

# Prevention of Arthrofibrosis After Anterior Cruciate Ligament Reconstruction Using the Central Third Patellar Tendon Autograft\*

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## ABSTRACT

A retrospective analysis was performed to explain the decreasing incidence of postoperative arthrofibrosis of the knee in 191 consecutive patients who had anterior cruciate ligament reconstruction using the central third patellar tendon from 1987 through 1991. Follow-up data were available on 188 patients (98%). Age, sex, time interval from injury, preoperative motion, and concomitant meniscal repair or partial meniscectomy were evaluated for their significance as risk factors. Twenty-two of 188 patients (12%) developed arthrofibrosis; the incidence was lower when the acute anterior cruciate ligament reconstruction was delayed at least 3 weeks from the injury, and when preoperative extension was 10° or better. Age, sex, preoperative flexion, and need for concomitant meniscal surgery were not risk factors. The postoperative motion protocol evolved during the study period. Group 1 patients were braced in 45° of flexion for 1 week before passive extension was allowed. In Group 2, motion was started after 48 hours. Group 3 patients were braced in full extension, with motion starting within 24 hours. With these changes, the incidence dropped from 23% to 3%. Decreases in the incidence of arthrofibrosis with modifications in operative technique and postoperative analgesia were not statistically significant.

Arthrofibrosis of the knee is one of the most significant complications of ACL reconstruction<sup>8,8,16</sup> and has been shown to have an adverse effect on outcome.<sup>1,14</sup> Loss of motion after knee ligament reconstruction can be more disabling than the instability for which the surgery was performed.<sup>8</sup> The incidence of arthrofibrosis after ACL surgery has been reported to vary from a low of 4% in subgroups of patients from three recent series of isolated ACL reconstructions,<sup>4,11,18</sup> to 23% in a group of patients where ACL reconstruction and medial collateral ligament (MCL) repair were performed together,<sup>11</sup> and to a high of 35% in a subset of patients from a mixed group who had acute ACL repair and reconstruction.<sup>23</sup>

The treatment of postoperative arthrofibrosis can be tedious and frustrating for patient, therapist, and surgeon. Patients need prolonged physical therapy and frequently require surgical intervention.<sup>1,4,15,20</sup> The surgical treatment of arthrofibrosis is demanding and requires familiarity with arthroscopic debridement techniques<sup>2,4,9,10,13,15,17,19,20</sup> and, in some cases, anterior and posterior arthrotomy approaches.<sup>1,7,14,22</sup> Lysis of adhesions surgery has been shown to significantly improve knee motion; however, final functional results are compromised, and there is a high incidence of degenerative changes seen radiographically.<sup>1,14</sup> Concern has been expressed over loss of motion and subsequent abnormal knee kinematics leading to degenerative articular changes.<sup>4,14</sup> Further study is needed to evaluate the progression of degenerative changes in these patients.

Several investigators have attempted to identify risk factors for the development of arthrofibrosis of the knee. Risk factors implicated include acute reconstruction (<4 weeks from initial injury,<sup>4,7</sup> <3 weeks,<sup>19,23</sup> or <2 weeks<sup>10</sup>), male sex,<sup>7</sup> concomitant MCL repair,<sup>6,7,11</sup> concomitant lateral extraarticular procedure,<sup>14</sup> concomitant meniscal repair,<sup>6,11</sup> prolonged immobilization,<sup>18,21</sup> infection,<sup>24</sup> reflex sympha-

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thetic dystrophy,<sup>6</sup> and method of reconstruction (central third patellar tendon autograft versus allograft).<sup>5</sup>

The purpose of this study was threefold: 1) to determine the incidence of arthrofibrosis in a defined population of patients who underwent ACL reconstruction using the central third patellar tendon; 2) to identify risk factors for the development of arthrofibrosis; and 3) to assess the benefits of modifications in operative technique, postoperative analgesia, and early postoperative rehabilitation regimens in preventing arthrofibrosis.

