ORIGINAL ARTICLE

Bone-patellar tendon-bone graft via a single minimally-invasive approach versus a classical approach in anterior cruciate ligament reconstruction: A prospective study

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KEYWORDS
Knee;
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Bone patellar tendon bone graft;
Anterior knee pain;
Minimally-invasive

Summary
Harvesting the patellar ligament for anterior cruciate ligament reconstructions can be a source of anterior knee pain and hypoesthesia of the lateral side of the knee. We analyzed the feasibility of a minimally-invasive technique via a single patellar approach and postulate that it reduces anterior pain and limits the hypoesthesia area.

Patients and methods: A prospective, comparative, non-randomized, single-center study was conducted on two groups: one undergoing surgery with the classical anteromedial approach, the other with the minimally-invasive approach. Each group included 20 patients. Both series were reviewed between the 6th and 8th month after surgery. The revision was clinical, radiological, and ultrasonographic.

Results: The grafts harvested via the classical approach in all 20 cases presented good characteristics, versus eight out of 18 for the grafts harvested via the minimally-invasive approach. A prominent anterior tibial tuberosity improved the quality of the tibial bone block. A hypoesthesia zone was found in 16 cases out of 18 in the classical approach group, it measured a mean 10.3 ± 5.6 cm². A surface area of 3 cm² was noted in one case from the minimally-invasive group. No significant difference was found for the subjective and objective IKDC and Lille patellofemoral scores between the two groups. Anterior pain was present in four patients in the classical group and six in the minimally-invasive group.

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Discussion: The minimally-invasive technique reduces the risk of cutaneous hypoesthesia. It does not prevent anterior pain related to harvesting the patellar tendon and a good-quality transplant can be obtained if the anterior tibial tuberosity is prominent.

Level of evidence: Level III: case-control study.

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Introduction

Reconstruction of the anterior cruciate ligament (ACL) with the patellar ligament is a validated technique. Studying the results shows the presence of anterior pain [1,2] and cutaneous hypoesthesia in the lateral side of the knee caused by the resection of the infrapatellar rami of the medial saphenous nerve [3–5]. Kurtus et al. [3], Tsuda et al. [4], Drain et al. [5], and Gaudot et al. [1] hypothesized that keeping the branches of the medial saphenous nerve intact using two minimally-invasive approaches centered on the patella and the anterior tibial tuberosity (ATT) would reduce anterior pain and limit the hypoesthesia area. We analyzed the feasibility of a minimally-invasive technique with a single patellar approach using original ancillary instrumentation. The objective was to analyze this innovative technique, its repercussions on the harvesting site and secondary cutaneous hypoesthesia, the quality of the transplant, and the healing of the patellar tendon. The secondary objective was to search for a correlation between anterior pain and the harvesting technique. We compared the short-term results of two groups of 20 patients, one group operated on via a classical anteromedial approach and the other via a minimally-invasive approach.

Patients and methods

Patients

Between May and November 2007, 40 patients were included in a prospective, comparative single-center, non-randomized study and treated by the same surgeon. Two groups of 20 patients each were created: patients were selected without randomization: a “classical” group and a “minimally-invasive” group (Table 1).

The inclusion criteria were complete unilateral rupture of the ACL, ligament harvesting on the homolateral knee, and absence of anterior pain before surgery. Patients with a history of knee surgery were excluded. Associated procedures (menisci and lateral meniscectomy) were not exclusion criteria (Table 2).

### Table 1 Patient characteristics in the two groups.

<table>
<thead>
<tr>
<th></th>
<th>Classical group</th>
<th>Minimally-invasive group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>25.9 ± 7.7 (16; 41)</td>
<td>25.4 ± 6.07 (17; 37)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.4 ± 10.8 (60; 95)</td>
<td>76 ± 6.8 (58; 90)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>177 ± 6.2 (163; 190)</td>
<td>175 ± 4.4 (164; 180)</td>
</tr>
<tr>
<td>Time from accident to surgery (months)</td>
<td>6.5 ± 15.1 (1; 66)</td>
<td>6.6 ± 9.6 (1; 44)</td>
</tr>
<tr>
<td>Caton-Deschamps Index</td>
<td>1 ± 0.1 (0.8; 1.2)</td>
<td>1 ± 0.1 (0.9; 1.1)</td>
</tr>
</tbody>
</table>

Surgical technique

Harvesting via the classical approach consisted in a 60-mm anteromedial pretendinous approach. The peritendon was opened with a reversed L-shaped incision. The graft took the middle third of the patellar tendon, was 10 mm wide, and the patellar bone block was harvested using the oscillating saw, 15 mm long and 10 mm thick, with the tibial block measuring 20 mm long and 10 mm thick. The patellar tendon was closed with separated stitches after scarification of the medial and lateral bands to prevent tension on the suture and optimize tendon healing. The peritendon was sutured.

