The Knee 18 (2011) 76–82

Contents lists available at ScienceDirect

The Knee

Knee proprioception following ACL reconstruction; a prospective trial comparing hamstrings with bone–patellar tendon–bone autograft

A.G. Angoules [a,*], A.F. Mavrogenis [b], R. Dimitriou [b], K. Karzis [a], E. Drakoulakis [a], J. Michos [a], P.J. Papagelopoulos [b]

[a] Department of Orthopaedics, Asclepeion Hospital of Voula, Greece
[b] Department of Orthopaedics, Athens University Medical School of Medicine, Athens, Greece

ARTICLE INFO

Article history:
Received 17 May 2009
Received in revised form 13 January 2010
Accepted 21 January 2010

Keywords:
Anterior cruciate ligament rupture
Hamstrings
Patellar tendon
JPS
TTDPM

ABSTRACT

We prospectively studied knee proprioception following ACL reconstruction in 40 patients (34 men and six women; mean age 31 years). The patients were allocated into two equal groups; group A underwent reconstruction using hamstrings autograft, and group B underwent reconstruction using bone–patellar tendon–bone autograft. Proprioception was assessed in flexion and extension by the joint position sense (JPS) at 15°, 45° and 75°, and time threshold to detection of passive motion (TTDPM) at 15° and 45°, preoperatively and at 3, 6 and 12 months postoperatively. The contralateral healthy knee was used as internal control. No statistical difference was found between the ACL-operated and the contralateral knees in JPS 15°, 45° and 75° at 6 and 12 months, in both study groups. No statistical difference was found between the ACL-operated and the contralateral knees in TTDPM 15° at 6 and 12 months, nor regarding TTDPM 45° at 3, 6 and 12 months, in group A. No statistical difference was found in JPS and TTDPM between the two grafts, at any time period. Knee proprioception returned to normal with ACL reconstruction at 6 months postoperatively, without any statistically significant difference between the autografts used.

1. Introduction

Proprioception is considered a variation of the sensory modality of touch and encompasses the sensations of joint movement (kinaesthesia) and joint position [1]. Proprioception is the effect of afferent nerve impulses from muscles, tendons and joints that controls reflexes and muscle tone [2]. Since its initial description, the term proprioception has been extended to include the interaction of afferent and efferent pathways of the somatosensory system [3]. The anterior cruciate ligament (ACL) is necessary for static and dynamic stability of the knee joint [4–7]; dynamic stability is supported by specific ligament mechanoreceptors found within the ACL such as the Ruffini and Paccini corpuscles, the Golgi tendon organs and a smaller number of free nerve endings that are important for proprioception [8–12].

Intra-articular knee injuries such as ACL ruptures, meniscal tears, aging and arthritis are associated with damage or dysfunction of the knee mechanoreceptors that result in disturbing knee position sense and kinaesthesia and reduced proprioception [13–16] The proprioceptive deficit of a knee joint with ruptured or non functional ACL is well documented [15,17–21]. The joint position sense (JPS) [17–19,22–31] that is the ability to determine where a particular body part exactly is in space as measured in degrees of an angle deviation from a starting position, and the time threshold to detection of passive motion (TTDPM) [1,17,20,25–27,30,32–42] that is the time between initiation of movement to the time that movement is appreciated by the patient have been the most commonly used methods to evaluate proprioception following ACL rupture.

The aim of the present prospective study was to evaluate knee proprioception following ACL reconstruction by using bone–patellar tendon–bone (BPB) and hamstrings tendon autografts. The primary analysis was whether and at what time knee proprioception improves after ACL reconstruction. The secondary analysis was to evaluate improvement of knee proprioception using either of the two grafts. To the best of our knowledge, this is the second study to evaluate knee proprioception using two different grafts for ACL reconstruction.

2. Materials and methods

We designed a study to evaluate knee proprioception following ACL reconstruction using two different autografts. Evaluation of proprioception was done in both knees of all patients, preoperatively and at the ACL-operated knee postoperatively using the JPS and the TTPDM. The contralateral healthy knee was used as internal control.

From September 2006 to December 2007, 40 patients with clinical and magnetic resonance imaging confirmed unilateral ACL rupture were included in this study. There were 34 men and six women, with a mean age of 31 years (range, 17–54 years). The criteria for selecting the patients for this study were unilateral ACL rupture, motivation and

* Corresponding author. Department of Orthopaedics, Asclepeion Hospital of Voula, 45 Karatheodori Street, 11525, Athens Greece. Tel./fax: +30 210 6721355.
E-mail address: antoniosangoules@yahoo.com (A.G. Angoules).

0968-0160/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.knee.2010.01.009

cooperation of the patients, without selection based on gender or the profession of the patients. Patients with associated meniscal tears or articular cartilage injuries and collateral or posterior cruciate ligament ruptures, as diagnosed clinically and with magnetic resonance imaging, prior history of ipsilateral knee, hip or ankle injury or surgical operation were excluded. Professional athletes were also excluded for the purpose to evaluate knee proprioception following ACL arthroscopic reconstruction in the general population, and to exclude the effect of specific athletic rehabilitation protocols aimed towards dynamic stability and knee proprioception. All patients were admitted and treated at the authors' institutions. After being informed about the methodology and the objectives of the study, the patients gave written informed consent and assured compliance for participation in this study. The study has been approved by the Institutional Review Board/Ethics Committee of the authors' institutions.

At the same time period of this study, 54 patients were admitted to the authors' institutions with knee injuries including ACL rupture. Of these, only 40 patients met the inclusion criteria of this study (non-professional athletes with unilateral ACL rupture without associated knee injuries); the remaining 14 patients were excluded from the study. At each stage and at the latest examination, the JPS and TTDPM measurements of all these 40 patients were available for main analysis. Since the sample size could be specified a priori, it has been evaluated retrospectively using a post-hoc statistical analysis. After the study has concluded, results of the post-hoc analysis indicated the sufficiency of the sample size.

