The Knee 21 (2014) 1018–1022

Contents lists available at ScienceDirect

The Knee

Radiodense ligament markers for radiographic evaluation of anterior cruciate ligament reconstruction

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ARTICLE INFO

Article history:
Received 5 January 2014
Received in revised form 2 May 2014
Accepted 5 July 2014

Keywords:
ACL rerupture
Graft failure
Soft tissue marker
ACL reconstruction

ABSTRACT

Introduction: Early clinical and radiographic diagnosis of failed or loosened anterior cruciate ligament (ACL) reconstructions can be challenging. The aim of the present study is to retrospectively evaluate the use of radiologically visible markers in the ACL graft, serving as a potential diagnostic tool in ACL graft rupture and insufficiency.
Methods: Twenty patients were included in the study. ACL reconstruction was performed with use of a hamstring autograft in hybrid fixation technique. The graft was marked with two radiodense suture knots, one at the tibial and femoral tunnel openings. Radiographs were performed postoperatively, after 6 weeks and 12 months. Four distances between markers and landmarks were measured in anteroposterior and three in lateral radiographic views and the positional change between the timepoints of measurement was calculated.
Results: Measurements of the marker distances on radiographs showed an excellent interobserver reliability ($\kappa = 0.97$). In two measured distal anteroposterior distances statistically significant changes could be detected between 6 weeks and 12 months postoperatively in one patient with MRI-documented ACL rerupture and in five patients with ACL elongation defined as anteroposterior-translation with side-to-side difference of ≥3 mm measured with a Rolimeter device. On lateral radiographs, marker distances were highly variable and did not correlate with clinical ACL elongation.
Conclusion: The application of radiodense ACL graft markers is a straight-forward, non-expensive and potentially useful diagnostic tool to identify the position of the transplant and for diagnosis of graft elongation or failure. However, the method is sensitive to the radiological projection, which should be further studied and optimized.

1. Introduction

The anterior cruciate ligament (ACL) is the second most commonly injured knee ligament and its reconstruction is among the most frequently performed orthopaedic operations [1]. The success rate of ACL reconstruction varies from 69% to 95%. However, clinical diagnosis of reruptures can be difficult due to swelling, joint effusion and pain, especially in the early postoperative or posttraumatic period. Commonly, standard anteroposterior (ap) and lateral knee radiographs are performed in patients after knee trauma and after ACL reconstruction. However, although the proper positioning of the bone tunnels and fixation material may well be evaluated, the integrity of the ACL auto- or allograft cannot. Therefore the migration of radiodense markers that are securely fixed within the graft material might be helpful in diagnosing elongation or rerupture and, thus, insufficiency of the reconstructed ACL.

Several studies have addressed soft tissue markers in order to measure ACL graft lengthening or rotator cuff reconstruction failure [2–7]. All of these in vivo or in vitro studies used radiostereometric analysis (RSA) to study relative motion in three dimensions. RSA is a well established technique for monitoring migration of prostheses relative to bone and also to detect soft tissue marker migration. However, practical use of RSA remains limited because the sophisticated radiological systems required are not commonly available in a routine practice. To the authors' knowledge, no prior study evaluated the use of intraligamentary ACL graft marking with standard radiographs in two planes without RSA. We hypothesized that due to the well-defined direction of the graft however the use of plain radiographs may be feasible with appropriate markers and measurement technique.

The aim of the present study was therefore to evaluate the use of radiodense ACL graft marking by measuring postoperative marker migration over time and consequently, to establish a new diagnostic tool for ACL graft rupture or insufficiency.

2. Materials and methods

Between September and December 2010 in 27 patients an ACL reconstruction was performed using a hamstring autograft marked with radiodense sutures. Eight patients had an additional meniscal procedure during surgery, either partial meniscectomy or meniscal repair. All

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http://dx.doi.org/10.1016/j.knee.2014.07.003
0968-0160/

surgical procedures were performed by the same two experienced orthopaedic surgeons.

All patients received on a regular basis clinical follow-ups after six weeks, three, six and finally 12 months after ACL reconstruction. Standardized anteroposterior (ap) (with an extended knee) and lateral (with 30° flexion) radiographs were performed postoperatively, after six weeks and 12 months. At 12-month follow-up measurement of anteroposterior translation in 30° knee flexion by using a Rolimeter (Aircast Europe, Neubeuern, Germany) device and clinical examination with IKDC (International Knee documentation committee) score was performed.

2.1. Surgical technique

The pes anserinus was visualized through a three centimeter incision anteromedially at the proximal tibia. The semitendinosus tendon was harvested with a tendon stripper and the length and thickness were measured. If the length or diameter of the quadrupled semitendinosus graft was not sufficient, gracilis tendon was harvested as well and the graft consisted of doubled gracilis and doubled semitendinosus tendon. Afterwards the grafts were prepared using a nonabsorbable braided suture to hold both ends using baseball stitches (FiberWire, Arthrex, Naples, FL, USA). Finally, two intra-ligamentary metallic suture knots (stainless steel monofilament, USP No. 4–0, Ethicon Inc., Somerville, NJ, USA), grasping approximately one to two millimeters of tendon tissue were placed in the approximate center of the graft. The positions were chosen such that the markers would be at or close to the tibial and femoral openings of the bone tunnels, resulting in a distance of about two centimeters between the knots.