The minimally-invasive technique included a 25-mm median cutaneous incision, with the lower limit of the incision opposite the apex of patella. The peritendon was opened at its proximal part and then separated from the tendon subcutaneously to the anterior part of the ATT. The 15-mm-long, 10-mm-wide patellar block was harvested under visual guidance using an oscillating saw. The rest of the harvesting procedure was carried out using a Smith & Nephew prototype T-shaped ancillary instrument (Le Mans, France) [6] (Fig. 1).

The tibial insertion of the patellar tendon was visualized with the arthroscope inserted through the patellar incision and localized using a percutaneous needle. The objective of this maneuver was to center the tendon harvested and locate the proximal part of the tibial block. The tendinous part of the 20-mm-long tibial bone block graft (with the thickness dependent on the ancillary tool) was harvested percutaneously, with the knee flexed at 90° (Fig. 2). The tibial bone block was released by inclining the ancillary instrument forward after extending the knee. The peritendon was resected by rotating the instrument 90°. The peritendon was verified using the arthroscope once the tendon had been harvested. The patellar ligament was left open, with the proximal part of the peritendon sutured.

The ACL reconstruction procedure was identical in the two groups, and the femoral tunnel was drilled outside in. The graft was passed from proximal to distal, impacted in the femoral tunnel (press-fit), and fixed using a LIGAFIX® SBM30 interference screw (SBM, Lourdes, France) in the tibial tunnel with the knee flexed 10–20°.
### Table 2  Associated procedures with ligament reconstruction.

<table>
<thead>
<tr>
<th>Associated procedures</th>
<th>Classical group</th>
<th>Minimally-invasive group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra-articular repair</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Medial meniscectomy</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Lateral meniscectomy</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Medial meniscal suture</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Lateral meniscal suture</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Evaluation method**

Eighteen patients in each group were evaluated: 15 clinically and radiologically (ultrasound and x-ray) between 6 and 8 months postoperative by an independent observer and the operator and three by questionnaire.

Conversion to the classical approach for two patients in the minimally-invasive group was necessary; this was accounted for in the analysis of the results. Two patients were lost to follow-up in the classical approach group.

The functional result was assessed using the objective and subjective IKDC scores [7] and the Lille patellofemoral score [8]. The 2007 French Arthroscopy Society (SF A) symposium criteria [1] were chosen to analyze anterior pain, and the Gaudot and Beaufils criteria [9] to localize the surface of the hypoesthesia zone. We completed the analysis with knee-walking test and kneeling.

Patellar height was evaluated using the Caton-Deschamps Index [10]. The shape of the ATT was defined by the ATT angles (diaphyseal and metaphyseal), which were measured.

**Figure 1**  T-shaped harvester with an open tube to verify the length and quality of the implant. The diameter is 10 mm and has a blunt asymmetrical extremity for its anterior third so as to protect the patellar ligament and a cutting edge for the rest of the cylinder to provide good bone penetration.

**Figure 2**  Single-approach minimally-invasive harvesting technique. A. Detachment of the peritendon from the patellar tendon. B. Harvesting of the patellar bone block using an oscillating saw. C. Basting the patellar bone block. D. Patellar ligament stripping using the T-shaped harvester. E. Tibial implant and detachment of the tibial bone block by extending the knee and inclining the T-harvester forward, then resection of the periosteum by making a quarter turn with the T-shaped harvester. F. Exit of the patellar ligament from the T-shaped harvester using a graft remover and a hammer.
using our protocol [11] on a lateral x-ray (Fig. 3). The ATT-diaphyseal (ATT-D) angle was the intersection between the diaphyseal anatomical axis and the anterior cortex of the ATT corresponding to the insertion of the patellar ligament. The ATT-metaphyseal (ATT-M) angle was the angle between the tangents of the metaphyseal anterior cortex and the anterior cortex of the ATT. Type I corresponded to a nearly smooth ATT (38%), type II to an ATT with a normal projection (31%), and type III to a prominent ATT (31%). The ultrasound study of the patellar tendon was conducted by a single operator using the same protocol throughout. The ultrasound exam was done on a Xario Toshiba device with a 12-MHz linear array transducer. The thickness of the tendon and the peritendon was measured at three levels: at the proximal and distal insertion and then at the middle third. The width and thickness of each patellar band as well as the space between them were quantified.

