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Healing of tibial bone tunnels after bone grafting for staged revision anterior cruciate ligament surgery: A prospective computed tomography analysis

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ABSTRACT

Aim: To quantify healing of tibial bone tunnels after bone grafting in two-stage ACL reconstruction revision.
Methods: Ten consecutive patients underwent autogenous bone grafting prior to ACL reconstruction revision (four females and six males, average age 28 years). The indications for two-stage surgery were as follows: (1) the enlargement of the tibial tunnel aperture was >20 mm in diameter or, (2) the existing tunnel was overlapped with the optimal tunnel and positioned more than a half tunnel diameter posterior to the optimal position. An autogenous iliac bone block was driven into a new tunnel. CT examinations were performed at three, 12 and 24 weeks after bone grafting. Evaluations were performed on 15 axial planes at one-millimeter intervals from the articular surface perpendicular to the long axis of the tibia using the following three parameters: occupying ratio (OR), union ratio (UR), and bone mineral density (BMD) of grafted bone.
Results: The average ORs were 81, 85 and 94%, and the average URs were 49, 75 and 89% at three, 12 and 24 weeks, respectively. Each parameter significantly increased over time. The average BMD was 510 and 571 mg/cm^3 at 12 and 24 weeks, respectively, with a significantly higher value at 24 weeks.
Conclusion: The average ORs, URs and BMD at 24 weeks after bone grafting were higher than those at 12 weeks, which suggests that at 24 weeks after bone grating, the condition of the patients' beds becomes favorable for safe implantation and fixation of ACL graft revision.
Level of evidence: Case series Level IV.

1. Introduction

Recently, the opportunities for re-injury among patients after primary anterior cruciate ligament (ACL) reconstruction have been increasing, as more return to their pre-injury activity level. In accordance, the number of ACL reconstruction revisions has also been increasing [1,2]. There are two methods of ACL reconstruction revision: one-stage surgery and two-stage surgery.

Generally, when creating a new tunnel at the same position in one-stage surgery, in order to facilitate graft-bone healing, it is necessary to enlarge the tunnel by refreshing an existing tunnel wall. When primary tunnels are created in the optimal location, problems also arise in making new ones. Difficulties exist in preparing grafts to match new larger tunnels, or anterior or posterior shifts of the implanted graft within the new larger tunnels. When tunnels are enlarged, procedures become more technically demanding, leading to a potential deterioration of clinical outcomes. In fact, many studies have reported greater residual anterior laxity in patients who underwent one-stage ACL reconstruction revision compared to primary reconstructions [3–11].

In contrast, two-stage surgery is theoretically free from technically demanding procedures because bone tunnels are filled with grafted bone. Thomas et al. reported that no significant differences were found in subjective and objective laxity assessments between primary ACL reconstruction and two-stage ACL reconstruction revision after bone grafting [2]. They considered that one of the possible reasons for this could be that equivalently secure initial graft fixation is expected in two-stage surgery due to the presence of good quality bone around the tunnels. However, there has been no quantitative evaluation performed during the healing process of grafted bone before staged ACL reconstruction. Therefore, it remains unclear whether it can be practically regarded as good quality bone, as the previous report mentioned. Moreover, there have been no reports with chronological evaluation of grafted bone healing. The optimal period from bone grafting to staged ACL reconstruction revision is unclear, although previous reports have shown the waiting periods to be six to 16 weeks [2,12–14].

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Therefore, the purpose of this study was to quantify healing of bone tunnels after grafting in patients who underwent autogenous iliac bone block grafting prior to two-stage ACL reconstruction revision. It was hypothesized that density and healing of the grafted bone at 24 weeks after bone grafting were improved from those at 12 weeks.

2. Methods

2.1. Patients

The subjects of this study were 10 consecutive patients who underwent autogenous iliac bone block grafting prior to ACL reconstruction revision due to abnormal anterior laxity after primary surgery, and who presented at the outpatient clinic between April 2008 and April 2013. The patients' characteristics are shown in Table 1. The average age of the patients was 28 years. Primary ACL reconstructions were performed using both hamstring tendons and patella tendons. The hamstring grafts were fixed with a cortical button at the femur and with a staple or double spike plate at the tibia. All of the patellar tendon grafts were fixed with interference screws at both femur and tibia. All knees gave positive results on the Lachman test and the pivot shift test immediately before bone grafting. The average side-to-side difference in anterior laxity at manual maximum force, measured by a KT-2000 arthrometer® (MEDmetric Corp. San Diego, CA), was 7.5 mm ± 1.7 (five to 10). The causes of the abnormal anterior laxity were as follows: five due to re-injury during sports activities; four for no particular reasons without any traumatic episode; and one resulting from arthroscopic debridement of the graft due to surgical site infection after primary surgery. The average period from primary surgery to bone grafting was 7.6 years (range one to 20).

