

Radiographic Assessment of the Knee after Patellar Tendon Reconstruction for Chronic Anterior Cruciate Ligament Deficiency

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Background: The aim of this study was to evaluate the patellar height and degenerative changes of the knee by radiographic assessment after patellar tendon reconstruction for chronic anterior cruciate ligament deficiency.

Methods: This series included 44 patients (44 knees) with an average age of 31 years and an average follow up of 58 months. The central one third of the patellar bone-tendon-bone was used to reconstruct the anterior cruciate ligament in all patients. Radiographic assessment of the patellar height was measured using the Insall-Salvati method, and the degenerative changes of the knee using the Ahlback classification.

Results: After harvesting the mid-third of the patellar tendon, 28 of 44 cases (64%) showed a shortening with an average of 9.1%, whereas 12 cases (27%) showing a lengthening of the patellar tendon with an average of 9.4%. Four patients (9%) showed no change in patellar tendon length. Despite the changes in patellar tendon length, the pre- and post-operative patellar height changes were only marginally significant ($p=0.061$). Patella baja was noted in eight knees (18.2%) and patella alta in four (9.1%). Of the 12 knees with patella alta or baja, knee pain was observed in one patient (8.3%). The incidence of degenerative changes was 74% in knees with anterior cruciate ligament (ACL) reconstruction plus meniscectomy, versus 41% with ACL reconstruction without meniscectomy ($p=0.031$).

Conclusion: Harvesting of the mid-third of the patellar tendon resulted in changes in the patellar tendon length, however, it only marginally affected the patellar height. Meniscectomy was associated with a higher rate of degenerative changes, however, ACL injury alone significantly contributed to the development of degenerative changes of the knee.

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Key words: patellar height, tendon, degenerative changes, radiograph, anterior cruciate ligament.

Most patients with knees with untreated anterior cruciate ligament (ACL) injury are at risk of

additional injuries to the meniscus and the articular surface, and subsequent development of degenera-

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tive changes of the knee.⁽¹⁻⁵⁾ The goals of ACL reconstruction include restoration of functional stability and prevention of additional injuries and subsequent degenerative changes of the knee. Although various autogenous and allogeneous grafts have shown satisfactory clinical results, autogenous patellar bone-tendon-bone (P B-T-B) graft remains one of the common methods in ACL reconstruction because of the superior graft strength and better bone-to-bone healing.^(2,3,6-8) However, harvesting of the patellar tendon is associated with risk of complications including donor site pain, patellar tendinitis, shortening of the patellar tendon, patella baja and infrapatellar impingement syndrome, and quadriceps weakness.^(1,9-12)

The effects of harvesting the patellar tendon on the tendon length remains controversial.^(6-8,11,12) Furthermore, the effects of ACL reconstruction on the prevention of degenerative changes of the knee, especially in chronic ACL deficient knees, has not been established.^(5,13-15) Radiographic examination is simple, convenient and inexpensive, and it provides prudent information including the knee alignment, patellar height and degenerative changes of the knee. The purpose of this study was to evaluate the patellar height and degenerative changes of the knee by radiographic assessments of 44 knees in 44 patients undergoing ACL reconstruction using autogenous patellar bone-tendon-bone graft.

METHODS

From 1995 through 1998, 52 consecutive cases of ACL reconstruction using autogenous patellar B-T-B graft were performed at our institution. Patients undergoing ACL reconstruction using other types of tendon grafts were not included. Eight patients were excluded because of incomplete data and poor compliance. This series consisted of 44 patients including 32 men and 12 women with an average age of 31 years (range, 19-57 years). The mechanisms of injury included 27 (61.4%) sports related injuries and 17 (38.6%) trauma injuries due to traffic accidents. The average duration from the time of injury to surgery was 23 months (range, 3-108 months), and the average follow-up period was 70 months (range, 46-86 months). ACL reconstruction using the central one third of the patellar bone-tendon-bone graft with interference screw fixation was performed in all

patients. The average size of the graft was 10 mm (range, 9-11 mm). The patellar tendon defect was not closed. Concomitant surgeries included 27 meniscectomies (12 medial and 15 lateral), five meniscal repairs (2 medial and 3 lateral) and one osteochondral graft for full thickness articular cartilage defect in the medial femoral condyle.

