ISSN 2395-1621

Benefits of Continuous Passive Motion Device for Fingers in Rehabilitation

[#1]Chalukya J, [#2]Ankush Nandan, [#3]Prashant Varshney, [#4]Prof. Pramod D. Ganjewar

[1]chalukyaj@gmail.com

[#1234]Department of Computer Science, MIT Academy Of Engineering, Alandi(D), Pune

ABSTRACT

There is a growing need for health-care products in every country, and India being one of the most densely populated countries it has an ever growing need for health-care products. The products are imported 95% of the times, contributing to the high rates and being unfordable to common-folk. These products include the Continuous Passive Motion Device for Fingers. Thus we are aspiring to develop it in our country itself to reduce the price to a dramatic 10% of the original product. CPM Device for Finger is an exoskeleton worn by patients who have lost sense and motion in their fingers because of paralysis, post traumatic conditions following operations, or burn surgery. As the name suggests the machine is passive and provides motion to fingers passively by pushing (for flexion motion) and pulling (for extension motion) them as it operates. This provides a stable rehabilitation for the patients and ensures reinstating of senses to their fingers with passing time. The primary objective of our design is to reduce cost dramatically to make it affordable to even the remotest and most rural parts of our society. Our design would also strive for better simplicity, user-friendliness and portability as its secondary objective.

Keywords: Arthroplasty, CPM, Extension, Flexion, Muscle Stiffness, Passive Exercise, Passive Motion, Physiotherapy

ARTICLE INFO

Article History

Received :13th April 2016

Received in revised form :

15th April 2016

Accepted : 18th April 2016

Published online :

20th April 2016

I. INTRODUCTION

Continuous passive motion has to be provided to the fingers on a daily basis in case of any tissue damage to finger muscles. This is done to reinstate the lost movement in the fingers. Providing passive motion helps because the muscles are basically locked in their place due to accumulation of salts in them, and hence the continuous movement being provided will result in the gradual wear and tear of the salts and eventually dissolves them. Thus Physiotherapists are supposed to provide the exercises to the fingers on a daily basis and the exercise has to be started as soon as possible after the surgery to prevent edema and muscle stiffness at early stages only. Alternate flexion and extension will prevent fluid accumulation in the joints too. The CPM is alternative to the exercises provided by the physiotherapist and the main objective of it is to provide all the exercises at a comparatively lower cost.

II. THE BASICS OF CPM (CONTINUOUS PASSIVE MOTION)

A. Brief Overview

Continuous Passive Machine is a device designed for providing physiotherapy in form of exercises to patients the same way a physiotherapist might. Most of the CPM's are some form of exoskeleton that would fit over the patient's affected area and provide the exercise to the them. There are various CPM devices depending upon the affected area which it is meant to treat. The CPM device that is mentioned in this paper is restricted to the

CPM for Fingers.

B. Control Variables

There are various variables in the simplest form of exercise, for e.g. how much time it has to be delivered, how many times it has repeated in one day, etc. Similarly, the physiotherapy exercise provided to the fingers have various variable factors associated with them. Basically three important variables are how much speed is the exercise supposed to be delivered at, how much will be the maximum flexion and extension angles and what will be the stretch and hold delay.

C. Factors and their Explanation

Speed: This will determine how much fast the device will be delivering the exercise and will be into 10 equally spaced speed gradients.

Angle of Flexion and Extension: These will affect the angle of motion the device will move the fingers in. These are very important as a too low setting will not help in improving the condition and a too high setting might end up exerting excessive stress on joint and damage them permanently.

Stretch or Hold Delay: This determines the time duration for which the device will hold the fingers in the extreme positions i.e. the minimum value of flexion and the maximum value of extension angle. This helps in increasing the range of motion and total angle of movement in the fingers.

Determination of the Values for the Variable Factors

In conventional physiotherapy the values of these variables are usually determined the physiotherapist after a complete and thorough study of the patient's condition and history.

