Effects of Continuous Passive Motion on Anterior Laxity Following ACL Reconstruction With Autogenous Patellar Tendon Grafts

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Continuous passive motion (CPM) is a modality used in the treatment, management, and rehabilitation of a variety of orthopedic problems. Recently, CPM devices have been therapeutically employed immediately after autogenous patellar tendon reconstruction of the anterior cruciate ligament (ACL). Whereas the concept of early motion is indicated, there is a concomitant concern that the implementation of immediate passive motion may stretch or rupture the graft. Twenty subjects scheduled to undergo ACL reconstruction were randomized into two groups (10 CPM and 10 non-CPM). All subjects performed the same postoperative rehabilitation with the exception of the CPM. Objective anterior tibial translation measurements were recorded with a KT-1000 for a 30-lb (133.5-N) Lachman test at 1 year postreconstruction. The results of this study indicated that the implementation of immediate continuous passive motion did not have any deleterious effects on the stability of the ligament reconstruction.

Continued development of technology and refinement of surgical techniques, emphasizing graft placement, graft fixation, and adequate notchplasty, have improved the orthopedic surgeon’s ability to perform an intra-articular anterior cruciate ligament (ACL) reconstruction. In turn, the rehabilitation programs following these procedures have been modified and accelerated to facilitate the patient’s return to activity in 6 to 7 months (4). However, rehabilitation specialists must realize that loss of motion is still a common complication following surgical intervention to reconstruct the anterior cruciate ligament (13, 16, 19, 22, 27, 29, 34). Sach et al. (29) reported flexion contractures greater than 5° strongly correlated with anterior knee pain, crepitus, and a poor postoperative functional result.

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Our review of the literature indicates that early joint motion following trauma reduces the occurrence of contractures and degenerative changes that are produced by immobilization (1, 8, 9, 11, 12, 15, 20, 21, 23–26, 30–32, 35). Furthermore, early motion minimizes the detrimental effects of immobilization and thus lessens the possibility of postoperative joint stiffness (5, 6, 16, 18–20, 27, 33). However, one major concern regarding the implementation of early continuous passive motion (CPM) following anterior cruciate reconstruction is strain on the intra-articular graft. Burks et al. (6) reported that anterior stability was adversely affected by CPM in the bone–patellar tendon–bone graft and the semitendinosus reconstruction. Gerber and Matter concluded that early motion after repair of the ACL could jeopardize the ligament (14). Further, Alms et al. (2) reported that the ACL grafts in dogs were placed under an increased strain during passive motion when the graft was improperly placed; Alms et al. believed that isometric placement of the graft was of vital importance and was absolutely necessary for initiating immediate passive motion.

Yates et al. (36) reported that subjects using CPM immediately following ACL reconstruction had significantly less (p < .05) circumferential joint swelling and intra-articular effusion than did subjects not using CPM. These authors (36) also reported that narcotic usage was significantly less and that CPM subjects had increased active and passive knee flexion. However, no differences were found in hemovac drainage and passive knee extension. Noyes and Mangine (22) reported no increase in joint swelling or joint laxity following an early passive motion rehabilitation protocol. In addition, Rosen et al. (28) reported that patients in the CPM device and those undergoing active motion did not realize any deleterious effect on stability of the knee joint after ACL reconstruction at 6 months postreconstruction.

This preponderance of literature on the therapeutic effects of CPM substantiates the benefits related to the healing processes and range of motion in postsurgical patients. However, the concern regarding the implementation of CPM immediately following surgical repair of the ACL and the resulting strain on the intra-articular graft requires further investigation. Therefore, the purpose of this study was to determine if the immediate use of CPM affects anterior knee laxity following ACL reconstruction at 1 year postoperative.

**Materials and Methods**

Twenty subjects with ACL deficiencies who underwent arthroscopically assisted ACL autograft reconstruction were randomly assigned to two groups by surgical date. Group 1 consisted of four males and six females (25.1 ± 10.5 years) who received CPM immediately following surgery (initiated in the recovery room). Group II consisted of four males and six females (24.8 ± 8.2 years) who did not receive CPM following surgery. All surgical reconstructions were performed using autogenous tissue from the middle third of the patellar tendon. All surgeries were performed by two physicians, and identical surgical procedures were employed. Subjects requiring other ligamentous repairs were excluded from this study. Each subject was advised of the purpose of this study and familiarized with the CPM treatment prior to giving consent to participate. All subjects gave informed consent prior to participation.

The CPM device used for treatment in this study was the Sutter CPM 9000.
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(Orthop Corp., San Diego, CA). This model has a full-length leg cradle hinged at the knee and ankle, a foot support, a motored controller, an electric plug, and a hand-held controller that allows the patient to turn the CPM on or off and to increase or decrease range of motion (ROM). The CPM device was measured, adjusted to fit, and placed on the patient in the recovery room by a CPM technician. The degree of motion (arc range) was set between 0° and 60°. The device ran continuously at Rate 5 (#5-cycle time in minutes = 4 min; 15 cycles per hour). CPM treatment consisted of a minimum of 16 hr per day during the 1st, 2nd, and 3rd postoperative days. Initial range of motion was 0° to 60°. The subjects were instructed in the operation of their machine and encouraged to gradually increase flexion to 90° as tolerated.