## MATERIALS AND METHODS

One hundred ninety-one consecutive patients underwent primary ACL reconstruction from 1987 through the end of 1991 using the central third patellar tendon autograft technique by two attending orthopaedic surgeons at the University of Rochester Medical Center (KED and WJS). The indication for ligament reconstruction was ACL rupture in young patients participating in high-demand sports, or functional instability in active patients with chronic ACL insufficiency. A total of 188 patients (98%) were available for this retrospective study. Three patients were excluded because followup was less than 3 months. None were believed to have arthrofibrosis at the time of their last visit. Twenty-two of the 188 cases were diagnosed with arthrofibrosis. Criteria for the diagnosis of arthrofibrosis included a knee extension deficit of 10° or greater from neutral, flexion of less than 125°, or both. Patients had a variety of additional complaints related to loss of motion including painful extension block, recurrent effusions, patellofemoral pain, and quadriceps muscle weakness. These had not been formally quantified.

Hospital and office charts for all patients were reviewed by one of us (AJC). Patient demographic information, time interval to reconstruction, bilateral knee range of motion, operative technique, concomitant meniscal surgery at the time of ACL reconstruction, postoperative motion protocol, and postoperative analgesia data were recorded from the charts.

Two surgical techniques were used for the central third patellar tendon ACL reconstruction during the study period. The "miniarthrotomy" technique involved harvest site exposure through a midline incision centered over the patellar tendon after initial arthroscopic examination. Intraarticular exposure was gained through the anterior fat pad, deep to the patellar tendon harvest site. Notchplasty and femoral and tibial tunnel site selection were performed under direct visualization.

All other patients had reconstructions using the arthroscopically assisted technique. Debridement, notchplasty, and tunnel placement were performed arthroscopically, and the graft was introduced into the joint through the femoral tunnel.<sup>3</sup> With both surgical techniques, meniscal injuries were addressed before ACL reconstruction. If a meniscal repair was necessary, sutures were placed, but not tied until the end of the reconstruction. Both techniques required a second incision laterally at the distal femur for femoral tunnel drilling and bone block fixation. In all cases, an isometer was used to verify tunnel position intraopera-

tively. Isometer measurement of up to 3 mm of excursion (tightening) as the knee extended to neutral from a flexed position was considered acceptable.

Three postoperative motion protocols were used during the study period, reflecting a gradual change in our philosophy on rehabilitation after ACL reconstruction. Patients in Group 1 were placed in a splint in the operating room locked at 45° of flexion and were immobilized for 7 days. At the end of the week, active flexion to 90° was allowed as well as intermittent passive extension to neutral. Patients in the second group were also splinted at 45° of flexion postoperatively, but they were allowed active flexion to 90° and passive extension to neutral at 2 days. Group 3 patients were splinted in full extension, with active flexion and passive extension starting on the 1st postoperative day.

Patients were seen in the office on a regular basis during the postoperative therapy period. After 1 year, patients were seen again on an annual or as-needed basis. In many cases they had been referred from long distances for their reconstructions so they returned to their colleges or local orthopaedic surgeons for followup after surgery. The most recent available range-of-motion data were used for each patient. In a few cases this information had to be obtained from other physicians.

Patients were recalled for examination for this study if they were noted to have had extension deficits of >10° from neutral or flexion of <125° when their last range-of-motion measurements were formally recorded. Knee range of motion was measured using a large rigid goniometer with patients in the supine position. The axis of the goniometer was placed in the center of the knee joint with the proximal hinge aimed toward the greater trochanter and the distal hinge aimed toward the lateral malleolus. Extension deficits were measured by lifting the patient's heel off the examination table, allowing the knee to extend passively. Flexion was measured with patients supine and instructed to actively flex their knees.

Potential risk factors for the development of arthrofibrosis were analyzed. Modifications in operative technique, postoperative analgesia, and postoperative motion protocol were correlated with the incidence of arthrofibrosis. Statistical analysis was performed by an experienced biostatistician using chi-square and Fisher's exact tests.

## RESULTS

The average age of all patients was 23.8 years (range, 13 to 45). There were 124 male (66%) and 64 female (34%) patients. The ACL reconstruction was conducted in an acute setting (interval from injury <3 weeks) in 38 cases (20%), and at a chronic stage (interval from injury >3 weeks) in the other 150 cases (80%). Average followup was 16 months (range, 3 to 60). There were two patients who were last seen at 3 months postoperatively. Neither was available for further followup. They were included in the study because they had no evidence of arthrofibrosis at the time. The development of arthrofibrosis was clinically evident in all 22 patients by 3 months after reconstruction, and no patients lost motion after 3 months.