Postoperatively, accelerated rehabilitation program including early ambulation with full weight bearing on the operated leg as tolerated, range of knee motion with emphasis on full extension, and quadriceps and hamstring exercises were applied to all patients with the exception of patients with meniscal repair. Patients with meniscus repair ambulated with partial weight bearing and limited the knee flexion below 90° for 4 to 6 weeks postoperatively. Patients were allowed to resume regular activities including sports 6 months or longer after surgery.

Radiographic examinations of the knee included standing anteroposterior (A-P), lateral and Merchant's views. The measurement of the patellar height was based on the Insall-Salvati method,⁽¹⁶⁾ and was determined by the ratio of the patellar tendon length over the diagonal distance of the patella bone on a lateral view radiograph with the knee at 20° to 30° of flexion. The normal value of patellar height was 1.0 ± 0.2 SD. Patella alta is defined when the ratio is greater than 1.2, and patella baja is defined when the ratio is 0.8 or less. The overall knee alignment, Fairbank lesion, subchondral sclerosis and osteophyte formation as well as the joint space narrowing were examined on A-P view radiographs. The radiographic assessments for degenerative changes of the knee were based on Alhback classification.⁽¹⁷⁾ The Merchant's view was examined for patellar instability and degenerative changes of the patellofemoral joint. The pre- and the postoperative data were compared statistically using paired t-test with statistical significance at $p < 0.05$.

RESULTS

Patellar height

The pre- and postoperative measurements of the patellar height are summarized in Table 1. Twelve knees (27.3%) showed a lengthening of the patellar tendon ranging from 0.6% to 33.3% with an average of 9.4%, whereas 28 knees (63.6%) showed a short-

ening of the patellar tendon ranging from 1.3% to 39.4% with an average of 9.1%. Only four knees (9.1%) showed no change in patellar tendon length. The average patellar height was 0.95 ± 0.13 before surgery versus 0.92 ± 0.13 at follow up, and the difference was marginally significant statistically ($p = 0.061$). Patella baja was observed in eight knees (18.2%) with two preoperatively and six postoperatively. The two knees with patella baja preoperatively showed no changes in patellar height postoperatively. Patella alta was noted in four knees (9.1%) with one preoperatively and three postoperatively. Of the 12 patients with patella baja or patella alta, only one patient developed patellar pain, and the remaining 11 were clinically asymptomatic.

Degenerative changes of the knee

The knee alignment was measured using the femorotibial angle on standing A-P radiograph of the knee. The average femorotibial angle was $4.9^\circ \pm 2.7^\circ$ valgus before surgery versus $3.3^\circ \pm 2.9^\circ$ valgus at the follow-up examination, and the difference was statistically significant ($p = 0.039$). The joint space narrowing was evaluated by the ratio of the medial over the lateral joint spaces on A-P view radiograph. The average ratio of medial-lateral joint spaces was $78\% \pm 16\%$ before surgery versus $73\% \pm 13\%$ at the fol-

low-up examination, and the difference was statistically significant ($p = 0.012$).

Radiographic assessments for degenerative changes of the knee were based on Alhback's classification. Fifteen knees (34%) showed no degenerative changes pre- or postoperatively; eleven knees (25%) showed the same or progressive degenerative changes; and 18 knees (41%) showed new development of degenerative changes postoperatively. Overall, degenerative changes were observed in 11 knees (25%) preoperatively, and 29 knees (66%) postoperatively ($p < 0.001$). Of the 11 knees with preoperative degenerative changes, two knees were symptomatic and nine knees asymptomatic. Of the 29 knees showing degenerative changes postoperatively, 14 knees (48%) were symptomatic and 15 knees (52%) asymptomatic (Table 2). The locations of degenerative changes included the medial compartment in 15, the lateral compartment in nine and the patellofemoral compartment in five knees. One knee with osteochondral graft for full thickness articular defect showed degenerative changes and was symptomatic.

