INTRAOPERATIVE CLINICAL TEST FOR KINEMATIC ASSESSMENT OF ACL GRAFT BEHAVIOUR WITH COMPUTER ASSISTED PROCEDURE

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This paper describes a protocol for an accurate and extensive computer–assisted in vivo evaluation of joint laxities during reconstructions of anterior cruciate ligament (ACL). The operating technique is a double bundle with over the top graft. Kinematic tests are performed, intraoperatively, before the ACL reconstruction, with ACL deficient knees, and after the ACL reconstruction. Results of first four in vivo cases, highlight that the reconstruction gives a complete restore of stability, in the antero-posterior direction, at 30° and 90° degrees giving and increased stability up to 73%, confirming the role of the ACL in the control of AP dislocation. Internal and external rotations were also satisfactorily restored after the graft fixation; in particular at 30° of flexion, the reconstruction gives a good control of the joint, reducing laxity up to 43%.

KEY WORDS: kinematic evaluation, anterior cruciate ligament

INTRODUCTION: Anterior cruciate ligament (ACL) reconstruction is one of the most frequent surgeries in sportsman. Although the results are certainly satisfactory, still in literature up to 25% of the patients had unfavourable outcome (Yamamoto Y., 2004). A tool that could permit the quantification at time zero of surgery of the restored knee stability could help surgeons to evaluate the outcome of the intervention and, therefore, modify graft fixation if stability is not satisfactorily achieved. At present computer-assisted system for ACL reconstruction are focused in guiding the surgeon during the execution of tunnel drilling (Jalliard R, Lavallee S & Dessenne., 1998; Sapega, AA, Moyer, RA, Schneck C& Komalahiranya., 1990; Mushal V, Burkart A, Debski RE, Van Scyoc A, Fu FH & Woo SL., 2003) , these system are not focused in the kinematic behaviour of the knee joint.
This paper describes a protocol for an accurate and extensive computer–assisted in vivo evaluation of joint laxities during reconstructions of anterior cruciate ligament. The paper reports in details the proposed acquisition procedure to be performed by the surgeon and the evaluation protocol, which will permit to estimate quantitatively and qualitatively the performance of the intervention. The study has only recently obtained ethical approval; therefore, there are reported results of first four in vivo cases, done after approval, including results of kinematic evaluation of joint laxities before and after ACL reconstruction with double bundle over the top technique (Marcacci M, Molgora AP, Zaffagnini S, Vascellari A, Iacono F. & Presti ML., 2003).

MATHERIALS AND METHODS: Four cases were investigated, age was 30, 20, 30 and 32, all patients were males.
Before the intervention anamnesis, qualitative evaluation of soft tissue structures of the knee and joint behaviour are recorded, by the operating surgeon, utilizing the standard evaluation form proposed by the American Orthopaedic Society for Sports Medicine (IKDC score).
The intraoperative setup has been designed to be minimally invasive and minimize possible interactions with surgical actions. To evaluate the joint behaviour an optical localizer has been used with tibial reference array fixed medially in the access for hamstring harvesting, while femoral array was inserted on lateral condyle near the femoral tunnel entrance, distally oriented.
During intervention, after tendon harvesting, leg is placed on a leg holder, in order to stabilize test, and kinematic acquisitions of ACL deficient knee, are executed. After graft fixation, the same tests are repeated.
Tests include:

- valgus/varus (VV) rotation at 0° and 30° of flexion at maximum force,
- internal/external (IE) rotation at 30° and 90° of flexion and at maximum force,

- drawer test (AP) at 30° and 90° of flexion at maximum force.

All tests are repeated four times by the operating surgeon and all the 6 degrees of freedom of the knee joint are recorded during tests. Internal and external reference points are digitized before kinematic acquisition in order to create standard anatomical coordinate systems (Martelli S., 2003). Bone reference systems are defined as following: for femur, Z axis is the femoral mechanical axis, X axis is the transepicondylar line and Y axis is the cross product of previous axes and defines the antero-posterior direction. For tibia, Z axis was defined as the tibial anatomical axis, X axis is defined as the medio-lateral direction acquired near tibial plateaux, Y axis is the cross product of the prevois axes and defines the antero-posterior direction.
Postoperative IKDC score is repeated after fifteen days.
Kinematic evaluation is performed off-line with dedicated software (www.studyjoint.org). All tests start with leg, positioned at the desired flexion, at neutral position (that means with no stress applied), which is used as first reference position for the computing of rotations and translations. Varus/valgus rotations were calculated as the rotation along the Y axis, centred in the most posterior point of ACL tibial insertion. Internal/external rotations were calculated as the rotation along tibial mechanical axis. To check stability of the rotations, helical axes of the movements were compared to mechanical axis. Anterior-posterior translations were calculated as the 3D displacement of the most posterior point of ACL tibial insertion.
All repetitions were checked in order to verify intra-patient repeatability, knee flexion during tests, direction of the rotations/translations and secondary laxities during (Zaffagnini S, Martelli S & Acquaroli F., 2004; Martelli S, Zaffagnini S, Falcioni B & Motta M., 2001). Mean values, of the tests, for each patient, were used for the study.
For the first 4 samples of data, preoperative average values and standard deviation of each test are compared with postoperative results. Future statistical investigation will be carried with classical parametric or non parametric tests (such as T-test or Mann-Whitney) in order to see if there is a statistical difference between preoperative and postoperative knee laxities.