Statistical analysis

The data were extracted on an Excel (Microsoft) spreadsheet and analyzed with Statistical Toolbox (Matlab). The significance level retained was \( P < 0.05 \).

Results

Graft harvesting

For the minimally-invasive technique, two harvesting procedures were converted to the classical approach, one because the venous tourniquet increased the risk of the subcutaneous part of the harvest procedure and the second following a poor quality transplant (insufficient tendon width, fragmented tibial bone block), with the objective of understanding the causes of the failure. The medium-term results were not analyzed for these two patients. The mean harvesting time was \( 14.7 \pm 2.37 \text{ min} \) (range, 13–20) for the minimally-invasive approach and \( 7.6 \pm 1.6 \text{ min} \) (range, 6–11) for the classical approach. The mean incision length was \( 28 \text{ mm} \) (range, 25–35). In three cases, the patellar graft width was insufficient (<10 mm). The mean length of the patellar block was \( 17 \text{ mm} \) (range, 10–20) for an optimal length of 15 mm, the tibial block measured a mean 17 mm (range, 10–28) for an optimal length of 20 mm. In eight cases, the tibial block presented a satisfactory aspect in terms of diameter and thickness, in five cases it was too short (considered to have no consequences on the quality of the graft in four cases), in three cases a thinned tendon-bone junction. In two cases the tibial block was mostly cortical bone.

In the type III ATTs, a graft of satisfactory quality was always obtained in the minimally-invasive group: the harvesting problems and poor tibial bone tibial were observed in types I and II.

In the classical technique, all the harvested ligaments met the required criteria.

Functional results

We found no significant differences in terms of pain related to the harvesting method \( (P = 0.72) \). In the minimally-invasive group, six patients out of 18 complained of anterior pain with a mean visual analog scale (VAS) score of 2.26 and four out of 18 in the classical group with a mean VAS of 2.66.

In the classical group, skin hypoesthesia was observed in 16 patients out of 18 (14 cases of hypoesthesia and two combined) versus one case of hypoesthesia out of 18 in the minimally-invasive group. The topography of the hypoesthesia surface varied in the classical group. The hypoesthesia zone in the classical group covered a mean \( 10.3 \pm 5.6 \text{ cm}^2 \) (range, 2.5–18) versus \( 3 \text{ cm}^2 \) for the patient in the minimally-invasive group.

For the knee-walking test and kneeling, no significant difference was observed (Table 3).

The mean subjective IKDC score was equivalent in the two groups: 85 (range, 73–97) for the minimally-invasive group and 84 (range, 70–100) for the classical group. The objective IKDC scores were equivalent in the two groups \( (P = 1) \).

The Lille patellofemoral score was equivalent in the two groups: 93 (range, 75–100) for the minimally-invasive group and 94 (range, 77–100) for the classical group \( (P = 1) \).

Radiological exam

The patellar ligament harvest did not cause patella infera in any patients: the Caton-Deschamps Index was \( 1 \pm 0.1 \) (range, 0.75–1.2) in the classical group and \( 1 \pm 0.1 \) (range, 0.9–1.1) in the minimally-invasive group.

Ultrasound

In the minimally-invasive group, the mean difference between the medial and lateral band thickness was 3.36 mm (range, 0–9.9) with no significant difference \( (P = 0.09) \).
Table 3 Results of kneeling and knee walking test tests.

<table>
<thead>
<tr>
<th></th>
<th>Kneeling</th>
<th>Knee-walking test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>Slight</td>
</tr>
<tr>
<td>Classical</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Minimally-invasive</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>Unpleasant</td>
</tr>
<tr>
<td>Classical</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Minimally-invasive</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>

patients with tendon band asymmetry greater than 4 mm had an “unpleasant” or “difficult” knee-walking test result in three cases out of four. The mean thickness of the peritendon was 1.57 mm (range, 0.73–2.33) in the three measurement zones versus 2.15 mm (range, 0.63–3.3) in the classical group.

