AN ORIGINAL STUDY
NONSURGICAL TECHNIQUE

Mechanical Therapy for Loss of Knee Flexion

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Abstract

We hypothesized that adding home mechanical therapy to traditional physical therapy by a physical therapist would significantly reduce the need for surgical management of loss of knee flexion after surgery or injury. From 1990 to 1999, we followed up on 34 patients who added home mechanical therapy after failure of physical therapy alone. Thirty-one (91.2%) of these patients regained functional flexion (defined as flexion to 115°) after 6.7 weeks. After surgery, these patients had waited a mean of 23.6 weeks before starting home mechanical therapy. Over the course of this therapy, mean knee flexion progressed from 70.8° to 130.6°. Only 2 patients in this study required surgical manipulation. We conclude that a home mechanical therapy program will reduce the need for surgical management of loss of knee flexion.

Persistent loss of knee flexion is the number one complication of knee surgery or injury.[1–9] Technical errors, bony malunions, and severe intra-articular damage are 3 possible causes, but most loss is caused by extra-articular or intra-articular fibrosis.[10] Often the surgeon waits until the knee is severely affected before instituting a treatment plan.[1,3] Nonoperative treatments include physical therapy (PT) and mechanical therapy. PT by a physical therapist requires hands-on treatment in a clinic, and the 7-days-a-week schedule may be prohibitive. Mechanical therapy involves at-home use of a mechanical device that stretches the joint and urges increased motion. By the time surgery is instituted, manipulation under anesthesia alone is not enough, and arthroscopic lysis of adhesions or open surgical release is necessary.[10,11] Even with surgery, the joint may not fully recover.[10–16] With patients and employers increasing their demands for full range of motion (ROM), attaining and maintaining full end ROM after knee surgery or injury are mandated both clinically and economically.

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Loss of knee flexion—defined as flexion of less than 125°, or loss of more than 20° when the knee is compared with the contralateral knee—occurs in up to 7% of patients undergoing anterior cruciate ligament (ACL) surgery, even after institution of an aggressive postoperative rehabilitation program.[1,3,4,6] Loss of knee ROM is not limited to ACL surgery. Up to 50% of patients with periarticular knee fractures or tendon ruptures have difficulty regaining full ROM.[2,8,9,17–20]

Loss of knee flexion can be caused by technical errors, bony malunions, or severe intra-articular damage. An anterior femoral tunnel created during ACL reconstruction can biomechanically contribute to loss of knee flexion.[10,21] Supracondylar femur fractures and tibial plateau fractures can be fixed in hyperextension to create an anatomical block to achieve full knee flexion. If the shape of the femoral condyle is distorted or flattened as a consequence of injury or disease, flexion may be impaired. Overall, most loss of knee flexion is due simply to the intra-articular or extra-articular fibrosis associated with knee injuries or surgery.[1–16]

We hypothesized that adding home mechanical therapy to PT by a physical therapist would significantly reduce the need for surgical management of loss of knee flexion after surgery or injury.

Materials and Methods

Between September 8, 1990, and March 8, 1999, 34 patients entered our prospective study of the efficacy of using home mechanical therapy to help patients regain knee ROM after loss of flexion. Our patients' cases reflect the distribution of complicated knee injuries referred to a major university orthopedic clinic. The sole focus of this article is on loss of knee flexion; therefore, inclusion criteria for the study were postsurgical or injured patients who did not have full knee flexion (compared with their opposite normal side) after 6 weeks of supervised outpatient PT. If a patient did not have flexion of 90° after 4 weeks of PT, the device was ordered and instituted at 6 weeks; if a patient had more than 90° of flexion after 4 weeks of PT but did not have full ROM after 6 weeks of PT, the device was ordered at 6 weeks and instituted as soon as possible. Patients who had surgery at our clinic underwent 6 weeks of postoperative PT before entering the study; patients who were referred for postsurgical loss of knee flexion underwent 6 weeks of PT before entering the study. The protocol we used for postoperative man-

