Use of Continuous Passive Motion in the Postoperative Treatment of Intra-Articular Knee Fractures

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**Background:** The use of continuous passive motion in the postoperative treatment of intra-articular fractures around the knee is increasing. The purpose of this study was to determine the effects of a continuous passive motion device on knee range of motion after operative treatment of intra-articular fractures around the knee.

**Methods:** Forty patients with intra-articular fractures of either the proximal part of the tibia or the distal end of the femur were prospectively randomized to the use of continuous passive motion or standardized physical therapy in the immediate postoperative period for forty-eight hours. The primary outcome was knee range of motion. Secondary outcome measures included pain scores, Lower Limb Outcomes Questionnaire scores, and Short Musculoskeletal Function Assessment scores. Evaluations were conducted at forty-eight hours, two weeks, six weeks, three months, and six months postoperatively.

**Results:** There was no significant difference in knee extension between the groups at any time point measured. Knee flexion was significantly greater at forty-eight hours in the group managed with the continuous passive motion device than in the group managed without the continuous passive motion device ($p < 0.005$). However, there was no significant difference in knee flexion at any other time point. There was no significant difference in knee pain at forty-eight hours between groups. Six (30%) of twenty patients were unable to tolerate the use of the continuous passive motion device. There were no significant differences in overall complications.

**Conclusions:** The results of this study suggest that the use of continuous passive motion in the immediate postoperative period following the treatment of intra-articular fractures offers no benefit with regard to knee motion at six months and is not tolerated by all patients.

**Level of Evidence:** Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.
reduction in knee motion can substantially affect a patient’s ability to perform activities of daily living. Simple activities such as sitting down or rising from a standard chair or ascending and descending stairs require approximately 100° of knee flexion. Getting in and out of a standard bathtub requires approximately 135° of flexion. Continuous passive motion (CPM) devices have been used extensively after knee arthroplasty with varying results. Multiple studies have found short-term increased range of motion as a benefit of the use of CPM after total knee arthroplasty. An earlier meta-analysis of fourteen trials concluded that the use of CPM increased postoperative range of motion at two weeks and decreased hospital length of stay and postoperative manipulations under anesthesia. However, a more recent meta-analysis reviewing twenty trials concluded that the small long-term improvements in range of motion with the use of CPM were likely clinically unimportant. The authors also stated there was low-quality evidence that CPM did not affect hospital length of stay, but CPM reduced the need for postoperative manipulation under anesthesia. Additional trials have found no change in the postoperative range of motion or functional scores with the use of CPM.

CPM devices are currently being used by many orthopaedic surgeons in the postoperative care of periarticular fractures about the knee. The main goal of CPM in the postoperative management of these fractures is to help improve a patient’s end result range of motion. Basic-science efforts have investigated the use of CPM compared with immobilization after an experimental intra-articular injury. Although several studies using animal models have shown promising results for cartilage healing and improved motion, there is no evidence in clinical trials that supports these findings. Currently, there is no high-level clinical evidence to support the use of CPM for improving knee motion in the postoperative treatment of intra-articular fractures. Without clinically important improvements in knee range of motion, function, and patient outcomes data, the incremental cost for treatment with CPM cannot be justified.

The goal of this study was to determine if the use of CPM in the early postoperative period affects knee range of motion in patients with an intra-articular fracture.

**Materials and Methods**

This was a prospective, nonblinded, single center trial using balanced randomization (1:1) conducted from 2007 to 2011. Institutional review board approval was obtained prior to enrolling patients. The trial was registered at www.clinicaltrials.gov (NCT00591929). All patients meeting the inclusion criteria were screened for participation. Once informed consent for both surgical treatment and study inclusion was obtained, the participant was randomized. Block randomization was conducted by a computer-generated random order of allocated treatments in blocks of four that were placed in sealed envelopes prepared by a study staff member not involved in subject enrollment. Surgical approach and method of fixation were determined by the operating surgeon in each case. The criteria for inclusion were an age of eighteen years or older and a diagnosis of an intra-articular fracture of the distal end of the femur or proximal part of the tibia (identified on either radiographs or computed tomography scan) requiring operative fixation. Patients must have been able to walk independently prior to the injury and willing to participate in the randomized trial. Patients were excluded if they had decreased knee range of motion prior to the injury because of osteoarthritis, previous fracture, or previous injury. Patients with concomitant ipsilateral injuries to the pelvis, hip, or ankle that would prevent them from being able to use the CPM device were also excluded. Patients with an open physia for the knee, pathological fracture, open fracture, compartment syndrome, neurovascular injury, fracture due to gunshot wound, injury to the extensor mechanism, or fractures treated with definitive fixation greater than twenty-one days from injury were excluded, to provide a more homogeneous patient group and decrease confounding variables. Finally, as this center is a tertiary referral center for orthopaedic trauma, patients who were unlikely to return for follow-up because of social or geographic limitations were also excluded.