The relationship of degenerative changes of the knee with meniscectomy is summarized in Table 3. Twenty-seven knees underwent concomitant meniscectomy, and 20 of the 27 knees (74.1%) developed

Table 1. Pre- and Postoperative Measurements of the Patellar Height Using the Insall/Salvati Method.

| | Preoperative | Postoperative | <i>p</i> * |
|--------------------------------|-----------------|----------------|------------|
| Number of Cases | 44 | 44 | |
| Patellar height | 0.95 ± 0.13 | 0.9 ± 0.13 | 0.061 |
| Lengthening of patellar tendon | - | 12 (27.3%) | |
| Shortening of patellar tendon | - | 28 (63.6%) | |
| Patella Baja | 2 | 6 | 0.103 |
| Patella Alta | 1 | 3 | 0.248 |

* Paired *t* test

Table 2. Association of Knee Pain and Degenerative Changes of the Knee.

| | Knees with degenerative changes | | |
|-----------------------------|---------------------------------|---------------|------------|
| | Preoperative | Postoperative | <i>p</i> * |
| Number of Cases | 11 | 29 | <0.001 |
| Number of Knee with pain | 2 (18%) | 14 (48.3%) | |
| Number of Knee with no pain | 9 (82%) | 15 (51.7%) | |

Mann-Whitney test

Table 3. Association of Meniscectomy and Degenerative Changes of the Knees

| Operation | # Cases | Degenerative changes of the knee | | <i>p</i> * |
|--------------------|---------|----------------------------------|-------------------|------------|
| | | (-) Preoperative | (-) Preoperative | |
| | | (-) Postoperative | (+) Postoperative | |
| ACL + meniscectomy | 27 | 7 (25.9%) | 20 (74.1%) | 0.031 |
| ACL reconstruction | 17 | 10 (58.8%) | 7 (41.2%) | |

Mann-Whitney test

degenerative changes postoperatively. Seventeen knees underwent ACL reconstruction without meniscectomy. Only seven of the 17 knees (41.2%) showed degenerative changes postoperatively. The difference in the incidence of degenerative changes between knees with and without meniscectomy was statistically significant ($p=0.031$). Five knees with meniscal repairs did not show degenerative changes postoperatively.

Subchondral bone sclerosis and osteophyte formation of the patellofemoral joint were observed in 28 knees (64%) preoperatively, and in 33 knees (75%) postoperatively. Five knees (11.4%) with negative radiographic findings of the patellofemoral joint preoperatively showed positive radiographic findings postoperatively. Only two knees (6%) had patellofemoral symptoms including pain and crepitus, and the remaining 31 knees (94%) were clinically asymptomatic. There were no correlations of patellar pain with the radiographic changes including subchondral sclerosis and osteophyte formation of the patellofemoral joint. None of the knees showed radiographic patellar instability.

DISCUSSION

The effect on the shortening of the patellar tendon after harvesting the central one third of the tendon remains controversial.^(1,6,7,10-12,15) Some authors reported that shortening of the patellar tendon would be expected to contribute to patellofemoral pain and flexion contracture, and the association between patella baja and patellofemoral pain.^(5,10,12) Sach et al.⁽⁵⁾ reported the three most common postoperative complications after harvesting the patellar tendon including quadriceps weakness, flexion contracture and patellofemoral pain. Paulos et al.⁽¹⁰⁾ reported on 28 patients with infrapatellar contracture syndrome, 19 had undergone ACL reconstruction and 16% of the knees developed patellar tendon shortening and patella baja. O'Brien et al.⁽¹⁵⁾ found relative postoperative shortening of the patellar tendon in 60% of 79 patients undergoing mid-third patellar tendon ACL reconstruction, and a statistically significant relationship between the ligament length changes and patient symptoms was noted. Tria et al.⁽¹²⁾ reported a 76% incidence of patella baja with two knees showing ligament lengthening in 29 patients undergoing the mid-third patellar tendon ACL reconstruction with

closure of the defect. The changes in the patellar tendon after harvesting the central one third was also demonstrated in animal studies.^(6,18) Burks et al.⁽¹⁸⁾ demonstrated an average of 10% patellar tendon shortening 6 months after harvesting the mid-third patellar tendon with bone blocks in a canine model. LaPrade et al.⁽⁶⁾ showed different mechanical properties, narrower and shorter, but thicker reharvested patellar tendon graft in a canine model.