The indications for two-stage surgery were as follows (Figure 1): (A) enlargement of the tibial tunnel aperture was >20 mm in diameter on a preoperative computed tomography (CT) scan or (B) the existing tunnel was overlapped with the optimal tunnel and positioned more than a half tunnel diameter posterior to the optimal position. A previous study described that the patients with a bone tunnel of >15 mm diameter were good candidates for grafting [17]. In this study, because a bone tunnel of 15 mm diameter with 45° of inclination resulted in a tibial tunnel aperture of >20 mm, a 20-mm tunnel aperture was regarded as a candidate for grafting. Moreover, to avoid potential graft falling, bone grafting was performed on patients with previously existing tunnels that overlapped the optimal tunnel, and were positioned more than a half tunnel diameter posterior to the optimal tunnel location. The former indication was applied to four cases and the latter to six cases.

The present study focused on the tibial side because on the femoral side it is very difficult to reproduce a set reference plane on the lateral wall of the intercondylar notch in order to quantitatively evaluate tunnel enlargement or overlap due to its individual morphological variation and the cone-shaped aperture enlargement.

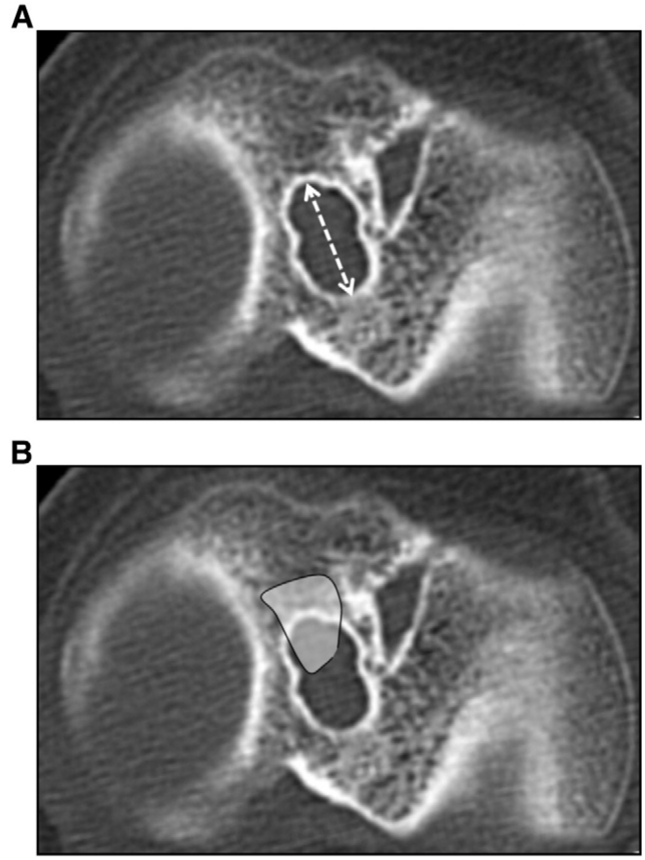

Figure 1. Evaluation of tibial tunnel aperture by CT imaging of the articular surface as an indication of iliac bone grafting.

A. The diameter at the long axis (white dotted arrow) of the tunnel aperture in primary ACL reconstruction.
B. The area of overlap between a tunnel aperture in primary ACL reconstruction and anatomical insertion of the ACL (light gray delta shape).

2.2. Surgical technique and postoperative regimen

Arthroscopic evaluation of transplanted grafts, meniscus and articular cartilage is summarized in Table 2. Tunnel apertures were neatly exposed after debridement of the transplanted graft or its remnant. Hardware was also removed if necessary. A 2.4-mm guide wire was inserted using the Director Drill Guide System® (Smith & Nephew Endoscopy) into the center of the tibial tunnel from the anteromedial aspect of the tibia to the femur. Under X-ray control, the new tunnel was created in a step-by-step manner to refresh an existing tunnel wall securely.

The guide wires were over-drilled using a cannulated reamer and curetted to remove the residual soft tissue graft or sclerotic bone wall

Table 1
Patient characteristics.

Case	Age (years)	Sex	Years from primary operation	Cause of laxity	Graft of primary operation	Tibial tunnel
A	20	Female	2	Surgical failure	Ham	Malposition
B	33	Female	14	Surgical failure	PT	Malposition
C	29	Male	8	Surgical failure	PT	Malposition
D	29	Male	2	Reinjury	PT	Widening
E	31	Female	12	Reinjury	Ham	Malposition
F	16	Male	1	Infection	Ham	Widening
G	24	Male	3	Surgical failure	Ham	Widening
H	38	Male	13	Reinjury	Ham	Malposition
I	17	Female	1	Reinjury	PT	Widening
J	43	Male	20	Reinjury	Ham	Malposition