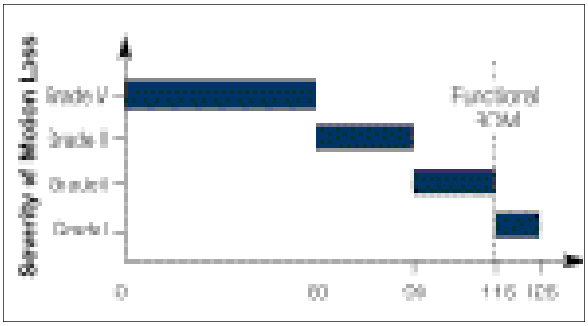

Figure 1. Classification of loss of range of motion (ROM) in the flexed knee.

agement of ACL reconstructions was described by DeMaio and colleagues.[22] Postoperative fracture management involved continuous passive motion (CPM) when permitted. Otherwise, immobilization was used to ensure adequate bone healing. Both manual and isokinetic stretch programs were used during the PT program. Postoperative radiographs were taken to confirm tunnel placement in ACL reconstructions and adequate bone healing in periarticular fractures. Laboratory tests and cultures were used to rule out postoperative infection as the cause of intra-articular fibrosis.

As Figure 1 shows, severity of flexion loss was graded I (115°–125° of flexion remaining after loss), II (90°–115° of flexion remaining), III (60°–90° of flexion remaining), or IV (<60° of flexion remaining).

Flexion was measured with the patient supine on the examination table and both knees flexed to their maximum position. A 12-inch goniometer was used from the center of rotation of the knee to the center of the greater trochanter and from the center of rotation of the knee to the lateral malleolus. Care was taken to ensure maximal knee flexion. If the distance from the heel of one foot to the buttock was the same as the distance from the other heel to the other buttock, then flexion of the injured knee was considered to be full in comparison with flexion of the opposite knee, and flexion was measured only in the injured knee. All patients had an injured knee and a noninjured knee. Table I shows the distribution of patients according to cause of flexion loss.

Each patient was followed up on until knee ROM was full, until the patient reached a satisfactory plateau with ROM, or until the patient required surgical manipulation under anesthesia. In the study group, mean follow-up was 4 years 8 months (range, 2 years 1 month–9 years 2 months). There were 18 females and 16 males. Mean age was 34.8 years (range, 12–66 years). Mean time from index surgery to initial use of mechanical therapy was 23.6 weeks (range, 6–156 weeks).

TABLE I. DISTRIBUTION OF PATIENTS BY CAUSE OF FLEXION LOSS

Condition	Grade I	Grade II	Grade III	Grade IV	Mean Age, y	Mean Follow-Up
Anterior cruciate ligament injury	2	3	6	3	32.3	4 y 7 mo
Peripatellar injury	—	—	4	3	35.1	4 y 5 mo
Fracture	—	1	1	2	49.8	5 y 5 mo
Miscellaneous	—	2	5	2	31.9	4 y 8 mo
Total	2	6	16	10	34.8	4 y 8 mo

The ERMI Knee/Ankle Flexionater® (ERMI, Inc, Atlanta, Ga) was used to provide mechanical therapy. The hydraulic load-application mechanism and the quick-release mechanism of this device (Figure 2) give patients complete control of stretching. Load is applied through the foot and at the buttock. Patient themselves can vary the load from 0 to 500 ft-lb of torque in 1° increments. The stretching protocol used in this study required that patients use the device 15 minutes per session 4 to 8 times per day. During each session, patients dynamically stretched the knee into current full flexion for 1 to 5 minutes. For recovery, they released the joint into extension for an equal amount of time. Then they stretched into current full flexion again for 1 to 5 minutes. This pattern was repeated until 15 minutes elapsed. We describe this protocol as *patient-actuated serial stretch* (PASS).

Two other stretching protocols *are low-load prolonged stretch* (LLPS) and *static progressive stretch* (SPS). LLPS uses a low-load force in a brace form that loads the joint in the direction of stretch for 6 to 8 hours per session. SPS uses a brace to force the joint into a specific degree of flexion or extension. After the patient can tolerate moving the joint farther in the direction of the stretch, the joint is moved more. Only at the end of the session is the load on the joint reversed completely. Recommended length of an SPS session is 30 minutes.