All subjects followed an identical postoperative rehabilitation program, with the exception of the CPM treatment for Group I. The immediate postoperative rehabilitation program consisted of wearing a postoperative adjustable hinge-type brace and performing active flexion and extension exercises.

On the 1st postoperative day, partial weight bearing (10% of body weight) was allowed. Subjects were instructed to walk with crutches using a modified four-point gait (toe touch). The postoperative adjustable hinge-type brace was blocked to allow motion between 10° and 90°. Each subject underwent two sessions of physical therapy and received supervised physical therapy and instructions on how to perform therapeutic exercise at home by the same physical therapist.

On the 2nd postoperative day, all subjects continued to ambulate with partial weight bearing. The brace continued to be blocked to allow motion between 10° and 90°. The brace was worn at all times except when subjects were using the CPM machine (Group I) or when a physical therapy session required the brace to be taken off (both groups).

On the 3rd postoperative day, each subject was seen for one physical therapy session. The subjects were then discharged from the hospital. Following discharge, subjects in Group I were instructed to use the CPM device at home for 6 hr per day until the 14th postoperative day. All subjects continued to follow a prescribed outpatient rehabilitation program under the supervision of the same physical therapist.

Objective anterior laxity testing using the KT-1000 instrumented arthrometer (MEDMetric, San Diego, CA) was performed on all subjects 1 year postreconstruction. The instrumented Lachman tests measured the actual millimeters of anterior tibial displacement relative to the femur under 133.5-N (30-lb) loads with the KT-1000 arthrometer. Three repetitions of the 133.5-N instrumented Lachman test were performed, first on the nonoperative knee and then on the operative (reconstructed) knee. Following the objective instrumented Lachman test the subjects were also evaluated by clinical examination. This subjective evaluation consisted of a manual Lachman and pivot shift tests. A 4-point scale (0–3), as described by Howe et al. (17), was used to grade the anterior laxity with the knee at 30° and 90° (Lachman) and pivot shift. The manual Lachman was graded with the following scale: 0 = no discernible laxity, 1 = minimal excursion with a hard endpoint, 2 = a pronounced excursion with solid endpoint, and 3 = pronounced excursion with soft or absent endpoint. The pivot shift phenomenon was graded with the following scale: 0 = no shift, 1 = a slight shift or pivot glide, 2 = a substantial shift with moderate subluxation, and 3 = a marked subluxation. All subjective evaluations were made by the same physical therapist.
Statistical Analysis

Descriptive techniques were used to determine means and standard deviations of the subjects' ages, the three trials of anterior tibial displacement values with the KT-1000 arthrometer, and subjective evaluation of the manual Lachman and pivot shift tests. The anterior tibial displacement values were calculated for all subjects on the operative (op) and nonoperative (non-op) knees in both groups. The difference between the op knee and the non-op knee was analyzed with a paired $t$ test (two-tailed) to determine if differences in the anterior tibial displacement (op minus non-op) existed between the two groups (CPM vs. non-CPM). Finally, the mean scores of the manual Lachman and pivot shift tests were analyzed with a paired $t$ test (two-tailed) to determine if differences existed between the two groups. An alpha level of 0.05 was set for all statistical procedures.

Results

The mean scores ($\pm SD$) of the objective anterior tibial displacements for the CPM group were 4.6 ($\pm 1.2$) mm for the op knee and 4.2 ($\pm 1.3$) mm for the non-op knee. The non-CPM group had a mean of 4.9 ($\pm 1.4$) mm for the op knee and 4.5 ($\pm 1.6$) mm for the non-op knee. The mean ($\pm SD$) difference between the op knee and the non-op knee for the CPM group was 0.4 ($\pm 1.6$) and 0.4 ($\pm 1.6$) for the non-CPM group. The paired $t$ test (two-tailed) between the two groups (CPM vs. non-CPM) resulted in a paired $t$ value of $-0.13$ ($p = 0.90$). This indicates that there were no differences in objective anterior knee laxity at 12 months postreconstruction. Furthermore, all subjects (CPM and non-CPM) demonstrated a stable knee ($\leq 3$ mm difference in AP drawer) at a 30-lb force with a mean difference of 0.4 mm between the involved and uninvolved knee (Figure 1).