Standard medial and lateral parapatellar arthroscopy portals were used. The femoral tunnel was drilled first via the anteromedial portal. A guide wire was placed with a guide system (Karl Storz, Tuttlingen, Germany) at the femoral footprint of the ACL in the intercondylar notch in a knee flexion of at least 100°. After overdrilling with a 4.5 mm drill, the final femoral graft tunnel was created by a cannulated drill with a diameter according to the prepared graft. Afterwards the tibial tunnel was prepared by using a drillguide (Karl Storz, Tuttlingen, Germany) targeted at the center of the tibial ACL footprint. Femoral fixation was achieved using a flipping device on the cortical bone (Fliptack, Karl Storz, Tuttlingen, Germany), combined with a resorbable interference screw compressing a bone wedge to the transplant (Megafix, Karl Storz, Tuttlingen, Germany). In the tibial tunnel the graft was secured with an interference screw (Megafix, Karl Storz, Tuttlingen, Germany) with the knee close to full extension. Additionally, the sutures of the tibial graft side were again fixed on cortical bone using a small plate (Endotack, Karl Storz, Tuttlingen, Germany) covering the bone tunnel.

Mobilisation was started the day after surgery with flexion limit of 120° and extension limit of 0° for six weeks. After six weeks free range of motion was allowed. Weight bearing was limited to half body weight on crutches in an extension brace for three weeks. Running was permitted after three months, high-demand pivoting sport was allowed after a minimum of six months postoperatively.

2.2. Marker distances and measurements

Seven radiographic marker distances were measured at three times (postoperatively, after 6 weeks and after 12 months) by two independent observers. Of these, four marker distances were determined in ap- (named "A1"–"A4") and three marker distances were determined in lateral X-rays (named "L1"–"L3") (Fig. 1 a and b).

Changes of marker distances over time were calculated for all seven distances and for all different time-points and named as ΔAa/ΔLa for the difference from postoperative to 6 weeks and as ΔAb/ΔLb for the difference from 6 weeks to 12 months. Changes were detected in proximal or distal directions and calculated as positive values no matter if the distances increased or decreased (Fig. 2).

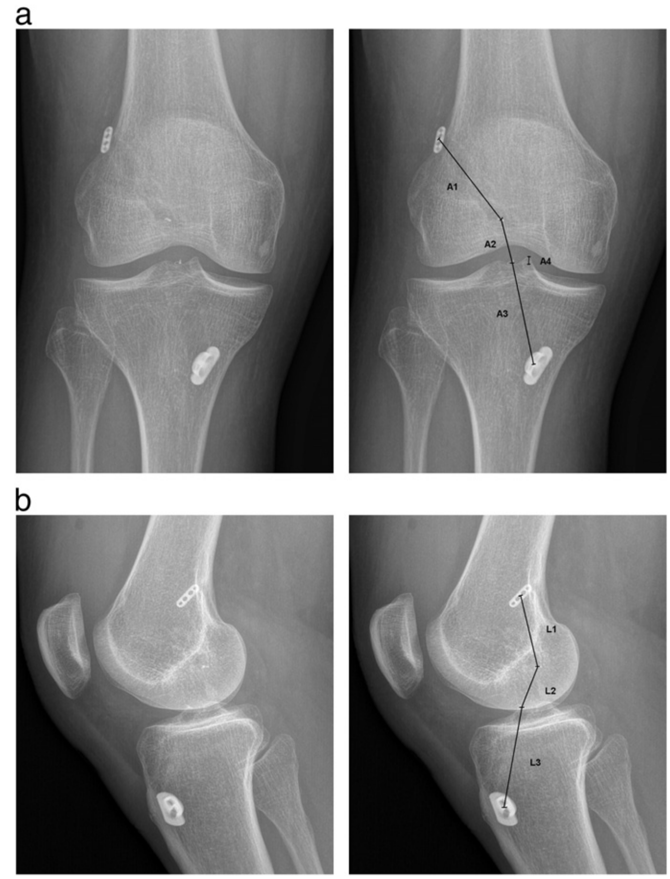

Fig. 1. a: Anteroposterior (ap) X-ray with four ap marker distances: A1: proximal fixation–proximal marker; A2: proximal marker–distal marker; A3: distal marker–distal fixation; A4: intercondylar eminence–distal marker. The center of the proximal fixation (Fliptack, Karl Storz, Tuttlingen, Germany) and distal fixation (Endotack, Karl Storz, Tuttlingen, Germany) device was used for measurements. b: Lateral X-ray with three lateral marker distances: L1: proximal fixation–proximal marker; L2: proximal marker–distal marker; and L3: distal marker–distal fixation.

2.3. Statistical analysis

Statistical analysis was performed using IBM SPSS® statistics software (version 20.0, Chicago, Illinois) by an independent biostatistician. Interclass observer correlation between two independent observers was measured. The intraclass correlation coefficient (κ) can have a value between 0 (no agreement) and 1 (absolute agreement) and was classified according to Fleiss as excellent if larger than 0.75. One-way paired Student t test was performed to analyse differences of marker distances between the time periods. Sub-groups of patients with ap-translation side–side difference of less than three millimeters and patients with side–side difference of minimum three millimeters were built. Unpaired Student t test was performed to examine the data. p-Values ≤ 0.05 were deemed to be statistically significant. Furthermore a Pearson correlation analysis was performed to examine the association between clinical changes of ap-translation and radiological distance changes.

3. Results

Of the 27 operated patients four emigrated within 12 months after surgery. Three patients did not show up for 12 months follow-up evaluation. One of them could not be traced and two refused a followup visit, despite a favourable clinical outcome as verified by telephone interview. All of these patients had to be excluded leading to a study group of twenty patients. However, three of them had history of an ACL reconstruction on the contralateral knee and were therefore excluded from the statistical analysis concerning side-to-side differences. In one case the distal marker dislocated out of the ACL graft. Therefore only the A1 distance could be calculated in this case.