In 1993, to confirm that laxity does not increase when patients use this device after ACL reconstruction, we used

Figure 2. ERMI Knee/Ankle Flexionater® (ERMI, Inc, Atlanta, Ga).

the KT-1000 arthrometer to follow up on a continual series of 50 patients. Data were obtained at 20 and 30 lb with the knee in 20° of flexion. Final KT-1000 results were obtained 9 to 12 months after index surgery. Of the 50 patients, the 12% whose cases were deemed "therapy failures" were started on a home mechanical therapy program; the other 88% were started on the standard postoperative ACL course previously described.

In the literature, we did not find an absolute definition of full knee flexion. Shelbourne and colleagues[6] reported 143° to be the mean amount of knee flexion in the opposite normal extremity (range, 130°–156°). In our study, though, several patients had less than 130° of flexion in their opposite normal extremity. As a result, we defined functional knee ROM to be at least 115°[23] and full flexion of the injured knee joint to be whatever full flexion of the opposite normal joint is.

Statistical analyses involved performing paired *t* tests on evaluations conducted before and after mechanical therapy. An unpaired *t* test assuming unequal variances was used to determine the significance of KT-1000 test data and associated ROM data. Regression analysis was performed on correlations among time before starting mechanical therapy, time in mechanical therapy, initial ROM, final ROM, and ROM progress. The Statistical Package for the Social Sciences and the advanced data analysis package in Microsoft Excel were used to administer these tests.

Results

In this study, mechanical therapy for loss of knee flexion had a 91.2% overall success rate for regaining functional ROM and a 74% success rate for regaining full ROM compared with that of the opposite normal knee. According to our index grading system, patients with grade I loss of ROM had a 100% chance of regaining full ROM; those with grade II, 83%; those with grade III, 81%; and those with grade IV, 40% (Table II). ROM progressed in all patients; patients with grade IV loss regained the most ROM (mean, 79°).

Fourteen patients who underwent ACL surgery lost knee flexion (Table III). Of these patients, 3 (21%) had an isolated injury; the other 11 (79%) also had meniscal surgery (4 patients), meniscal transplantation (3 patients), multiple ligament

Table II. Loss of Range of Motion in the Knee: Results by Index Grade

Index		Results						
Index Grade	ROM°	No. Patients	Functional ROM % (n) Patients	Full ROM % (n) Patients	ROM Progression Mean Degrees (Range)	LOM Mean Degrees (Range)	End ROM Mean Degrees (Range)	Normal ROM Mean Degrees (Range)
I	>115	2	100 (2)	100 (2)	31 (25–37)	0	146 (140-152)	146 (140-152)
II	90–115	6	100 (6)	83 (5)	33 (23–45)	3.5 (0–20)	135 (118–146)	138.5 (135–140)
III	60–90	16	94 (15)	81 (13)	61.3 (27–82)	3.3 (0–20)	131.8 (102-152)	135.1 (122-152)
IV	0–60	10	80 (8)	40 (4)	79.1 (50-104)	13.8 (0–34)	122.7 (95-140)	136.5 (126-152)

*ROM indicates range of motion; LOM, loss of motion.

Table III. Summary of Mean Data (Including Ranges) for All 34 Patients

Condition	No. Patients	Time Since Surgery,wk (Range)	Initial Flexion Mean Degrees (Range)	End Flexion Mean Degrees (Range)	ROM Progression Mean Degrees (Range)	Time on Flexionater,wk (Range)
Anterior cruciate ligament injury	14	16.7 (6–104)	79.8 (22–115)	131.6 (95–152)	51.9 (25–104)	5 (2–12)
Peripatellar injury	7	53.4 (6–156)	57.7 (44–70)	130.3 (118–152)	72.6 (65–82)	8.6 (4–16)
Fracture	4	12	61.3 (30–95)	125.8 (118–130)	64.5 (23–95)	6 (4–8)
Miscellaneous	9	16.4 (6–52)	71.2 (50–98)	131.2 (110–142)	60 (44–88)	8.1 (3–12)

*ROM indicates range of motion; LOM, loss of motion.