The reconstruction was performed using the miniarthrotomy technique in 101 patients (54%), and the arthroscopically assisted technique in 87 (46%). Sixty-nine patients (37%) underwent a concomitant meniscal repair at the time of the ACL reconstruction (50 medial only, 10 lateral only, 9 combined medial and lateral). Fifty-six patients (30%) underwent a partial meniscectomy (26 medial only, 22 lateral only, 8 combined medial and lateral). Eight patients (4%) had a meniscal tear that was stable and was therefore left alone (five lateral, two medial, one both medial and lateral). Six patients (3%) underwent concomitant ligamentous surgery (five MCL repairs, and one combined MCL and posterior cruciate ligament [PCL] repair). Only Grade 3 MCL tears were routinely repaired during the study period. Because of the small number of necessary concomitant ligamentous procedures, we cannot comment on their significance as risk factors.

The 64 patients (34%) in Group 1 had splints placed in the operating room that were locked at 45° of flexion and were held immobilized for 7 days. At the end of the week, active flexion to 90° was allowed as well as intermittent passive extension to neutral. The 49 patients (26%) in the second group were also splinted at 45° of flexion postoperatively but were allowed active flexion to 90° and passive extension to neutral at 2 days. The 75 patients (40%) in Group 3 were splinted in full extension, with active flexion and passive extension starting on the 1st postoperative day.

The average preoperative knee range of motion at the time of ACL reconstruction was 3° of flexion (3° short of neutral) to 126° of flexion. Average motion on the contralateral side was 3° of hyperextension to 146° of flexion. The final average postoperative range of motion for all patients (including those who developed arthrofibrosis) was 0° of extension to 142° of flexion.

Twenty-two of 188 patients (12%) developed arthrofibrosis; 20 patients had at least 1 operative procedure; the remaining 2 patients declined further surgery. All had extension deficits of 10° or more from neutral, knee flexion of 125° or less, or both. Patients had a variety of additional complaints including painful extension block, recurrent effusions, patellofemoral pain, and quadriceps muscle weakness. No formal attempt was made to measure quadriceps muscle strength or effusion size, or to quantify pain.

Age and sex were not found to be significant risk factors for developing arthrofibrosis. The average age of all patients who developed arthrofibrosis was 23.2 years compared with 23.8 for those who did not. Nine of 64 female (14%) and 13 of 124 male patients (10%) developed arthrofibrosis of the knee ( $P > 0.05$ ).

Patients requiring concomitant meniscal repair or partial meniscectomy were not found to be at higher risk for developing arthrofibrosis. Seven of 69 patients (10%) developed arthrofibrosis after meniscal repair (4 medial and 3 lateral), compared with 15 of the 119 patients (13%) who did not need meniscal repair ( $P > 0.05$ ). Four of 56 patients (7%) undergoing concomitant partial meniscectomy (3 medial and 1 lateral) developed arthrofibrosis of the knee, compared with 18 of 132 patients (14%) not requiring par-

tial meniscectomy ( $P > 0.05$ ). Of the eight patients with stable meniscal tears, one (13%) developed arthrofibrosis ( $P > 0.05$ ).

Patients undergoing ACL reconstruction within 3 weeks of their injuries had a significantly higher risk of developing postoperative arthrofibrosis. Eight of 38 acute cases (21%) developed arthrofibrosis compared with 14 of 150 chronic cases (9%) ( $P < 0.05$ ; Fig. 1).

Arthrofibrosis was also more likely to develop in patients demonstrating preoperative motion deficits. Nine of 38 patients (19%) with preoperative extension deficits of 10° or greater developed arthrofibrosis compared with 13 of 150 patients (8%) with preoperative extension deficits of less than 10° ( $P < 0.05$ , two-tailed Fisher's exact test) (Fig. 2). Seven of 34 patients (21%) with preoperative flexion of less than 100° developed arthrofibrosis compared with 15 of 154 (10%) with preoperative flexion of better than 100°. This difference, however, was only in the statistical trend range ( $P = 0.08$ , two-tailed Fisher's exact test).