The mean score ($\pm SD$) for the subjective Lachman in the CPM group was 1.0 ($\pm .82$) and the mean score ($\pm SD$) for the subjective pivot shift was 0.7 ($\pm .82$). The mean score ($\pm SD$) for the subjective Lachman in the non-CPM group was 1.0 ($\pm .82$) and the mean score ($\pm SD$) for the subjective pivot shift was 1.0 ($\pm .67$). The paired $t$ test (two-tailed) between the two groups (CPM vs. non-CPM) for the subjective Lachman resulted in a paired $t$ value of 0.0 ($p = 1.0$). The paired $t$ test (two-tailed) between the two groups for the subjective pivot shift resulted in a paired $t$ value of $-1.0$ ($p = 0.34$). All subjects demonstrated a firm endpoint on the Lachman test and all subjects presented with equal stability during pivot shift examination (Figure 2).

Discussion

A major goal following ACL reconstruction is to facilitate early range of motion without compromising stability. The main findings of the present study indicate that there were no differences in objective anterior tibial displacement, in subjective Lachman test, or in subjective pivot shift test 1 year postoperatively between the CPM group and the non-CPM group. Thus, the immediate use of a CPM device in this investigation did not adversely affect anterior knee laxity or jeopardize the graft during a 1-year follow-up evaluation.
One of the most significant advances in rehabilitation following ACL reconstruction is the inclusion of early terminal extension exercises (7). The immediate postoperative use of CPM has been shown to allow earlier range of motion within the first 3 weeks following surgery (36). Although the present study did not focus on range of motion, it does support the use of CPM to achieve motion and does not adversely affect the integrity of the autogenous graft. This concurs with the findings of Arms et al. (3), who reported that only minimal stress is placed on the ACL during passive extension and flexion. In turn, Yates et al. (36) reported no significant differences in knee extension with subjects utilizing CPM and active exercise and subjects performing active exercise only. Rosen et al. (28) found no differences in knee extension for patients who performed only active motion, patients who only utilized CPM, and patients who used both active motion and CPM following ACL reconstruction.

Another major goal of the surgeon and the patient following surgery is to achieve a degree of subjective normalcy following rehabilitation. One year postoperatively, the subjects in the present study demonstrated a stable knee against force, and 8/10 (80%) of the CPM group demonstrated less than or equal to 2 mm of anterior displacement difference between the involved and uninvolved knee. These findings are supported by Daniel et al. (10), who reported that 92% of their 338 noninjured subjects had right–left knee differences of no more than 2 mm.

In conclusion, the findings of this investigation indicate that the initiation of immediate continuous passive motion did not have any deleterious effects on
objective anterior tibial displacement, subjective Lachman test, or pivot shift test at 1 year following intra-articular reconstruction of the ACL utilizing patellar tendon autogenous grafts. However, if the initiation of immediate CPM is going to become a standard practice in rehabilitation following ACL reconstruction, subsequent examinations are also needed at 2 to 5 years postoperatively. Therefore, due to the small sample size in this investigation and the short-term nature of the follow-up, we feel that further research, including long-term follow-up, is needed to support these findings and further substantiate the use of CPM devices immediately following ACL reconstruction.

References


24. O’Driscoll, S.W., F.W. Keeley, and R.B. Salter. Durability of regenerated articular cartilage produced by free autogenous periosteal grafts in major full-thickness defects


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A Comparison of Prescribed Rigid Orthotic Devices and Athletic Taping Support Used to Modify Pronation in Runners

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The purpose of this study was to compare the effects of four different treatments on the control of the amount and rate of foot pronation while running. The four treatments were the reverse 8-stirrup taping technique, the low-dye taping technique, prescribed rigid orthotic devices, and no support in the running shoe. Six intercollegiate cross-country runners were filmed from the rear while running on a treadmill, and the film data were analyzed. A two-way MANOVA indicated no significant overall treatment effect for the dependent variables. A one-way ANOVA indicated that the reverse 8-stirrup taping technique significantly reduced the amount of maximum pronation when compared to shoes—no support and low-dye taping techniques. The reverse 8-stirrup also had significantly fewer degrees of total rear foot movement when compared to the low-dye taping technique. No other significant comparisons were realized. It was concluded that the reverse 8-stirrup would be as effective a treatment for excessive pronation in runners as the prescribed rigid orthotic device.

Pronation is a natural part of foot movement while running. Cooper and Fair (11) concluded that 4° of pronation is ideal and any additional pronation would be excessive or abnormal. The severity of pronation can be graded as mild, moderate, or severe. The mildly pronated foot usually has 4° to 6° of calcaneus valgus with a mild forefoot eversion. The moderately pronated foot has 6° to 10° of calcaneus valgus with increased forefoot eversion, while the severely pronated foot has 10° to 12° of calcaneus valgus with more severe forefoot eversion (11).

In the majority of cases, excessive pronation occurs at the subtalar joint (4, 14, 21). Estimates directly link excessive pronation to 75% of all running injuries (10, 12, 21, 25). Common “overuse syndromes” such as patellofemoral pain syndrome, tibial stress syndrome, Achilles peritendinitis, plantar fasciitis,