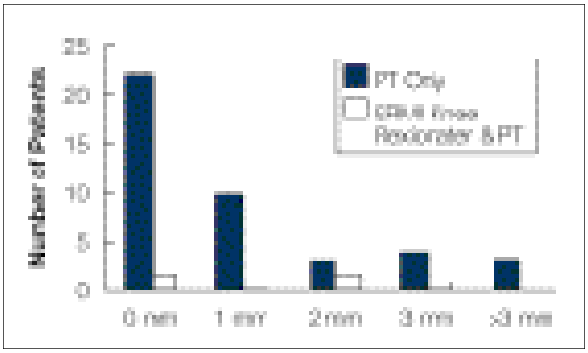

Figure 3. Results of KT-1000 arthrometer study. PT indicates physical therapy.

injuries (2 patients), meniscal transplantation and multiple ligament injuries (1 patient), or an osteochondral lesion (1 patient). After a mean of 16.7 weeks since surgery, mean flexion was 79.8°. When patients plateaued in PT, home mechanical therapy was added for a mean of 5 weeks. Over those 5 weeks, ROM progressed a mean of 51.9° (range, 25°–104°) to a mean of 131.6°.

KT-1000 results are presented in Figure 3. There was no statistical difference in end ROM in the injured knee between the PT-only group and the PT-plus-mechanical-therapy group ($P>.10$). Furthermore, there was no statistical difference in KT-1000 results between the 2 groups ($P>.50$).

The 7 patients who had the most difficulty regaining ROM had significant loss of knee flexion after a peripatellar injury—patellar fracture, patellar realignment, quadriceps tendon rupture, or patellar tendon rupture (Table III). A mean of 53.4 weeks since surgery, mean flexion was only 57.7°. Over a mean of 8.6 weeks of home mechanical therapy, ROM progressed a mean of 72.6° (range, 65°–82°) to a mean of 130.3°. All 7 patients regained functional ROM, and 4 of the 7 regained full ROM. No patient required surgery.

For the 4 patients with supracondylar femur and tibial plateau fractures, mean flexion was only 61.3° after 12 weeks since surgery (Table III). Over a mean of 6 weeks of home mechanical therapy, ROM progressed a mean of 64.5° (range, 23°–95°) to 125.8°. No patient required surgery.

The 9 patients in the miscellaneous group had posterior cruciate ligament (PCL) reconstruction (1 patient), a medial meniscal tear (1), isolated medial meniscal transplantation (2), isolated osteochondral allograft (2), high tibial osteotomy (1), synovial chondromatosis (1), or posterior knee dislocation (1). A mean of 16.4 weeks after surgery, mean flexion was 71.2°. Over a mean of 8.1 weeks of home mechanical therapy, ROM progressed a mean of 60° (range, 44°–88°) to a mean of 131.2° (range, 110–142°).

Only 3 of the 34 patients did not regain functional ROM. One of these 3 patients had ACL reconstruction plus medial and lateral meniscal transplantations. Plateauing at 95° after PT plus home mechanical therapy, she required medial and lateral retinacular releases and manipulation under anesthesia. She restarted home mechanical therapy, and ROM progressed to 126°, equaling opposite-side ROM. The second patient had sustained an ACL/PCL/lateral collateral ligament injury that required 3-ligament reconstruction. This patient's stature (height, 5 ft 2 in; weight, 275 lb) limited ROM in the normal knee to 122°. After ROM failed to progress past 102° with mechanical therapy, we attempted knee manipulation under anesthesia. Three surgeons could not move the patient's knee. At surgery, she did not give permission for surgical release of soft tissue to regain ROM. The third patient, whose hemicondylar osteochondral allograft failed (with resultant subchondral collapse and subsequent structural changes in the femoral condyle), later required total knee arthroplasty.

The difference between initial ROM and final ROM in the entire group of 34 patients is statistically significant at $P>.000001$. Time before starting mechanical therapy did not correlate statistically with time in therapy ($R=.16$), final ROM ($R=.05$), or ROM progress ($R=.16$). In addition, time before starting mechanical therapy and initial ROM did not correlate ($R=.17$).