Although CPM's are designed to reduce the involvement of the physiotherapist in the treatment process to lower the cost of treatment, this is one area where the involvement of physiotherapist can't be avoided. As there are numerous factors which affect these factors, the process is calculation of values would normally be handled by the physiotherapist. Although there might be provision for patient or the user to set the variable on his own, it is not recommended as it can result in further damage to the patient.Despite these limitations the CPM will still be able to introduce the changes in the values of variables as the treatment progresses, like increasing of speed, or increasing total angle of motion or increasing the stretch and hold delay.

III.RELEVANT STUDIES CONDUCTED

Clinical Studies have been conducted to find out the working and effectiveness of Continuous Passive Machines. As CPM is only referring to type of physiotherapy exercises provided by machines rather than physiotherapist, studies conducted for CPM's effect on other joints are still applicable for estimating its effect on finger joints.

Effectiveness of prolonged use of continuous passive motion (CPM), as an adjunct to physiotherapy, after total knee arthroplasty [1]: This clinical study tried to determine the effects of the prolonged use of CPM post-surgery. Study took a total of sixty patients who had underwent surgery as the sample size.

The results are as shown in the Table I and Fig. 1 shows the study design and outcome assessment.

Conclusion: The Study found that although results indicate that prolonged CPM use might have a small short-term effect on Range of Motion (RoM), routine use of prolonged CPM in patients with limited RoM at hospital discharge should be reconsidered, since neither long-term effects nor transfer to better functional performance was detected.

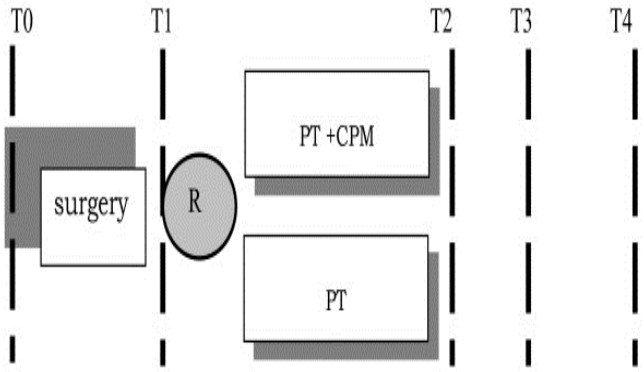

Fig 1. Study design and outcome assessment. T0 baseline assessment, one week before surgery, T1 assessment 4 days after surgery, T2 assessment 17 days after surgery, T3 assessment 6 weeks after surgery T4 assessment 3 months after surgery, R = randomization**.**

Table 1. Timing of the outcome Assessment

	T0 1 Week Prior to Surgery	T1 End of Clinical Phase	T2 17 Days After Surgery	T3 6 Weeks After Surgery	T4 12 Weeks After Surgery
Range of Motion	X	X	X	X	X
Knee Society Score	X	X	X	X	X
WOMAC	X		X	X	X
Perceived Effect			X	X	X
Pain Medication		X	X	X	X
Satisfaction with Treatment			X	X	X
Satisfaction with results			X	X	X
Adherence			X	X	X
Quantity, Duration and Kind of Treatment			X	X	X

Efficacy of Continuous Passive Motion Following Total Knee Anthroplasty: A Metaanalysis:
This study was designed to examine the effectiveness of CPM following total knee anthroplasty (TKA). This metaanalysis used the methodology proposed by the Cochrane Collaboration.

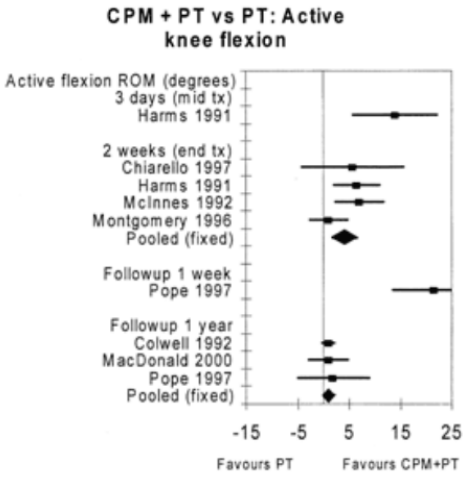

Fig. 1. Statistical significance determined by a weighted mean difference and confidence interval of 95% for active ROM.

