designing and manufacturing of a continuous passive motion device is given below in figure 3.

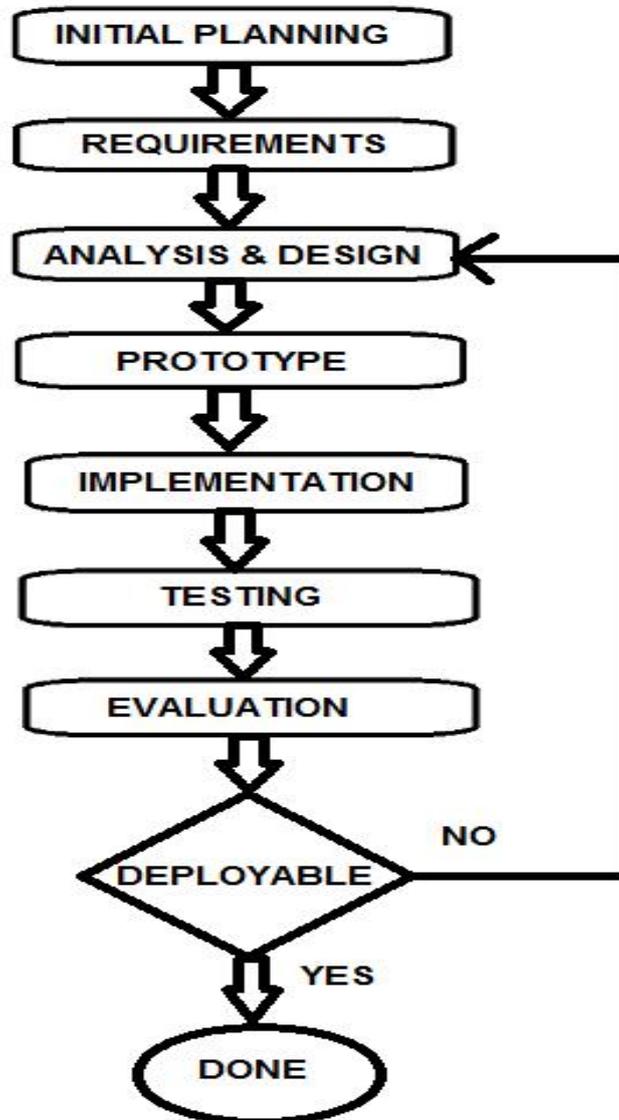


Figure 3: Flow chart of steps followed for proposed work

According to the planning I acquired all the electrical components required for the project. According to the planning I acquired all the electrical components required for the project. The Atmega 328P-PU is used as the main processor of this device on the Arduino Mega 328 platform. It takes in inputs from the switches and unfolds logic analogues to the algorithm written onto it. An algorithm is written in C language in Arduino IDE software to iterate the motion initially set. It provides an input signal to the motor based on the number and speed input data registered. L298N motor driver is used to take a low current control signal and then convert it into a higher current signal that can drive a motor. It is being used to control the direction and speed of the motor. It provides more torque and higher speed precisely. A 16X2 liquid crystal display is used here to show all parameter data entered such as number of flexion/extension, speed and operating time allowing continuous monitoring to the patient and the doctor. A belt drive mechanism is accustomed for conversion of a rotational motion into a linear motion and to drive the belt a motor is required to displace the joint over a range of motion, smoothly, uniformly and slowly. So Nema17 stepper motor is used to drive the belt so that the knee and hip of the patient are in passive repetitive motion.

By analysing the requirements I designed a prototype of proposed project which is given below in figure 4.