Discussion

The single minimally-invasive harvest procedure presents an advantage in esthetic terms since the size of the incision is a mean 28 mm, for a reduction of 32 mm compared to our classical approach. Tsuda et al. [4] proposed two horizontal incisions for a better esthetic result, Drain et al. [5] described two vertical incisions, each one 20–25 mm, the first above the patellar apex and the second centered on the anterior tibial tuberosity, which in the end produces a 40- to 50-mm scar. In their cadaver study, Kartus et al. [12] found 11 cases of medial saphenous nerve rami passing near the tibial tuberosity that could be injured by a vertical 25-mm incision, but found only two cases of nerve rami passing in front of the patellar apex out of 60 knees. Other publications [13–17] examined the topography of these nerve branches. The single incision at the patellar apex, in our minimally-invasive group, confirms the results reported in the literature in observing a reduction of the frequency and surface area of cutaneous hypoesthesia compared to a classical incision.

The surfaces of the hypoesthesia zones in the classical and minimally-invasive groups were comparable to those in the literature since Gaudot et al. [1,9,18] reported, in a study comparing a minimally-invasive double approach and a classical approach, a reduction in the hypoesthesia surface with a mean zone measuring 11 cm² for the classical approach and 4.9 cm² for the double approach. Kartus et al. [18] found a mean loss of sensitivity on the anterior side of the knee of 16 cm² on 604 knees operated on for ligament reconstruction via the classical approach.

Several criticisms can be raised against the minimally-invasive technique reported herein. The problem centering the implant on the middle third of the patellar tendon demonstrates the difference in ligament band widths. Bonin et al. [14] harvested material using the same technique on 26 cadaver knees and only noted this centering defect on one. The increase in harvesting time should be noted: 15 min for the single minimally-invasive approach, 17 min for Gaudot et al. [9] in a double minimally-invasive approach, whereas it was 8 min in our series for the classical approach.

The quality of the transplant via the minimally-invasive approach is the most limiting factor. The shape of the anterior tibial tuberosity seems to be a discriminant component. A jointly conducted study [11] classified the shape of the ATT into three types. A type III tibial tuberosity, i.e., prominent, is the best indication for the minimally-invasive transplant because it allows the ancillary instruments to take a good quality transplant for the tibial part, whereas in types I and II the risk of following the wrong pathway is greater. In types I and II, the double approach [9] is the best option.

Anterior knee pain is sometimes abusively blamed on the transplant harvest. It can also be secondary to pre- and postoperative rehabilitation. Shelbourne and Trumper [19] observed that the motion deficit, in particular extension deficit, is responsible for anterior pain. Dijian et al. [20] observed a correlation between anterior knee pain and extension deficit. Kartus et al. [21] described several sources of anterior knee pain at the bone harvest site, neurological pain due to lesions to the infrapatellar nerve branches but rarely tendinitis. This pain was found in 12–45% of the cases depending on the series during the first 2 years and again in 5–9% at 7 years [22].

In our minimally-invasive group, anterior knee pain was found in six patients. Two patients experiencing pain at the ATT had partial effacement of the ATT. Four patients presented pain at the patellar apex and belonged to the group of eight patients presenting a difference in lateral and medial band width of the patellar ligament, with thickening of the narrowest band. This thickening may be a reaction to the asymmetry of the mechanical stresses in each tendinous band and may also submit the patella to unequal stresses, a source of patellofemoral pain syndrome.

For the classical group, anterior knee pain was found in four patients (22%), comparable to the data found in the literature.

The mean intensity of this pain as evaluated on the VAS was close in the two groups. At a mean 34 months, Gaudot et al. [9] found a mean VAS pain score of 1.33 (1.28 for the classical group and 1.38 for the double approach group).

Patients with anterior pain were operated on a mean 3 months after their accident, whereas patients with no anterior pain were operated on a mean 8 months after their accident. This observation is comparable to the study conducted by Wasilewski et al. [22] who found anterior pain in 17% of the patients operated in an acute situation and 9% in patients operated on for chronic conditions, and in Gaudot et al. [9], who wrote that the risk of anterior knee pain is greater if the patients underwent surgery before the 9th month after their accident.
The subjective and objective clinical scores are comparable for the two series. Like Gaudot et al. [9], we found no significant difference between these two groups on the objective and subjective IKDC scores and the Lille femoropatellar score. Only the knee-walking test showed a non-significant difference.

Conclusion

This single-approach minimally-invasive harvesting technique requires a long learning curve. It should only be proposed in cases with type III prominent tibial tuberosity. This type of transplant is advantageous in esthetic terms with the mean incision measuring 28 mm, but also limits the risk of cutaneous hypoesthesia. There is no significant difference in the functional results. However, the follow-up is short.

Disclosure of interest

A. Ioncu, R. Mader and N. Bonin declare that they have no conflicts of interest concerning this article.

D. Dejour: royalties from SBM interference screws.

References