Results: This review of 14 studies (952 patients) found significant improvements in active knee flexion and analgesic use 2 weeks postoperatively with the use of CPM and physiotherapy (PT) compared to PT alone. In addition, length of hospitalization and need for knee manipulations were significantly decreased in the CPM group. Fig. 2 shows the statistical significance of the study for active ROM.

Conclusion: CPM combined with PT may offer beneficial results for patients post-TKA. However, the potential benefits will need to be carefully weighed against the inconvenience and expense of CPM.

- *Continuous passive motion in rehabilitation following total knee arthroplasty A Randomized Controlled Trial:*

Continuous passive motion (CPM) has been shown to increase the amount of knee flexion in knee patients at the acute care hospital. Changing postoperative management leads to shorter hospitalization periods. The objective of the present randomized controlled trial was to assess whether there is additional benefit in CPM use during such a short hospitalization period.

Results: The results indicate a significant difference in function score, pain and strength between the CPM group and the control group.

Conclusion: The results indicate that in addition to an improved range of motion, a protocol including CPM seems to have a favorable effect on pain and muscle strength in the first two weeks after surgery.

- *Continuous passive motion (CPM): Theory and principles of clinical application*: Stiffness following surgery or injury to a joint develops as a progression of four stages: bleeding, edema, granulation tissue, and fibrosis. Continuous passive motion (CPM) properly applied during the first two stages of stiffness acts to pump blood and edema fluid away from the joint and periarticular tissues. This allows maintenance of normal periarticular soft tissue compliance. CPM is thus effective in preventing the development of stiffness if full motion is applied immediately following surgery and continued until swelling that limits the full motion of the joint no longer develops. This concept has been applied successfully to elbow rehabilitation, and explains the controversy surrounding CPM following knee arthroplasty. The application of this concept to clinical practice requires a paradigm shift, resulting in our attention being focused on preventing the initial or delayed accumulation of periarticular interstitial fluids.

Conclusion: The principles on which the concept of CPM is based are twofold. First, joint motion is necessary for the maintenance of articular cartilage. Second, and relevant to the present discussion, joint homeostasis requires maintenance of normal periarticular soft tissue compliance. For CPM to accomplish this requires that the motion be full, and that the soft tissues be subjected to tension immediately following surgery in order to prevent swelling. It is this early maintenance of motion that is the key determinant of the joint's long-term mobility. The application of this concept to clinical practice requires a paradigm shift, resulting in the focus of our attention on preventing the initial or delayed accumulation of periarticular interstitial fluids.

IV. CONCLUSION

There can be potential issues with CPM such as inconvenience for the patient or some kind of added expense. So the CPM device in itself should be more affordable to reduce these issues. And if these issues still exist a balance might be found out between them and the positive aspects.Although all the study conducted on the effects of CPM show that CPM offer positive results for post joint surgery and the results are even better when it's combined with physical therapy. Early use of CPM prevents from fluid accumulation and joint stiffness. It also has beneficial effects when used for reducing the symptoms of paralysis. So CPM is definitely an effective tool in the post-operative phase of joint surgeries like arthroplasty and anthroplasty.

V. APPENDIX

Patient with hemiparesis and finger reconstructive surgeries or muscle fibrosis needs a physiotherapy named continuous passive motion. Present practice is providing CPM manually to the patient by the physiotherapist which takes about half an hour for every session which sometimes also has human errors.It is believed that CPM reduces the four stages of stiffness. The Four Stages of Stiffness:

Bleeding
Edema
Granulation Tissue
Fibrosis

Stage 1: Bleeding
The first stage, occurring within minutes to hours following articular surgery or trauma, is caused by bleeding, which results in distension of the joint capsule and swelling of the periarticular tissues. Depending on the individual joint, the capsule achieves a maximum potential volume at a certain joint angle. In the knee, the maximum capacity of the joint capsule has been found to occur at approximately 35° of flexion (23-26); in the elbow, it occurs at 80° of flexion (27). Any attempt to flex or extend a joint beyond its position of maximum capacity, when the joint and/or periarticular tissues are markedly swollen, creates extremely high hydrostatic pressures within the joint and periarticular tissues. Associated with these high pressures are severe pain and a marked increase in resistance to motion. Immediately following injury or surgery to the joint, the natural tendency is to hold the joint in the position of maximum articular volume to minimize painful stretching of the joint capsule and the pressure of the intra-articular hematoma.