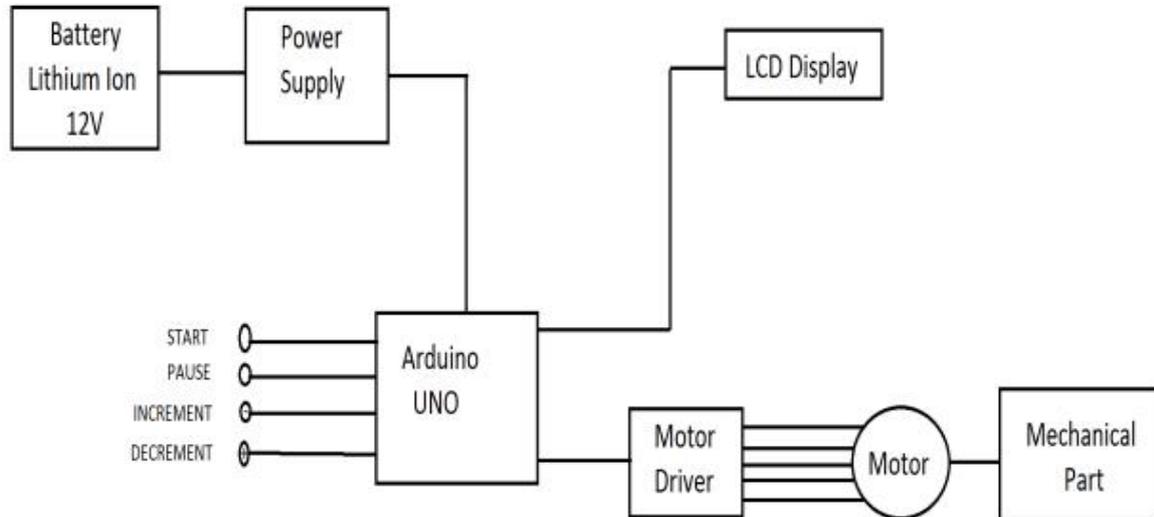


Figure 4: The main parts of CPM machine

As shown above, the data is entered into Arduino using switches which is also displayed on liquid crystal display for continuous monitoring. According to the command to the motor driver it drives the stepper motor accordingly. As per mechanical part is concerned the CPM structure is designed in 3D with the CATIAV5 software as presented in figure 5 below.

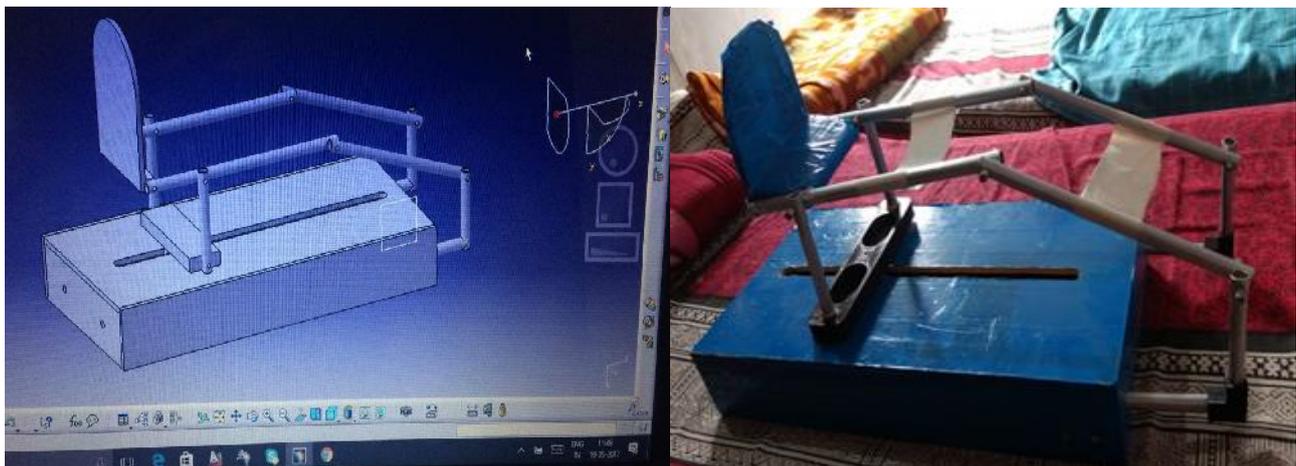


Figure 5: Schematic view of apparatus in the CATIA V5 software and the final product

Whenever the motor rotates, the belt also move and hence resulting in motion of the leg. While the stepper motor revolves in clockwise direction, the belt will also move identically hence resulting in the extension of the leg. Oppositely, while the stepper motor rotates in anticlockwise direction, the belt will move onward the route to the opposite direction. This condition will lead to the flexion of the leg shown below in figure 6.