Discussion

The most important finding in this study is that 31 (91.2%) of our 34 patients—who had complicated cases involving severe loss of knee flexion and who had undergone a failed course of PT—regained functional ROM with the addition of home mechanical therapy. In addition, all 34 patients regained at least some knee flexion after performing home mechanical therapy, with all patients improving at least 2 grades (Table IV). Furthermore, 25 patients (74%) regained full ROM (defined as equal to full ROM in the noninjured knee). Clearly, patients with the highest degree of flexion loss at index evaluation were at highest risk for not regaining full ROM; nevertheless, 80% of these patients regained functional

TABLE IV. INDEX VERSUS FINAL GRADE FOR LOSS OF KNEE FLEXION

Index Grade	Full Range of Motion	No. Patients, Final Grade I	II	III	IV
I	2	—	—	—	—
II	5	1	—	—	—
III	13	2	1	—	—
IV	4	4	2	—	—

TABLE V. COST COMPARISON: SURGERY VERSUS MECHANICAL THERAPY

Treatment for Loss of Range of Motion	Time, wk	Cost	Multiplier	Total Cost
Surgery	5	$13,500.00	70 (7% of 1000 patients)	$945,000.00
Mechanical therapy	5	$3366.50	70 (7% of 1000 patients)	$235,655.00
Savings				**$709,345.00**

ROM. On the other hand, surgical treatment with arthroscopic débridement and manipulation has a high failure rate and a reoperation rate ranging from 1 in 15 to 19 in 44 (43%).[10]

Three patients using a home mechanical therapy program did not regain functional ROM. All 3 patients had additional surgery. One of these patients responded well to surgical release and knee manipulation under anesthesia, restarted home mechanical therapy, and regained full ROM. The second patient had not regained any ROM by the time knee manipulation was performed. After hemicondylar osteochondral allograft, the third patient developed persistent knee pain that ultimately required total knee arthroplasty. In this group of patients for whom mechanical therapy had failed, only 1 seemed to have isolated arthrofibrosis (the knees of the other 2 patients may have had structural changes that prevented them from regaining at least functional ROM).

This concept of soft-tissue relaxation with PASS is considerably different from the current surgical approach to loss of knee flexion. Surgical lysis of adhesions and manipulation under anesthesia help patients regain full ROM quickly, though at the expense of tissue tears (in addition, these procedures recreate the environment in which ROM was lost in the first place). PASS uses the patient's self-imposed pain threshold to limit damage to tissue while improving ROM. The short duration of each end ROM stretch, combined with the frequency of stretches, seems to be better tolerated by articular cartilage.[24]

Unlike CPM, PASS is focused on progression of only end ROM. Postoperative use of CPM only maintains the flexion regained during surgery. Research has shown that, for every 6 hours spent in CPM each day, only 30 minutes is spent in actual therapeutic stretching.[4] Therefore, only 15 minutes of every 6 hours spent on a CPM machine is actually spent working in end range flexion.

The surgeon's goal should always be to guide regaining of full ROM. Although timing of mechanical therapy seems not to affect outcome, our data show that an earlier start leads to earlier regaining of full ROM. Given this result, we suggest that mechanical therapy be instituted as soon as medically safe in patients likely to lose a large amount of flexion. For our patients receiving worker's compensation, earlier regaining of functional ROM translates into significant reductions in total cost of recovery.

The difference in costs between surgical and nonsurgical treatment of loss of knee flexion is significant. At our hospital, surgical management of loss of knee flexion costs approximately $13,500, which includes surgeon costs for arthroscopic lysis of adhesions and knee manipulation under anesthesia as well as costs for operating room time, anesthesia, medication, and postoperative PT. These costs were based on a 7% incidence of loss of knee flexion after ACL reconstruction in 1000 patients. We assumed that postoperative PT would be continued as long as mechanical therapy. All patients in the surgical-treatment group had lysis of adhesions and manipulation under anesthesia, whereas only 0.29% of patients in the mechanical-therapy group needed this surgery. Results are presented in Table V. Furthermore, the costs to society for the worker's inability to regain full knee ROM represent a substantial portion of final worker's compensation claims.

Conclusion

Using home mechanical therapy to regain flexion lost after surgery or injury has proved to be an efficacious and cost-effective alternative to surgical management of loss of ROM in the knee. Other nonoperative treatments have not proved to be as effective in regaining and maintaining ROM in patients with variable causes of loss of ROM. Eliminating the need for manipulation after knee surgery or injury significantly lowers the cost of injury management and avoids the risks associated with surgical treatment.

Authors' Disclosure Statement

Dr. Branch wishes to note that he is Medical Director, ERMI, Inc.,Atlanta, Georgia.

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