The likelihood of developing arthrofibrosis was closely related to the postoperative motion protocol used. Group 1 patients were immobilized at 45° of flexion for 7 days before the initiation of passive extension and active flexion. Fifteen of 64 patients (23.4%) developed arthrofibrosis. In Group 2, patients were immobilized at 45° of flexion for 2 days before motion was allowed. Five of 49 patients (10.2%) developed arthrofibrosis. Of the 75 patients in Group 3 who were placed in full extension postoperatively, only 2 (2.7%) developed arthrofibrosis. The difference in incidence of arthrofibrosis between groups was highly statistically significant ( $P < 0.0005$ , chi-square test for trend) (Fig. 3).

Early in the study, all patients had reconstructions using the miniarthrotomy technique. Patients in the first postoperative motion protocol group had reconstructions using only this technique. During the second and third postoperative motion protocol periods, reconstructions were performed using both the miniarthrotomy and the arthroscopically assisted surgical techniques. Four of 37 patients (11%) from Groups 2 and 3 who had reconstructions with the miniarthrotomy technique developed arthrofibrosis, compared with 3 of 87 (4%) of the patients who had recon-

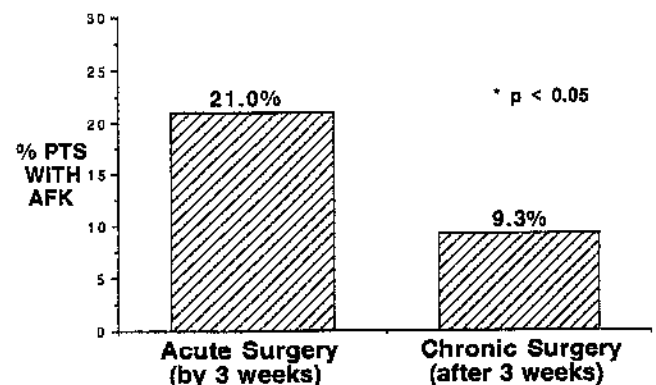
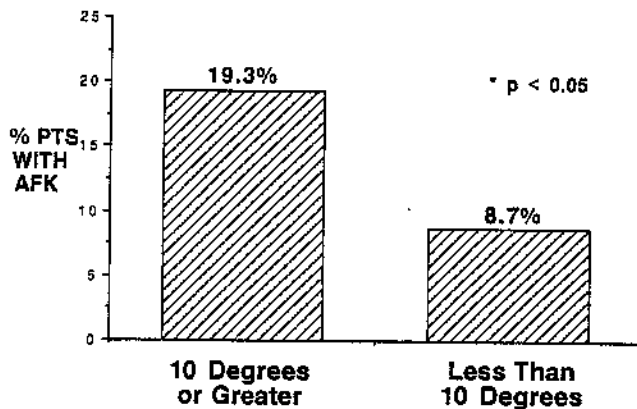
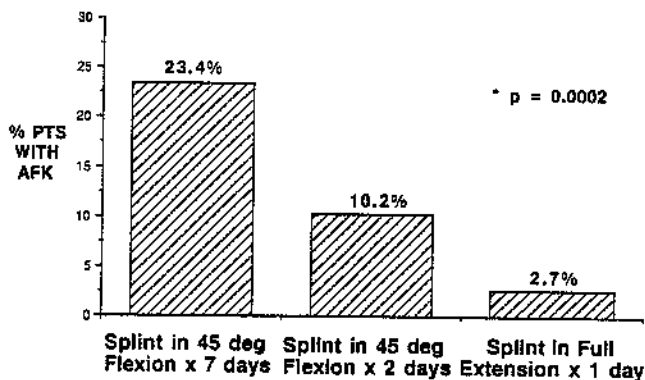


Figure 1. Incidence of arthrofibrosis by the time interval to reconstruction. Eight of 38 acute cases (21%) developed arthrofibrosis compared with 14 of 150 chronic cases (9.3%).



**Figure 2.** Incidence of arthrofibrosis by preoperative extension deficit. Nine of 38 patients (19.3%) with preoperative extension deficits of 10° or greater developed arthrofibrosis compared with 13 of 150 patients (8.7%) with preoperative extension deficits of less than 10°.



**Figure 3.** Incidence of arthrofibrosis by early postoperative motion protocol. Group 1 patients were immobilized at 45° of flexion for 7 days before the initiation of passive extension and active flexion; 15 of 64 patients (23.4%) developed arthrofibrosis. Group 2 patients were immobilized at 45° of flexion for 2 days before motion was allowed; 5 of 49 patients (10.2%) developed arthrofibrosis. Of the 75 patients in Group 3 that were placed in full extension postoperatively with motion starting on the 1st day, only 2 (2.7%) developed arthrofibrosis. The difference in incidence of arthrofibrosis between groups was highly statistically significant.

structions with the arthroscopically assisted technique. This difference was not statistically significant ( $P > 0.05$ ).