RESULTS: All ACL reconstructions were performed according to the technique, tunnel holes were within ACL insertions at 10.30 o'clock. Intra-patient repeatability of the tests was very high; in the same patient all repetitions of the tests remained within 2 mm/2° of distribution. The stability of the test was very high, secondary displacements and rotations of tibia with respect to femur during the tests, remained within 3 mm/3°.
After ACL reconstruction varus laxities decreased, at 0° of flexion, by 67% and at 30° by 53%, external rotations decreased at 30° by 46% at 90° by 66%, anterior laxities decreased at 30° by 36% and at 90° by 73%; the other laxities, also, decreased after the reconstruction. Varus valgus laxities did not show significant changes, average values of postoperative tests were within or near standard deviation of preoperative results; anyway it may be observed that reduced laxities confirm the overall stability of the knee after reconstructions. Average postoperative IE rotations and AP displacements, were significantly different from preoperative results and were consistent with literature (Yamamoto Y., 2004; Martelli S, Zaffagnini S, Falcioni B & Motta M., 2001; Martelli S., 2003). In all patients stability improved from preoperative value of an average of 46%. See Figure 1 for results.

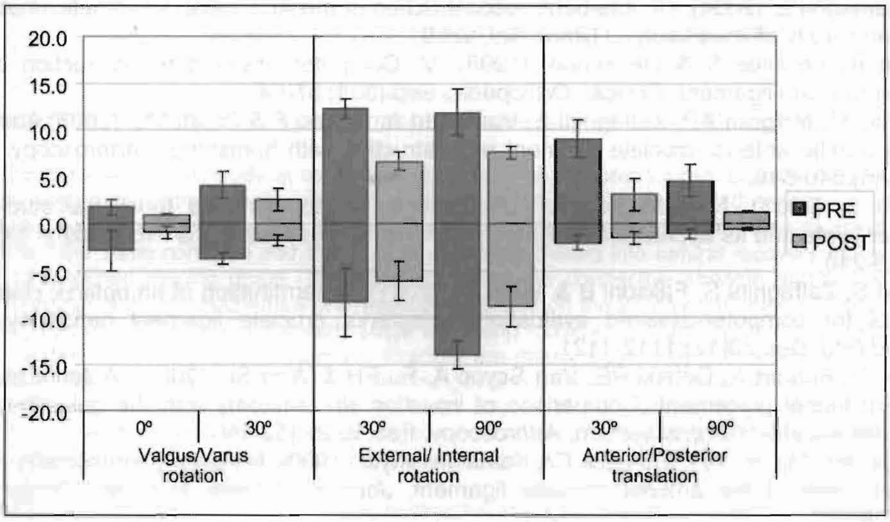

Figure 1 Results (avg±st.dev) of the kinematic tests for four patients. Values are reported in degrees for rotations (VV and IE) and in mm for AP translations.

All the procedure, including reference array fixation, references point acquisitions and tests, was performed in less than 15 minutes.

DISCUSSION: The proposed protocol, designed to optimize surgical times and minimize invasiveness, gave excellent results. An extensive analysis, including VV AP and IE tests, of kinematic behaviour of the reconstructed ACL is possible by increasing the surgical times only 15 minutes. The fixation of reference arrays directly to femur and tibia avoids having the noise of skin artefacts during the execution of the tests and allows computing the joint kinematic within the uncertainty of the optical navigation system. The invasiveness of this method is reduced by utilizing small pins for fixation and inserting these pins in the accesses done for surgical technique, avoiding further skin incision and time for surgery.

The protocol allows quantifying the effect of ACL reconstruction on overall stability of the knee joint by using classical clinical test. The high repeatability and stability of the tests allow, also, the evaluation of the contribution not only of the ACL but also of other damaged structures. Two of four cases, presented also associated lesions to the medial structures that lead to an increased variation on ACL deficient knees, while postoperative results showed a low distribution, confirming the effectiveness of the reconstruction.

For all patients the reconstruction gave a complete restoration of AP stability at 30° and 90° degrees giving and increased stability up to 73%, confirming the role of the ACL in the control of AP dislocation (Marcacci M, Molgora AP, Zaffagnini S, Vascellari A, Iacono F & Presti ML., 2003; Yamamoto Y., 2004). The rotational laxities were also satisfactorily restored after the graft fixation, at 30°, in particular, the reconstruction gives a good control of the joint, reducing laxity up to 43% (Yamamoto Y., 2004; Marcacci M, Molgora AP, Zaffagnini S, Vascellari A, Iacono F & Presti ML., 2003; Martelli S. 2003).

This protocol could be used to document and evaluate ACL reconstruction during surgery time and could permit to better evaluate the effect of residual peripheral laxities on ACL reconstruction. We don't know, in fact, how often anteromedial or anterolateral associated instabilities are able to determine graft failure or knee laxity after the reconstruction. With this system we are able to distinguish small differences in joint laxity, at time zero, that could predict, in future, a graft failure.

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