The primary outcome in this investigation was knee range of motion. The range of motion of both knees was measured with the use of a two-arm goniometer centered over the joint line with the arms parallel to the axis of the limb segment. This arc of motion was measured by the examining physician, physical therapist, or other trained personnel. Knee range of motion was evaluated as a total arc and its components, extensor lag and maximum flexion. Secondary outcome measures were pain scores assessed according to the visual analog scale, the Lower Limb Outcomes Questionnaire, and the Short Musculoskeletal Function Assessment (SMFA). Demographic information included injury and surgical history, Orthopaedic Trauma Association (OTA) classification, length of hospitalization, type of surgical fixation and implants used, complications, deviations from the treatment protocols, and repeat operative procedures, including manipulations under anesthesia. The timing of surgical fixation and the need for provisional stabilization using an external fixator were determined by the treating surgeon in each case. All patients received postoperative physical therapy services and were discharged when deemed medically stable.

Patients randomized to the CPM group were placed in a CPM device in the recovery room immediately after operative treatment. The range of motion was initially set at 0° to 120°. However, if the patient was unable to tolerate the initial setting, the arc of motion was decreased in increments of 20° until a tolerable arc was reached. After tolerating that motion arc for four hours, it was then increased at 20° increments until reaching 120°. All patients in the treatment group were required to use the CPM device at all times except during therapy for at least forty-eight hours. Patients allocated to the No CPM group participated in the same physical therapy regimen as the CPM group, but without the use of the CPM device.

Outcomes were assessed at forty-eight hours, two weeks, six weeks, three months, and six months after the open reduction and internal fixation (ORIF) or when the knee reached full range of motion and had documented radiographic union. At each follow-up evaluation, range of motion was measured with a goniometer by the examining physician or other trained personnel. Outcome assessors were not blinded to the study treatment. The Lower Limb Outcomes Questionnaire and the SMFA were completed at baseline and six months. All patients were restricted from weight-bearing on the injured limb for twelve weeks.

**Sample Size**

In calculating sample size, we used our primary outcome of arc of motion. In attempting to perform a power analysis for comparing the two groups, data available on range of motion following fractures about the knee were utilized. The average knee arc of motion has been shown to be 107° after intra-articular distal femoral fractures and 105° after proximal tibial fractures. We estimated a clinically important increase in arc of motion to be 15°. Using an alpha of 0.05 and a statistical power of 80%, the power analysis suggested a need for seventeen patients in each group. We enrolled forty patients to allow for 80% power and a 15° difference in range of motion, along with an approximately 20% rate of dropouts and/or patients lost to follow-up.

**Data Analysis**

Study data were collected prospectively and were stored in an encrypted database. Range of motion, pain scores, and functional outcomes scores were compared at each follow-up time point using two-sided Student t tests. Demographic data between groups were analyzed using chi-square analysis and the two-tailed Fisher exact probability test to evaluate whether differences existed between the two randomized groups prior to treatment with CPM. Due to
the high percentage of crossover from the CPM group to the No CPM group, the data were analyzed according to strict intention-to-treat principles and as-treated to identify whether the crossover affected results. Missing data at each time point were accounted for using the “last observation carried forward” method. Results with a p value of <0.05 were determined to be significant.