Early in the study all patients were treated for postoperative pain with intravenous or intramuscular narcotics. The option of receiving epidural analgesia was available only to patients in Groups 2 and 3. Selection of the agents used for pain management was made by the anesthesiologist in conjunction with the patient's wishes. In several cases an initial attempt at epidural pain management was abandoned and intramuscular or intravenous narcotics were used instead. Three of 77 patients (4%) from Groups 2 and 3 who were treated successfully with indwelling epidural catheters developed arthrofibrosis, compared with 4

of 47 patients (9%) who received IM or IV narcotics. This difference was not statistically significant ( $P > 0.05$ ).

## DISCUSSION

Arthrofibrosis of the knee is one of the most significant complications of ACL reconstruction surgery.<sup>6,8,18,23</sup> While a small limitation in knee motion may be only bothersome to most people, it can be devastating to the competitive athlete. Flexion contractures lead to athlete dissatisfaction because of knee pain and quadriceps muscle fatigue.<sup>18</sup> Contractures of as little as 5° have been shown to correlate with patellar irritability.<sup>19</sup> Contractures of 10° can cause a noticeable limp. Flexion deficits of 10° can have a detrimental effect on stride and may slow a running athlete's speed. A more worrisome concern is the impact that arthrofibrosis has on normal knee mechanics. The disruption of normal knee kinematics caused by the arthrofibrotic process leads to knee joint arthrosis<sup>14</sup> and can lead to progressive degenerative changes.

When investigators have specifically looked for this complication, the incidence of arthrofibrosis after ACL reconstruction surgery has varied from 4% to 23%.<sup>4,11,18</sup> Many factors contribute to the development of this complication. Some of the risk factors cited in the past have included the following: sex,<sup>7</sup> pain tolerance,<sup>5</sup> development of reflex sympathetic dystrophy,<sup>8</sup> timing to reconstruction,<sup>4,7,10,19,23</sup> sepsis,<sup>24</sup> surgical technique,<sup>5</sup> concomitant MCL surgery,<sup>6,7,11</sup> concomitant lateral extraarticular procedure,<sup>11</sup> concomitant meniscal repair,<sup>8,11</sup> and prolonged postoperative immobilization.<sup>18,21</sup>

Many investigators agree that the risk of developing arthrofibrosis of the knee is related to the timing of ACL reconstruction surgery.<sup>4,7,10,19,23</sup> It is known that patients who undergo ACL reconstruction during the early proliferative and cellular stages of healing are prone to develop an aberrant healing response.<sup>22</sup> Shelbourne et al.,<sup>19</sup> Strum et al.,<sup>23</sup> Harner et al.,<sup>7</sup> and Mohtadi et al.<sup>10</sup> have shown that arthrofibrosis was a greater problem when ligament surgery was performed in the acute setting. Our impression has been that the period of increased risk lasts about 3 weeks from the time of injury, although in some patients it may be substantially shorter or longer.

We believe that motion deficits in acute knee injuries may be one manifestation of the normal inflammatory response occurring as a result of the knee injury. It has been our observation that this response is variable from patient to patient. We have found that in those patients with a minimal overt inflammatory response and nearly normal knee motion, the ACL can be safely reconstructed sooner than 3 weeks. Conversely, if clinical evidence of significant inflammation persists past 3 weeks, it is prudent to delay surgery and continue with therapy to regain motion until the knee "cools down." Other possible causes for a preoperative motion deficit would be a displaced meniscal tear, an impinging ACL stump, or an entrapped loose body. Clinical or radiographic evidence of any of these would be a strong argument for earlier intervention.