Stage 2: Edema
The second stage of stiffness, which occurs during the next few hours or days, is very similar but progresses less rapidly. It is due to edema, caused by inflammatory mediators that are released by platelets and dead and injured cells. These mediators cause nearby blood vessels to dilate and leak plasma, resulting in swelling of the periarticular tissues, thereby diminishing their compliance. With swollen and less compliant tissues surrounding it, the joint becomes physically more difficult to move and movement becomes more painful (24,27). Up to this point, stiffness and loss of periarticular tissue compliance are simply due to the accumulation of fluid. In the next two stages, fluid is replaced by extracellular matrix deposition, marking a significant transition.

Stage 3: Granulation Tissue
The third stage consists of the formation of granulation tissue. This occurs during the first few days or weeks following trauma or surgery. Granulation tissue is a highly vascularized, loosely organized tissue with material properties somewhere between a highly organized blood clot and loose areolar fibrous
tissue. As this granulation tissue appears within and surrounding the joint, the stiffness previously due to fluid accumulation becomes increasingly due to the deposition of a solid extracellular matrix.

Stage 4: Fibrosis
The fourth stage of stiffness represents fibrosis. During this stage, the granulation tissue matures, forming dense, rigid scar tissue. This scar tissue has

a high concentration of collagen type I fibers in its extracellular matrix.

Principles of CPM Application

Using this theory, the role of CPM in preventing joint stiffness can be clarified. In the first few days following injury or surgery, CPM is useful primarily to minimize joint hemarthrosis and periarticular edema; CPM has been found to increase the clearance of a hemarthrosis from a rabbit knee (28). In the presence of a joint effusion, movement of the knee away from the position of maximum volume and compliance causes an increase in intra-articular pressure. The greater the effusion, the greater the pressure generated at a certain degree of joint flexion (23-27). CPM causes a sinusoidal oscillation in intra-articular pressure (29), as shown in Fig.

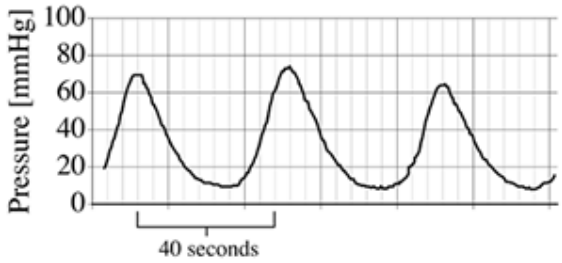

Fig. 2 An actual tracing of the intra-articular pressure in one knee during CPM reveals that, with 2 ml of fluid in the joint, the pressure oscillates in a regular sinusoidal fashion. This results in a "pumping effect" which is responsible for clearing blood and edema fluid from the joint and periarticular tissues

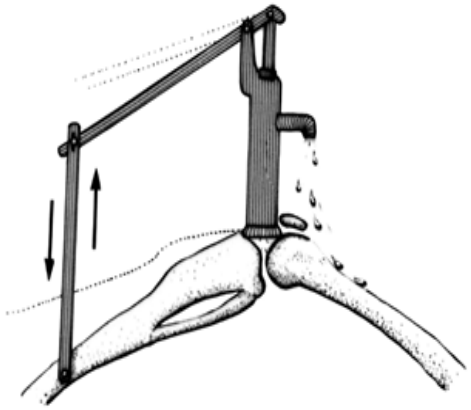

Fig. 3 Alternate flexion and extension of the joint by CPM raises and lowers the hydrostatic pressure in the joint and periarticular tissues resulting in a "pumping effect" that forces fluid out of the joint and periarticular tissues.