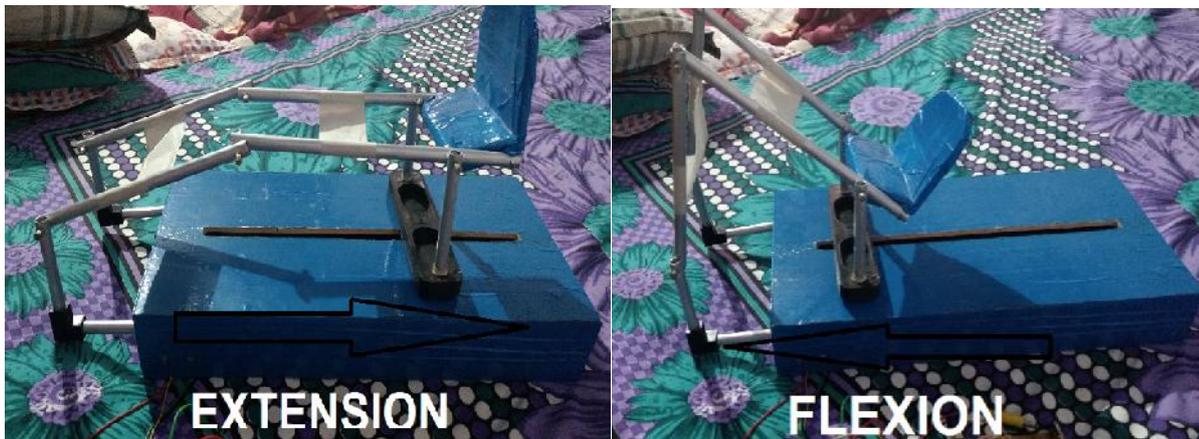


Figure 6: Extension and Flexion of the CPM

The initial setting for the range of motion is predicted on a patient's level of relief, joint stability and other factors that are estimated intra-operatively. The device can be paused or stopped at anytime if the patient feels uneasy with the assistance of a stop button. The range of motion then is incremented as endured by the patient. Hence the proposed CPM is shown in figure 7 below.

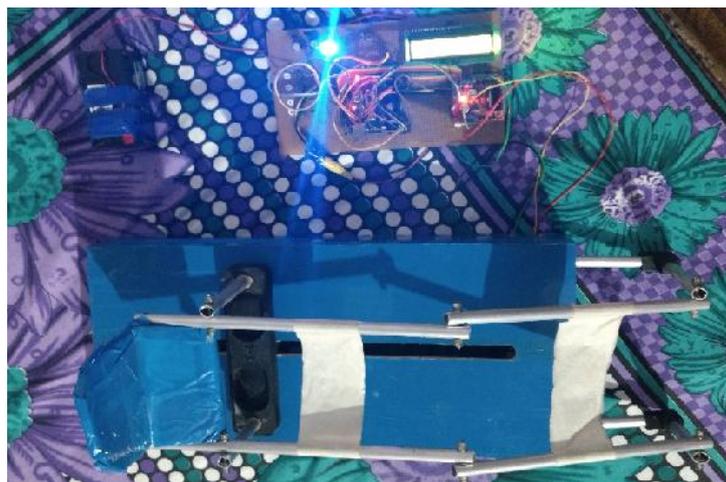


Figure 7: The final prototype of CPM as proof of concept

CONCLUSIONS

The knee joint is crucial to daily living activities, thus making it susceptible to a variety of injuries and disorders. Therefore, reduction or loss of joint function will decrease the quality of life. The long run effect of the CPM machine is yet to be established but according to the afore mentioned study results show that following a knee replacement surgery or ACL reconstruction operation, the CPM machine brings about certain degree of comfort and flexibility in the initial stage just after the surgery is done. It is found that initial increase in motion of the stiff knees after the surgery is quite pronounced in comparison to those who do not use CPM machine. The initial stage right after the surgery, the effect on the patient's knee movement is miraculous. According to the study done, the basic principle on which the CPM is based is that joint motion is important for the maintenance of articular cartilage.

The purpose of this research was to design and develop a new, light, cost effective and portable CPM machine with a user friendly interface. In the proposed design, the Atmega 328P is the main processor used to control the whole system. Four switches are used to input data in Arduino, then the Arduino unfolds a logic analogues to the algorithm written in Arduino IDE software using C language. According to the command given to the motor driver it drives the stepper motor accordingly. Whenever the motor rotates, the belt also move and

hence resulting in motion of the leg. The device can be paused or stopped at anytime if the patient feels uneasy with the assistance of a stop button. The system can be designed in such a way that it can rehabilitate both left and right knees and can easily adjusted to accommodate for different limb dimensions. The system can be further improved by using telemetry applications to send periodic information about the patient's vitals and progress to the specific doctor.

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