In addition to delaying acute ACL reconstruction,<sup>5,7,10</sup> recommendations for preventing postoperative motion loss

have included locking the postoperative brace at 0°,<sup>5,7</sup> performing less concomitant extraarticular surgery,<sup>7</sup> instituting accelerated postoperative rehabilitation,<sup>10,18</sup> and emphasizing postoperative quadriceps muscle reeducation, patellar mobilization, and reinstatement of normal gait patterns.<sup>5,7</sup>

The adverse effects of prolonged immobilization on cartilage, bone density, ligaments, and periarticular structures are well known.<sup>21</sup> Shelbourne and Nitz<sup>18</sup> and Shelbourne and coworkers<sup>19</sup> found that patients who were allowed early motion and weightbearing had better ultimate motion than those initially splinted in slight flexion. They regained their extension quicker and were less likely to need surgical procedures for extension loss. Even patients undergoing acute reconstructions had significantly better motion when treated with an accelerated postoperative rehabilitation program. One concern expressed regarding early motion is the possible adverse effect on graft healing. Our current study does not address the issue of knee laxity, but studies by Noyes et al.<sup>12</sup> and Shelbourne and Nitz<sup>18</sup> found no detrimental effect on graft function by starting motion immediately after reconstruction, even though different surgical techniques were used.

In this study, the postoperative rehabilitation program used strongly influenced the knee range of motion. Three comprehensive protocol changes were made during the study period, reflecting a changing philosophy on rehabilitation after ACL reconstruction. Group 1 patients who were immobilized in 45° of flexion for a week had a 23.4% incidence of arthrofibrosis. The incidence was lower in Group 2 patients who were allowed motion at Day 2 (10.2%). The lowest incidence (2.7%) was in the Group 3 patients who were splinted in extension and allowed to start motion on the 1st postoperative day. It is unclear whether the significantly lower incidence of arthrofibrosis is because of the splinting in full extension, motion on the 1st postoperative day, or both factors.

When indwelling epidural catheter analgesia was used for at least 48 hours postoperatively, only 3 of 77 patients (4%) developed arthrofibrosis. Of the 47 patients whose treatment included intramuscular intravenous analgesia and reconstruction after indwelling epidural catheter analgesia was routinely available, 4 (9%) developed arthrofibrosis ( $P > 0.05$ ). Despite the fact that epidural analgesia provided no statistically significant difference, we believe that it can offer some advantages. In a symposium with Fu et al.,<sup>5</sup> Gillquist stated that stiff knees often occurred in patients with a low pain threshold. Ulrich et al.<sup>24</sup> pointed out the benefits of indwelling epidural anesthesia in a series of 22 patients after lysis of adhesions for arthrofibrosis.

There are obvious limitations to this retrospective study. In addition to the rehabilitation protocol changes, the gradual conversion to the arthroscopically assisted technique and use of indwelling epidural analgesia complicated statistical analysis. Consequently, multiple variant analysis techniques were not useful in isolating the relative importance of individual variables. This points out the need for prospective randomized studies examining each of these variables independently. Because the incidence of arthrofibrosis has fallen to a relatively low rate (approx-

imately 3%), future studies will need much larger numbers of patients to demonstrate significant differences. There is also error inherent in measuring knee extension and flexion that should be minimized by using a standardized measurement technique.

This study has several strengths. All of these patients underwent ACL reconstruction at the same hospital using central third patellar tendon autograft. There were only two surgeons involved in the study, and the postoperative treatment protocols were carefully standardized. We collected follow-up motion data on all but three patients (98%). Although the length of followup in our study is not sufficient for determining the overall success of the reconstruction procedure, it was sufficient for identifying all patients who developed arthrofibrosis.

## CONCLUSIONS

In our study of 191 consecutive ACL reconstructions performed using the central third patellar tendon autograft technique, 12% developed arthrofibrosis necessitating surgical treatment. We identified two preoperative factors that placed our patients at risk for this complication: reconstruction within 3 weeks from the time of injury and reconstruction when the knee lacked extension of 10° or more from neutral. Based on this data, we advise delaying acute ACL reconstruction at least 3 weeks, or until the patient has achieved nearly normal knee motion. We believe that a rehabilitation motion protocol consisting of postoperative splinting in full extension with immediate knee motion is the single most important factor in preventing arthrofibrosis. This protocol also emphasizes quadriceps muscle isometrics, straight-leg raises, patellar mobilization, and immediate protected weightbearing ambulation. Use of the arthroscopically assisted surgical technique and postoperative indwelling epidural analgesia may also be beneficial, although they did not cause statistically significant decreases in the incidence of arthrofibrosis of the knee in our study population.

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