Other authors reported no effects occurred to the patellar tendon length after harvesting the mid-third patellar tendon. Using intraoperative measurements and postoperative radiographs in 36 patients, Shaffer et al.⁽¹¹⁾ showed that no patient demonstrated evidence of patellar tendon shortening greater than 5.5% and the tendon defect closure resulted in negligible tendon shortening. Based on magnetic resonance imaging studies in 15 patients, Meisterling et al.⁽⁷⁾ reported that harvesting the central one third of the patellar tendon did not significantly affect the length, width, or thickness of the tendon at least 22 months after bone-patellar tendon-bone ACL reconstruction.

The results of the current study showed that harvesting of the central third of the patellar tendon resulted in a tendency toward shortening of the patellar tendon in 63.6% and lengthening in 27.3% of the knees. However, the patellar height was only marginally affected. The incidence of patella baja and patella alta was 18.2% and 9.1% respectively, and patellar pain was noted in one out of 12 knees with patella baja or patella alta. The results of this study are in agreement with the results of Shaffer et al.⁽¹¹⁾, Meisterling et al.⁽⁷⁾ and Tria et al.⁽¹²⁾. The authors speculated that the accelerated rehabilitation program might have affected the remaining patellar tendon. Shortening of the patellar tendon will occur when there is excessive scar tissue formation and contraction, whereas lengthening of the tendon may result from tissue proliferation and hypertrophy. The accelerated rehabilitation protocol in this study including early range of knee motion and muscle strengthening exercises may be beneficial to the proliferation of tissue and the prevention of scar tissue formation and are less likely to cause severe patellar tendon shortening or patella baja.

Many researchers have documented the increased incidence of degenerative changes of the knee after meniscectomy.^(1,13,19) In addition, full thick-

ness articular cartilage defects are likely to result in deterioration of the cartilage and degenerative changes of the knee.⁽¹⁾ However, the causal relationship between ACL injury and degenerative changes of the knee has not been clearly established. The results of the current study showed significant changes in the overall knee alignment and joint space narrowing after ACL injury. The incidence of degenerative changes was 74% in the knees with combined ACL reconstruction and meniscectomy, and 41.2% in the knees with ACL reconstruction without meniscectomy. Although meniscectomy has been associated with a higher rate of degenerative changes, ACL injury alone especially in knees with chronic ACL deficiency also significantly contributed to degenerative changes of the knee. Therefore, meniscectomy alone is not the sole factor responsible for the development of degenerative changes.

The results of this study showed subchondral sclerosis of the patellofemoral joint in 75% of the cases with only 6.1% having patellar pain. The authors speculated that subchondral sclerosis may be suggestive of early sub-clinical patellofemoral disorder associated with the harvesting of the patellar tendon.

In conclusion, harvesting of the central third of the patellar tendon resulted in a tendency for change in the patellar tendon length, however, it only marginally affected the patellar height. Although meniscectomy has been associated with a high rate of degenerative changes of the knee, ACL injury alone significantly contributed to the development of degenerative changes. The radiographic finding of subchondral sclerosis suggests early sub-clinical patellofemoral disorder after harvesting the mid-third patellar tendon.

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用自體髌骨韌帶重建前十字韌帶缺失後膝關節的影像評估

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背景： 本文是經由自體髌骨韌帶重建前十字韌帶後，用X光評估髌骨高度及膝關節退化現象。

方法： 本系列包括44位病人，平均年齡31歲，平均追蹤時間是58個月，擷取髌骨韌帶中間三分之一做前十字韌帶重建手術。用站立前後、側面及Merchant view的X光來分析。

結果： 28病例 (64%) 髌骨韌帶縮短 (平均9.1%)，12例 (27%) 的韌帶拉長 (平均9.4%)，只有4例 (9%) 韌帶長短沒變。雖然髌骨韌帶長度有改變，但是術前及術後之髌骨高度的變化有限。低位髌骨有18.2%，高位髌骨有9.1%，12個膝關節有髌骨位置高低變化，只有一例有疼痛。前十字韌帶重建合併半月板切除後的膝關節退化比率是74%；只做前十字韌帶重建後膝關節退化比率是41%。

結論： 擷取髌骨韌帶造成韌帶長短變化，但不影響髌骨高度。雖然半月板切除會導致較高低比率的退化性關節炎，但是前十字韌帶損傷本身也會影響膝關節退化現象。
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關鍵字： 髌骨高度，髌骨韌帶，關節退化，前十字韌帶，X光檢查。

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