The mean time from ACL rupture to arthroscopic reconstruction was 6 months (range, 2–24 months). The patients were sequentially allocated into two surgical groups depending on their order of presentation. Group A included 20 patients (16 men and four women) in whom a four strand ipsilateral hamstring (semitendinosus/gracillis) autograft has been used; group B included 20 patients (18 men and two women) in whom ipsilateral bone–patellar tendon–bone autograft has been used. All intra-operative factors such as graft fixation techniques were standardized; all procedures were arthroscopic assisted and performed by the same surgeons.

Postoperative recovery was uneventful in all patients of both groups; in addition, all patients were rehabilitated by the same postoperative rehabilitation protocol of the operated knee, and were assessed in a similar fashion. There was no protocol deviation from study as planned in any of the patients of this study.

Evaluation of proprioception was done in both knees of all patients, preoperatively and at the ACL-operated knee at 3, 6 and 12 months postoperatively, using the JPS according to modified Barrack's method [15], and the TTPDM according to Lephart's method [1,13,20]. Assessment was done by moving the knee joints passively in angular velocity of 2° per second using the isokinetic dynamometer Con-Trex MJ (Con-Trex, Zyrich, Switzerland).

All patients were included in the postoperative evaluation and main analysis, and were blinded to the graft used; evaluation of all patients was done by the same therapist who was also blinded to the operation performed. In addition, both knees of the patients were covered with elastic stockinet so that the examiner would also be blinded to the operated knee. During knee testing, all the necessary precautions were taken into consideration so that external influences could be minimized. The subjects were blindfolded for all visual input to be removed, and a source of constant low volume music was used to prevent any auditory cues from the dynamometer. A pneumatic boot was placed below the knee joint to keep the ankle in the neutral position and to minimize cutaneous sensation [1].

The JPS was measured at 15°, 45° and 75° in two full distances from extension to flexion [15,38]. The knees were positioned in extension (0°), and were passively flexed by the apparatus to 15°, 45° and 75°; the patients were asked to recognise the joint position and to actively flex the knee to that particular position [15]. The mean angle deviation from the starting position following three repetitions for each measured angle was recorded. Nine JPS assessments were performed for each knee joint. The final score for each test was calculated by the mean score of the three different predetermined angles for each knee.

The TTDPM of flexion and extension movements was measured at starting angles of 15° (near-terminal range of motion) and 45° (midrange of motion) [1,13,20]. A button was pressed by the patient at the moment that any degree of joint motion was felt. Six TTDPM assessments were performed for each knee joint; three TTDPM assessments at each angle moving into either flexion or extension. The mean time was calculated.

2.1. Statistical analysis

Data is expressed as mean ± standard deviation (SD) or median (in case of violation of normality) for continuous variables and as percentages for categorical data. The Kolmogorov–Smirnov test and normal probability plot were utilised for normality analysis of the parameters.

The precision of measurements was estimated by calculating the standard error of measurement (SEM), the smallest detectable difference (SDD) and the standardised coefficient of variation (CV). Relative reliability, the degree to which individuals maintain their position in a sample with repeated measurements, was evaluated using the intraclass correlation (ICC) that is the error in measurements as a proportion of the total variance. Absolute reliability, the degree to which repeated measurements vary for individuals and evaluated using the coefficient of variation (CV) that is the intrasubject variation between two measurements [43]. We considered an ICC over 0.90 as high, between 0.80 and 0.90 as moderate and bellow 0.80 as insufficient [44].

Statistical analysis of the measurements obtained from the assessments of the operated and the contralateral healthy knees was done using the paired Student's *t*-test. The comparison of the percentage change of the measurements from baseline to each time point between the hamstring and patellar tendon grafts was analysed using the Mann–Whitney test because of violation of normality. All tests are two-sided; statistical significance was set at $p<0.05$. Statistical analyses were done using the SPSS vr 13.00 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, Ill., USA).

3. Results

The intraclass correlation coefficient (ICC) for the JPS measurements ranged from 0.95 to 0.99. The standard error of the measurement ranged from 0.19° to 0.24°. Minimal detectable change ranged from 0.32° to 0.57°. Coefficients of variation ranged from 8.6% to 13.8%. The intraclass correlation coefficient for the TTDPM measurements ranged from 0.78 to 0.96. The standard error of the measurement ranged from 0.15° to 0.25°. Minimal detectable change ranged from 0.24° to 0.41°. Coefficients of variation ranged from 11.68% to 22.70% (Table 1).

Table 1
The standard error of measurement (SEM), coefficients of variation (CV) intraclass correlation coefficients (ICC) and smallest detectable difference (SDD) of measurements.

Healthy	SEM	CV	ICC (95% CI)	SDD
JPS 15°	0.243	8.58%	0.96 (0.86–0.99)	0.40
JPS 45°	0.197	4.71%	0.99 (0.95–1.00)	0.32
JPS 75°	0.353	13.76%	0.95 (0.81–0.99)	0.57
TTDPM 15° flexion	0.192	22.70%	0.78 (0.49–0.94)	0.31
TTDPM 45° flexion	0.251	18.44%	0.89 (0.59–0.97)	0.41
TTDPM 15° extension	0.236	14.86%	0.96 (0.84–0.99)	0.38
TTDPM 45° extension	0.150	11.68%	0.96 (0.85–0.99)	0.24

JPS = joint position sense; TTDPM = threshold of detection of passive motion.