**Source of Funding**
This research was funded by a resident grant from the Orthopaedic Trauma Association.

**Results**
Forty patients were enrolled and randomized to one of the two treatment arms (Fig. 1). There were no differences in demographics between the two groups with respect to age, race, or smoking status. There were more men in the CPM group (85%) than in the No CPM group (55%) (p = 0.04), and patients in the CPM group had definitive surgery later than patients in the No CPM group by an average of 3.3 days (p < 0.03). There was no difference in OTA classification by treatment group (see Appendix). All patients who completed six-month follow-up had achieved radiographic union. All but one patient in this trial completed follow-up through three months, but the compliance rate after this point decreased in both groups with a total of thirty patients (sixteen in the CPM group and fourteen in the No CPM group) returning for follow-up evaluation at six months. There was no significant difference between the groups with respect to the rate of those lost to follow-up.
Six of twenty patients randomized to the CPM group declined to utilize the CPM device. Four of those patients demanded the device be taken off permanently because of increased pain, one patient demanded the device be removed for several hours, and one patient declined to use the device at all after seeing it in the recovery room. When the data were analyzed using strict intention-to-treat principles, the CPM group had a significant increase in range of motion at forty-eight hours after ORIF compared with the No CPM group, with a difference of $39^\circ$ in total arc of motion ($p < 0.005$). In the as-treated analysis, the difference increased to a $43^\circ$ advantage for the CPM group ($p < 0.001$). There was no significant difference in knee extension between the groups at any time point. The difference in range of motion was primarily attributed to the difference in knee flexion between the groups ($p < 0.01$), with the CPM group having greater knee flexion at forty-eight hours (Fig. 2). However, the difference in range of motion dissipated by the two-week follow-up period. Figure 3 shows the average range of motion as a percentage of the uninjured knee for each group at each follow-up visit. There was no significant difference
in range of motion at any time point after forty-eight hours using both the intention-to-treat and as-treated analysis (Table I). There was no difference in pain scores or the Lower Limb Outcomes Questionnaire scores at any time point. The No CPM group had significantly better SMFA dysfunction scores than the CPM group at baseline (34.9 versus 39.1) (p < 0.03), but this difference was not found at the six-month follow-up. There was no significant difference in overall complications between treatment groups; however, the types of complications were different for each group (Table II). There were two deep infections and one superficial infection in the CPM group compared with no infections in the No CPM group. In the No CPM group, there was one manipulation under anesthesia and one non-fatal pulmonary embolus. There were no manipulations or thrombotic events in the CPM group.

**Discussion**

To our knowledge, this is the first comparative trial evaluating the efficacy of CPM after surgical treatment of intra-articular fractures of the knee. Our results parallel consensus findings in both the total knee arthroplasty literature as well as the anterior cruciate ligament reconstruction literature. We found modest increases in range of motion only in the early postoperative period with use of CPM. There were no differences in range of motion beyond forty-eight hours after ORIF, and there were no differences in pain scores at any point. Additionally, there were no differences in functional outcomes scores at any follow-up time point and no difference in the overall complication rate.

Patients in both groups demonstrated consistent improvement in knee range of motion throughout the follow-up period and had regained most of the motion by three months. At three months, average knee flexion was 127° in the CPM group and 117° in the No CPM group, but the difference was not significant (p > 0.05). At the six-month follow-up, both groups had average knee flexion of >120°, which is substantially higher than that in previous reports of range of motion after intra-articular knee fractures, which have ranged from 105° to 107°.

Intra-articular knee fractures comprise a wide spectrum of severity, depending on both patient-related and mechanistic factors. These injuries may be a source of substantial morbidity to the patient both in the short and long term. Appropriate treatment of these injuries is essential to minimizing long-term functional deficits. Anatomic reduction of articular fragments decreases posttraumatic arthritic changes. Maintaining anatomic length and alignment of the lower limb is also crucial to minimizing gait disturbance and functional deficits. Achieving osseous union and regaining knee motion are of primary concern in the postoperative rehabilitation.

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**TABLE I Range of Motion as a Percentage of That of the Uninjured Knee for Both Intention-to-Treat and As-Treated Analyses**

<table>
<thead>
<tr>
<th>Time of Evaluation</th>
<th>CPM (%)</th>
<th>No CPM (%)</th>
<th>P Value</th>
<th>CPM (%)</th>
<th>No CPM (%)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 hr</td>
<td>60.7</td>
<td>31.3</td>
<td>0.00079</td>
<td>66.6</td>
<td>33.5</td>
<td>0.00039</td>
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<tr>
<td>2 wk</td>
<td>61.3</td>
<td>63.9</td>
<td>0.35</td>
<td>67.8</td>
<td>60.1</td>
<td>0.13</td>
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<tr>
<td>6 wk</td>
<td>80.6</td>
<td>81.6</td>
<td>0.43</td>
<td>78.9</td>
<td>75.6</td>
<td>0.36</td>
</tr>
<tr>
<td>3 mo</td>
<td>88.7</td>
<td>85.1</td>
<td>0.23</td>
<td>90.1</td>
<td>84.3</td>
<td>0.13</td>
</tr>
<tr>
<td>6 mo</td>
<td>92.0</td>
<td>89.9</td>
<td>0.28</td>
<td>92.0</td>
<td>87.8</td>
<td>0.14</td>
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</tbody>
</table>

*CPM = continuous passive motion.

