Improvement and Analysis of Passive Motion Knee Devices

This group assignment contributes 7% toward the 40% project portion of your overall class grade. This is a group project in which all members are engaged in this type synthesis exercise. The objective is to search the patent and product literature related to CPM mechanisms for knee rehabilitation. The Google Patents and USPTO databases (along with many other search engines) can be used to find CPM mechanisms -related patents. Search engines can also find companies with products in this area.

Background

In the past rehabilitation after human joints have been surgically repaired did not include specified motion requirements to accelerate healing. However, early physical therapy is now recommended so that healing can proceed, scar tissue will not form and full range of motion may return. Visiting physical therapists every day is not an option for many individuals. Trips to hospitals and clinics are difficult when someone else is required to drive to that location. Electro-mechanical devices have been created to assist in rehabilitation called Continuous Passive Motion (CPM) machines. Once a patient is trained, these devices can be used at home.

Figure 1 shows two simple CPM devices that are on the market. There are more than 20 of these machines (see Figure 2 for example). The question is, for a specific patient, which machine is the best for that specific rehabilitation need? Each person has a different prognosis and timeline for recovery. For example, which designs would satisfy the specific range of motion (ROM) with the proper force and torques required over the recovery time period?

Figure 1. Two simple CPM devices

Purpose and Goals of Project

Physical therapists strive to shorten recovery time and enhance the healing process following surgery or athletic injuries. They recognize the importance of instituting joint motion as soon as possible, within the safe limits of tissue healing. Several studies have reported potential advantages of initiating early motion, including allowing early controlled forces to act on collagen tissue. The present indications for the use of Continuous Passive Motion (CPM) include rehabilitation following knee manipulations, stable fixation of intra-articular and extra-articular fractures of most joints, soft tissue procedures about the knee, joint sepsis, knee arthroplasty, anterior cruciate reconstruction, and operative procedures of the knee extensor mechanism.

While Figure 1 shows two simple mechanisms for having a motor passively move the upper and lower leg of a patient through a range of motion (ROM) specified by a clinician (this ROM will increase over time as healing occurs), Figure 2 shows several other options on the market that involve more complex mechanical linkage mechanisms with more adjustments and degrees of freedom (DOF).

Figure 2. (a) DJO OptiFlex-K1 Knee CPM or ARTROMT K1 Knee CMP (b) Kinetec Spectra CPM Knee Machine, (c) CPM Continuous Kneeflex Es Passive Motion Therapy Machine, (d) Knee CPM Model DC2480

These more complex designs may or may not offer benefits to a patient or a particular class of patients. Many questions can be asked that this project will begin to address:

Which machine is best (not overly complicated and costly) for a particular patient recovering from knee surgery?
How many different designs are there?
How many are equivalent?

How important are the adjustments?
How many new designs might there be that have not been discovered as yet?

Further Background Information

Today, the increasing demand for CPM has introduced a growing marketplace of rehabilitation options. Continuous passive motion devices have been designed for the hand/wrist, knee, hip, shoulder, elbow, and ankle. The knee joint has received the greatest attention, with more than 20 CPM devices designed to assist knee motion. Continuous passive motion should be applied through an adequate ROM without causing distress. The speed of movement through the ROM should be based upon patient comfort and the desired number of repetitions in a unit of time.

Important questions that have not been answered scientifically include: What ROM is sufficient? How should CPM be applied? What is the duration of treatment? What is the best method of application? Are there any detrimental effects from the use of such equipment? Continuous passive motion appears to be potentially beneficial with a wide range of applications in physical therapy, but it is only through continued research that precise recommendations for CPM can be offered.

There is a need for a formal procedure to analyze the currently available CPM machines and compare their ROM, adjustment capability for patient specific use. Also, there is a need to determine whether the performance of each matches the specific clinical need. In addition, are there new designs that may offer an advantage over existing devices, whether in ROM or simplicity of adjustment or reduced cost to the patient or the health system? Can one or more of these designs be simplified without sacrifice of motion performance? Can this simplification result in less manufacturing cost and therefore lowering the cost to the patient and/or the insurance company?

Specific Assignment

One of the tools to be used will be to create tables for comparing different design concepts which is illustrated in Table 1 for the first device shown in Figure 1.

Reference Number	Name of Device (and link if available)	Patent # or other Identifying Information	# of Links	# of Springs, Cams etc. F_2	# of Pins, Sliders, etc. F_1	Degrees of Freedom	Number of Links in BKC	Any Recognizable Chains/Structures? (If so, name them)	Mechanism Task

1	Skrilix	Skrilix	n = 4	0	1 slider	DOF - 1	4	4 -Bar Linkage	motion
2									
3									
4									
5…									

Table 1. Template for recording critical information about each CMP device

Only one row is filled above, but other designs can be found in product literature and in patent data bases. Your team charge is to fill out this table. This will help in the classification of currently known CMP devices and to help formulate sets of design rules and processes that future engineers can use as templates for new mechanism design efforts.

Each group shall analyze a minimum of four CMP patent (or products) per team member. Your final document should use a common format and style for each example. Using the materials described in class, which include the type synthesis handout, the redesign of a complex Instrument tools handout, and the sections in the books, the following analysis is to be compiled by each group:

Name of and members of your team. For each CMP mechanism submitted by your team, please include the following information:

(A) Source - include pertinent information

(B) Image(s) of device - enough images to convey the key elements of the mechanism.

(C) Neat drawings showing the progression of starting with a hand (or CAD) sketch of each mechanism and ending with the basic kinematic diagram (BKC) - with just lower pair pin joints. See figure 6 in the bio-kinematics paper for an example of what is required here.

(D) For answer C, derive the degrees of freedom of the original mechanism and the final lower pair equivalent mechanism. The type synthesis handout, and the “Redesign of a complex

Instrument" handout can be used as guides here.

(E) Describe observations that you can make with respect to each CPM mechanism. For example, are there familiar kinematic chains, are there some positive or negative aspects of each design and do you observe some pluses and/or minuses with respect to the assembly and manufacturing of each device?

(F) Please comment on the opportunity for improvement of each mechanism. For example, complexity of the mechanical system, location of spring elements and other aspects of the types synthesis process, illustrated in the course handouts. You may answer this question at a high-level, but with some specificity.