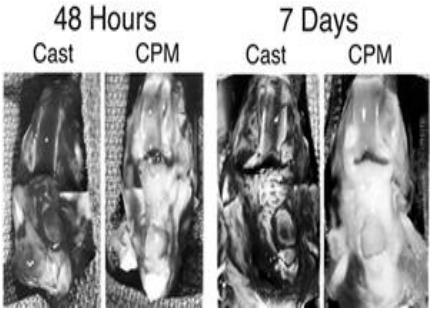

Fig. 4 Effect of CPM on clearance of a hemarthrosis. CPM rapidly accelerates the clearance of blood from the joint in the periarticular soft tissues, as seen in these comparison photographs at 48 hours and 7 days following injection of 2 cc of blood into both knees of a series of rabbits. The rabbits were treated by immobilizing one knee in a cast and moving the other knee on a CPM machine immediately following surgery and then continuously for 7 days. At 48 hours, the knee that had been immobilized in a cast (left) was still grossly bloody, whereas the opposite knee (right) treated by CPM was almost free of blood. At 7 days, the cast knee contained free blood in the joint while the CPM knee from the same rabbit was clear. In contrast to the immobilized knees, most of which contained small amounts of blood in the synovium at 7 days, all of the CPM knees appeared normal.

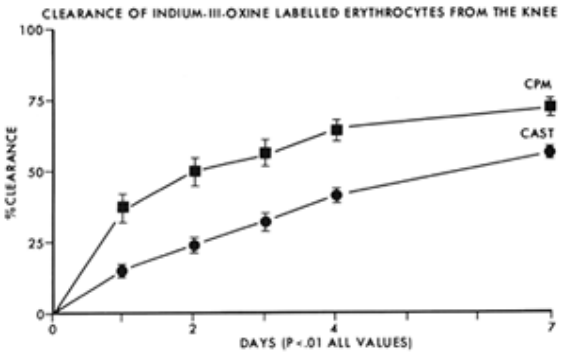

Fig. 5 Treatment with CPM enhanced the rate of hemarthrosis clearance by more than 100 percent. Values expressed as mean±1 standard error of the mean.

This accelerates the clearance of a hemarthrosis (Fig. 4). The enhanced clearance of blood from within the joint (Fig. 5) as well as the clearance of blood from the periarticular tissues (Fig. 6) due to CPM has been documented and quantified by tracking radiolabeled erythrocytes.

The principles on which the concept of CPM is based are twofold. First, joint motion is necessary for the maintenance of articular cartilage. Second, and relevant to the present discussion, joint homeostasis requires maintenance of normal periarticular soft tissue compliance. For CPM to accomplish this requires that the motion be full, and that the soft tissues be subjected to

tension immediately following surgery in order to prevent swelling. It is this early maintenance of motion that is the key determinant of the joint's long-term mobility. The application of this concept to clinical practice requires a paradigm shift, resulting in the focus of our attention on preventing the initial or delayed accumulation of periarticular interstitial fluids.

VI.ACKNOWLEDGEMENT

I would like to express my deepest appreciation to all those who provided me the possibility to complete this report. A special gratitude I give to our final year project guide, Prof. Pramod D. Ganjewar, whose contribution in stimulating suggestions and encouragement, helped me to coordinate my project especially in writing this report.

Furthermore, I would also like to acknowledge with much appreciation the crucial role of the staff of Department of Computer Engineering, who gave the permission to use all required equipment and the necessary materials to complete the task of research on the topic of Continuous Passive Motion. I have to appreciate the guidance given by other supervisor as well as the panels especially in our project presentation that has improved our presentation skills thanks to their comment and advices.

REFERENCES

[1] Lenssen, Ton AF, et al. "Effectiveness of prolonged use of continuous passive motion (CPM), as an adjunct to physiotherapy, after total knee arthroplasty." BMC Musculoskeletal Disorders 9.1 (2008): 1.

[2] Brosseau, Lucie, et al. "Efficacy of continuous passive motion following total knee arthroplasty: a metaanalysis." The journal of rheumatology 31.11 (2004): 2251-2264.

[3] Lenssen, A. F., et al. "Continuous passive motion (CPM) in rehabilitation following total knee arthroplasty: a randomized controlled trial." Physical Therapy Reviews 8.3 (2003): 123-129.

[4] O'Driscoll, Shawn W., and Nicholas J. Giori. "Continuous passive motion (CPM): Theory and principles of clinical application." Journal of rehabilitation research and development 37.2 (2000): 179.