**TABLE II Complications**

<table>
<thead>
<tr>
<th>Case</th>
<th>Treatment Group*</th>
<th>Age (yr)</th>
<th>Fracture Type</th>
<th>External Fixation</th>
<th>Approach</th>
<th>Time From Surgery</th>
<th>Complication</th>
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<tbody>
<tr>
<td></td>
<td>No CPM</td>
<td>56</td>
<td>OTA 33-B3 Femur</td>
<td>No</td>
<td>Medial</td>
<td>6 mo</td>
<td>Knee manipulation</td>
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<td>2</td>
<td>No CPM</td>
<td>61</td>
<td>OTA 41-B2 Tibia</td>
<td>No</td>
<td>Lateral</td>
<td>15 days</td>
<td>Pulmonary embolus</td>
</tr>
<tr>
<td>3</td>
<td>CPM</td>
<td>57</td>
<td>OTA 41-C3 Tibia</td>
<td>Yes</td>
<td>Both</td>
<td>12 days</td>
<td>Deep infection</td>
</tr>
<tr>
<td>4</td>
<td>CPM</td>
<td>65</td>
<td>OTA 41-C1 Tibia</td>
<td>Yes</td>
<td>Lateral</td>
<td>5 mo</td>
<td>Deep infection</td>
</tr>
<tr>
<td>5</td>
<td>CPM</td>
<td>66</td>
<td>OTA 41-B3 Tibia</td>
<td>No</td>
<td>Lateral</td>
<td>16 days</td>
<td>Superficial infection</td>
</tr>
</tbody>
</table>

*CPM = continuous passive motion. †OTA = Orthopaedic Trauma Association.
Routine use of CPM in the postoperative period is one strategy used to maximize knee range of motion after surgical treatment of these fractures; however, there is no evidence regarding its efficacy, and there is a direct cost associated with its use. At our institution, a single postoperative inpatient physical therapy session results in a charge of $75. Using a CPM machine creates an additional $125 charge. In this study protocol, the CPM machine was used for forty-eight hours, but there is no consensus in the arthroplasty literature regarding the optimal timing and duration of CPM utilization in the acute postoperative period.\(^{15}\)

Mechanical thromboprophylaxis is one purported benefit of CPM according to Lynch et al.\(^{9}\). There was one pulmonary embolus in the No CPM group compared with none in the CPM group. However, our study is underpowered regarding thrombotic events, and no conclusions should be made regarding the efficacy of CPM for thromboprophylaxis in our patients.

Another benefit of routine use of CPM identified in the arthroplasty literature may be a decrease in the rate of postoperative manipulations under anesthesia.\(^{13,16}\) There was one manipulation in the No CPM group compared with none in the CPM group, but again this study was underpowered to identify a significant difference in manipulations between treatment groups.

The three patients in the CPM group who later developed infections were treated initially with delayed ORIF at ten, nineteen, and nineteen days, respectively. The OTA fracture classification for each of these patients was 41-C3, 41-B3, and 41-C1. Two of the three patients had spanning external fixation prior to ORIF (one with dual plating and one with lateral plating only). The other patient had ORIF with lateral plating without previous spanning external fixation. To our knowledge, there are no previously published data linking the use of CPM with postoperative infection. While this trial is underpowered to declare a significant correlation, it is possible that friction from the CPM device straps across incisions could have increased the chances of skin flora being seeded into the wound, contributing to the higher infection rates. Other potential reasons for the infections could be related to the motion of the subfascial muscle structure beneath the suture lines (the patients with the two deep infections both tolerated an arc of only 0° to 45°, and the patient with the superficial infection had an arc of 0° to 80°, making this less likely) or potentially more severe soft-tissue injury could have contributed to the infection rate.

We found a high rate of intolerance to the use of CPM in the immediate postoperative period. This could be attributed to a variety of factors related to the patients and their expectations as well as the degree of trauma to the knee with these injuries.

This trial has several limitations. The small sample size makes it difficult to arrive at any definitive conclusions beyond the primary outcome of knee range of motion. We also experienced difficulty with patients failing to return for follow-up. However, on the basis of the arthroplasty literature, if a difference in range of motion exists, it was more likely to be identified in the early postoperative period. Therefore, we doubt there would be any significant changes in range of motion at the more remote follow-up periods, making the impact of the patients lost to follow-up minimal. Another limitation includes the inability to blind the outcome assessors to the treatment arm. Early outcomes were assessed immediately following study treatment (approximately forty-eight hours after surgery). Follow-up outcomes were generally assessed by the operating surgeon.

In conclusion, the routine use of CPM in the immediate postoperative period after surgical treatment of intra-articular fractures of the knee does not provide any incremental benefit in range of motion or patient outcomes over physical therapy alone. The early difference in range of motion is not maintained at two weeks or beyond, and does not justify the added expense.

**Appendix**

A table showing the OTA fracture classification by treatment group is available with the online version of this article as a data supplement at jbjs.org.

**References**


